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MONITORING OF SECURITY OF AGRICULTURAL CROPS WITH MINERAL MATERIALS BY REMOTE DETECTION

Abstract

The need to produce organic food and increase yields plays a significant role in the planning of agricultural production and the economy of the state in general. Monitoring and modeling of all stages of production implies the establishment of smart agriculture concepts based on the use of remote sensing results. This work procedure implies abandoning the classic homogenization in the approach to the cultivation of agricultural land and provides the possibility of anticipating problems and timely action, which should provide an increase in yield with environmental production conditions.

Keywords: remote sensing, multispectral sensors, smart agriculture.

МОНИТОРИНГ ОБЕЗБИЈЕЂЕНОСТИ ПОЉОПРИВРЕДНИХ УСЈЕВА МИНЕРАЛНИМ МАТЕРИЈАМА ДАЉИНСКОМ ДЕТЕКЦИЈОМ

Сажетак

Потреба за производњом органске хране и повећање приноса игра значајну улогу у планирању пољопривредне производње и економији државе уопште. Праћење и моделовање свих фаза производње подразумијева успостављање концепата паметне пољопривреде која се темељи на употреби резултата даљинске детекције. Овај поступак рада подразумијева напуштање класичне хомогенизације у приступу обради пољопривредних површина и пружа могућност предвиђања проблема и правовременог дјеловања што треба да обезбиједи повећање приноса уз еколошке услове производње.

Кључне ријечи: даљинска детекција, мултиспектрални сензори, паметна пољопривреда.

1. INTRODUCTION

Remote sensing is a method of measuring the properties of objects based on the intensity of wavelengths through systems that are not in direct physical contact with a phenomen or object. Remote sensing systems give a continuous and consistent view of the Earth, providing information that can help ensure sustainable development. This is especially important in the modernization of agricultural production and the establishment of smart agriculture concepts.

The special significance of the application of remote sensing in the field of agriculture is reflected in the spectrum of electromagnetic (EM) bands whose wavelengths are absorbed by the Earth's atmosphere. Gathering information of a large number of ranges is called multispectral or hyperspectral data ranges. When solar radiation reaches the Earth's surface, some of the energy is absorbed and the rest is reflected or transmitted through the surface material. The reflection of radiation of one type of cover varies at different wavelengths in the EM spectrum and represents the spectral signature.

Measuring soil health indicators (SHIs), particularly soil total nitrogen (TN), is an important and challenging task that affects farmers decisions on timing, placement, and quantity of fertilizers applied in farms [1]. There are several studies in which plant biomass is estimated from spectral and structural data, while nitrogen concentration is determined only from spectral characteristics [2]. Nitrogen is negatively associated with dry biomass and can be determined from crop height. Adequate nitrogen (N) supply is essential for healthy crop growth. With the advent of cheap drones (UAVs), several authors have offered solutions for accurate tools and remote sensing methods for determining nitrogen concentration based on multispectral aerial photographs [3]. One of the most commonly used methods is based on the determination of reflection elements in the visible and near-infrared (NIR) spectrum using hyperspectral sensors [4, 5]. Adequate supply of nitrogen (N) is mandatory for healthy crop growth, but negative consequences are known due to the lack of N concentration on the environment [5]. According to Guerif et al., Nitrogen concentration is determined by variables such as leaf area index (LAI) and chlorophyll content (Cab). Precision is achieved when previous information on the distribution of variables is used and when LAI is multiplied by Cab to obtain chlorophyll content, which is very suitable for quantification of nitrogen content [6].

The aim of the research is to obtain a unique model based on multi-year surveys of wheat crops, at precisely defined time intervals under the same conditions, which will provide sufficient quality information on the concentration of nitrogen and phosphorus in the plant stem based on spectral signatures. This leads to a transformation towards the concepts of organic agriculture, where on the basis of these results the treatment is carried out only in those zones where the concentration values of these minerals are critical. Those zones are given as digital maps. The paper presents the results of a scientific project funded by the Ministry of Scientific and Technological Development, Higher Education and Information Society, project number 19.032 / 961-133 / 19.

2. SMART AGRICULTURE BASED ON REMOTE SENSING PRINCIPLES

One of the most important benefits of using platforms based on the concepts of photogrammetry and remote sensing is the detection and monitoring of crops, ie. crop conditions. Most global food stocks depend on the cultivation of several crops produced during the season, including corn, wheat, soybeans and rice. In recent years, a number of government agencies around the world have used satellite remote sensing to monitor and quantify these crops, as well as estimate yields. Remote sensing techniques are widely used in agriculture. The use of remote sensing is necessary, as agricultural activities face special problems that are not common to other economic sectors. First, agricultural production follows strong seasonal patterns associated with crop biological cycles. Production depends on the physical landscape, as well as on the climate and agricultural practices. These parameters vary highly with changes in time and space. Production may change in a short period of time, due to unfavorable weather conditions, so monitoring of crops must be timely. Remote detection can significantly contribute to the timeliness and accuracy of the agricultural sector, as it is suitable for collecting information over large areas, with high temporal resolution. The contribution of remote sensing in the agricultural sector has been discussed in the work of Clement Atzberger [7].

