BOOK OF ABSTRACTS

I. SESSION DESCRIPTION

ID: T5

Ecosystem Services Modelling for Nature-based solutions

Hosts:

	Name	Organisation	E-mail
Host:	Stoyan Nedkov	National Institute of Geophysics, Geodesy and Geography, Bulgaria	snedkov@abv.bg
Co-host(s):	Kremena Burkhard Thomas Elliot Bart de Knegt Roy Remme Mario Balzan	Leibniz University Hannover, Aalborg University, Wageningen University & Research, Leiden University, Malta College of Arts	burkhard@umwelt.uni-hannover.de thomaselliot@plan.aau.dk bart.deknegt@wur.nl r.p.remme@cml.leidenuniv.nl mario.v.balzan@gmail.com

Abstract:

The interconnected and interdependent relation between human health and healthy environment is becoming increasingly clear and the concept of Nature-based Solutions (NbS) can act as a way to bridge the gaps between conservation and public health for holistic approaches (WTO-IUCN, 2023). NbS are tools for enhancement and operationalisation of specific Ecosystem Services (ES) for solving particular societal challenges. Therefore, applying NbS requires an integrated understanding of the environmental, economic and social systems and their interactions. The ES models can be appropriate tools to identify the most suitable NbS by quantifying the benefits and trade-offs they provide.

The session on ES models for NbS at the previous European ESP conference 2022 in Crete included various contributions covering different aspects from application of models in real world case studies to interactions between biophysical, economic and the social systems. The contributions in the session covered a range of ecosystems and their services in various environments and at

multiple scales. Group work during the session emphasized the essential components of ES modelling (frameworks) in assessing NbS. The most highly rated components were inclusion of multiple ES, validity of the models and uncertainty analyses. Incorporation of ecosystem structures, functions and services and use of high quality spatial and temporal data were also defined as important elements. The main gaps identified during the group work were: not taking into account feedback loops and interactions; monetary valuation; side effects of NbS; lack of accessible and understandable communication of multiple values. Stakeholders' involvement and synergies and trade-offs were identified as both essential elements and gaps.

The studies on synergies and trade-offs in ecosystem management can effectively reveal the effects of NbS on environmental health and the consequent relation to human health. Understanding such synergies and trade-offs requires effective modeling methods such as system dynamics, land use matrices, and participatory approaches. System dynamics models reveal complex ecosystem interactions, while land use matrices quantify the impacts of land use practices on biodiversity and ecosystem services. Participatory approaches engage stakeholders, ensuring diverse perspectives are considered. Integrating these methods informs sustainable land management and collaborative environmental governance. This session aims to build on the achievements of the previous session by further searching for best practice examples of model implementations for identifying NbS and quantifying benefits and trade-offs. The session is open to ES modelling for NbS in all environments, with specific space reserved for cases from small and medium islands.

We invite speakers to present advancements in modelling of NbS in relation to:

- Application of ES models for NbS in real world case studies with stakeholders and end-users
- Linking NbS to ES and Societal challenges, including human health, through models
- Modeling the interactions between the biophysical, economic and the social system
- Good and bad practices in the development and application of ES models for NbS
- Multiscale ES modeling for NbS (from single ecosystems to landscapes) – the impacts of local NbS on landscape scale ES
- ES modelling as decision-making support tool for robust policy-making and sustainable development
- Modeling impacts of NbS implementation on ES and trade-ofs with other solution options

Given the collaboration with the COST Action SMILES, we would like to invite speakers working in small-medium islands to share their experiences with NBS uptake and implementation. Therefore, part of this session is dedicated to NbS in small and medium European islands, aiming

at showcasing the effectiveness and co-benefits arising from NbS. Such islands are hotspots of biological and cultural diversity, with high vulnerability and co-dependencies related to human and environmental health. Thus, small and medium islands can provide appropriate and challenging case studies in ES modeling for NbS, such as restoration projects, protection initiatives, and sustainable coastal management practices.

