



# TERRA

---

# ENVISION

8-11 July, 2025  
Granada  
Spain



UNIVERSIDAD  
DE GRANADA



Rijkswaterstaat



GRANADA  
TIERRAVIVA



**SEDER**  
soil erosion  
and degradation  
research group





# **TerraEnVision 2025**

## **Nature-based Solutions to Facilitate the Transitions for living within the Planetary Boundaries**

**Granada, Spain, 8-11 July, 2025**

### **Editors**

Jesus Rodrigo-Comino, University of Granada, Spain

Saskia Keesstra, Senior researcher, Sustainable Land and Water Management at Climate-Kic, The Netherlands

Margot de Cleen, Senior Advisor, Soil and Water Ministry of Infrastructure and Water Management, The Netherlands

Artemi Cerdà, Professor in Physical Geography, University of Valencia, Spain

Ioannis Daliakopoulos, Assistant Professor, Hellenic Mediterranean University, Greece

### **Publication**

Hellenic Mediterranean University, Estavromenos, 71 410 Heraklion, Greece

First published on July 11, 2025, in Heraklion, Greece by Hellenic Mediterranean University, School of Agriculture, Department of Agriculture.

ISBN: 978-5-9807-7215-4

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, nor be otherwise circulated in any form of binding or cover, without prior permission of the publisher.

© Copyright 2025 by the Hellenic Mediterranean University, School of Agriculture, Department of Agriculture. The individual essays remain the intellectual properties of the contributors.

# Table of Contents

The Mission of TerraEnVision 2025 .....	1
Organizing Committee .....	3
Keynote speakers .....	5
Conference Program .....	12
Conference Abstracts .....	32
Keynotes .....	33
<i>Nature-Driven Spatial Strategies to Create a Green Metropolis</i> .....	34
<i>Restoring Burnt Forests For the Future: Shifting Paradigms Towards Nature-     Based Solutions</i> .....	36
<i>Salvemos La Vega - Vega Educa: 20 Years Involving Society and Institutions in     the Protection and Revitalization of the "Vega De Granada".</i> .....	37
<i>Paludiculture - Silver Bullet Solution For Landscape-Level Nbs (Bridging the     Agricultural-Conservation Divide)</i> .....	38
UR3: Nature based solutions for restoration of urban water cycle .....	39
<i>Improved Modeling of Tree Rainfall Interception in Urban Hydrology:     Quantifying the Stormwater Reduction by Birch (Betula Pendula Roth.) and     Pine (Pinus Nigra Arnold) Trees</i> .....	40
NH2: Forest fires: Their impact on land and their restoration strategies. A scientific and stakeholder approach .....	42
<i>Carbon Stock Modeling For Better Understanding Forest Ecosystems Through     Soil Information System (Case of Tunisia)</i> .....	43
AN1: Soil and water conservation for sustainable land management .....	45
<i>Froof Biotech Code of Good Regenerative Agricultural Practices</i> .....	46
<i>Land Use Planning (Lup) Tool to Achieve Land Degradation Neutrality (Ldn):     Tunisia Case Study</i> .....	48
<i>Emerging Contaminants in Soil Ecosystems: Microbial Disruption and     Antimicrobial Resistance From a One Health Perspective</i> .....	50
AN3: Climate-Resilient Land Management: Integrating Nature-Based Solutions for Sustainable Land Use in a Changing Climate .....	52
<i>Sponge Measures in Agricultural Landscapes: Results From Implementing     Nature-Based Solutions in the Upper Thames Catchment, Uk</i> .....	53
AN5: Innovative Solutions for Sustainable Andalusian Agriculture: Showcasing AEI Operational Groups .....	54
<i>Soil Carbon (Soc) Prediction Using Remote Sensing and Artificial     Intelligence.Remote. Case of Andalusia.</i> .....	55
NH3: Human impact on erosion and connectivity in agricultural land .....	56
<i>Assessment of Soil Erosion and Redistribution in Steep Slope Vineyards by     Sedimentological and Temporal Analysis</i> .....	57
AN5: Innovative Solutions for Sustainable Andalusian Agriculture: Showcasing AEI Operational Groups .....	58
<i>Implementation of Innovative Practices For the Reduction of the Alcohol Content     of Andalusian Biologically Aged Wines</i> .....	59
<i>Social-Agri: Digital Innovation and Collaboration For Sustainable Agriculture</i> .....	61
<i>Approach to a Potential Strategy For Improving Agricultural Soil Quality     Through the Use of Pig Slurry in Olive and Cereal Crops</i> .....	63
<i>Gososviti: Innovation in Viticulture Through an Integrated Dss (Decision Support</i> .....	

<b>System) For Soil and Water Conservation</b> .....	65
<b>Perception and Use of Precision Agriculture Technologies in Viticulture:</b>	
<b>Preliminary Results From the Go Sosviti Project</b> .....	67
<b>AN1/2/3: Climate-Resilient Soil and Water Conservation: Integrating Nature-Based</b>	
<b>Solutions for Sustainable Land Management in Grazing Systems</b> .....	69
<b>Mapping Soil Erodibility by Means of Machine Learning Models in a Semi-Arid</b>	
<b>Watershed</b> .....	70
<b>Enhancing Climate-Resilient Irrigation For Fruit Production Through Reference</b>	
<b>Evapotranspiration Calibration and Nature-Based Solutions in Bosnia and</b>	
<b>Herzegovina</b> .....	72
<b>Farm Dams as Climate-Smart Adaptations For Agricultural Water Storage in</b>	
<b>Sweden.</b> .....	74
<b>Flood Risk Communication Infrastructure For Risk Reduction and Resilience</b>	
.....	75
<b>Assessment of Nature-Based Agricultural Practices For Soil and Water</b>	
<b>Conservation Using Swat+</b> .....	76
<b>Past Herbivore Grazing Pressure on Highly Diverse Open Ecosystems in Central-</b>	
<b>Eastern Europe: a View From Coprophilous Fungal Spores</b> .....	78
<b>Multi-Objective, Stakeholder-Oriented Planning of Nature-Based Small Water</b>	
<b>Retention Measures in an Agricultural Catchment</b> .....	79
<b>Exploring the Roman Centuriation Northeast of Padua as a Historical Nature-</b>	
<b>Based Solution For Better Flood and Drought Resilience</b> .....	81
<b>Spatial Patterns of Soil Bacterial Communities in Mediterranean</b>	
<b>Agrosilvopastoral System</b> .....	83
<b>Biochar as a Nature-Based Solution in Runoff and Soil Erosion Control: Plot-</b>	
<b>Scale Measurements Under Natural Rainfall</b> .....	84
<b>Biogas Residues in the Battle For Terrestrial Carbon Sequestration in the</b>	
<b>Grassland Soils of the Greater Region</b> .....	85
<b>Using Policy Innovation to Scale Biochar as a Nature-Based Solution For</b>	
<b>Climate-Resilient Land Management: Insights From Ireland</b> .....	86
<b>Principles For the Assessment of Natural Source Zone Depletion Based on</b>	
<b>Temperature Measurements in the Subsoil</b> .....	88
<b>Soil Erosion in New Citrus Plantations. Rainfall Simulation Experiments.</b>	
<b>Montesa Experimental Station, Eastern Iberian Peninsula</b> .....	90
<b>Soil Erosion in Agriculture Land in Spain: a Review</b> .....	93
<b>Soil Erosion Control in Citrus Plantations. the Use of Chipped Pruned Branches</b>	
<b>in Sloping Terrain as a Mulch.</b> .....	97
<b>Soil Erosion Control in Citrus Plantations. the Case of Cover Crops in the</b>	
<b>Montesa Experimental Station</b> .....	100
<b>The Effect of Biochar From Pruning Wastes on Co2 Emissions, Hydrophysical and</b>	
<b>Soil Biological Properties</b> .....	102
<b>Assessing Climate Impact in Vineyards of Bodegas Calvente (Padul, Granada)</b>	
<b>Through Advanced Data Processing and Bioclimatic Indices</b> .....	103
<b>Assessing the Impact of Afforested Species on Carbon Sequestration in the Green</b>	
<b>Zones of an Industrial Site Located in Arid Regions of Iran</b> .....	105
<b>Soil Erosion Dynamics in Rehabilitated Apple Orchards, Hilly Region, Central</b>	
<b>Iran (Use of Magnetic Susceptibility and Cs-137 Techniques)</b> .....	108
<b>Proposing a Soil Quality Index For Cereal Croplands in Campo De Cámara</b>	
<b>(Málaga, Spain)</b> .....	110
<b>Connected Cities - Strengthening Green Infrastructure Through Data and</b>	
<b>Collaboration</b> .....	111
<b>Projection of Drought Tendencies in the Horné Pohronie Region (Central Europe</b>	
<b>- Slovakia) For the Period 2025-2050</b> .....	113

