

REVIEW

by Assoc. Prof. Dr Svetla Bratanova-Doncheva, Institute of Biodiversity and
Ecosystem Research, Bulgarian Academy of Sciences (IBER-BAS),

of the PhD dissertation by Assistant **Vanya Emilova Stoycheva** entitled "*Integrated Assessment of Regulating Ecosystem Services in Urban Areas*", submitted for the award of the educational and scientific degree "Doctor" in professional field 4.4. "Earth Sciences", scientific specialty "Physical Geography and Landscape Ecology"

Scientific supervisor: **Prof. Dr Stoyan Tsvetanov Nedkov**

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The present review has been prepared in accordance with Order No. 01-149/02.07.2026 of the Director of the National Institute of Geophysics, Geodesy and Geography – BAS, pursuant to Article 4, paragraph 2 and Article 9, paragraph 1 of the Law on the Development of the Academic Staff in the Republic of Bulgaria (LDASRB), Article 2, paragraph 2 and Article 30, paragraph 3 of the Regulations for the Implementation of the LDASRB, paragraph 1, item 3 of the Supplementary Provisions to the Regulations for the Implementation of the LDASRB, and Article 27 of the Regulations on the Conditions and Procedure for Awarding Scientific Degrees and Holding Academic Positions at NIGGG-BAS, and in connection with Report No. 281/02.07.2026 of the Acting Head of the Department of Geography.

Personal details of the doctoral candidate

Vanya Emilova Stoycheva was born on 17 June 1997. She completed a Bachelor's degree in Geography at Sofia University "St. Kliment Ohridski" in 2020, and subsequently continued her education in the Master's programme in Landscape Ecology at the same university. Since 2022, she has been a doctoral student at the National Institute of Geophysics, Geodesy and Geography – BAS. Her professional development at NIGGG has been purposeful and continuous: technical organiser (2019–2020), geographer (2020–2022), full-time doctoral student (2022–2025, completed with the right to defend her dissertation), and, since March 2025, Assistant.

Her professional career is closely related to geography and landscape ecology, as well as to the collection, processing and analysis of spatial data. Vanya Stoycheva has participated in eight scientific projects related to the assessment and mapping of

ecosystems and ecosystem services in Bulgaria and Europe. She works as an expert in the field of ecosystem services, including as an IPBES Contributing Author, and as a consultant to the World Bank in connection with the project “Support for the Preparation of River Basin Management Plans and Flood Risk Management Plans in Bulgaria”.

1. General characteristics and relevance of the dissertation

The dissertation consists of an introduction, five publication-based chapters, a synthesis, a reference list, appendices, a list of abbreviations, a list of figures, a list of tables, a list of publications, and a declaration of originality. The dissertation comprises 201 pages, including 61 figures and 13 tables. The reference list contains 285 sources.

The dissertation has been prepared in a publication-based format and contains all elements required for this type of presentation. It is structured into eight chapters and follows the established logic of scientific research: Chapter 1 – Introduction – relevance of the topic and objectives; Chapter 2 – Methodological basis, including a literature review and formulation of the objectives and research tasks; Chapters 3–7 – Publications presenting the **results and discussion** related to the formulated tasks; Chapter 8 – Synthesis – analysis of the results, assessment of the applicability of the models and databases, development of an integrated approach, limitations and uncertainties of the methods used, opportunities for further development of the research, conclusions and contributions.

The abstract meets the generally accepted requirements, comprises 66 pages, follows the main structure of the dissertation, and summarises its principal aspects. It demonstrates systematicity and originality.

The topic is well justified. The dissertation is devoted to the development of a methodological approach for the integrated assessment of regulating ecosystem services in an urban environment, with a specific application to the territory of Sofia Municipality.

The topic is relevant from both scientific and applied perspectives. The development of the concepts of ecosystem services, natural capital, green infrastructure and nature-based solutions increasingly raises the issue not only of identifying and quantitatively assessing ecosystem services, but also of their spatial distribution, societal demand, and the correspondence between supply and needs.

This issue is particularly important in urban environments, where ecosystems are highly fragmented, anthropogenic pressure is high, and demand for regulating services is substantial but spatially uneven. In this context, the development of approaches capable of integrating different types of spatial information and different assessment methods has clear scientific and practical value.

The dissertation has been developed in a **format based on scientific publications**. This feature is important when assessing the structure and scientific coherence of the work. In the present case, the publication-based format has been used convincingly. The publications are not mechanically assembled independent studies; rather, they represent successive stages in the development of a common scientific and methodological concept.

The logic of the research can be traced as follows:

diagnosis of the spatial information base → assessment of input data → comparison and adaptation of models → integration of supply and demand → multi-tier integrated assessment of several regulating ecosystem services.

