REVIEW

of PhD thesis elaborated in the field of higher education 5.1. "Mechanical Engineering", field of higher education 5 "Technical Sciences", a field of higher education 5 "Technical Sciences"

Author of the dissertation: Assistant Eng. Asparuh Ivanov Atanasov, PhD student in the doctoral program "Applied Mechanics", MME, Faculty of Mechanical Engineering, Technical University – Varna

Dissertation topic: "RESEARCHING THE APPLICABILITY AND EFFICTIVNESS OF SENSOR SYSTEMS IN AGRICULTURE"

Reviewer: Prof. Ivan Dimitrov Kiryakov, PhD, Technical University – Varna, professional direction 6.2. Plant Protection, designated as a reviewer according to Order No. 3/05.01.2024 of the Rector of TU - Varna.

I. General characteristics of the dissertation and the abstract.

The dissertation presented for review is developed on 151 pages and includes 89 figures, 35 tables and 5 appendices. The dissertation is structured as follows: Introduction; List of symbols and abbreviation used; Literature review; Results and discussion organized in 4 chapters; Contributions, Summary of results obtained; Publications related to the dissertation work; Applications; Bibliography amounting to 211 titles in Latin and 16 links to sites with scientific information.

The presented abstract of the dissertation meets the requirements of TU - Varna. It includes 13 figures and a table presenting the main directions of the research and the formulated conclusions and contributions.

II. Relevance of the studied problem.

The aspiration of agricultural producers is mainly aimed at reaching the biological potential of cultivated varieties and hybrids while reducing the cost of production. The rapid development of computer technologies and their introduction into agricultural practice makes it possible to refine the cultivation technology at the micro level, i.e. decision-making within a particular crop or section of it. The timely collection of data on the development of a given crop, in a specific crop, during the growing season is of primary importance for timely detection of disorders in plant development caused by abiotic or biotic stress factors. At the present moment, the positioning of agricultural machinery based on GPS technologies is increasingly used in the preparation of areas, sowing, digging, conducting plant protection measures. There is growing interest in using Unmanned Aerial Vehicles (UAVs) equipped with sensor technologies that enable tracking the condition of the respective crops. Unfortunately, we still lack sufficient accumulated data collected through these technologies on the specific crops, especially considering the wide range of cultivars and hybrids, as well as the different soil types.

The above gives me a reason to consider the present development as a significant contribution to the further development of precision agriculture in our country.

III. Literary knowledge and theoretical competence of the candidate.

Based on a significant number of literary sources, Eng. Atanasov consistently and skilfully tracks a large part of the currently existing: Sensors and methods for determining soil properties; Global Positioning Systems; The sensors for measuring displacement and speed; Remote spectral sensing sensors; Color separation sensors; Multisensor devices. In this chapter, the object and subject of research is formulated, namely survey of agricultural crops in North-Eastern Bulgaria by means of sensor systems with application in precision agriculture used in UAV. It is noteworthy that a significant part of the cited literature was published after 2000. Information presented, illustrated with 13 figures and 11 tables, *shows the very good awareness of the PhD student on the application of sensor monitoring systems in crop production.* The skillful presentation and analysis of scientific information enables the doctoral student to correctly formulate the purpose of the research and the tasks for its achievement.

IV. Methodological approach

The research was conducted in the period 2019-2022 on crops of winter cereals, sunflower and corn in the South Dobruja, region. Dobrich. 185 images of commercial and experimental crops were taken by UAV, in different phases of crop development, and 93,500 photos were taken of the studied areas. Changes were tracked in 4 indices based on images from the MAPIR Survey 3W camera, using the Pix4Dampper software product. The collected photographic material with RGB and NIR cameras were processed with MatLab software platform to determine four indices. Photographs from MAPIR Survey 3W and Hasseblad L1D-20 cameras processed with Pix4Dampper were used to compare vegetation index curves of wheat crops. To establish trends in the dependence of the NDWI index on meteorological data, a regression analysis was conducted. The changes of eight vegetation indices in maize crops were established by applying descriptive analysis. A series of tests were conducted on the developed soil moisture sensor. *I believe that the research methods and approaches used by the doctoral student guarantee the fulfilment of the set tasks and the achievement of the formulated goal.*