<b><i>The Impact of Historical Land Cover Change on Soil Organic Carbon in Malagasy Open Grassy Ecosystems : a Stable Isotope Approach</i></b> .....	115
<b><i>Exploring the Saprolite Horizons as Proxies For Enhanced Rock Weathering in Tropical Soil.</i></b> .....	117
<b><i>An Integrated Multi-Process Evaluation of Land Degradation in Europe</i></b> .....	119
<b><i>Optimal Soil Management For Carbon Sequestration</i></b> .....	120
<b>NH1: Innovative solutions for increasing resilience to water-related hazards and soil erosion in agricultural areas</b> .....	122
<b><i>Spaceborne Monitoring of Vineyards: Optical and Multipolarized Radar-Based Indices Tested on a Wine-Producing Area in Northern Italy in the Context of the Nodes Project</i></b> .....	124
<b><i>Temporal Analysis of Dual-Pol Scattering Powers Over Wet and Dry Sown Rice Fields: a Case Study in Northern Italy</i></b> .....	126
<b><i>Analysis of Tomato Yield Predictions With Sentinel-2 and Uav-Based Ndvi: a Case Study in Northern Italian Farms</i></b> .....	128
<b><i>Water as a Foundation For Climate Resilience: Integrating Energy Production and Agricultural Sustainability at Cascina Vialone</i></b> .....	130
<b><i>Evaluation and Innovative Study of the Vine According to New Agronomic Scenarios For Oltrepò Pavese, Italy</i></b> .....	132
<b><i>Hydrogeological Characterization of Steep Vineyard Slopes Through a Combined Approach For Shallow Slope Failures Susceptibility Estimation</i></b> .....	134
<b><i>Nature-Based Solutions in Vineyards of Oltrepò Pavese (Northern Italy): Effects on Land Degradation</i></b> .....	136
<b><i>Environmental Factors Regulating the Fire Effects on Soil Organic Carbon Across Malagasy Ecosystems</i></b> .....	138
<b><i>Mechanical Behavior of Clayey Soil Treated With Trichoderma Asperellum</i></b> .....	140
<b><i>Effect of Fungal Treatment With Penicillium Chrysogenum on Mechanical Properties of a Clayey Soil</i></b> .....	142
<b><i>A Probabilistic Approach For the Analysis of Susceptibility to Shallow Landslides in Different Soil Managements</i></b> .....	144
<b><i>Participatory Mapping For Wildfire Prevention: a Stakeholder-Based Approach in Sardinia (Italy)</i></b> .....	145
<b><i>Green Horizons Farmers Network: Supporting Farmers Towards Sustainability and Resilience</i></b> .....	147
<b>MET1/2/4: Advances and Best Practices in Ecosystem Restoration and Environmental Remediation: Integrating Remote Sensing, Machine Learning, and In Situ Technologies</b> .....	148
<b><i>Full-Scale Application in Italy of an Erd Technology For the Treatment of an Aquifer Impacted With Chlorocarbons Near a Salt Pond Ecosystem</i></b> .....	149
<b><i>Hazardous Elements and Pharmaceuticals in Soils of a Mediterranean Wetland (L'albufera De Valencia, Spain). Possible Interactions.</i></b> .....	151
<b><i>Google Earth Engine-Based Land Use/Land Cover Mapping in Granada, Spain Using Sentinel-2 and Machine Learning Techniques</i></b> .....	153
<b><i>"Fertile Islands From Above": Utilizing Uav Photogrammetry to Map Fertile Forest Patches in a Unesco Biosphere Reserve</i></b> .....	155
<b><i>Deriving Forest Cover Rates From Map Sources: a Contribution to Official Statistics and Environmental Reporting</i></b> .....	157
<b><i>Land Restoration Effectiveness Assessed by Satellite-Based Remote Sensing Technologies as a New Monitoring Approach</i></b> .....	160
<b><i>Ai-Generated Landscape Imagery: Towards a Comprehensive Assessment</i></b> .....	162
<b><i>Meo-Carbon: a Decision-Support Tool to Identify Critical Areas and Guide Ecosystem Restoration</i></b> .....	163

<i>Can Soil Water Repellency Impact the Function and Efficiency of Bioretention Cells?</i> .....	165
<i>Comparative Assessment of Enriched Compost and Biochar Application in an Olive Orchard in Crete</i> .....	166
<i>Revealing Land Management Practices Effects on Ecosystem Recovery Using Ndvi</i> .....	168
<b>MET3: Social Innovation Labs: A Collaborative Space for Co-creation and Social Transformation</b> .....	170
<i>How Living Labs Can Support Lasting Transformation</i> .....	171
<i>Soil Living Labs as Tools For Sustainable Land Management: a Conceptual and Operational Framework Based on a Systematic Review</i> .....	172
<i>Implementing Nbs Solutions to Enhance Regional Climate Resilience Through the Co-Creation Approach of the Natalie Transformations Labs</i> .....	174
<i>A Soil Database For the Province of Granada to Support Pedoclimatic Modelling and Environmental Degradation Assessment</i> .....	176
<b>AN6: Nature-based solutions for water quality and quantity in Agricultural land</b> .....	178
<i>Hydrogeological Experiments on Mar Efficiency in Oaxaca, Mexico</i> .....	179
<i>Integrating Hydrogeological and Agronomical Sciences to Assess Agmar Suitability in North Indian Region</i> .....	181
<i>Territorial Center For Nature-Based Solutions (Nbs): an Inclusive Mechanism to Bridge Policy, Science, and Local Action in Southern Mauritania</i> .....	183
<i>Learning to See the Invisible - Experimental Approach to Understanding Microplastic Pollution Processes in Vineyard Soils</i> .....	185
<i>Effect of Hedgerows and Vegetation Cover as Decentralized Flood Protection Measures on the Drainage Behaviour of Arable Soil With a Historical Plough Pan</i> .....	186
<i>Short-Term Influence and Potential Long-Term Impacts of Cover Crops on the Health of Southern United States Inceptisols</i> .....	188
<b>MET5/6: Nature-based solutions for transformation journeys</b> .....	190
<i>Disentangling the Green, Grey, and Hybrid in a Complex Nature-Based Framing</i> .....	191
<i>Making Monitoring Work: Addressing Implementation Challenges in Nature-Based Solutions</i> .....	192
<i>Forests and Forest Management as Nbs: Lessons Learned From Co-Creation Processes in the Upper Allgäu (Germany)</i> .....	194
<i>Balancing Urban Densification and Climate Resilience With Nature-Based Solutions: Insights Into 3D Spatial Patterns and Cooling Effects Via Remote Sensing</i> .....	196
<i>Moroccan Vernacular Knowledge: the Genius of Durability and Adaptivity</i> .....	198
<i>Scaling Soil-Based Farm Management: an Action Perspective on Carbon Sequestration and Agricultural Transition</i> .....	199
<i>Circularity and Interconnectivity of Sustainable Bioeconomy and Agriculture - Optimisation of Approaches to the Nature-Based Solutions.</i> .....	200
<i>Making Nbs Work For Transformational Adaptation at the Local Level: What Can We Learn From Comparative Approaches?</i> .....	201
<i>Dendrogeomorphology in Intertropical Mountain Environments: Case of El Rosario, Michoacán.</i> .....	203
<b>NH3/4: Scaling and Integrating Nature-Based Solutions for Climate Action: Frameworks for Classification</b> .....	205
<i>Enhancing Regional Climate Resilience: a Comprehensive Evaluation Framework From the Natalie Project</i> .....	206
<i>Comparative Analysis of Yolo Models For Vineyard Abandonment Detection in</i>	

