BOOK OF ABSTRACTS

I. SESSION DESCRIPTION

ID: T19b

Artificial Intelligence and Ecosystem Services – Advancements in AI in the field of ecosystem services for transformative change

Hosts:

	Name	Organisation	E-mail
Host:	Vince van 't Hoff	Foundation for Sustainable Development	vince.vanthoff@fsd.nl
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Abstract:

Artificial intelligence (AI) is quickly emerging as a powerful tool for rethinking the way we understand, monitor, and manage ecosystems and their services. From satellite image analysis to natural language processing, AI technologies offer innovative solutions for extracting valuable insights from complex data types and provide a way to effectively and efficiently gather and analyze vast amounts of data. In a world with increasing reliance on technological advancements to map, model, assess and monitor ecosystem service changes, harnessing the power of AI has the potential to transform the way we understand and approach ecosystem services (ES) and their

functions (EF). This is not a goal in itself, but it should ultimately serve to account for the value of nature in an equitable way in decision making. Taking a one health perspective allows to balance environmental, social and economic needs with intrinsic value of nature.

This session aims to contribute to transformative change via highlighting and discussing advances in the field of ES related to AI. We aim to set the scene by highlighting the transformative potential and key challenges of AI. We will discuss best practices and inspiring examples to spark imagination to use AI in the diverse field of ES. For example, how can learning algorithms such as machine learning, deep learning and transfer learning support the assessment of ES and EF? Given the diverse methods available, including using GeoAI to derive indicators from remote sensing images, data extraction to effectively gather, streamline and standardize relevant information from scientific literature (and contribute to the ESVD), how can AI be leveraged to enhance the assessment and modelling of the supply, demand and flow of ES and EF? How does AI contribute to meeting the growing demand for inclusion to cater to "peoples' obligations to nature" and "nature's contribution to people" in ES and EF assessment? What are the trade-offs and synergies among ES and EF in different scenarios?

Furthermore, the session will highlight the importance of collaborative efforts in guiding the rapid developments in AI and ES research. By fostering discussion, awareness of each other's projects and interdisciplinary collaborations between ecologists, data scientists, policymakers, and other stakeholders, we can leverage collective expertise to address key challenges and discuss new opportunities in ES assessment and management.

We cordially invite you to contribute to our session with an abstract related to a broad range of perspectives regarding the transformative potential of AI for ES. Not limited to and including best practices and ethical, methodological, applicational considerations of AI in mapping and assessing ES. Communications to be presented at this session will be possibly considered for either a synthesis paper or a review paper showcasing knowledge gaps in AI use in ES in empirical or modelling contexts.

Goals and objectives of the session:

- Explore Recent Advancements: To showcase and discuss the latest advancements in AI technologies and methodologies relevant to ecosystem services research, including data extraction, analysis, and interpretation.
- Promote Collaboration: To foster interdisciplinary collaboration and knowledge exchange among researchers, practitioners, policymakers, and other stakeholders interested in leveraging AI for ecosystem services assessments and management.
- Share Best Practices: To identify and share best practices for integrating AI technologies into existing research methodologies and workflows.

- Address Ethical Considerations: To raise awareness and facilitate discussions around the ethical considerations, potential biases, and limitations associated with AI-driven approaches in ecosystem services research, and to explore strategies for mitigating risks and ensuring responsible use of AI technologies.
- Inspire Innovation: To inspire innovation and creativity in the application of AI technologies to address pressing environmental challenges and promote sustainable management of ecosystems and their services.
- Identify Opportunities: To identify opportunities for future research, collaboration, and capacity building in the intersection of AI and ecosystem services, with the aim of advancing scientific understanding, informing policy decisions, and enhancing conservation efforts.

Planned output / Deliverables:

Possibly a special issue/a paper based on discussions during the day.