Goals and objectives of the session:

This session is organized by the ESP Thematic Working Group on Modelling ES (TWG5) in collaboration with the COST action SMILES ("Enhancing Small-Medium Islands resilience by securing the sustainability of Ecosystem Services). It has two main goals:

- to further develop the understanding on the applications of ES models for NbS;
- to demonstrate the effectiveness of implementation of NbS in diverse environments, with emphasis on small-medium islands.

Planned output / Deliverables:

This session will be used to further develop collaboration and a research agenda within the ESP Thematic Working Group on Modelling ES.

II. SESSION PROGRAM

Room: Expert Street 6

Date of session: 19th of November 2024

Time of session: 16:00-18:00

Timetable speakers

Time	First name	Surname	Organization	Title of presentation
16:00-16:05	Stoyan	Nedkov	NIGGG-BAS	Welcome and introduction
16:05-16:17	João	David	Humboldt-Universität zu Berlin, Geography Department	Assessing Urban Ecosystem Services to Support the EU Climate-Neutral and Smart Cities Mission
16:17-16:29	Margot	Neyret	Alpine Ecology Laboratory, Grenoble, France	One cannot have it all: trading-off ecosystem services and biodiversity bundles in landscape connectivity restoration

Time	First name	Surname	Organization	Title of presentation
16:29–16:41	Arnout	van Soesbergen	UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)	Modelling and valuing agricultural NBS impacts on ES in the Pemba-Lichinga Integrated Development Corridor in Mozambique
16:41–16:53	Nicolas	Grondard	Wageningen University	Assessing benefits of Nature-based Solutions for freshwater ecosystems restoration with a biophysical – economic modelling framework
16:53–17:05	Davide	Stucchi	Dipartimento di Elettronica Informazione e Bioingegneria, Politecnico di Milano; National Biodiversity Future Center	Developing a Dynamical and Individual-based Urban Forest Model: how much Species diversity impact ES supply?
17:05–17:17	Swantje	Gebhardt	Copernicus Institute of Sustainable Development, Utrecht University	Investigating the interactions of habitat configuration and pesticide toxicity for pollination to evaluate opportunities for natural landscape element restoration
17:17–17:29	Aline	Pingarroni	Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México; Instituto de Investigación en Ecosistemas y Sustentabilidad, Universidad Nacional Autónoma de México.	Synergies and trade-offs between biodiversity and ecosystem services in tropical landscapes
17:29–17:41	Davide	Longato	University IUAV of Venice	Assessing ecosystem service demand in urban areas to support the spatial allocation and prioritization of nature-based solutions: an application in Valletta, Malta
17:41–18:00	Stoyan	Nedkov	NIGGG-BAS	Discussion and wrap up

III. ABSTRACTS

The first author is the presenting author unless indicated otherwise.

1. Investigating the interactions of habitat configuration and pesticide toxicity for pollination to evaluate opportunities for natural landscape element restoration

First authors(s): Swantje Gebhardt
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The restoration of natural landscape elements is a prominent pathway within Nature-based Solutions towards conservation, and it is also widely suggested to improve wild pollinator abundance, diversity, and their pollination services in intensively used agricultural landscapes. However, the intended natural refuges for pollinators can become exposed to agrochemicals applied on surrounding agricultural fields. In order to effectively plan habitat restoration for pollinators, the effect of land use configuration on pesticide exposure and pollination service has to be thoroughly investigated.

To address this knowledge gap, we created a mechanistic pollination model that simulates the spatial processes of pollinator exposure to toxic pesticides and the subsequently reduced pollination service. We calculated pollination for a set of artificial binary landscapes, which vary in habitat amount and aggregation, as well as in toxicity of pesticides applied on agriculture. Preliminary results suggest that in landscapes with limited habitat amount and highly toxic pesticides, pollination services in the landscape are mostly safeguarded by aggregated patches of habitat, as this configuration shelters habitat from pesticide exposure. With increasing habitat amount and/or less toxic pesticide application, more dispersed patches of habitat achieve a better pollination service for the landscape.