<i>Oltrepò Pavese</i> .....	208
<b>Mainstreaming Nature-Based Solutions in Practice Across Coastal and Riverine Areas of Europe</b> .....	210
<b>Mapping Soil Erosion in Vineyards to Create the First National Database: the Isum Web-Based Approach</b> .....	212
<b>UR: Upscaling and effects of nature-based solutions in urban regions and metropolises</b> .....	213
<b>Developing a Comprehensive Framework For Upscaling Nature-Based Solutions For Wastewater Treatment in Urban India: a Case of Kachchh, Gujarat</b> .....	214
<b>Rejuvenating India'S Water Bodies: Nature-Based Solutions For Sustainable Water Security</b> .....	216
<b>Green Walls For Water and Waste Circularity in Urban Water-Scarce Environments</b> .....	218
<b>Free the Wai</b> .....	220
<b>Suds For Water and Climate Challenges in Murcia: a Cardimed Case Study</b> .....	222
<b>Assessing the Short and Long-Term Impact of Green Roofs on Urban Air Quality: Eindhoven Case-Study</b> .....	224
<b>From Water Scarcity to Resilience: Indicators For Nature-Based Solutions in Semi-Arid Urban Environments</b> .....	225
<b>Agave Salmiana as a Functional Component of Bioretention Devices in Semiarid Climates</b> .....	226
<b>Nature-Driven Greening Metropolis; the Case of Monterrey, Mexico</b> .....	228
<b>Outdoor Urban Milpa System Next to the Tec Greenhouse in Monterrey, Nuevo León</b> .....	229
<b>Making a Post-Earthquake Urban-Rural Landscape Resilient: Landscape Planning Approach in Kahramanmaras Province</b> .....	231
<b>From Fallow to Flourishing: Nbs Ideas and Implementation Strategies For Belfast</b> .....	233
<b>SB1/2/3: Inclusive and Collaborative Governance of Nature-Based Solutions:</b>	
<b>Advancing Awareness, Partnerships, and Socio-Environmental Justice</b> .....	234
<b>Introducing the Landscape Digital Twin</b> .....	235
<b>Measuring What Matters: Co-Creation Indicators For the Socio-Political Dimensions of Nature-Based Solutions</b> .....	237
<b>Assessment and Perception of Rural Socio-Ecological System Development in Suburban Conditions in Central Europe</b> .....	239
<b>Designing For Transformation: a Framework For Resilient and Sustainable Food Systems Within Safe and Just Operating Spaces</b> .....	240
<b>Advancing Climate Adaptation Through Forest-Based Nature-Based Solutions: a European Database Approach</b> .....	242
<b>Index</b> .....	245



# The Mission of TerraEnVision 2025

Our Planet suffers from human activities. Scientists know more and more about our environment, about processes, rates of change, new threats and risks. However, the challenges seem to grow quicker than the solutions that can be created. To find the right, feasible and viable solutions to make the transition towards a society that stays within the planetary boundaries, it is needed that scientists, policy makers and to join forces with industry.

This conference aims to focus on finding solutions for the societal issues of our time. TERRAenVISION promotes to exchange scientific research, solutions from industry and insights from policy for interdisciplinary collaboration and networking. To bring scientists and stakeholders that have the same goal, work on the same societal issue, but have different backgrounds. By bringing the people and their knowledge together, we may be able to take the steps towards solutions that can bring our society to a more sustainable situation. In this conference, we want to link to International policies such as the Sustainable Development Goals, the UN Climate conventions, the Green Deal, COP and CAP.

This conference is framed around themes which are connected to the big transitions of our time. Each theme is kicked off by two plenary keynote speeches of 20 min, followed by a discussion. After the plenary session, a range of different parallel sessions will be organised.

We want to stress that this conference is not only for scientists, but also for those people from outside the scientific world working on transitions towards climate mitigation and adaptation, sustainable cities and agriculture and a circular economy with a focus on the sustainable use and management of the natural system.

The Chair of the TerraEnVision Organizing Committee,

Saskia Keesstra

Chair of the TERRAenVISION Foundation



# Organizing Committee

1. JESUS RODRIGO-COMINO, University of Granada, Spain
2. SASKIA KEESSTRA, Senior researcher, Sustainable Land and Water Management at Climate-Kic, The Netherlands
3. MARGOT DE CLEEN, Senior Advisor, Soil and Water Ministry of Infrastructure and Water Management, The Netherlands
4. ARTEMI CERDA, Professor in Physical Geography, University of Valencia, Spain
5. IOANNIS DALIAKOPOULOS, Assistant Professor, Hellenic Mediterranean University, Greece



# Keynote speakers

## **Belén Pérez Pérez**

### **Post doctoral researcher, University of Granada**

PhD Geography and Territorial Management from the University of Granada. Post doctoral researcher at the Instituto of Regional Development at the University of Granada. Her main lines of research are related to the planning and management of renewable energies from a multiscale and multidimensional perspective to achieve a fair and balanced energy transition that puts people at the centre. She has participated as a researcher in a dozen European, national and regional research projects and has conducted research at universities in France and Austria and taught at several universities in Portugal. She has participated in various conferences as a guest speaker and/or as a member of the scientific committee in Mexico, Portugal, Austria, and Spain. As a result of her academic activity, she has produced more than thirty scientific publications on these topics.



## **Javier Cabello**

### **Professor of Botany, University of Almería**

Professor of Botany at the University of Almería, he also serves as Director of the Andalusian Centre for Global Change - Hermelindo Castro (ENGLOBA). His academic work focuses on biodiversity conservation and monitoring, global change, socio-ecological systems, and the functions and services of ecosystems.

His research centres on the assessment of ecosystem functioning and ecosystem services, with a current emphasis on the ecohydrological processes that underpin ecosystem dynamics. A strong advocate for integrating scientific knowledge with policy and management, he actively promotes dialogue and knowledge exchange among scientists, land managers, decision-makers, and local communities.

He works closely with protected area authorities and has contributed to various co-production processes supporting nature-based solutions and multifunctional landscape management. As a representative of the Andalusian public universities, he serves on the Participation Council of the Sierra Nevada Natural and National Park and on the Andalusian Council of Biosphere Reserves. In both roles, he has worked to incorporate the concept of ecosystem services into planning, decision-making, and social discourse—particularly in the context of Mediterranean mountains and cultural landscapes.