II. SESSION PROGRAM

Room: Expert Street 5

Date of session: 18th of November 2024

Time of session: 14:00–15:30 & 16:00–17:30

Timetable speakers

Time	First name	Surname	Organization	Title of presentation
14:00–14:05	Vince	Van 't Hoff	Foundation for Sustainable Development (FSD)	Introduction
14:05–14:20	Ferdinando	Villa	ARtificial Intelligence for Environment & Sustainability (ARIES)	**Keynote**: From open to integrated ES science with AI
14:20–14:30	Felicia O.	Akinyemi	Karlstads Uiversity	A Spatial Data Science and Remote Sensing approach to predicting drought impacts on agricultural production in tropical dryland contexts
14:30–14:40	Hugo	Deléglise	Université Grenoble Alpes	Integrating optimization-based AI methods, ecosystem services and ecological connectivity to strengthen Peru's protected area system towards the 30*2030 target.
14:40–14:45	**Q&A**			**Presentations 1&2**
14:45–14:55	Nils	Barthel	Leibniz University Hannover	Comparative Analysis of MaxEnt and Deep Learning Approaches for Modelling Humpback Whale Distribution in Northern Iceland
14:45–15:05	Robbe	Neyns	Free University Brussels	Automated mapping of bee-friendly trees: a novel approach to enhance pollinator conservation
15:05–15:10	**Q&A**			**Presentations 3&4**
15:10–15:20	Pedro	Cabral	Nanjing University of Information Science & Technology	Assessing Determinants of Forest Gross Primary Productivity in China Using Machine Learning Approaches

Time	First name	Surname	Organization	Title of presentation
15:20–15:30	Jinzhou	Wu	Free University Brussels	Mapping the allergenicity of urban green spaces using very-high-resolution remote sensing data
15:30–15:35	**Q&A**			**Presentations 5&6**
16:00–16:05	Vince	Van 't Hoff	Foundation for Sustainable Development (FSD)	Introduction
16:05–16:15	Philip	Roche	French National Institute for Agriculture, Food, and Environment (INRAE)	Leveraging AI for Enhanced Systematic Reviews: Insights from Ecosystem Condition Indicators
16:15–16:25	Stefano	Balbi	ARtificial Intelligence for Environment & Sustainability (ARIES)	Navigating connected data and models through semantics for better ecosystem services modelling and accounting
16:25–16:35	Robert	Costanza	University College London	Beyond GDP with AI
16:35–16:45	**Q&A**			**7&8&9**
16:45–17:10	Small groups	Discussion		Discussion 4 statements on ES and AI considering data, ethics and the future
17:10–17:25	Plenary	Discussion		Discussion 4 statements on ES and AI considering data, ethics and the future
17:25–17:30	Vince	Van 't Hoff		Wrap-up

III.ABSTRACTS

The first author is the presenting author unless indicated otherwise.

1. A Spatial Data Science and Remote Sensing approach to predicting drought impacts on agricultural production in tropical dryland contexts

First authors(s): Hannah Kemper

Presenting author: Felicia O. Akinyemi

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Droughts represent a threat to agricultural production and ecosystem services. Considering the expected impact of global warming, the severity and damages by droughts will increase further. To address this issue, the implementation of a drought early warning system is a crucial step to avoid crop failure, malnutrition, and hunger. For the conceptualization of such an early warning system, the study employs a GeoAI approach based on Spatial Data Science and Remote Sensing. There is the need to define thresholds for specific indicators, disseminate the warning and a proper understanding of drought dynamics.

The research was conducted for the study area of Botswana using a combination of yield statistics and remote sensing based data on vegetation conditions and rainfall. Further variables included the Southern Oscillation Index (SOI) to describe effects of El Niño. The methodology centers around data processing and applying geospatial analytics in python, e.g. Exploratory Data Analysis and Machine Learning.

The results confirm correlations between temperature, rainfall and crop yields, as previously identified by theory. Furthermore, the study concludes with reasonable thresholds of the most important variables (including the Standardized Precipitation Index (SPI) and SOI), value classifications and crop predictions that are essential for the creation of drought early warning systems and the improvement of food security.

The identified methodology successfully derived reasonable thresholds for further use in practice. Considering the large amount of input data, our GeoAI approach captures the complex dimension of droughts, e.g. the impacts on the production of staple crops as a form of food

provisioning ecosystem services. The potential to use this GeoAI led approach for data gathering from varied data sources and analyzing indicators effectively was recognized. Several shortcomings include the quality of the input data, the spatial scale selected for the analysis. Further research is required to validate these thresholds.

Keywords: Drought, machine learning, early warning system, remote sensing, Standardized Precipitation Index

2. Navigating connected data and models through semantics for better ecosystem services modelling and accounting

First authors(s): Stefano Balbi
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We present the role of AI in the ARIES (ARtificial Intelligence for Environment and Sustainability) modelling approach of federating data and models through a shared semantic layer, enhancing traceability, accountability, and reuse of scientific products.