Our ongoing research, whose results will be presented at the conference, utilizes our findings on the interaction of landscape configuration and pesticide toxicity to design landscapes where strategic nature restoration enhances pollinator health and pollination services. This model application will contribute to evaluate implementations of Nature-based Solutions such as habitat restoration and reduced pesticide application for pollination services and biodiversity

conservation. The results will be discussed with regards to informing policies to include beneficial landscape configuration measures that target the tradeoff between providing refuges for pollinator and facilitating spillover into agricultural landscapes to improve productivity.

Keywords: Pollination service, Spatial configuration, Pesticide exposure, Habitat restoration

2. Assessing benefits of Nature-based Solutions for freshwater ecosystems restoration with a biophysical – economic modelling framework

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Freshwater ecosystems are biodiversity hotspots that provide key services, but their degradation impacts species habitats and service delivery. Nature-based solutions (NBS) offer opportunities for ecosystem restoration. The MERLIN project (Mainstreaming Ecological Restoration of freshwater-related ecosystems in a Landscape context: INnovation, upscaling, and transformation) showcases NBS for freshwater ecosystem restoration in 18 European case studies. To implement and finance NBS on a large scale, benefits must be quantified in biophysical and monetary terms. However, this quantification is challenging due to complex ecosystem and social processes and the lack of accessible modelling tools and data. Consequently, cost-benefit analyses often fail to capture ecosystem services and benefits, disadvantaging NBS compared to grey infrastructure alternatives.

Within MERLIN, a framework that couples biophysical and economic models is being developed to provide an accessible solution for quantifying and monetarily valuing benefits of freshwater ecosystem restoration at the catchment level. This framework is designed for applicability across Europe, utilizing continent-wide datasets. It integrates the newest version of the Soil and Water Assessment Tool (SWAT+) with a set of ecosystem services valuation models based on ecohydrological model results. The current development stage allows for the quantification of flood risk mitigation and water purification economic benefits from different restoration measures (peatlands rewetting, rivers restoration, floodplains reconnection).

In this presentation, we introduce this modelling framework and demonstrate its applicability using a MERLIN case study: the rewetting of peatlands in the Forth catchment (Scotland, UK). First, a catchment-scale restoration scenario is built. A SWAT+ model is developed, the restoration measures are simulated, and resulting output variables are used to model economic benefits of flood risk mitigation and water purification. To test the framework robustness, the sensitivity of outputs to different data sources is quantified. The results highlight the economic benefits of restored peatlands, emphasizing the value of NBS in ecosystem restoration.

Keywords: Freshwater ecosystems, ecosystem services, Nature-based solutions, Cost Benefit Analysis, Natural Capital.

3. Assessing ecosystem service demand in urban areas to support the spatial allocation and prioritization of nature-based solutions: an application in Valletta, Malta

First authors(s): Davide Longato
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Mapping and assessing the demand for ecosystem services (ES) in urban areas can support the allocation of nature-based solutions (NbS) to deliver the desired ES where they are most needed. This study presents a method that combines spatial assessments of the demand for selected ES in a city with ES supply scores reflecting the capacity of different typologies of NbS to potentially deliver the demanded ES. The method was applied to simulate the spatial allocation and prioritization of NbS in a number of potentially suitable sites across the urban area of Valletta, Malta, considering 11 NbS types and 5 priority ES (i.e., runoff regulation, microclimate mitigation, air purification, noise reduction, and nature-based recreation). The proposed approach supports both the prioritization of potentially suitable NbS sites and the allocation of the specific NbS types which maximize the benefits to residents by providing the best balance of multiple ES. Results show that urban forest is the most needed NbS type across the study area, being the one with the highest capacity to supply most of the ES selected as a priority for the study area. However, there are specific cases in which other typologies are more suitable, according to the existence of hotspots of demand for specific ES, such as noise reduction and nature-based recreation; as well as sites where size, shape, or land use

constraints hinder the implementation of urban forests. Our approach can be used and adapted to support a variety of planning decisions dealing with the prioritization and spatial allocation of NbS in urban development/transformation projects.