There are research results that have involved the use of satellite platforms such as satellite missions Sentinel, Landsat, Modis in tracking crops in macro-locations with a lower level of sensitivity of the treated area. With the greater use of unmanned aerial vehicles and monochrome sensors that have the ability to collect data in the invisible part of the spectrum, it is possible to provide more accurate data on the state of land and crops at micro-locations. Table 1 shows the ranges of all wavelengths used in remote sensing.

Table 1.Wavelengths of electromagnetic spectra in remote sensing

Area			Wavelength	Frequency
Ultraviolet			100A ~ 0.4μm	750 ~ 3000 THz
Visible			0.4μm ~ 0.7 μm	430 ~ 750 THz
Infrared	Near infrared		0.7 ~ 1.3 μm	230 ~ 430 THz
	Short wave infrared		1.3 ~ 3 μm	100 ~ 230 THz
	Intermediate infrared		3 ~ 8 μm	38 ~ 100 THz
	Thermal infrared		8 ~ 14 μm	22 ~ 38 THz
	Far infrared		14 μm ~ 1 mm	0.3 ~ 22 THz
Radio wave	Submilimeter		0.1 mm ~ 1 mm	3 ~ 3 THz
	Micro wave	Milimeter (EHF)	1 ~ 10 mm	30 ~ 300 MHz
		Centimeter (SHF)	1 ~ 10 cm	3 ~ 30 GHz
		Decimeter (UHF)	0.1 ~ 1 m	0.3 ~ 3 GHz
	Very short wawe (WHF)		1 ~ 10 m	30 ~ 300 MHz
	Short wave (HF)		10 ~ 100 m	3 ~ 30 MHz
	Medium wave (MF)		0.1 ~ 1 km	0.3 ~ 3 MHz
	Long wave (LF)		1 ~ 10 km	30 ~ 300 KHz
	Very long wave (VLF)		10 ~ 100 km	3 ~ 30 KHz

The essential principle of monitoring crops is with the help of various vegetation indices, which are formed by various combinations of wavelengths of the corresponding spectrum. In addition to using visible light, remote detection also uses invisible light (infrared), which allows us to detect changes before they are noticed visually. To understand the application of vegetation indices (VI), changes in leaf-level plants must first be understood. It is these findings that have contributed to the application of remote sensing in the field of agriculture. As the authors in their study [7] state, leaves contain chlorophyll a and b as essential pigments for the conversion of light into chemical energy. The amount of solar radiation absorbed from the leaves is a function of the photosynthetic content of the pigment. Therefore, chlorophyll may directly affect photosynthetic potential and production [7]. VI, the indices used in remote sensing, are based on changes in the amount of chlorophyll. With the growth of the culture, the content of chlorophyll also increases, and based on that, the values of VI change. In other words, chlorophylls absorb blue and red in large quantities, and reflect green, and therefore are represented by green, and VIs represent reflected, absorbed and transmitted light.

The beginnings of remote sensing in this area date back to the early 1970s, at the initiative of NASA. An experiment called Crop Identification Technology Assessment for Remote Sensing (CITARS) was started in 1973 to quantify crop identification with several automated classifications. An attempt was made to identify wheat yields for large regions during 1974-1977. Data from the Landsat 1 platform were then used. Later, a six-year program called Agriculture and Resource Inventory Survey Through Aerospace Remote Sensing (AGRISTARS) began in 1988. Since then, many experiments and studies have begun across Europe and the world. Today, remote sensing is an integrated part of the U.S. Department of Agriculture (Remote Sensing Applications in Agriculture at the USDA National Agricultural Statistics Service).

Also, one of the most famous programs in Europe is Monitoring Agriculture through Remote Sensing (MARS). The MARS project has developed Rapid Crop Monitoring for the Crop Growth and Monitoring System (CGMS), which incorporates crop simulation models, agrometeorological models and real-time data for yield estimation and evaluation. Another program for the classification of cultures in Europe is the Coordination of Information on the Environment (CORINE). Corine Land Cover (CLC) was initiated in 1985. There have been four updates since then, in 2000, 2006, 2012 and the last in 2018. It consists of 44 classes that cover the Earth's surface. The CLC minimum mapping size is 25 ha for surface elements and 100 m for linear elements. Various sensors and platforms were used to classify surfaces: Landsat 5, 7, Spot 4, 5, IRS P6 LISS and RapidEye [9].Copernicus is the European Union's Earth observation programme. It offers information services that draw from satellite Earth Observation and in-situ (non-space) data. In the domain of agriculture, EU policies aim to foster the development of practices that preserve the environment and sustainable productivity. Agriculture is probably the most promising market in terms of the impact of

Copernicus, especially through precision farming. Indeed, Copernicus helps assessing agricultural land use and trends, crop conditions, yield forecasts, farm management recording and irrigation management. The domains of application of Copernicus also include seasonal mapping of cultivated areas, water management and drought monitoring, as well as subsidy controls.

As part of this research, based on accurate sowing plan data, for the time period of one sowing season, Sequoia sensors (Parrot Disco Pro AG sensor) and composite Normalized Difference Vegetation Index (NDVI) first determine the phenophases of monitored crops (wheat) to identify the beginning and end of the season for individual culture. During the sowing season, the development of plants was monitored through phenophases with plant inventory by making appropriate digital terrain models in order to identify changes and crop growth with appropriate differences between models. The state of phosphorus and nitrogen was monitored by creating indexed maps, on the basis of which the treatment zones were defined.