An example of distributed architecture developed under the European Space Agency (ESA) project “Pioneering Earth Observation Applications for the Environment – Ecosystem Accounting” (PEOPLE-EA) is presented, which allows for the integration and composition of models with distributed building blocks. In this architecture, ARIES serves as the semantic front-end powered by the k.LAB software stack; OpenEO provides data and processing workflows via UDP/UDF catalogues; and INCA prepares ecosystem services data and models according to EU ecosystem accounting standards.

In this work we demonstrate the relevance of Earth Observation (EO) for ecosystem accounting, suggesting new avenues for the integration of state-of-the-art technological solutions that also serve as a blueprint to enable a new paradigm for open and integrated science.

The system supports retrieval and processing of data from satellite EO programs like ESA Sentinel and NASA Landsat. This architecture facilitates the creation of models that are integrated and composed of distributed building blocks.

The architecture delineates a clear separation between resources (data and models) and semantics (used to precisely define their content), with resources being uniquely identified and peer-reviewed. Semantics orchestrates these resources, enabling dynamic execution of computational workflows based on user queries.

This work emphasizes the transition from open science to deeply integrated science, ensuring that data and model resources live online, independent of their semantic orchestration, and are peer-reviewed and maintained on the web.

In conclusion, we advocate for building and maintaining a common knowledge base on ecosystem services, promoting good practices, standards, datasets, algorithms, protocols, and platform APIs. This integration aims to bridge communities, data, and models for intercomparison and reuse, ultimately contributing to a better global understanding of nature's role in human wellbeing.

Keywords: Artificial Intelligence, Semantics, Ecosystem services modelling, SEEA-EA, Integrated Natural Capital.

3. Comparative Analysis of MaxEnt and Deep Learning Approaches for Modelling Humpback Whale Distribution in Northern Iceland

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This paper compared the established MaxEnt and a more novel deep learning approach for modelling the distribution of humpback whales (Megaptera novaeangliae) in northern Iceland. It examined the mechanisms, structures, and optimisation techniques of both approaches, highlighting their differences and similarities. For this, monthly distribution models for the

Skjálfandi Bay were created, spanning from 2018 until 2021, using presence-only sighting data and satellite remote sensing data. Additionally, the trained models were used to create distribution projections for the year 2022, solely based on the available environmental data. The results were compared using the established Area Under the Curve value. The findings indicate that both approaches have their limitations and advantages. MaxEnt does not allow continuous updating within a time series, yet it mitigates the risk of overfitting by employing the maximum entropy principle. The deep learning model is more likely to overfit, but the larger weight network increased the model's capability to capture complex relationships and patterns. Ultimately, the results indicate that the deep learning model had a higher predictive performance in modelling both current and future humpback whale distributions. Additionally, the outcome provides insight into the interaction between environmental influences and the distribution of humpback whales. Despite inherent limitations, deep learning in particular showed promising results and prompts further research in a broad range of applications, such as biodiversity monitoring and the sustainable management of marine resources.

Keywords: Distribution Models, Artificial Intelligence, Environmental Drivers, Comparative Analysis, Skjálfandi Bay

4. Integrating optimization-based AI methods, ecosystem services and ecological connectivity to strengthen Peru's protected area system towards the 30*2030 target.

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Previous conservation planning in Peru, a mega-biodiverse country, focused primarily on biodiversity. Achieving the 30% target set by the Kunming-Montreal Global Biodiversity Framework (GBF) requires addressing numerous ecological and social aspects. We present a conservation planning approach integrating with AI methods: biodiversity, ecosystem services, human impact, ecological connectivity, and ecoregional representativity.

Our approach emphasizes two key ecosystem services in Peru: carbon and water services. We evaluate carbon services using the realized carbon value index, which equally weights carbon

sequestration, carbon stored in living plant biomass and soil carbon. For water services, we consider the realized water provisioning services index, focusing on human needs for clean water, and the water retention index, focusing on ecosystem vitality.

Most existing frameworks are based on human expert analysis and/or classic spatial planning methods (e.g., GIS software, heuristic methods), which are not always sufficient to tackle the problem in all its complexity. Advanced AI methods, including integer linear programming and constraint programming, achieved optimal, constraint-satisfying and balanced protected area selections. These methods offer a robust alternative to heuristic approaches to address complex issues such as multi-criteria optimization and ecological connectivity integration.