Keywords: Urban planning, Green infrastructure, Ecosystem service mapping, Ecosystem service assessment, Decision support tool

4. One cannot have it all: trading-off ecosystem services and biodiversity bundles in landscape connectivity restoration

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Countering the impacts of habitat loss and fragmentation on ecosystems requires complementing conservation areas with Other Effective area-based Conservation Measures within landscapes as nature-based solutions to jointly promote biodiversity and multiple ecosystem services (ES). However, critical knowledge gaps persist in where and how natural elements should be restored to improve landscape connectivity to simultaneously support, and reduce trade-offs between biodiversity and ES. In virtual landscape experiments that allow exploring the effects of spatial pattern systematically, we generated alternative landscape restoration scenarios aimed at fostering ecological connectivity. Scenarios varied in the location and size of restored areas complementing existing natural areas. We analysed the impact of these scenarios on four bundles representing distinct priorities of target ES and biodiversity-related values. All bundles were favoured by increasing restored area in the landscape, but were promoted by different spatial configurations. Restoration scenarios that fostered high aggregation of natural habitats promoted biodiversity and cultural value-related bundles, while smaller natural elements dispersed throughout the landscape were more beneficial for the sustainable production and climate adaptation bundles. These contrasts were most pronounced at low restoration efforts, where landscape configuration had greatest impacts on biodiversity and ecosystem processes. Effective spatial planning of restoration initiatives within landscapes and landscape-level nature-based solutions should consider these trade-offs, along with context-specific constraints, when prioritizing areas for restoration or conservation. Our findings contribute to a more comprehensive understanding of how protected and restored

areas can be integrated within landscapes to jointly support connectivity for both biodiversity and people.

Keywords: Restoration, virtual landscape modelling, ecosystem services, spatial planning

5. Synergies and tradeoffs between biodiversity and ecosystem services in tropical landscapes

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Rapid changes in tropical agricultural frontiers pose significant challenges in balancing tradeoffs between ecosystem service (ES) supply, biodiversity conservation, and the livelihoods of local communities. This study aimed to analyze the spatial patterns of biodiversity and the potential supply of multiple ES in the transformed Marqués de Comillas region in Mexico, employing three spatial modeling tools: GLM, InVEST, and soil functions. We produced detailed maps for 18 ES categories (provisioning, regulating, and cultural) and two biodiversity types (species richness and functional diversity). We identified ES spatial patterns by calculating average pixel values within 1 km² grids. Linear models were used to evaluate the relationship between biodiversity and ES across three observation scales: plot, landscape (1 km²), and village. Our findings, which are pioneering in the field of ES and the study of transformed tropical forests, offered robust spatial models and detailed maps at a local scale (3,556 km²) with high spatial resolution (225 m²). Importantly, land cover type, the red band texture index, and proximity to rivers and towns were identified as key variables for map generation. Tradeoffs in ES spatial patterns were observed, particularly between agriculture-related services and those linked to forests and water bodies. The landscape scale was generally effective for establishing relationships between biodiversity and most ES, except for hydrological ES, where the village scale proved more relevant. We highlight the necessity of conserving adjacent reserves to sustain the provision of services and biodiversity in the region. These results offer valuable tools for a comprehensive understanding of tropical forests and support collaborative landscape planning in the region.

Keywords: Spatial modelling, biophysical supply, rainforest, spatial trade-offs, transformed landscape

6. Developing a Dynamical and Individual-based Urban Forest Model: how much Species diversity impact ES supply?

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With an increasing urban population, there is a growing need for green spaces to enhance citizen's quality of life. As a type of green space, and nature-based solution, urban forests stand out for their extensive ecosystem services (ES) supply and derived benefits. Current models for quantifying ES supply by urban forests typically project future ES supply under the assumption that historical trends persist. However, they often neglect changes in underlying ecological dynamics and exogenous variables over time, which influence future ecosystem condition (status) and ES supply. Modelling this dynamism is critical for representing future climate-related scenarios and evaluating different urban forest management alternatives. Here we develop a pilot dynamic model for urban forests that evaluates changes in ecosystem condition over time, including changes in species diversity, and how they influence ES supply. Our individual-based, mechanistic model describes tree growth and permits interactions between trees and with the surrounding environment. The foundational equations are based on key ecological processes such as net primary productivity. These equations are parametrized using scientific literature data and tuned to better represent common tree species in Milan and fed with realistic series of exogenous variables (e.g. weather and air pollution). Progressing from a single tree to a small urban forest patch, we start modelling a few ES over time, such as carbon storage and air filtration. The model is tested in a case study in Milan, unveiling how business-as-usual tree planting policies perform differently from alternative scenarios (e.g., enhanced species diversity), thus offering valuable insights for urban forest management. Future steps include expanding the set of ES and testing the model's capacity to inform forest performance under future climate and/or technological scenarios. The goal is to obtain a dynamic model sensible to changes in internal and exogenous variables for informing sustainable urban forest management.

