

OPINION



on a dissertation for obtaining the educational and scientific degree "Doctor" in the field of higher education 6. Agricultural Sciences and Veterinary Medicine, professional field 6.1 Crop Production, scientific specialty "Forage production and grasslands"

Author of the dissertation: Ivelin Dimitrov Markov full-time PhD student at the Department of Crop Production at the Agricultural University, Plovdiv.

Thesis topic: "Investigate the impact of different sustainable turf management practices on soil C sequestration on intensively maintained sand-based putting greens and how their implementation affects the annual carbon budget"

Reviewer: Prof. Dr. Vanya Atanasova Delibaltova, Agricultural University, Plovdiv. Crop Production Department, in the field of higher education 6. Agricultural Sciences and Veterinary Medicine, professional field: Crop Production, scientific specialty "Crop Production", appointed as a member of the scientific jury by order № РД16-209/02.02.2026 from the Rector of AU.

1. Relevance of the problem.

Increasing urbanization replaces forests and agricultural lands with maintained green areas such as lawns, meadows, parks, sports fields, and golf courses. Within this green infrastructure, sports turf and golf courses represent a high-profile and management-intensive component. Golf courses, and putting greens in particular, require precise and sustainable management of nutrients, irrigation, and cultural practices to maintain high-quality playing surfaces and achieving environmentally sustainable levels of soil carbon.

In this connection, the presented dissertation is not only relevant but also important for the science and practice, because demonstrates the transformative potential of data-driven, AI-enhanced practices to optimize resource inputs, improve turf resilience, and predict turf behavior under environmental stress – guiding a new generation of sustainable turfgrass management on sand-based greens. The work is linking fundamental turf management challenges with advanced decision support technologies, and provides a scalable framework for sustainable, precision management of golf course greens and other turfgrass systems.

2. Purpose, tasks, hypotheses and methods of research.

The purpose of the dissertation work is clearly and precisely formulated, corresponding to the proposed title and predetermining the direction of the scientific work. In unison with the set main goal and four secondary goals During the period 2019 – 2025, experiments were conducted on two golf courses in Bulgaria and China. The methodological part is formulated correctly and occupies an important part of the dissertation work. The methods and approaches used are up-to-date and scientifically sound. It should be noted that the scope of the study is quite large, conducted under

field conditions and valuable from a practical and applied point of view .

3. Visualization and presentation of the results obtained.

The dissertation has a volume of 243 standard pages and includes 10 main sections, which in terms of volume , structure and balance between the hotel parts correspond to fully meet the requirements for awarding the ONS "Doctor". The received results are summarized and very well illustrated , through skillful use of 43 tables and 94 figures , which show precision in the doctoral student's work and contribute to a better understanding of the thesis.

4. Discussion of the results and literature used .

A comprehensive and in-depth literature review on the topic has been conducted, presenting the views of a number of researchers on the problem under consideration.

The literature review is presented on 54 pages, and includes 456 sources in Latin, which comprehensively reflect the problem. It is evident that the doctoral student is well informed, skillfully uses literary sources and is familiar with the topic of the dissertation work in depth.

The discussion of the results is done consistently, competently and thoroughly, by interpreting the results in accordance with modern scientific achievements in this field. In the discussion, the doctoral student skillfully compares, compares and comments on the results obtained based on the data of other authors. The dissertation shows that the doctoral student can conduct independent experimental work and correctly interpret a large volume of obtained data, which are analyzed in detail, and the results of the analysis are used to formulate conclusions and recommendations.

5. Contributions to the thesis.

The results obtained allow to form following groups of contributions:

Scientific contributions

Introduces a carbon-aware “narrow operating envelope” framework for intensively managed sand-based putting greens.

Explainable temporal irrigation dynamics with actionable VWC and ETc thresholds.

Spatial irrigation heterogeneity as a within-green diagnostic layer.

Establishes predictable seasonal rooting trajectories and stable treatment hierarchies under contrasting irrigation regimes

Defensible remote-sensing pipeline, enabling consistent multi-year monitoring on heterogeneous golf-course imagery.

Probabilistic integration and validation of a Bayesian Network DSS.

Scientifically applied contributions

An “operating range” framework is applied to aid field diagnostics of whether carbon risk is dominated by moisture, oversupply , deficiency or repeated exposure to stress, rather than assuming that turfgrass performance is a sufficient indicator of resilience. Irrigation planning rules based on VWC and ETc thresholds are introduced , as well as a workflow for spatial remediation of uneven moisture. Spatial diagnostic approaches allow for practical distinction between irrigation planning problems and applied water distribution problems.

Root mass loss risk prediction is applied to refine irrigation thresholds and “nitrogen” safety margins. Evidence nodes are introduced for routine monitoring and integration into a decision support system (DSS). The proposed Bayesian decision support system based on artificial intelligence (BN-DSS) translates empirical results into operational probabilistic reasoning and allows quantitative comparisons of irrigation and fertilization strategies, reducing the reliance on static schedules or univariate approximation rules and increasing the transparency of the logic behind decision making.

Practically applied scientific contribution:

A functional, modular dashboard was developed as the user-facing implementation layer of the SMART BN-DSS, translating the dissertation’s thresholds and state definitions into day to-week operational decisions. The dashboard consolidates weather and sensor evidence, computes shared derived drivers used across modules and presents aligned state interpretations across irrigation, fertilisation, root development, canopy monitoring, and organic-matter tracking.

As a practical decision-support tool, the dashboard enables site-specific historical diagnosis, short-horizon planning, and scenario exploration while maintaining an auditable record of actions and outcomes. By integrating temporal rules, spatial diagnostics and remote-sensing evidence, it provides a coherent interface for adaptive management under uncertainty and supports carbon-aware optimisation within routine maintenance constraints.

6. Critical notes and questions.

I have no critical remarks, questions or recommendations regarding the dissertation.

7. Published articles and citations.

Three publications directly related to the dissertation work are attached, of which two are independent and one is co-authored with the scientific supervisor. The total number of points is 35 (30 points required) and exceeds by 16.7% the minimum required for the acquisition of the educational and scientific degree "Doctor" according to Law for the Development of the Academic Staff.

No document has been submitted to cite the articles.

The submitted abstract objectively reflects the structure and content of the dissertation. The abstract is presented in a synthesized form, meets the requirements and provides a clear idea of the achievements of the doctoral student.

CONCLUSION:

On the basis of the various research methods, learned and applied from the PhD student, the correctly performed experiments, the summaries and the conclusions made, I consider, that the submitted dissertation meets the requirements of the Law for the Development of the Academic Staff of Republic Bulgaria and the Regulations of the Agricultural University for its application, which gives me a reason to evaluate it **POSITIVE.**

Taking into account the extensive experimental material, the originality of the results achieved and the importance of the scientific and scientific applied contributions in the dissertation, as well as the undoubted personal contribution of the PhD student, I dare to suggest to the venerable Scientific Jury also to vote positively and award **Ivelin Dimitrov Markov** the educational and scientific degree „**Doctor**” in scientific specialty “Forage production and grasslands”

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Plovdiv

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