V. Significance and persuasiveness of the results obtained, interpretations and conclusions.

The results of the study are reflected in four main chapters, and relevant conclusions are drawn for each of them. The data presented in Chapter 2 show that the DJI mavic 2 UAV is suitable for monitoring small and medium-sized areas, which enables its application in conducting scientific research. Evidence is presented for the efficacy of remote sensing in identifying trends in the curve of major vegetation indices associated with the assessment of abiotic and biotic stress types. Processing of the imaging data with MetaLab and ImageJ software products provides a promising assessment for small area surveys. Imaging with near-infrared light cameras allows early diagnosis of epiphytotic disease development in common winter wheat crops. The results reflected in Chapter 3 prove the presence of correspondence between the change in the NDVI index with the climatic conditions during the observation period. The PhD student concludes that the MetaLab software platform is a convenient tool for calculating vegetation indices. The accumulated data allow the use of a set of indicators to determine the rate of development of individual genotypes. Evidence is presented of the effectiveness of infrared cameras in the early diagnosis of lesions caused by stress factors during the growing season. The results referred to in Chapter 4 present evidence for the applicability of UAV equipped with an infrared camera in monitoring moisture in the upper soil layers. A direct relationship was established between soil moisture and the stage of crop development at the time of photography. Based on regression analysis, a model was developed giving information about the influence of three factors, which represent the digital value of the three colours captured by the camera. Chapter 5 presents information about a sensor developed by Eng. Atanasov for determining soil moisture. The sensor provides observations of soil moisture trends as a low-cost alternative to professional weather stations.

I believe that the very good literary awareness of the doctoral student, as well as the correctly selected methods and approaches for analyzing the results, are the basis of the convincing interpretation of the data and the formulated conclusions.

VI. Contributions of the dissertation.

I accept the reference submitted by the doctoral student for the contributions resulting from his scientific research. They highlight the strengths of the dissertation, point out novelties, and build on established results and conclusions *that are the doctoral student's own work*. In summary, they can be presented as follows:

Scientific and scientifically applied contributions:

- A database has been created for the trends and dynamics of changes in the vegetation indices NDVI, EVI2 and SAVI for a set of varieties of common winter wheat under specific soil-climatic conditions of Southern Dobrudzha, which enables the use of UAV in breeding programs;

- Correlation dependences between the spectral data and the reflection of the investigated crops in terms of phenological, biometric and physiological indicators have been proven, enabling the timely detection of disturbances in the crops, the result of abiotic and biotic stress;
- A trend has been established for the factors that have the greatest importance for the moisture index (NDWI) - relative humidity, air temperature and solar radiation, enabling the monitoring of soil moisture in the initial stages of crop development;
- It has been proven that the range of the NDVI vegetation index for common winter wheat in South Dobrudzha is in the interval -1 to 0.5, and these data are original for our country.

Applied Contributions:

- An original method for extracting information from the pixel matrices has been applied, using the MatLab software platform, enabling the tracking of plant vegetation. The method is suitable for monitoring small experimental areas;
- An original prototype WiFi sensor for soil moisture and air temperature was created, with an autonomous electrical supply, significantly cheaper than professional weather stations;
- A database was created for the phenological development of the crops by recording the reflection from specific spectral areas, giving the possibility to predict the biomass content and the potential of the studied plants.

As a specialist in a professional field 6.2. Plant protection I believe that the present dissertation is a significant contribution to the implementation of sensor technologies in the monitoring of diseases in cultivated plants, which would be missed by conventional methods and approaches of examination. This, in turn, would enable timely and adequate decisions to be made to prevent their epiphytotic development.

VII. Assessment of the quality of scientific publications reflecting the results of the dissertation.

Ten scientific articles have been published on the materials related to the dissertation work, two of them in Bulgarian and the rest in English. One of the publications is independent, in four of them the doctoral student is the lead author, and in the rest the second or subsequent author. Five of the publications were printed in proceedings of scientific forums abroad, and the rest in scientific journals or proceedings of scientific organizations. One of the publications is indexed in the SCOPU scientific platform database. One of the publications was printed in 2019, and the others in the period 2020-2023, which also determines the lack of reference to their citations, because they have not become known to

the wider scientific community. The publications reflect the main parts of the dissertation are designed according to the requirements of the editorial boards, with a high scientific level and will undoubtedly attract the attention of specialists in the field of research.

VII. Critical remarks, recommendations and questions.

The dissertation is written at a high scientific level, and well-formed, and the observed gaps are insignificant and do not reflect its scientific value. As a *critical* note, I can point out the incorrect use of some terms related to plant breeding.

I *recommend* Eng. Atanasov to continue his research in the field of sensor technologies in agriculture by expanding the range of crops and research areas.

I have the following *questions* for Eng. Atanasov:

1. Is it possible to determine the species composition and population density of weeds and pathogens in individual crops through remote monitoring?

2. What are the possibilities and limitations of remote sensing technology from the point of view of soil-climatic conditions?

CONCLUSION

Based on the research methods and approaches applied by the doctoral student, the correctly conducted experiments, the generalizations and conclusions made, the scientific and scientific applied contributions, and last but not least, the high scientific level in shaping and presenting the scientific information, I believe that the present dissertation corresponds to the requirements laid down in the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Application and the Regulations of the Technical University - Varna. All this gives me a reason to evaluate this dissertation work **POSITIVELY**.

I take the liberty of recommending to the members of the respected Scientific Jury to vote **POSITIVELY** for awarding the educational and scientific degree "Doctor" to Assistant Eng. **Asparuh Ivanov Atanasov** in professional direction 5.1 "Mechanical Engineering", doctoral program "Technical Mechanics".

Date 20 February 2024 Reviewer:

TU – Varna /Prof. Ivan Dimitrov Kiryakov, PhD/