This sequence is one of the principal strengths of the dissertation.

Chapter 8 is particularly important in the publication-based format because it fulfils the role of an overarching scientific synthesis. It does not merely repeat the results of the individual publications, but reconstructs the common methodological framework, discusses limitations and uncertainties, and outlines directions for future development.

For this reason, I consider that the dissertation possesses the necessary scientific coherence irrespective of its publication-based format.

2. Scientific problem, aim and objectives

The central **scientific problem** is clearly identifiable: the need for a methodological approach for an integrated, spatially explicit assessment of regulating ecosystem services in an urban environment in the presence of spatial data differing in quality, resolution and accessibility.

The stated **aim** – to develop a methodological approach for the integrated assessment of urban regulating ecosystem services – is appropriate to the identified problem.

I particularly appreciate that the research is not limited to assessing the potential **supply** of ecosystem services. Spatial **demand** is introduced successively and, on this basis, the **balance between supply and demand is assessed**. This represents an

important step from a purely biophysical assessment towards an assessment with the potential to support actual management and spatial-planning decisions.

The research tasks are logically interconnected and enable a gradual progression towards the main result – the development and demonstration of an integrated multi-tier approach.

3. Structure and logic of the research

The structure of the dissertation demonstrates the sequential development of the scientific problem.

The literature analysis identifies priority regulating ecosystem services, methods for their assessment, required data, and major knowledge gaps.

In the next stage, a critical analysis of the national ecosystem database was conducted. The identified inconsistencies in typology, coding and spatial compatibility of the data were not left as isolated findings, but became the basis for subsequent improvement of the information base. This was developed further in a publication through comparison of two surface-runoff regulation models and analysis of the influence of input data on the results.

The next step is the integration of supply and demand for two highly important regulating services in an urban environment – cooling regulation and filtration of fine particulate matter (PM10). Finally, the approach is synthesised and extended to six regulating ecosystem services through a multi-tier framework.

Thus, the publications fulfil different scientific functions:

- **Publication 2** – diagnosis of the information base;
- **Publication 3** – analysis of the relationship between data and modelling;
- **Publication 4** – integration of supply, demand and balance;
- **Publication 5** – synthesis and extension to a multi-tier integrated assessment.

It is precisely this sequence that allows the publication-based format to be evaluated as a **cumulative scientific study** rather than as a collection of unrelated publications.

4. Methodology and information base

The methodological toolkit is broad and appropriate to the complexity of the problem. GIS analyses, remote-sensing data, spatial modelling, spatial statistics, spatial proxies, expert assessment, and ecosystem-service assessment models have been applied.

The work with the spatial information base is particularly impressive. The comparison and integration of the national ecosystem typology, Urban Atlas, CORINE, and green-infrastructure information constitutes a substantial component of the methodological work. Here the dissertation demonstrates an important but often underestimated aspect of spatial ecosystem-service assessment: **the result depends not only on the selected model, but also on the quality, compatibility and spatial resolution of the input data.**

The comparison of InVEST and IMECOGIP/EnhanceES demonstrates precisely this point. It is important to clarify that the scientific originality does not consist in developing fundamentally new models for individual ecosystem services. Existing tools have been used. The scientific contribution lies in **adapting, localising, comparing and integrating these tools with local spatial data, and in developing procedures for assessing supply and demand within a common methodological framework.**

In my view, this formulation most accurately reflects the actual scientific value of the work.

5. Main results

5.1. Analysis and improvement of the spatial database

The first substantial result is the critical assessment of the national ecosystem database. The identified problems in typology, coding, spatial integrity and compatibility of the individual layers have significance extending beyond the specific study.

This result is important because it demonstrates the need for a reliable and internally consistent spatial information base for any subsequent assessment of ecosystem condition and ecosystem services. **The integration of different sources of spatial information is a logical and necessary continuation of this result.**

5.2. Significance of input data for modelling

The comparison of surface-runoff regulation models under different input-data conditions is one of the methodologically important results. It demonstrates that **spatial resolution, thematic accuracy and compatibility of the input information can substantially affect the final assessment of an ecosystem service.**

This supports the subsequently proposed multi-tier concept, in which the choice of method is not made independently of the information environment.

5.3. Integrated assessment of supply and demand

The assessment of regulating services – cooling regulation and filtration of PM10 – represents a substantial development of the research. I particularly appreciate the inclusion, in the assessment of demand, of components related to hazard, exposure and vulnerability.

This makes it possible to move from the question:

“Where do ecosystems provide a given regulating service?”

to the more practical question:

“Where does service provision correspond to the spatially distributed need for it?”

This transition is important for turning ecosystem-service assessment into a tool for spatial planning.

5.4. Multi-tier integrated assessment

In my view, this is the central methodological result of the dissertation.