2.1. RELATED WORKS

Satellite missions and the Advanced Very High Resolution Radiometer (AVHRR) are products globally [10]. Crop characteristics can be quite different, for the same crops. Each crop has a special phenology, ie. special phenophases. Based on the follow-up of phenology, special cultures can be classified. The problem arises when classifying crops with similar phenologies, such as corn and soybeans, or corn and sunflowers, such In addition to remote sensing, ancillary products such as seeding structures and high-resolution images, such as images taken by drones, must be used. Another problem is mixing crops with natural vegetation, grass or forests. In a study [10], the authors classified crops globally using multispectral imaging bands, the Normalized Difference Vegetation Index (NDVI), and thermal bands. Samples from 39 years were used. The results show a better classification for soybeans and maize than for other crops. High-resolution temporal monitoring of crops further improves the monitoring of phenology and classification possibilities. One of the possible platforms that can be used for these purposes is the Landsat platform with 30 m spatial resolution and 16-day temporal resolution.

On the other hand, monitoring crops in larger areas using LANDSAT requires a large number of cloud-free images to perform manual interpretation [11]. AVHRR and MODIS are imposed as two possible solutions. There are various studies based on vegetation indices (VI) with AVHRR [12, 13 , 14]. However, these studies have been applied more globally than locally, due to the spatial resolution of 1 km to 8 km. Then there can be a problem of mixed pixels and it can happen that the monitored regions are not homogeneous, which is why the results are not reliable, ie. phenological indicators are unreliable [15, 16]. MODIS sensor on the Terra platform is satisfactory solution for large area temporal crop monitoring. This sensor provides spatial resolution of 250 m and the temporal resolution that is daily for territories above 30 degrees latitude [10]. Due to this resolution, larger areas must be monitored again, but not as in the case of AVHRR. MODIS also has better image quality than AVHRR due to radiometric resolution (12 bits) and improved geometric registration and atmospheric corrections [17, 18, 19].

One of the more interesting initiatives that incorporates remote crop detection and monitoring is the Hungarian Crop Monitoring and Production Forecast Program (CROPMON) [20]. CROPMON was operational from 1997 to 2003. CROPMON is a direct collaboration of the Hungarian Ministry of Agriculture and Remote Sensing (FÖMI Remote Sensing). It was used to estimate and monitor yields and monitor droughts and floods. It was an information system that made detailed maps based on recordings and ground truth data and estimated yields using an estimation model. CROPMON has collaborated with the Land Parcel Identification System, Drought monitoring system and Flood monitoring applications. Comparing the data obtained with Cropmon with the data from the Statistical Office, a difference of 0.8% to 3.7% in the yield estimate for the whole of Hungary was shown. In the Cropmon model, LANDSAT, AVHRR, Spot and IRS satellite images were used. This is a proof of good cooperation between remote sensing and crop monitoring at the level of one country. In a study [21], the authors estimated maize and soybean yields in the United States (Iowa and Illinois) using MODIS 8-day composite bands 1 and 2 (MOD09Q1 product). Based on these bands, they get NDVI for a composite period of 8 days. They also use MODIS product 11A2, the temperature of the earth's surface. Multiple regression was performed with these parameters after classification. The results obtained by the authors were strongly correlated with data from the US Department of Agriculture. The number of parameters that affect yields that can be used to evaluate inventoried individuals is diverse. The authors in [22] in addition to NDVI with AVHRR use air temperature, soil moisture and rainfall as indicators of yield for a sample of 19 years. They also state that these parameters are not linearly related to yield and use nonlinear regression (Quasi-Newton method) for estimation. It can be concluded that by increasing the monitored parameters and increasing the monitored years, the relationship between yields becomes nonlinear and multiple linear regressions cannot be used.

2.2. STUDY AREA

The research was conducted in the area of the City of Banja Luka, the site of the Agricultural School of Banja Luka. The site has been treated for many years so there is a history of sowing with all the information about the treatment of crops and land. Therefore, it was convenient to perform a comparative analysis of land for which there is a sufficient amount of historical information.