This work is co-produced with Peruvian stakeholders in the choice of methodology, data sources and parameters. Regular meetings, workshops and capacity building were organized to ensure the relevance, trust and effective use of results.

Our results identify Peruvian areas of high ecological value to supplement the existing 17.88% of protected areas, aiming to achieve the 30% target in terms of biodiversity, carbon and water related ecosystem services, ecoregional representativity, and ecological connectivity.

This work serves as a fundamental component of Peru's territorial planning, supporting the GBF's objectives. It highlights the importance of integrating advanced spatial conservation planning methods with co-production approach, ecological and social factors, paving the way for further research and practical applications.

Keywords: Conservation planning; Water availability; Carbon sequestration; Ecological connectivity; Artificial Intelligence.

5. Automated mapping of bee-friendly trees: a novel approach to enhance pollinator conservation

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The worldwide decline in bee populations has sparked concerns regarding the stability of global ecosystems and agricultural productivity. As pollinators, bees are essential for the reproduction of numerous plant species, including those in urban environments. This study aims to assess the relationship between wild bee nesting sites and critical floral resources in cities. Thirthy-four wild bee species collect pollen and nectar from willows , yet most of these species are oligolectic. We focus on a monolectic bee species, the Andrena vaga (grey-backed mining bee). They solely rely on the pollen of Salix trees as a source of protein for the growth and development of offspring. Specifically, we investigate the influence of the proximity to Salix (willow) trees on the preferred nesting locations and nest aggregation size of the Andrena vaga. The location of bee nesting sites were gathered through field work. We produce a city-wide tree Salix map using an automated approach to mapping bee-friendly trees. Our methodology utilizes multi-temporal satellite imagery, a tabular transformer deep learning algorithm, and a LiDAR-derived 3D tree model. The satellite imagery dataset consists of 40 (8-band) PlanetScope images with a spatial resolution of 3 m, these are used to extract and identify the unique phenological pattern associated with Salix trees. To ensure the adequate transferability of the deep learning model, the tabular transformer is extended with an enhanced spatio-temporal embedding. We apply this approach to the middle-size city of Braunschweig, Germany, to produce a comprehensive map of Salix occurrence throughout the city. The resulting map enhances our understanding of the relationship between these floral resources and bee nesting sites. Our method hopes to contribute to scalable and efficient solutions for identifying and conserving critical floral resources for the provision of pollination services in an urban context.

Keywords: Deep learning, pollinator conservation, remote sensing

6. Leveraging AI for Enhanced Systematic Reviews: Insights from Ecosystem Condition Indicators

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Effective evidence synthesis is crucial for integrating scientific research into decision-making processes, particularly in the environmental sciences. The exponential growth of scientific publications poses significant challenges in conducting comprehensive systematic reviews. This presentation explores the application of Generative AI, specifically the GPT-3.5 model, to streamline the systematic review process for studies on ecosystem condition indicators.

As part of the Horizon Europe SELINA project, our study demonstrates the development and implementation of an AI-driven approach to literature screening, emphasizing the importance of precision in prompt design and query parameter settings. We employed the GPT-3.5 model to classify publications based on their relevance to the topic of ecosystem condition indicators, achieving significant improvements in efficiency and accuracy compared to traditional manual screening methods.

The model was trained using a robust set of inclusion and exclusion criteria tailored to the multidimensional nature of ecosystem condition. We iteratively refined the prompt to enhance the model's performance, ultimately achieving an 83% accuracy rate, compared to human reviewers, in selecting relevant literature. This process involved the systematic identification of key terms and the exclusion of unrelated studies, ensuring a comprehensive and focused evidence synthesis.

Our findings highlight the potential of AI tools to reduce the time and resources required for systematic reviews while maintaining high standards of rigor and replicability. We also discuss the implications of this approach for future research, including the potential for integrating AI models into various stages of the systematic review process, from initial screening to full-text analysis.

By presenting a case study in ecosystem condition indicators, this presentation underscores the transformative potential of AI in environmental science research. It offers valuable insights for

researchers and policymakers seeking to enhance the efficiency and scope of evidence synthesis in the face of an ever-growing body of scientific literature.