The developed framework enables six regulating ecosystem services to be assessed at different levels of methodological detail depending on the availability and quality of data. This approach is particularly valuable because it treats information heterogeneity as a real condition of the research.

In practice, it is unrealistic to expect equally high-quality information for all ecosystem services. Therefore, **the possibility of assessing different services at different levels while including them within a common analytical framework represents a practically significant methodological result.**

6. Scientific and methodological contributions

The contributions claimed in the dissertation are, in substance, well founded. However, I consider that their scientific weight should be differentiated.

First contribution – scientific-analytical

A systematic synthesis has been conducted of priority regulating ecosystem services, methods for their assessment, required spatial data, appropriate scales, and major knowledge gaps in the urban context. This contribution is primarily **analytical and synthesising** rather than the independent development of a new theory.

Second contribution – methodological

Existing models have been adapted to local conditions and data; crosswalk procedures have been performed and the spatial information base has been

improved. **Procedures for assessing** the supply and demand of regulating ecosystem services have been developed and applied.

Third contribution – principal scientific-methodological contribution

A **multi-tier integrated framework** has been developed and demonstrated for assessing the supply, demand and balance of regulating ecosystem services, in which the methodological level selected is adapted to the availability, quality and uncertainty of the data.

This is the contribution that I regard as **the most significant** in terms of the scientific originality of the dissertation.

Fourth contribution – methodological-applied

Different spatial databases have been integrated, and Hot Spot and Local Moran's I analyses have been applied to identify spatial configurations that may indicate potential synergies, conflicts, and areas with deficits or surpluses of regulating ecosystem services.

It should be emphasised here that these analyses reveal spatial associations, but do **not in themselves demonstrate causal ecosystem interactions**.

7. Scientific assessment and issues for discussion

My positive assessment of the dissertation does not preclude several methodological issues which, in my view, are important for scientific discussion and the future development of the approach.

7.1. Comparability of the different Tier 1–3 levels

The multi-tier approach is both a strength and a methodological challenge. Tier 1, Tier 2 and Tier 3 rely on substantially different sources and methods – from expert assessment and spatial proxies to quantitative modelling. Therefore, normalisation of the results enables their mathematical integration, but does not eliminate differences in their reliability and uncertainty.

This raises an important question for the future development of the approach: **can the uncertainty associated with the different tiers be explicitly incorporated into the final integrated assessment?** In my view, this would be a natural next methodological development of the proposed framework.

7.2. Independent empirical validation

The dissertation contains substantial work on improving and checking the spatial data. This is undoubtedly an advantage.

However, a clear distinction should be made between verification of the spatial information base and independent empirical validation of the ecosystem-service models themselves.

Due to the limited availability of field data, validation has been performed only to a limited extent. This does not compromise the methodological value of the dissertation, but it places a limitation on the quantitative interpretation of the results obtained.

7.3. Equal weights in the integration of services

The use of equal weights is a transparent and readily reproducible solution, but it represents a normative assumption. It cannot be assumed that all services have equal relative importance in every urban area.

Therefore, future applications of the approach could include **sensitivity analysis with respect to different weighting schemes, including schemes based on expert assessments or stakeholder preferences.**

7.4. Synergies and trade-offs

The applied spatial statistical methods are appropriate for identifying spatial associations. However, **they do not in themselves demonstrate causal relationships between ecosystem services.**

Therefore, I consider it scientifically more precise to define the identified configurations as **potential synergies and conflicts**, which should be confirmed through additional ecological and functional research.

7.5. Transferability of the approach

The methodological framework is demonstrated for Sofia. This is acceptable and justified for a case study with a methodological objective. Its applicability to other cities, however, should be regarded as a **potential for transfer** rather than as already demonstrated **universality**. The dependence on local data and conditions is both a limitation and a characteristic of the proposed framework.

I would raise several substantive questions, for example:

1. How does the author ensure comparability among Tier 1–3 when integrating them?
2. How does the lack of independent empirical validation affect the reliability of the quantitative results?
3. How is the choice of equal weights among the six services justified?

4. To what extent do Hot Spot/Local Moran analyses allow one to speak of synergies and trade-offs rather than merely spatial co-occurrences?

5. What is specifically novel in the proposed framework compared with existing multi-tier / MAES / InVEST / EnhancES approaches?

I would not present these as “remarks that need to be addressed or explained and analysed”, but rather as **scientific discussion questions** on which I would like to hear the doctoral candidate’s views.

7.6. Significance and confidence of the results, interpretations and conclusions

The results of the dissertation are significant primarily from a **methodological and scientific-applied perspective**. They consistently demonstrate the importance of the quality and compatibility of spatial data for ecosystem-service assessment and demonstrate the applicability of a multi-tier approach under varying availability and quality of information. Particularly significant is the integration of assessments of supply, demand and balance for several regulating ecosystem services within a common spatial framework.