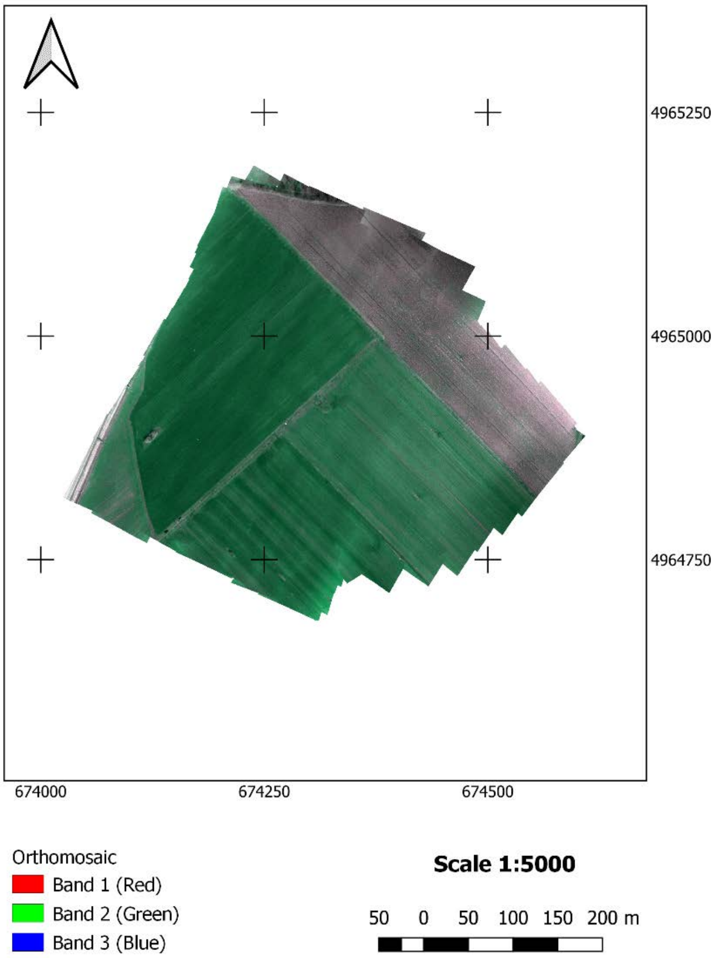
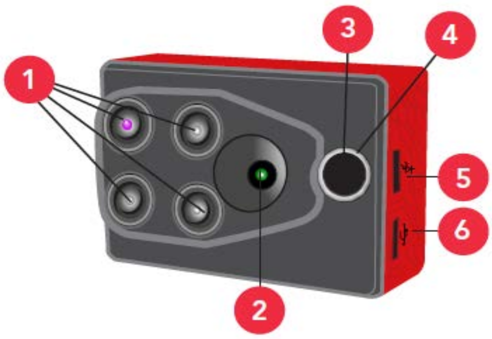


Figure 1. *Study area*

2.3. MULTISPECTRAL SENSOR USED FOR CROP DETECTION

Data acquisition was performed using a Parrot Dico Pro AG and DJI Phantom 4 Pro drone using a Sequoia multispectral sensor. It is intended for use in agricultural production. It is designed according to three main criteria: exceptional precision, minimum size and weight, and ease of use. The Sequoia sensor is designed to suit all types of drones, those with fixed wings and helicopters.



1 – 1.2 Mpx monochrome sensor which perform registration by bands
2 – 16 Mpx RGB sensor
3 – indicator
4 – switch
5 – carrier port
6 – device port

Figure 2. *Sequoia sensor caracteristics*

It can be used to obtain images of agricultural fields in several spectral bands that measure the state of vegetation: Green (550 nm wavelength, 40 nm range), red (660 nm wavelength, 40 nm range), Red Edge (735 nm wavelength, width band 10 nm) and near infrared (790 nm wavelength, 40 nm band). Images recorded with this sensor can then be analyzed using various software. They will be used to create index maps (such as NDVI, NDRE) and to make recommendations regarding fertilization, which are indicated through the nitrogen content, as the main mineral that affects the development of the plant. Nitrogen content can be determined using near infrared (780–800 nm) and either green (540–560 nm) or red-edge (730–750 nm) spectral bands [23]. Figure 2 shows the Sequoia sensor with its characteristics. In addition to the data obtained with the multispectral camera, the data of the European Space Agency for Sentinel 2 satellite missions are used.

2.4. METODOLOGY

Remote sensing uses data from satellite sensors that measure the wavelengths of light absorbed and reflected by green plants in order to study phenology. Certain pigments in the plant strongly absorb red light wavelengths. On the other hand, the reflection of infrared light is great, which is invisible to the human eye. As the structure of the plant changes from the beginning to the end of the season, these reflections also change. Many remote sensing sensors measure and record these reflections. Vegetation index is a numerical indicator that defines greenery - relative density and health of vegetation. Indices are obtained by simple mathematical operations and by combining appropriate bands. One of the best known and certainly most used is the Normalized Difference Vegetation Index (NDVI). In theory NDVI values range from -1 to +1, in practice this limit is a bit narrower, so the upper limit goes to 0.8. Bare areas of rock, sand, or snow typically have very low NDVI values of 0.1 or less. Rare vegetation has higher values from 0.2 to 0.5, as well as crops in gradual growth. Areas under dense vegetation, forests or agricultural crops have high NDVI values in their maximum vegetation period. By transforming raw satellite data into NDVI values, researchers can create images and other products to generate rough measurements of vegetation types, quantities, or conditions on the Earth's physical surface. NDVI is extremely useful for global monitoring of vegetation because it can compense for the angle of view of the sensor on the ground or the influence of the sun. NDVI values can be monitored over time to establish normal conditions in which vegetation grows for specific regions. Determining these values by phenophases can serve as a kind of template for future monitoring of crops. It was first used by Rose [24]. NDVI is calculated as follows:

$$NDVI = (NIR - RED) / (NIR+RED) \quad (1)$$

NIR- Near-Infrared reflection, RED- RED reflection

By generating time series, NDVI provides a temporal curve that summarizes the various stages that green vegetation goes through throughout the season. Such a curve can be analyzed in order to define key phenological events, such as the beginning and end of the growing season, the peak season and the end of the season. Different phenological scales are used to identify the phenological phases of plants, but two are the most commonly used: Feekes [25, 26, 27], and the BBCH scale [28]. These phenological scales describe the basic stages of growth and development of small grains such as: germination, germination, budding, wilting, flowering and pollination, as well as stages of grain maturation. Phenological analysis during the life cycle of plants reveals periodic morphological changes of plants, which in addition to identifying the phenological phase indicates the necessary and timely agro-technical intervention in the crop [29]. The vegetative phase lasts differently depending on the time of sowing and genotype, as well as on the sequential appearance of leaves on the primary tree (phyllochron), but also on the differentiation of the flower, which is conditioned by the process of vernalization and photoperiod. Among other things, phyllochrone depends on temperature [30], water [31], and available nitrogen content [32]. The reproductive phase of ontogenesis implies the differentiation of reproductive organs (flower, inflorescence, fruit). This (Biologische Bundesanstalt, Bundessortenamt and CHemische Industrie) with identification keys for small grains. In this scale, 10 basic stages of growth were identified, but for the purposes of the research, the following were monitored (Figure 3):

- Main growth phase 1 (leaf development) - covers the period marked with BBCH 10–19, which includes the growth period from the first open leaf to n number of open leaves (expected 3 leaves) of wheat. Depending on the sowing date, it will be possible to record wheat plants in the autumn with a multispectral camera at the end of November, and depending on the environmental conditions, it is possible that the wheat will enter the winter dormancy phase after that.
- Main growth phase 2 (budding) - includes the period marked with BBCH 20–29, ie the period until the end of the biological budding process. Depending on the time of sowing

and average temperatures in the autumn period, it is possible that wheat will start with autumn harvesting, this phase will last until the spring of next year and will end in early April. It is potentially possible to record plants with a multispectral camera outdoors 2 times (December if there is no snow cover and March).

- Main growth phase 3 (tree elongation) - covers the period marked with BBCH 30-39, covers the period of growth and development from the beginning of tree growth to the stage when the flagellum leaf is fully developed and the ligula is slightly visible. The mentioned phase will take place during April, one recording with a multispectral camera is necessary.
- Main growth phase 4 (immediately before grading) - includes the period marked with BBCH 41–49, means the period of elongation of the flagellum leaf arm to the visible axis phase (for axial forms). This phase is expected to be relatively short.
- Main growth phase 5 (grading) - covers the period marked with BBCH 51–99, ie the period from the beginning of grading to the moment when the inflorescence is fully visible. This phase takes place in the first half of May, one recording with a multispectral camera is necessary.
- Main growth phase 6 (flowering) - covers the period identified by BBCH 61–69, and means the period from the beginning of flowering to the end of flowering. This phase takes place soon after the previous phase, another recording with a multispectral camera at the end of May is recommended;
- Main growth phase 7 (fruit development) - includes the period marked with BBCH 71–77, ie the period from the water state of the grain to the late milk maturity of the grain. This phase is expected to last from the end of May to the middle of June, and one multispectral camera recording will be required;
- Main growth phase 8 (maturation) - covers the period from BBCH 83–89, refers to the period from the early doughy phase to full maturity. At this stage, the fruit is still being poured, which is why it is interesting to perform another recording with a multispectral camera of wheat plants in the second half of June.