Keywords: ES model, Biodiversity, Carbon sequestration, Pollutant regulation, System dynamics

7. Modelling and valuing agricultural NBS impacts on ES in the Pemba-Lichinga Integrated Development Corridor in Mozambique

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To support green economic transition in Africa, there is an urgent need to help financial institutions and governments make more nature-positive investment decisions on a routine basis. This study in an agricultural development corridor in northern Mozambique employs a spatial modelling and valuation approach to explore possible trade-offs and synergies between cropland intensification as a land-use (project baseline scenario) and investment to reforest riparian croplands and develop agroforestry in existing croplands (natural capital approach scenario). The natural capital approach scenario demonstrates how a nature-based solution approach can deliver on multiple development objectives. It estimates increases in benefits from improved dry season water flows, avoided sedimentation of watercourses, climate change mitigation and wood fuel supply in physical and monetary terms, compared to the project baseline scenario.

Results show that returns from establishing riparian forest and agroforestry ecosystems in current cropland areas are estimated to be $42/ha/year in terms of benefits to Mozambique based on the four ecosystem services valued. This increases to $90/ha/year when global costs of climate change mitigation are included (i.e. when the US social cost of carbon is applied to value climate change mitigation benefits). By ways of comparison, studies suggest conventional tillage maize farming in Mozambique generates profits of around $100/ha/year. However, economic benefits realized through agroforestry crop production were not monetized. Additional co-benefits under the natural capital approach scenario include improved pollination and increases in biodiversity.

This natural capital assessment can be used by the project designers to inform nature-based solutions to agricultural irrigation issues, delivering wider community benefits (e.g. wood fuel security) and achieving national objectives for climate change mitigation and biodiversity.

Mainstreaming natural capital approaches into these types of development projects can support NbS into planning processes and foster transition to green economies, delivering better outcomes for nature and people in landscapes and seascapes.

Keywords: Agroforestry, reforestation, ES models, valuation, trade-offs

8. Assessing Urban Ecosystem Services to Support the EU Climate-Neutral and Smart Cities Mission

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Urban Ecosystem Services (UES) - the benefits humans obtain from urban ecosystems - significantly enhance the quality of life in cities by providing air cooling and air purification, temperature regulation, flood risk mitigation, habitat quality, and other vital services. However, climate and land cover changes impact UES, presenting challenges to urban areas as environmental hotspots. Therefore, mapping and quantifying changing provisioning of UES is essential for informed policy-making and scientific research.

Recently, the European Union initiated the "Climate-Neutral and Smart Cities" mission to promote selected cities in achieving climate neutrality by 2030. To meet this ambitious target, these cities must closely monitor their environmental metrics and track their progress towards sustainability. This research aims to provide key ecological insights to support the EU's mission, assisting cities in their journey towards climate neutrality.

The study employs a modelling framework that integrates publicly available high-resolution land use data with other spatial datasets and biophysical models to assess UES for this target city sample. Preliminary results assess UES potential, revealing spatial dependence and patterns of various UES within each city. These results offer accessible data for policymakers and urban planners regarding the current state of urban ecosystems. Future research will incorporate climate scenario trends and land use change projections, providing a comprehensive understanding of UES dynamics and their potential role in climate change mitigation and adaptation in EU urban areas. By delivering detailed analyses and updated spatial information,

this research project aims to enhance urban sustainability and resilience, supporting the EU's broader environmental objectives.

Keywords: Urban Ecosystem Services; Climate-Neutral Cities; Urban Sustainability; Ecological Modelling