## **Doug McMillan**

### **Co-founder, Green Restoration Ireland Cooperative**

Doug McMillan has a PhD in Environmental Sciences. He has over 25 years of combined experience in academic research, consultancy, environmental monitoring and training in the fields of ecology, environmental science, EHS, laboratory, carbon, energy, sustainability and quality management systems and auditing. He is a co-founder of the Green Restoration Ireland Cooperative (GRI) which was established in 2019. GRI is currently managing the *Peatlands for Prosperity* project funded by the Government of Ireland and EU Just Transition Fund. This project is showcasing suitable new paludiculture crop and carbon income options to peatland farmers for their agricultural peatlands and 'cutover' lands. This follows on from the work of the Farm Carbon E.I.P. which aimed to reduce carbon emissions from peat grasslands



## **Juan Francisco Delgado Morales**

### **Vice President, European Foundation for Innovation**

Senior executive with over 20 years of leadership in digital transformation, public-private innovation, and strategic development in the agri-food and artificial intelligence sectors. Vice President of the European Foundation for Innovation (INTEC) and Executive Vice President of the Spanish Association for Innovation in Artificial Intelligence. Recognized as a WBAF Senator and founder of international forums such as SmartAgriFood Summit. Committed to building bridges between technology, entrepreneurship, and sustainable rural development.



## **Víctor F. Rodríguez Galiano**

### **Professor, Department of Physical Geography and Regional Geographical Analysis, University of Seville**

Victor F. Rodríguez-Galiano is a Full Professor at the Department of Physical Geography and Regional Geographical Analysis, University of Seville (Spain). His research focuses on remote sensing for environmental monitoring, artificial intelligence applied to geospatial modelling, and land surface phenology. He appears in the “World Top 2% Scientist Ranking” by Stanford University and has led numerous national and European research projects. He is the Principal Investigator of the ESA-funded project EO4CerealStress, and is responsible for the validation of the Copernicus High Resolution Vegetation Phenology and Productivity (HR-VPP) product under contract with the European Environment Agency (EEA). He co-chairs the Phenology Focus Area of the CEOS Land Product Validation (LPV) subgroup, an international initiative under the Committee on Earth Observation Satellites (CEOS) that coordinates the global validation of satellite-derived biophysical products. The LPV subgroup is chaired by NASA, and he actively collaborates with its secretariat in developing the validation protocol for satellite-based phenology products. He also serves as convenor of the dedicated session on phenology at the ESA Living Planet Symposium.



## **Manuela Martínez**

### **President, Salvemos la Vega-Vega Educa**

President of "Salvemos la Vega-Vega Educa" since 2015 and responsible for the Activism and Society Area. She has been part of the InterVegas Federation's Standing Committee since its establishment in 2015, where platforms and entities operating for their historic agrarian and forestry territories throughout Spain come together.



## **Rob Roggema**

### **Professor of Regenerative Culture, Tecnológico de Monterrey, Mexico**

Prof. Dr. Rob Roggema is Faculty of Excellence Professor of Regenerative Culture at Tecnológico de Monterrey, Monterrey, Mexico, and director/founder of Cittaideale, office for adaptive design and planning. He is one of the lead-authors of the Architecture, Urban Design and Planning chapter of the third assessment report of the UCCRN (Urban Climate Change Research Network). He is a Landscape Architect and an internationally renowned design-expert on sustainable urbanism, climate adaptation, water-sensitive landscapes, nature-driven design, and urban agriculture. He held several professorship positions in Mexico, the Netherlands and Australia, as well as visiting professorships in Northern Ireland, Australia and Japan, and has written multiple books on nature- and landscape-driven planning and design of landscapes and cities and is series editor of 'Contemporary Urban Design Thinking' (Springer). He recently led regenerative design projects on rewilding and greening urban landscapes, such as Green Monterrey Metropolis, Reinventing Traditions; Foodscapes of the Noreste, Mexico, Regenerative Regions and The Miyawaki forests of Mexico. He was the leader of the climate adaptive design 2021 team for the Groningen region ('Moeder Zernike'), initiated the Food-Energy-Water-nexus project 'the Moveable Nexus' (SUGI/JPI-Europe), lead the design team of 'Nature-Rich Netherlands' and Greening NEOM. For his PhD, he developed the Swarm Planning concept, a dynamic way of planning urban landscapes for future adaptation to climate change impacts. He designed and led more than 30 design charrettes around the world, involving communities, academics, governments, and industries in design processes for more resilient communities.



## **Gerd Lupp**

### **Research Associate, Technical University of Munich**

Dr. Gerd Lupp has been working as a research associate at the Chair for Strategic Landscape Planning and Management at the Technical University of Munich since 2013. After completing his PhD in Forestry at the University of Freiburg, he was engaged in many self-acquired inter- and transdisciplinary research projects in Germany and Europe. His broad research and work interests comprise ecosystem services, urban forests, Nature-based Solutions, societal demands on nature, human-nature relationships, participatory processes and planning approaches, nature-related recreation and renewable energies from biomass. Research projects at the Chair are "Urban Forest 2050" project (funded by the Bavarian Forestry Administration with grants from the Bavarian Ministry of Food, Agriculture, Forestry and Tourism), PHUSICOS (EU Horizon 2020) and TRANS-lighthouses (EU Horizon).



## **Jorge Castro Gutiérrez**

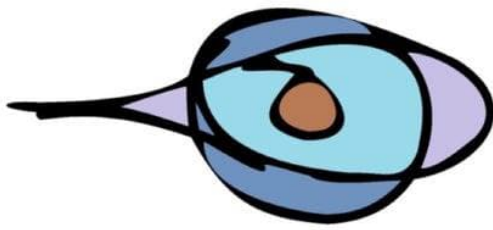
### **Professor of Ecology, University of Granada**

I am Professor of Ecology at the University of Granada. I have worked as a researcher, teacher or visiting professor in different institutions of Spain, Sweden, UK or USA. I currently teach and/or mentor different pre-and post-graduated courses of Ecology at Granada University as well as for American institutions with visiting programs in Granada, such as the Institute for Education of Students (IES, Chicago) or the Consortium for Advanced Studies Abroad (CASA program, Brown University). My research scope is related mostly to Forest Ecology, Restoration Ecology and ecophysiology, including aspects such as plant-animal interactions, plant-plant interactions or plant-soil interactions, with a strong focus on the effect of climate change and global change in Mediterranean forests. I am author or coauthor of ca. 130 publications, including scientific papers, book chapters, and articles for broad distribution, and I have participated in ca. 25 national or international research projects related to these fields of research. I have acted as consultant for the Spanish Environmental Agency and for the International Union for Conservation of Nature (UICN)





# Conference Program



TERRA  
**ENVISION**

**Program TERRAenVISION 2025**  
**Nature-based Solutions to Facilitate the**  
**Transitions for living within the**  
**Planetary Boundaries**  
**Granada, Spain, 8-11 July, 2025**  
**(pre-post conferences 6-7 and 12-13 July)**

Organisers:

Jesús Rodrigo Comino, Associate Professor, University of Granada, Spain

Saskia Keesstra, Senior researcher, Climate- Kic Foundation, The Netherlands

Margot de Cleen, Senior Advisor, Ministry of Infrastructure and Water Management, The Netherlands

Artemi Cerdà, Professor in Physical Geography, University of Valencia, Spain

Ioannis Daliakopoulos, Assistant Professor, Hellenic Mediterranean University, Greece



