

**OPINION**  
**for dissertation**  
**for the acquisition of an educational and scientific degree “Doctor”**

Area of higher education:	4. Natural Sciences, Mathematics and Informatics
Professional field:	4.6. Informatics and Computer Science
Doctoral program:	Informatics
Dissertation topic:	Adaptive Neural Network for Processing Satellite Data with Different Spatial and Spectral Characteristics
Author of the dissertation:	Ventsislav Yuriev Polimenov
Scientific supervisors:	Assoc. Prof. Krassimira Minkova Ivanova, PhD
Author of the opinion:	Prof. Nina Hristova Dobrinkova, PhD Institute of Information and Communication Technologies at BAS
Based on:	Order of the Director of IMI No. 44/18.05.2026

The opinion has been prepared in accordance with the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Application, and the Regulations on the Conditions and Order for Acquiring Scientific Degrees and Occupying Academic Positions at BAS and IMI-BAS, as well as based on the Decision of the Scientific Jury (Minutes No.5/15.05.2026) regarding the distribution of activities among the members of the Scientific Jury under the procedure.

The main documents for the doctoral procedure have been submitted – the dissertation text with a declaration of originality, abstracts in Bulgarian and English, and the publications on which the dissertation is based, the order confirming the completion of the doctoral program, and a report on the fulfillment of the minimum requirements for obtaining the Doctoral degree (PhD).

**GENERAL DESCRIPTION OF THE DISSERTATION**

The dissertation is written in English and contains 108 pages of main text, 25 figures, 19 tables and a bibliography of 127 literary sources. The dissertation is dedicated to current and significant scientific and applied issues in the field of remote sensing of the Earth, artificial intelligence and processing of satellite images. The object of the study is multispectral satellite data from various satellite platforms for observing the Earth's surface and the possibilities for their joint use in assessing biophysical parameters of vegetation. The subject of the study is the methods and models for automated processing and analysis of satellite images with different spatial and spectral characteristics using deep neural networks. The main goal of the dissertation is the development and validation of an adaptive neural network capable of processing data from various satellite sensors in a unified architecture and providing reliable estimation of the Leaf Area Index (LAI), used as an important indicator of the condition and productivity of vegetation. To achieve the set goal, the author

develops a comprehensive methodology for generating training data, builds a multi-sensor architecture of a deep neural network and conducts a series of experiments to evaluate the accuracy, robustness and generalization capabilities of the proposed approach.

The first chapter, “Introduction”, justifies the relevance of the study and formulates the scientific problem. The motivation for developing a unified approach for processing multispectral images from different satellite platforms is presented, as well as the limitations of existing methods for estimating the leaf area index. The goal, tasks, working hypotheses and main directions of the study are formulated. The author argues for the need to use deep learning to integrate data from Sentinel-2 and Landsat 8/9 and outlines the challenges associated with the different spatial and spectral resolution of the data used.

Chapter two “Research Background” contains an in-depth literature review of modern approaches to remote sensing of vegetation and assessment of biophysical parameters using satellite data. The main characteristics of the satellite platforms and sensors used are analyzed, vegetation indices, atmospheric correction methods and modern approaches to LAI estimation are reviewed. Particular attention is paid to the development of methods based on machine and deep learning. The literature review is well structured and shows excellent knowledge of the state of the scientific field.

In the third chapter, “Methodology”, the methodology developed by the author for multisensor LAI estimation is presented. The process of generating training data by combining different vegetation indices is described, a complete data processing chain is built, and an original architecture of an adaptive neural network ANNSIA is proposed, based on U-Net, Conditional Batch Normalization, and Atrous Spatial Pyramid Pooling. The strategies for data preparation, normalization, training, and model validation are discussed in detail. A significant contribution is the proposed approach for balancing data from different sensors, which allows for stable training and prevents the dominance of larger data sets.

In the fourth chapter “Experiments and Results” the experimental studies and the obtained results are presented. Spatially correct validation was performed using geographical blocks, which allows a realistic assessment of the generalization capabilities of the model. Comparative experiments were conducted between single-sensor and multi-sensor models, the influence of individual spectral channels was analyzed and the model’s ability to transfer to new geographical areas and different time periods was assessed. The obtained results demonstrate high accuracy of the proposed approach and confirm the effectiveness of multi-sensor training.

The fifth chapter, “Conclusions”, summarizes the main scientific results and contributions of the dissertation. The advantages and limitations of the proposed approach are analyzed, directions for future research and opportunities for expanding the model to other biophysical indicators and additional data sources are formulated. The presented conclusions are logically justified and arise directly from the conducted research and experimental results.

The dissertation is original and independently developed by the author. The sources used are correctly cited.

## **ASSESSMENT OF THE DISSERTATION ABSTRACT**

The abstract is presented in Bulgarian and English, in accordance with the law requirements. It adequately reflects the main goals, methods, and results of the research. It provides sufficient information to understand the significance of the development and successfully summarizes the author's key contributions.