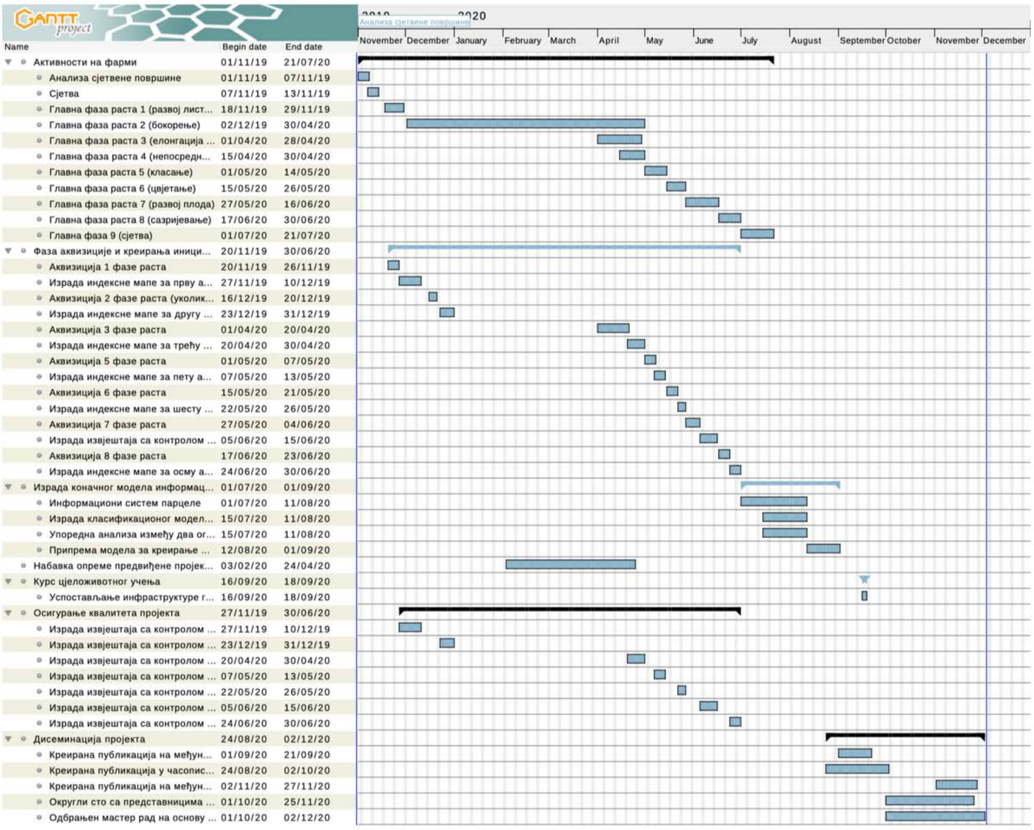


Figure 3. *Gantogram of the project*

In this study, we used DJI Phantom 4 Pro and Parrot Disco Pro AG. Missions were performed at 30 m altitude. The RGB image resolution was 1.56 × 1.56 pixel and capture was set to 80% side and 80% front image overlap. Image acquisition was conducted on the same dates as ground fieldwork when the biomass collection is conducted. The flight plans for each field were made in the Pix4D software suite "Pix4Dcapture" app and were processed in Pix4D Fields app. Using this software in every point is conducted: the chlorophyll index rededge (CI_RE), the normalized difference vegetation index (NDRE), normalized difference vegetation index (NDVI). The last one is used for purpose of crop monitoring and biophysical estimation. Chlorophyll estimation have been found to be related to plant nitrogen content as the photosynthetic enzyme, consuming the largest proportion of nitrogen in leaves [10]. Chlorophyll reflects green and NIR radiation and absorbs more than 70% of blue and red radiation [10]. So this bands will be used for the estimation alghoritm for the nitrogen detection. An important step in producing a high-quality final image is radiometric calibration considering the sensor influence and scene illumination of the UAV flight. Prior to each flight over a field, the sensor was calibrated to take a minimum of five white reference images for each band. Nitrogen concentration weight is calculated using this method NW = LNC x Wd, where NW is nitrogen weight (g/m2), LNC is leaf nitrogen content (g/m2) and Wd is dry biomass weight (g/m2).

For the estimation of the Nitrogen content there is established the relationship between nitrogen and chlorophyll content. Relationship between N and leaf level contents (Cab) are robust. According to numerous researchs we used definition that there is confirmed strong relationship between leaf chlorophyll content per unit soil area. In the analysis we use Wd to represent dry weight of the aerial shoots in t.ha-1. According to the planed acquisition of data and estimation of the Nitrogen level in the laboratory we conducted linear relationship between Cab and Nitrogen level. It is represented with correlation as N=a Cab + b. Coefficient a and b are linear regresion coeficients obtained with the use of the parameters of N concentration from laboratory for the sampled area. Changes between two acquisitions on the ΔN make assumptions about the efficiency of the fertiliser, which can however be estimated from the absorption deficit and the amounts. On this basis we create recommendation map which will reflect the variability observed by remote sensing. For proposed model we dervided indicies to vector format so we can use them in the analysis. LAI and ΔN values are derived from the remote sensing acquisitions and compared to the values got from the laboratory. Laboratory check of the samples is quality assurance of the proposed model and verification method.

3. RESEARCH RESULTS

The research was realized according to the phases defined in the previous chapter. In all phases, a comparative analysis was performed by remote sensing and laboratory research. Sobred is a medium early variety. The plant is on average about 80 cm tall. This very high-yielding variety of wheat has a very good tolerance to lodging and diseases such as spotting, rust and fusarium head blight. The sowing norm is 400-500 germinating grains per m².

Graindor is a variety with an excellent ratio of yield and quality. It is a medium-early variety in terms of vegetation. The average height of the plant is about 92 cm. Resistance to powdery mildew and Septorium tritica is average, to Fusarium very good, and to leaf and yellow rust excellent. The sowing rate is 380 to 420 germinating grains per m².

Sobred and Grandior wheat crops were sown in the experimental field. In each phenophase, crop recording was performed using a multispectral sensor and field sampling of the aboveground part of the plant and the leaf blade of the apical leaf for which nitrogen concentrations were determined in the laboratory (Table 2).