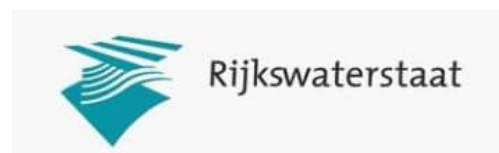
UNIVERSIDAD  
DE GRANADA



GRANADA  
**TIERRAVIVA**



**SEDER**  
soil erosion  
and degradation  
research group



# Pre-conference excursions

Date	Topic
5/07/2025	<p><b>From the Badlands of Gorafe to the Sierra Nevada periglacial ecosystems. A visit with two walks to understand the impact of altitudinal gradients and related processes affecting the geomorphological, pedological and biogeographical environmental conditions.</b></p> <div></div>
6/07/2025	<p><b>With “Salvemos La Vega, La Vega-Educa”, we will learn how traditional and modern production can articulate a vulnerable territory close to Granada city. Nature-based solutions as key environmental tools to achieve sustainable development.</b></p> <p><b>Meeting point (8:00): <a href="https://maps.app.goo.gl/WsQwyymJGRcyKTtS9">https://maps.app.goo.gl/WsQwyymJGRcyKTtS9</a> (on front of the Congress venue, close to the hotel Granada center).</b> Visit to the farm that recover the Andalusian Donkey, to the project that restore land via poplar plantations and the irrigation system of Monachil.</p> <div></div>

07/06/2025

Tropical fruit production, cultivation and development of past emerging crop and current consolidated sector (Vélez Málaga).

Meeting point (7:30): <https://maps.app.goo.gl/WsQwyymJGRcyKTtS9> (on front of the Congress venue, close to the hotel Granada centre). 9:00 in Vélez Málaga with prof. José María Senciales-González (University of Málaga).

The Delta of the River Vélez was visited to understand the retreated of the coastal land due to the lack of sediments and the sea level rise. The impact of coastal constructions is also a key issue in this area. The visit to the nursery of avocados show us the high technological change that induce the increase of tropical fruit production in the south of Granada and the coast of Málaga.



## Tuesday 8th of July:

8.30-10.00 City walk for NBS in Granada city.

Meeting point: (main entrance at the Paseo Prof. Juan Ossorio, <https://maps.app.goo.gl/1PBPTob1aHnHWSxA6>)



10.00-11.00 Registration: Main Hall, -2 floor of the Escuela Técnica Superior de Ingeniería de Caminos, Canales y Puertos de la Universidad de Granada

<https://g.co/kgs/BNMVL2C>



**11.30-12.10** Opening by University of Granada: Vice-cancellor of transference (Eteban Romero), Dean of Faculty of philosophy and letters, and director of the Polytechnic school

Link: Main room → <https://meet.google.com/vur-mtqt-pka>



**12.10-13.30** Opening panel: Innovative solutions for sustainable agriculture in Andalusia  
chair: Jesus Rodrigo-Comino

Pitches by panelists:

- Margarita Sepulveda: Approach to a Potential Strategy for Improving Agricultural Soil Quality Through the Use of Pig Slurry in Olive and Cereal Crops
- David Colado: SOCIAL-AGRI: Digital innovation and collaboration for sustainable agriculture
- Laura Cambronero Gonzales Vivar: GOSOSVITI: Innovation in Viticulture through an Integrated DSS (Decision Support System) for Soil and Water Conservation
- Jesus Vivar: Perception and Use of Precision Agriculture Technologies in Viticulture: Preliminary Results from the GO SOSVITI Project
- Lourdes Vega Espinar: Implementation of innovative practices for the reduction of the alcohol content of Andalusian biologically aged wines

Discussion

Link: Main room → <https://meet.google.com/vur-mtqt-pka>

**13.30-15.00** LUNCH

**15:00-16.30** Parallel session

**AN1/3: Soil and water conservation for sustainable land management in grazing**  
Organisers: Manuel Seeger and Jesus Barrena

1. Spatial patterns of soil bacterial communities in Mediterranean agrosilvopastoral system by Jesus Barrena Gonzalez
2. Enhancing Climate-Resilient Irrigation for Fruit Production through Reference Evapotranspiration Calibration and Nature-Based Solutions in Bosnia and Herzegovina by Natasa Cerekovic

3. Farm dams as climate-smart adaptations for agricultural water storage in Sweden by Melissa Reidy
4. Using Policy Innovation to Scale Biochar as a Nature-Based Solution for Climate-Resilient Land Management: Insights from Ireland by Lena Grobusch
5. Environmental factors regulating the fire effects on soil organic carbon across Malagasy ecosystems by Miralalaina Lovafitia Ratovoarimanana
6. Biochar as a nature-based solution in runoff and soil erosion control: plot-scale measurements under natural rainfall by Atollah Kavian (online)
7. Assessment of Nature-Based Agricultural Practices for Soil and Water Conservation Using SWAT+ by Brigitta Szabo (online)

ROOM 1: LINK: <https://meet.google.com/wsj-aejy-njp>

**NH1: Innovative solutions for increasing resilience to water-related hazards and soil erosion in agricultural areas**

**Organisers: Valerio Vivaldi, Valentina Vaglia, Chiara Toffanin**

1. Water as a Foundation for Climate Resilience: Integrating Energy Production and Agricultural Sustainability at Cascina Vialone by Nadia Bertolino
2. Evaluation and innovative study of the vine according to new agronomic scenarios for Oltrepì Pavese, Italy by Giovanni Marchese
3. Hydrogeological characterization of steep vineyard slopes through a combined approach for shallow slope failures susceptibility estimation by Valerio Vivaldi
4. Nature-based Solutions in vineyards of Oltrepì Pavese (Northern Italy): effects on land degradation by Antonio Gambarani
5. Mechanical behavior of clayey soil treated with *Trichoderma asperellum* by Ali Hajian
6. Effect of fungal treatment with *Penicillium chrysogenum* on mechanical properties of a clayey soil by Kima Saber Sichanii
7. Spaceborne monitoring of vineyards: optical and multipolarized radar-based indices tested on a wine-producing area in Northern Italy in the context of the NODES project by Fabio Dellacqua (online)

ROOM 2: LINK: <https://meet.google.com/wce-hqnf-dhk>

**16.30-17.00** Coffee/tea break

**17.00-18.30** Plenary session **NATURE BASED SOLUTIONS FOR AGRICULTURE AND NATURE AREAS (SOIL, WATER AND LANDSCAPE) (Aula): Saskia Keesstra**  
**Keynote: Juan Francisco Delgado (EU Foundation, Spain)**  
*Cultivating Resilience: Nature-Based Solutions for Soil, Water, and Agricultural Landscape in the Era of Climate Change (2025/26)*  
**Keynote: Douglas McMillan (GRI, Ireland)**  
*Paludiculture – Silver Bullet Solution for landscape-level NBS (Bridging the agricultural-conservation divide)*  
**Panel discussion**

Link: Main room → <https://meet.google.com/vur-mtqt-pka>



18.30-  
20.00 Poster session with refreshments

## Wednesday 9<sup>th</sup> July

8.00-9.00 Registration: **Main Hall, -2 floor** of the Escuela Técnica Superior de Ingeniería de Caminos, Canales y Puertos de la Universidad de Granada  
<https://g.co/kgs/BNMVL2C>