The interpretations and conclusions are, overall, logical, well substantiated and consistent with the results obtained. The author demonstrates a good ability to discuss the limitations and uncertainties of the data and models used. The confidence in the quantitative interpretation of the results could be further strengthened through broader independent empirical validation and sensitivity analysis of the choice of weights used to integrate the individual ecosystem services.

These limitations, however, are clearly recognised and discussed in the dissertation and do not diminish its scientific or research-applied value.

8. Personal contribution of the doctoral candidate

The declared CRediT contributions provide a sound basis for assessing the candidate’s personal involvement. In the last two publications, she is identified as contributing to virtually all major stages of the research – conceptualisation, data collection and processing, methodology, formal analysis, software implementation, validation, visualisation, and preparation of the original manuscript.

The scientific supervisor has made substantial contributions to conceptualisation, methodology, provision of resources, supervision and editing.

On this basis, I consider that the doctoral candidate has made a **clearly identifiable personal contribution** to the development and implementation of the scientific research.

9. Publication activity

The publication output is directly related to the topic of the dissertation. It is particularly positive that the publications represent different stages in the development of the scientific concept rather than repeating the same methodology with different datasets.

Publication 2 establishes the information base, **Publication 3** analyses the relationship between data and modelling, **Publication 4** develops the concept of supply–demand–balance, and **Publication 5** synthesises it within a multi-tier framework.

In the formal assessment of the publication activity, the actual status of the individual publications should be taken into account. The publication in Urban Climate is indicated as “Under review”, while that in Acta geographica Slovenica is listed as “Submitted”. Their formal status as publications should therefore be distinguished, but this does not diminish the **scientific value** of the manuscripts developed.

10. Practical significance

I assess the practical significance of the dissertation as high.

The proposed approach has potential applications in:

- urban and spatial planning;
- planning and management of green infrastructure;
- identification of areas with deficits of regulating ecosystem services;
- prioritisation of nature-based solutions;
- climate change adaptation;
- assessment of urban vulnerability;
- planning of green corridors and other green-infrastructure elements.

Particularly valuable is the transition from mapping ecosystem services to **identifying spatial mismatches between their supply and societal demand**. This substantially increases the potential of the results for real-world management applications.

11. Overall assessment

In summary, I would characterise the dissertation as **a methodologically oriented scientific study with high applied relevance and I rate it highly.**

Its principal scientific merit does not lie in creating fundamentally new models for individual ecosystem services, but in constructing an **integrated methodological architecture** in which:

- data quality is part of the method-selection process;
- different services can be assessed at different levels;
- supply assessment is linked to demand assessment;
- results are integrated through spatial balance;
- multiple regulating services are considered within a common framework;
- spatial statistical analyses support the identification of potential synergies, conflicts and priority areas.

This constitutes a real **methodological contribution.**

I also particularly appreciate the scientific integrity with which the author presents the **limitations** of her research – related to data quality, the lack of sufficient independent observations, model uncertainty, expert assessments, and limited testing of transferability.

In this context, I would make one important clarification: **the multi-tier approach does not eliminate uncertainty; rather, it structures it and makes it explicit, while allowing the choice of method to be adapted to the available information base.** This is precisely where I see one of its important advantages.

The most significant scientific-methodological result is **the development and demonstration of a multi-tier integrated approach for the spatial assessment of the supply, demand and balance of regulating ecosystem services, adapted to differences in the availability, quality and uncertainty of the information base.** Significant contributions also include the critical analysis and improvement of the spatial information base, demonstration of the influence of input data on modelling results, and integration of multiple regulating ecosystem services within a common analytical framework.

The doctoral candidate demonstrates the ability to formulate a scientific problem, critically analyse the existing scientific and information base, select and adapt appropriate methods, work with complex spatial data, and integrate the resulting

findings into a common methodological framework. This is also the principal objective of doctoral education – to prepare the doctoral candidate for independent scientific research.

12. Conclusion

The dissertation entitled ***“Integrated Assessment of Regulating Ecosystem Services in Urban Areas”***, submitted by Assistant **Vanya Emilova Stoycheva**, represents a independent scientific study devoted to a relevant and significant scientific and applied problem.

I consider that the dissertation possesses the necessary scientific and scientific-applied qualities and demonstrates the required level of scientific maturity and independence of the doctoral candidate.

On this basis, I give a positive assessment of the dissertation and recommend the esteemed Scientific Jury award Assistant Vanya Emilova Stoycheva the educational and scientific degree “Doctor” in professional field 4.4. “Earth Sciences”, scientific specialty “Physical Geography and Landscape Ecology”.