Table 2.Nitrogen content (N) in wheat samples 2019/2020

Nmb	Sort	Analyzed organs	$\bar{X} \pm S_{\bar{X}}$
1	Sobred	Overhead part	21,19 ± 1,05
		Leaf blade of apical leaf	27,69 ± 1,67
2	Grandior	Overhead part	26,61 ± 1,19
		Leaf blade of apical leaf	35,31 ± 2,24

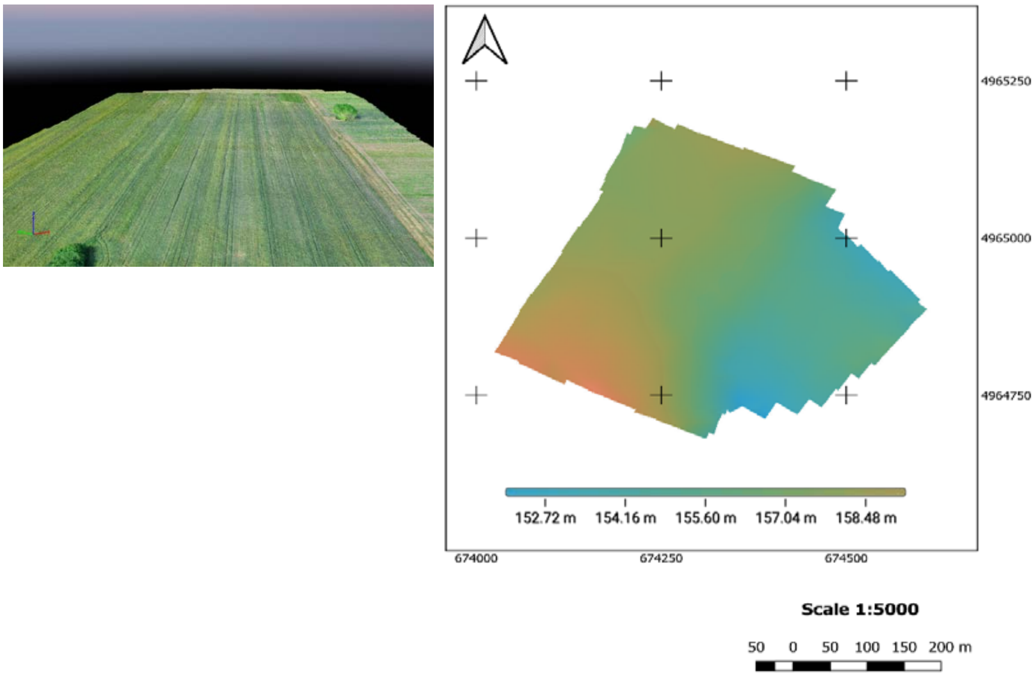


Figure 4. *Digital elevation model*

Field measurements and processing of the collected images to determine the concentrations of nitrogen were performed within the software Pix4D Capture, Pix4D Mapper and Pix4Dfields. In each phase of monitoring, an orthophoto area and a digital elevation model were created, based on which plant growth is measured per pixel (Figure 4).

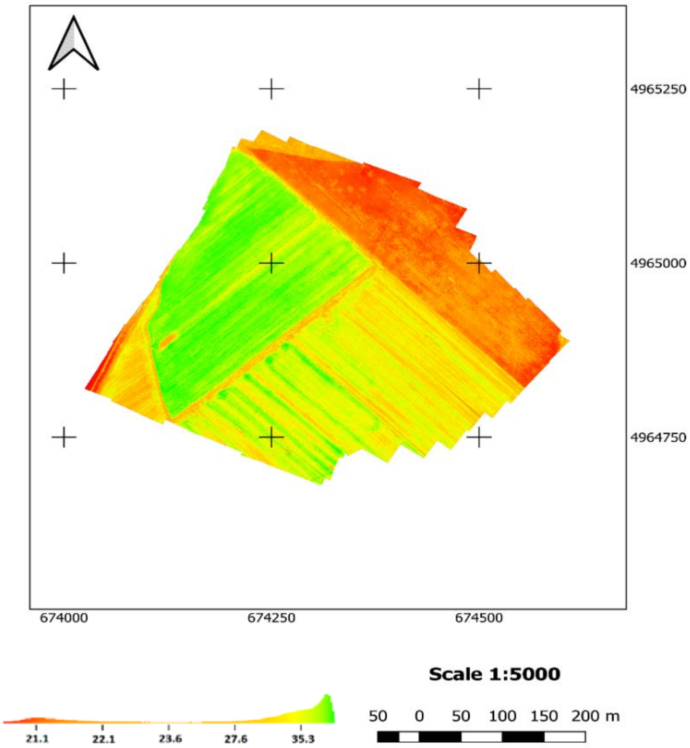


Figure 5. *Concentraction of the Nitrogen in the leaves conducted throught alghoritm using UAV multispectral images*

An index map was created to monitor the surface condition of the plant. Also for the purpose of inventory, a point cloud obtained by the method of structures from motion was used (Figure 5). Based on the results shown in the Table 2, the distribution of the NDRE index on the observed plot can be observed. In most cases shown of Figure 5, values between 20 and 24 correspond to areas with sparse vegetation; moderate vegetation tends to vary between 24 and 30; anything above 30 indicates the highest possible density of green leaves and plants with highest N concentration.

To conduct estimation of nitrogen in leaves it was used regresion model created by the use of the five band reflectanses results (green, blue and NDRE values per pixel), plant height, topographic parameters and laboratory conducted values of nitrogen in specific points. Proportion is used to calibrate the dataset using exact values and 4 samples were used for model validation. In table 3 is given statistics for calibration model.