9.00-10.30 Plenary session theme Methodologies: how to measure processes and impact of Nature-based solutions (Aula) chair: Manuel Seeger  
Keynote 1: **VÍCTOR RODRÍGUEZ GALIANO (Universidad de Sevilla, Spain)**  
*Using hyperspectral remote sensing to detect effects of salinity and nutrient deficit in rice crops*  
Keynote 2: **Javier Cabello (University of Almeria, Spain)**  
*Traditional water management systems in the Mediterranean mountains.*  
Discussion between keynotes and audience  
Link: Main room → <https://meet.google.com/vur-mtqt-pka>



10.30-11.00 Coffee/tea break

11.00-12.30 Parallel session  
**MET1/2/4: Advances and Best Practices in Ecosystem Restoration and Environmental Remediation: Integrating Remote Sensing, Machine Learning, and In Situ Technologies**  
Organisers: Yannis Louloudakis and Alberto Leombruni

1. **MEO-Carbon: A Decision-Support Tool to Identify Critical Areas and Guide Ecosystem Restoration** by N. Sfaksi
2. **Hazardous elements and pharmaceuticals in soils of a Mediterranean wetland (L'Albufera de Valencia, Spain). Possible interactions** by Vicente Andreu
3. **Fertile Islands from above: Utilizing UAV photogrammetry to map fertile forest patches in a UNESCO biosphere reserve** by Lars Stefan Engelmann
4. **Emerging Contaminants in Soil Ecosystems: Microbial Disruption and Antimicrobial Resistance from a One Health Perspective** by Lyudmyla Symochko
5. **AI-Generated Landscape Imagery: Towards a Comprehensive Assessment** by Phoebe Koundouri and Fivos Papadimitriou (online).

	<p>6. Full-scale Application in Italy of an ERD Technology for the treatment of an Aquifer Impacted with Chlorocarbons near a salt pond ecosystem by Alberto Leombruni (online)</p> <p>7. Land Restoration Effectiveness Assessed by Satellite-Based Remote Sensing Technologies as A New Monitoring Approach by Ghadir Zbedat (online)</p> <p>ROOM 1: LINK: <a href="https://meet.google.com/wsj-aeyj-njp">https://meet.google.com/wsj-aeyj-njp</a></p>
	<p><b>MET3: Social Innovation Labs: A Collaborative Space for Co-creation and Social Transformation</b></p> <p><b>Organisers:</b> Lucía Moreno-Cuenca, Maria Teresa González-Moreno</p> <ol style="list-style-type: none"> <li>1. How Living Labs can support lasting transformation by Sonia Pietosi</li> <li>2. A soil database for the province of Granada to support pedoclimatic modelling and environmental degradation assessment by Lucía Moreno-Cuenca</li> <li>3. Soil living labs as tools for sustainable land management: a conceptual and operational framework based on a systematic review by María Teresa Gonzalez-Moreno</li> <li>4. Implementing NBS Solutions to enhance regional climate resilience through the co-creation approach of the NATALIE Transformations Labs by Beatriz Medina (online)</li> <li>5. Participatory Local Governance of Soil Health by Josefa Sánchez Contreras and dr. Alberto Matarrán Ruiz (online)</li> </ol> <p>ROOM 2: LINK: <a href="https://meet.google.com/wce-hqnf-dhk">https://meet.google.com/wce-hqnf-dhk</a></p>
<p>12.30-14.00</p>	<p>Lunch break</p>
<p>14.00-15.30</p>	<p><b>Plenary session theme: Nature-based solutions for natural hazards (Fire, Floods and Droughts) (Aula) chair: Artemi Cerdà</b></p> <p><b>Keynote 1: Jorge Castro, (University of Granada, Spain)</b> <i>Restoring Burnt Forests for the Future: Shifting Paradigms Towards Nature-Based Solutions</i></p> <p><b>Keynote 2: Elisa Furlan (CMCC, Italy)</b> <i>Transformative Nature-Based Solutions for building climate resilience and addressing environmental challenges</i></p> <p><b>Discussion between keynotes and audience</b></p> <p>Link: Main room → <a href="https://meet.google.com/vur-mtqt-pka">https://meet.google.com/vur-mtqt-pka</a></p> 
<p>15.30-16.00</p>	<p>Coffee/tea break</p>

<p>16.00- 17.30</p>	<p>Parallel session  <b>MET5/6: Nature-based solutions for transformation journeys</b>  <b>Organisers: Elisa Furlan and Denyse Julien</b></p> <ol style="list-style-type: none"> <li>1. <b>Circularity and interconnectivity of sustainable bioeconomy and agriculture</b>  <b>An optimisation of approaches to the nature-based solutions. By Lena Madden</b></li> <li>2. <b>Making Monitoring Work: Addressing Implementation Challenges in Nature-Based Solutions by Pilar Andres</b></li> <li>3. <b>Forests and Forest Management as NBS: Lessons learned from Co-Creation processes in the Upper Allgiu (Germany) by Gerd Lupp</b></li> <li>4. <b>Making NbS work for transformational adaptation at the local level: What can we learn from comparative approaches? By Lena Grobusch</b></li> <li>5. <b>Developing a Comprehensive Framework for Upscaling Nature-Based Solutions for Wastewater Treatment in Urban India: A Case of Kachchh, Gujarat by by Aswin S Kumar (online)</b></li> </ol> <p><b>ROOM 1: LINK: <a href="https://meet.google.com/wsj-aejy-njp">https://meet.google.com/wsj-aejy-njp</a></b></p>
	<p>Parallel session  <b>AN6: Nature-based solutions for water quality and quantify in Agricultural land</b>  <b>Organiser: Dara Park</b></p> <ol style="list-style-type: none"> <li>1. <b>Hydrogeological experiments on MAR efficiency in Oaxaca, Mexico by Roel Dijkema</b></li> <li>2. <b>Geomorphodynamic changes by land-use change in South Spain by Manuel Seeger</b></li> <li>3. <b>Short-term Influence and Potential Long-term Impacts of Cover Crops on the Health of Southern United States Inceptisols by Dara Park</b></li> <li>4. <b>Effect of Hedgerows and Vegetation Cover as Decentralized Flood Protection Measures on the Drainage Behaviour of Arable Soil with a Historical Plough Pan by Mathias Jackel</b></li> <li>5. <b>Integrating Hydrogeological and Agronomical Sciences to Assess AgMAR Suitability in North Indian Region by Jadav Kartikkumar (online)</b></li> <li>6. <b>Territorial Center for Nature-based Solutions (NbS): An Inclusive Mechanism to Bridge Policy, Science, and Local Action in Southern Mauritania by Almamy Soumary (online)</b></li> </ol> <p><b>ROOM 2: LINK: <a href="https://meet.google.com/wce-hqnf-dhk">https://meet.google.com/wce-hqnf-dhk</a></b></p>
<p>17.30- 19.00</p>	<p>Poster session with refreshments</p>



## Thursday 10th July

8.00-9.00 Registration: **Main Hall, -2 floor** of the Escuela Técnica Superior de Ingeniería de Caminos, Canales y Puertos de la Universidad de Granada  
<https://g.co/kgs/BNMVL2C>

9.00-10.30 Plenary session theme: **SCIENCE BROKERS FOR TRANSITIONING TO A CLIMATE RESILIENT AND CIRCULAR SOCIETY** chair: Saskia Keesstra  
 Keynote 1: Gerd Lupp (Technische Universität München, Germany)  
*The socio-cultural and socio-political dimensions of NBS and the relevance of Social Sciences and Humanities for mainstreaming NBS*  
 Keynote 2: Manuela Martinez Jimenez (NGO "Salvemos la Vega-Vega Educa", Spain)  
*Salvemos la Vega-Vega Educa: 20 years involving society and institutions in the protection and revitalization of the "Vega de Granada"*  
 Discussion between keynotes and audience  
 Link: Main room → <https://meet.google.com/vur-mtqt-pka>