Keywords: Systematic review, Large Language Models, Screening

7. AI and economic valuation - Leveraging AI for extraction and annotation of scientific literature into the Ecosystem Services Valuation Database

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The Ecosystem Services Valuation Database (ESVD) is the largest global database with monetary values of ecosystem services, consisting of 10,800 monetary values from 1,355 scientific studies and official reports. The ESVD consists of over 100 variables with information on ecosystem types and services, location and valuation methods among others. Effective annotation of these studies into the ESVD structure is crucial to leverage the value of research on ecosystem services into different forms of public and private decision-making. This abstract pilots the application of Generative AI, specifically the GPT-3.5/4 models, to extract and annotate data from scientific studies on ecosystem services in the ESVD.

Developing tailored large language models has the potential to significantly reduce the time of coding the thousands of valuation studies currently analyzed by human efforts, while also reducing human-made errors in the coding process.

In collaboration with Symbaiosys, the Foundation for Sustainable Development (FSD) conducted a small piloting study for the Dutch Ministry of Nature using GPT-3.5/4 for data annotation from valuation studies. The pilot project demonstrates the development and implementation of an AI-driven approach to analyze scientific papers and extracting relevant information to be directly integrated in the ESVD structure. We trained and tested the 3.5/4 model in the extraction and analysis of monetary valuation data and compared results with existing valuation data already in the ESVD.

Our findings highlight progression over time, with almost 0% accuracy on many variables to relatively high levels of accuracy (70%) in the annotation of several variables in relatively simple

studies (defined as containing only 1 monetary value). The project emphasized the importance of prompt design, parameter settings and the understanding of relation between variables in the context of scientific information. Dealing with challenges related to the model's understanding of relation, ambiguity and interpretation, which are highly associative tasks, is pivotal for this endeavor to be successful.

Keywords: Large language models, GPT-3.5/4, scientific literature, monetary valuation

8. Mapping the allergenicity of urban green spaces using very-high-resolution remote sensing data

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Over the past decades, pollen allergy has become one of the most widespread public health issues. The number of individuals having allergies to pollen has dramatically increased, especially in urban and industrial areas. Quantifying the allergenic potential of urban green spaces and developing allergy sensitive strategies for green space management and planning are therefore becoming increasingly important. Mapping the allergenicity of urban parks requires detailed information on tree species and tree crown volume which for many cities is not available or is not updated on a regular basis. This study assesses the potential of very high-resolution remote sensing for mapping allergenic tree genera and proposes a workflow for quantifying the allergenic potential of urban green spaces (UGS). Using a convolutional network approach six allergenic genera are mapped within 52 urban green spaces across the Brussels Capital Region. The classification model achieves an overall accuracy of 0.86, with precision for the six genera ranging from 0.82 to 0.92. By combining the obtained map with tree crown measures derived from airborne LiDAR data an assessment of the allergenicity of the 52 UGS is made, accounting for misclassification bias in the mapping of tree genera. Allergenicity values are generally lower for more formally designed parks in the center of Brussels, while higher values are obtained for parks located in the periphery of the region.

Keywords: urban green spaces; allergenic trees; allergenic potential; remote sensing; LiDAR; convolutional neural networks; deep learning

9. Assessing Determinants of Forest Gross Primary Productivity in China Using Machine Learning Approaches

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The global carbon balance is significantly impacted by gross primary productivity (GPP), which is influenced by different drivers at varying degrees. In this study, we assess the performance of two machine learning models (Random Forest and XGBoost) in explaining 29 years of forest GPP in China mainland (1990–2018). Using open datasets, we model forest GPP with climatic, topographic and anthropogenic variables. To evaluate the performance of the forest GPP models, three metrics were used, namely the coefficient of determination (R2), the Mean Absolute Error (MAE), and the Root Mean Square Error (RMSE). The Random Forest outperformed XGBoost model using 10 explanatory variables and identified the most important forest GPP drivers as being temperature (26%), precipitation (19%), solar radiation (11%), forest fragmentation index (FFI) (9%) and soil moisture (8%). A spatial heterogeneity assessment using geodetectors confirmed 4 out of the 5 most important factors identified by the RF model. Additionally, it identified the climate zones as also being an important driver. Overall, we conclude that climatic drivers play a very important role in determining forest GPP in China. However, FFI also emerges as an important anthropogenic factor that needs to be efficiently monitored and managed for achieving China carbon neutrality objectives. Machine learning approaches using open data sources seem to be a very straightforward way of estimating climate related variables.

Keywords: Machine learning, Ecosystem services, Geodetectors, Forest fragmentation; Climate change