Table 3.Statistics parametars for the calibration of the UAV estimated nitrogen concentration

Date	Model	R^2	**RMSE (g/m^2)**
25.4.2020.	UAV estimation	0.91	26.4

4. DISCUSSION

Results presented in the research gives quality model for the estimation of the Nitrogen concentration in the plant leaves. Model can be used to predict the changes of the N concetrations according to the phase of the plant development and to give farmers instructions how and with which quantity to perform fertilization in which area.

Proposed method obtained quantitative benefits:

Saving time on field analyzes: one of the main benefits is the reduction in the time required by farmers to spend each week during the crop development season on the monitoring and sampling determining the signs of plant disease. Through this way of monitoring plants, there is a possibility of research and possible reduction of plant treatment.

Less use of chemical products: data from multispectral sensors can help to prolong the interval between fertilizers if the crops show good condition. Diseases that are detected by recording with a multispectral camera at the beginning of the season can be affected during the season, by treating them with appropriate agro-technical measures on the detected hotspots. The biggest problems are reflected in diseases during the main growing season. With appropriate monitoring, it is possible to reduce the use of chemicals, in the sense that it is not necessary to use the same amount of material in all parts of the crop. Research on potato crops has shown that about 50% of the field can withstand reduced spraying.

Increasing yields: It is believed that more efficient use of input data, fields will have higher yields and this is one of the main goals of the project. As the data are added, a higher yield is assumed compared to that obtained by using classical agro-technical measures. If the technical maturity of the wider community became higher and if data were collected over several years, the potential increase would be significant.

Optimum crop collection: It is possible to give recommendations to farmers on the optimal harvest time to get the largest product from the field. By using defined input data, it is possible to obtain a precise harvest date.

Yield quality: Better knowledge of crop conditions will lead to increased yield quality which will be of greater value to the processing industry. There are many elements that affect the physical factors of the product, which can be influenced with timely and comprehensive information. There is a clear economic benefit here.

Water: As a condition for the development of the method, one field can be recorded at the beginning of the growing season, and the results act as a reference for other fields. Water level and soil moisture vary considerably from field to field, but the farmer must understand the relationship between the reference field and other areas on which the crop is sown.

Environmental impact: Today, many politicians and citizens are concerned about the increased use of chemicals on agricultural land and the possible impact on health due to the presence of crops and drinking water. This leads to new legislation controlling the use of pesticides, fungicides and fertilizers. Fertilizers are usually applied several times during the development of the plant. Currently, farmers treat fields as homogeneous entities although fields are usually very diverse with different needs for chemicals in different field locations. Knowledge of field performance during previous years, together with measurements taken from satellite images and drones, will enable the production of maps with different data and variables. This will reduce the amount of fertilizer applied, which will be more adapted to the needs of the plants. More precise application leads to much better uptake and greatly reduced excess in the soil. As a result, the amount of manure released into the environment and surface water sources is greatly reduced.

- Farmer awareness: the use of these concepts will certainly give a better overview of agricultural fields and operations, and raise farmers' awareness of their farm characteristics, which can lead to improved decisions in the long run.
- Digitization: has the potential to raise awareness of digital tools available to farmers and generally supports digitalisation in the agricultural sector, thus acting as a catalyst for the use of digital tools. Many organizations evaluate digital tools and instruments that will bring huge economic benefits to farmers and the agricultural sector in general.
- Contactless field monitoring (remote monitoring): In large agricultural plants and farms there is an increase in arable land, which is why additional workers must be hired for cultivation. Therefore, the areas that need to be analyzed and treated are larger. As a result, farmers risk spending more time in the fields, whether it is reconnaissance, spraying or other field operations. In general, farmers with a total size of 400-600 ha, have very scattered fields. By using remote sensing, it is possible to reduce the need for a physical tour of the terrain, as well as by determining the zones that need to be treated, which automatically leads to a reduction in the need for additional manpower.
- Knowledge of field history: Many farmers can benefit from archived data. They do not know the potential of some of their fields for growing crops, because they have to comply with the regulations regarding crop rotation. In addition, some farmers rent fields and do not know the specific characteristics of the fields. Through the use of this technology, it is possible to provide information and data on the performance of fields in recent years, so that the farmer can make better decisions and actions in his fields. This in turn should lead to better production and a larger product.

5. CONCLUSION

Remote sensing observations in the visible and near infrared spectral domains allow mapping of leaf chlorophyll content. This gives key variables of crops for the terms of growth and health. According to this we can estimated nitrogen status for the specific moments of the growing season. This variables modeled from the remote sensing data, laboratory estimated contents used us for the creation of the model where was possible to get the content of the variable rate of the nitrogen in the plant for the fertilization purposes. According to this we can promote precise agriculture.
Through the project, this developed method, gave significant results in the field of obtaining timely information using several types of data. Combined data were provided through the Copernicus Sentinels program, multispectral cameras, weather conditions and field measurements (soil sampling). Thanks to the proposed model, users received accurate information on the state of yield, predictions, as well as measures of action and treatment of the plant.
Through this technology and defined methodology, it is possible to:

- Access to crop-level information
- Monitoring crop development through plant growth and health parameters
- Mapping of spatial variables at the crop level
- Improving the condition and development of crops
- Estimation of harvest date and yield during the season
- Reduction of losses in production and quality

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