10.30-11.00 Coffee/tea break

11.00-12.30 Parallel session  
**NH3/4: Scaling and Integrating Nature-Based Solutions for Climate Action: Frameworks for Classification, Prioritization, and Resilience Strategies**  
 Organisers: Saskia Keesstra

1. Comparative Analysis of YOLO Models for Vineyard Abandonment Detection in Oltres Pavese by Sohail Anwar
2. Enhancing Regional Climate Resilience: A Comprehensive Evaluation Framework from the NATALIE Project by Jesus Soler
3. Mainstreaming nature-based solutions in practice across coastal and riverine areas of Europe by Geert van der Meulen

4. Rejuvenating India's Water Bodies: Nature-Based Solutions for Sustainable Water Security by Ankit Kumar (online)
5. Exploring the Roman Centuriation Northeast of Padua as a Historical Nature-Based Solution for Better Flood and Drought Resilience by Tanja Kremenic (online)

ROOM 1: LINK: <https://meet.google.com/wsj-aeyj-njp>

Parallel session

UR2: Upscaling and effects of nature-based solutions in urban regions and metropolises

1. Assessing the short and long-term impact of green roofs on urban air quality: Eindhoven case-study by Miguel Rosa
2. Landscape based solutions for people and biodiversity by Nico Tillie
3. From water scarcity to resilience: Indicators for Nature-based Solutions in semi-arid urban environments by Liliana Mendiola
4. Green walls for water and waste circularity in urban water-scarce environments by G Vazquez
5. From fallow to flourishing: NBS ideas and implementation strategies for Belfast by Sean Cullen
6. Making a post-earthquake urban-rural landscape resilient: Landscape planning approach in Kahramanmaraş Province by Nilgun Karadeniz, Sule Kusakurek and Sebahat Aciksoz
7. Free the Wai by Matthew Bradbury

ROOM 2: LINK: <https://meet.google.com/wce-hqnf-dhk>

12.30-14.00 Lunch break

14.00-15.30 Plenary session theme: Theme Nature-based solutions for urban and industrial areas (soil, water and spatial planning). (Aula) chair: Jesus Rodrigo-Comino

Keynote: Belén Pérez Pérez (University of Granada)

*Title: City and access to energy. Energy Communities from the Social Economy.*

Keynote: Rob Roggema (Tecnológico de Monterrey Mexico)

*Nature-driven spatial strategies to create a green metropolis*

Panel discussion

Link: Main room → <https://meet.google.com/vur-mtqt-pka>



15.30-16.00 Coffee/tea break

16.00-17.30 Parallel session

SB1/2/3: Inclusive and Collaborative Governance of Nature-Based Solutions: Advancing Awareness, Partnerships, and Socio-Environmental Justice

Organisers: Pavel Raska and Gerd Lupp

1. SUDS for Water and Climate Challenges in Murcia: A CARDIMED Case Study by Elena De Vicente
2. Measuring What Matters: Co-Creation Indicators for the Socio-Political Dimensions of Nature-Based Solutions by Gerd Lupp
3. Designing for Transformation: A Framework for Resilient and Sustainable Food Systems within Safe and Just Operating Spaces by Denyse Julien
4. Introducing the Landscape Digital Twin by Henk Alkemade (online)

ROOM 1: LINK: <https://meet.google.com/wsj-aevj-njp>

Parallel session

URW2: Cultivating resilience: Urban agriculture as a nature-based solution

Organisers: Greg Keeffe, Sean Cullen and Rebecca McConnell

Talk by Igor Rubio-Cisneros (online): Outdoor urban milpa system next to the TEC greenhouse in Monterrey, Nuevo Len

ROOM 2: LINK: <https://meet.google.com/wce-hqnf-dhk>

17.30-19.30 Poster session with refreshments and closing of indoor event



**Posters to be presented all days**

- 1. Mapping Soil Erodibility by means of Machine Learning Models in a Semi-arid Watershed by Artemi Cerdà**
- 2. Past herbivore grazing pressure on highly diverse open ecosystems in Central-Eastern Europe: a view from coprophilous fungal spores by Angelica Feurdean (online)**
- 3. Disentangling the green, grey, and hybrid in a complex nature-based framing by Pavel Raska**
- 4. Multi-objective, stakeholder-oriented planning of nature-based small water retention measures in an agricultural catchment by Ronald Andrees Kolcsar (online)**
- 5. BIOGAS RESIDUES IN THE BATTLE FOR TERRESTRIAL CARBON SEQUESTRATION IN THE GRASSLAND SOILS OF THE GREATER REGION by Bella Tsachidou**
- 6. Principles for the Assessment of Natural Source Zone Depletion Based on Temperature Measurements in the Subsoil by Daniel Daz Casado**
- 7. Soil erosion in agriculture land in Spain. A review by Artemio Cerda**
- 8. Soil erosion control in citrus plantations. The use of Chipped Pruned Branches in sloping terrain as a mulch. By Artemio Cerda**
- 9. Soil erosion control in citrus plantations. The case of cover crops in the Montesa Experimental station by Artemio Cerda**
- 10. The effect of biochar from pruning wastes on CO<sub>2</sub> emissions, hydrophysical and soil biological properties by Gabriel Gasco**
- 11. ASSESSING CLIMATE IMPACT IN VINEYARDS OF BODEGAS CALVENTE (PADUL, GRANADA) THROUGH ADVANCED DATA PROCESSING AND BIOCLIMATIC INDICES by Lucia Moreno Cuenca**
- 12. Moroccan vernacular knowledge: the genius of durability and adaptivity by Youssra ELMarini**
- 13. Scaling Soil-Based Farm Management: An Action Perspective on Carbon Sequestration and Agricultural Transition by Jennie van der Kolk**
- 14. Balancing Urban Densification and Climate Resilience with Nature-Based Solutions: Insights into 3D Spatial Patterns and Cooling Effects via Remote Sensing by Karolina Zieba-Kulawik (online)**
- 15. Deriving forest cover rates from map sources: A contribution to official statistics and environmental reporting by Alessia D'Agata**
- 16. Google Earth Engine-Based Land Use/Land Cover Mapping in Granada, Spain Using Sentinel-2 and Machine Learning Techniques by Sinan DEMiR (online)**
- 17. Analysis of Tomato Yield Predictions with Sentinel-2 and UAV-Based NDVI: a case study in Northern Italian farms by Fabio Dell'Acqua (online)**
- 18. Dendrogeomorphology in intertropical mountain environments: case of El Rosario, Michoacin. by Violeta Rangel-Velarde**
- 19. Soil erosion in new citrus plantations. Rainfall simulation experiments. Montesa experimental station, Eastern Iberian Peninsula. By Artemio Cerda**
- 20. Can Soil Water Repellency Impact the Function and Efficiency of Bioretention Cells? By Jack Cuneo**
- 21. Agave salmiana as a Functional Component of Bioretention Devices in Semiarid Climates by Gabriela Vezquez-Rodriguez**