## **CONTRIBUTIONS OF THE DISSERTATION**

The main contributions of the dissertation can be classified as follows:

### **Scientific Contributions:**

1. A multi-sensor deep learning model integrating U-Net, Conditional Batch Normalization and Atrous Spatial Pyramid Pooling into a single architecture for sensor-invariant learning without prior input data alignment is developed. The approach is validated with Sentinel-2 and Landsat 8/9 for leaf area index (LAI) estimation.
2. A method for balancing training on multisensor data is proposed by augmenting and equalizing the participation of individual sensors within the training epochs. A degradation regime is identified in the case of an imbalance in the number of training examples, in which the majority sensor dominates and limits the intersensor generalization ability. Balancing the participation of sensors ensures stable operation of Conditional Batch Normalization and sensor-invariant training for unevenly distributed data.
3. A methodology for generating pseudo-reference LAI data by ensemble combining Beer-Lambert transformed vegetation indices (NDVI, GNDVI and SAVI) has been developed. The selected indices provide complementary sensitivity to vegetation density, chlorophyll content and soil background, while being sensor-agnostic to Sentinel-2 and Landsat 8/9. The approach allows training of deep neural models in the absence of large-scale field measurements.
4. A multi-level framework for validation of LAI estimation models with circularity in training labels based on vegetation indices is proposed. The framework integrates five levels: (1) spatial block cross-validation on a 4×4 geographic grid, (2) comparison with operational products (SNAP Biophysical Processor), (3) physically based verification using PROSAIL, (4) analysis of geographic and temporal transferability through zero-shot transfer and intersensor consistency, (5) comparative analysis against empirical vegetation indices 40 and their ensemble. The approach provides a reproducible validation protocol without spatial data leakage, assessing statistical robustness, physical consistency, and spatiotemporal generalization.

### **Scientific-Applied Contributions:**

1. A comprehensive methodology for estimating the leaf area index (LAI) from multi-sensor satellite data over agricultural areas in Bulgaria has been implemented, based on freely available images from Sentinel-2 and Landsat 8/9.
2. It has been experimentally proven that the proposed multi-sensor model outperforms single-sensor approaches and classical vegetation indices, with spatially rigorous validation achieving significant improvements in accuracy in LAI estimation.
3. The possibility of geographical and temporal generalization of the proposed model has been demonstrated by successful application on independent regions and images acquired in different periods without additional training.

### **Applied Contribution:**

1. An integrated computational framework is developed for processing multispectral satellite images, training deep neural models, and generating full-scene LAI maps on a high-

throughput infrastructure. The output of results from entire scenes is performed through a sliding window with seamless merging of overlapping fragments, which provides continuous output maps for landscape monitoring.

## **PUBLICATIONS AND OTHER ACTIVITIES RELATED TO THE DISSERTATION TOPIC**

**Ventsislav Polimenov** presents three publications related to the topic of the dissertation, two of which are co-authored with the scientific supervisor. The three articles are visible in Scopus, and the article in the international conference SGEM2024 also has an SRJ (2025) = 0.141, which meets the minimum requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Application for acquiring the ONS "doctor". The publications reflect essential elements of the research on the dissertation.

The three publications were presented at relevant international conferences, which gave the presented results visibility among a wider expert community. The publication “Remote Sensing for Smart Agriculture Monitoring Pepper Crops” also has two citations visible on the Scopus platform.

## **CRITICAL NOTES**

The dissertation work is developed at a high scientific level and contains a significant amount of theoretical and experimental research. As a recommendation for future development, the need to expand the experimental validation by using a larger volume of field measurements of LAI, which would allow for additional confirmation of the absolute accuracy of the proposed model, can be indicated. Also of interest is the expansion of the approach to additional biophysical indicators and the inclusion of other types of remote sensing data.

The above remarks do not reduce the value of the obtained scientific results and do not question the qualities of the dissertation work.

## **CONCLUSION**

The dissertation complies with the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria, the Regulations for its Application, and the Regulations on the Conditions and Order for Acquiring Scientific Degrees and Occupying Academic Positions at BAS and IMI-BAS for acquiring an educational and scientific degree “doctor” in a professional field 4.6. Informatics and Computer Science, doctoral program “Informatics”. **Ventsislav Polimenov** possesses theoretical knowledge and professional skills for conducting independent scientific research.

I give my positive assessment of the presented dissertation work and propose to the Honorable Scientific Jury to award **Ventsislav Yuriev Polimenov** the educational and scientific degree “Doctor” in area of higher education 4. Natural Sciences, Mathematics and Informatics; professional field 4.6. Informatics and Computer Science; doctoral program “Informatics”.

25.06.2026

Sofia, Bulgaria

Signature:

Prof. Nina Dobrinkova, PhD