22. Assessing the impact of afforested species on carbon sequestration in the green zones of an industrial site located in arid regions of Iran by Shamsholla Ayoubi (online)
23. Soil erosion dynamics in rehabilitated apple orchards, hilly region, Central Iran (Use of magnetic susceptibility and Cs-137 techniques) by Shamsholla Ayoubi (online)
24. Proposing a Soil Quality Index for Cereal Croplands in Campo de Comara (Malaga, Spain) by Jesus Rodrigo-Comino
25. Mapping Soil Erosion in Vineyards to create the first national database: The ISUM Web-Based Approach by Jesus Rodrigo-Comino
26. A probabilistic approach for the analysis of susceptibility to shallow landslides in different soil managements by Matteo Giganti,
27. Connected Cities Strengthening Green Infrastructure through Data and Collaboration by Maria Glushkova (online)
28. Participatory Mapping for Wildfire Prevention: A Stakeholder-Based Approach in Sardinia (Italy) by Michela Bazzoni
29. Comparative Assessment of Enriched Compost and Biochar Application in an Olive Orchard in Crete by FENIA GALLIOU
30. Projection of Drought Tendencies in the Horno Pohronie Region (Central Europe, Slovakia) for the Period 2025,Äì2050 by Paulina Nalevankovi
31. Temporal Analysis of Dual-pol Scattering Powers over Wet and Dry Sown Rice Fields: A Case Study in Northern Italy by Fabio Dell'Acqua (online)
32. Revealing land management practices effects on ecosystem recovery using NDVI by Giannis Louloudakis
33. The impact of historical land cover change on soil organic carbon in Malagasy open grassy ecosystems : a stable isotope approach by Miralalaina Lovafitia Ratovoarimanana
34. Exploring the saprolite horizons as proxies for Enhanced Rock Weathering in tropical soil by Thairis Gomes dos Santos
35. An integrated multi-process evaluation of land degradation in Europe by Remus Pravalie
36. Join the Green Horizons farmers network: a European network of networks for farmers that want to transition to sustainability by Saskia Keesstra
37. Advancing Climate Adaptation Through Forest-Based Nature-Based Solutions: A European Database Approach by Saskia Keesstra
38. Optimal Soil Management For Carbon Sequestration. By Ruben Dummer

## 11<sup>th</sup> July: Conference excursion

Join Us for an Exclusive Vineyard & Orchard Tour!

Meeting point (8:00): <https://maps.app.goo.gl/WsQwyymJGRcyKTtS9> (on front of the Congress venue, close to the hotel Granada center).

Jesús Rodrigo Comino, Laura Cambronero, Jesús González Vivar and Víctor Duran Suazo

Discover the cutting-edge agricultural research happening in our experimental vineyard between Padul and Cozvíjar, part of regional (GOSOSVITI) and European (SOILCRATES & SOSVITI-MCSE) projects. Explore innovative sustainable practices in our olive and almond groves in Lanjarón, where experimental plots feature cover crops, aromatic plants, and more handled by IFAPA, the Agriculture Research Institute of Andalucía.





# Post-conference excursions

(see details on other page)

Date	Topic
12/07/2025	<p>The impact of forest fires. Rehabilitation and restoration. A visit with the professor in Ecology Jorge Castro to show the impact of forest fires and the recovery after fires under different treatments.</p> 
13/06/2025	<p>Traditional water management systems in the Mediterranean mountains. A visit to the traditional aquifer recharge system in the slopes of Sierra Nevada guided by professor Javier Cabello</p> 



# Conference Abstracts

# Keynotes

## **Nature-Driven Spatial Strategies to Create a Green Metropolis**

Rob Roggema

*Tecnológico de Monterrey*

### **Abstract**

Globally, many metropolises suffer from overheating, disaster risks, urban pressure, and environmental problems. The current (economic) system focuses on continuing the urban reliance on external resources and the degradation of ecological features, thus exaggerating existing problems. The connection with supporting natural systems has been lost. To regenerate these, often invisible, systems nature-driven strategies can be employed to enhance the health and quality of urban environments for humans and non-humans alike.

This presentation will use the case of the Monterrey Metropolis to illustrate how nature-driven strategies and practices can support the increase of basic environmental qualities as well as the wellbeing and quality of life of its inhabitants. The core question here is how can we make progress in achieving a more regenerative future for intensively used conurbations? It is evident that moving forward on the current pathway will not bring us this highly urgent desirable future.

To discover the strategies and practices that can bring this future nearer, an extended Landscape-First methodology is applied. This starts with identifying the landscape pain in the metropolis. This pain is apparent in the city through excavated quarries, intrusion of illegal constructions in nature reserves, (ultra) large scale low density industrial buildings, and spatial barriers such as high- and railways. Additionally the natural creek and river system is invisible or broken in many (over 17,000) places within the metropolis. Regeneration of the natural systems, those that are supportive of the flourishing of the urban dwellers, starts with rekindling and reconnecting the natural springs and waterways, then supporting these by extensive nature-driven aligning spaces hence forming a city-wide ecological and green network. It allows the city to reconquer impermeable and abandoned spaces and turn these into an eco-web which can provide clean air, water and soil, and enhancing biodiversity at large. Once this support system of eco-uses is established, urban use can be embedded within. It comes without saying that the healing of the landscape pain will also provide much needed extra green spaces for all residents.

The last element in the methodology is not to stop at the metropolitan planning scale, but to actively deploy small scale eco-acupuncture interventions. In Monterrey several of these interventions have already be implemented, together shaping the overall nature-driven transformation. the transition takes place by planting a series of Miyawaki forests and Urban Milpa's to grow regional and healthy food. Both of these interventions are small scale so they can be located close to people, within neighborhoods, and based on native and regional species and agricultural methods. Together these little projects

substantiate the long-term nature-driven strategy at the metropolitan scale.

**Keywords:** Landscape First, Green metropolis, Nature-driven, Monterrey, Landscape pain

**References**

Roggema, R.; Rubio Cisneros, I.I.; Junco López, R.; Ramirez Leal, P.; Ramirez Suarez, M.; Ortiz Díaz, M. Loving and Healing a Hurt City: Planning a Green Monterrey Metropolitan Area. *Land* 2025, 14, 164. <https://doi.org/10.3390/land14010164>

## **Restoring Burnt Forests For the Future: Shifting Paradigms Towards Nature-Based Solutions**

Jorge Castro

*University of Granada*

### **Abstract**

Post-fire forest restoration has traditionally followed a highly interventionist approach, largely reliant on machinery and technological tools. This paradigm stems from a classical, engineering-oriented view of nature which, while it has undoubtedly contributed to significant advances in forest recovery, has often overlooked the natural processes and elements that can drive regeneration. In this talk, I will present examples illustrating how working with, rather than against, nature can enhance post-fire forest recovery. Such an approach aims to reduce management costs and ecological impacts, while simultaneously accelerating the regeneration process. This framework is grounded in the concept of nature-based solutions, which support natural regeneration by fostering positive ecological interactions and mitigating negative ones, ultimately increasing the forest's resilience to future disturbances. I advocate for what we term precision restoration (Castro et al. 2021), a restoration strategy that integrates broad ecological knowledge with a diverse set of tools and methodologies, ranging from low-tech to cutting-edge technologies. The objective is to maximize the likelihood that each plant or seed—whether sown by humans or naturally recruited—successfully grows into a mature tree, while minimizing both economic costs and disturbance to the environment.

**Keywords:** forest restoration, precision restoration, succession, ecological interactions

### **References**

Castro J, Morales-Rueda F, Navarro FB, Löf M, Vacchiano G, Alcaraz-Segura D (2021). Precision restoration: a necessary approach to foster forest recovery in the 21st century. *Restoration Ecology* 29, e13421 (doi: 10.1111/rec.13421).

## **Salvemos La Vega - Vega Educa: 20 Years Involving Society and Institutions in the Protection and Revitalization of the "Vega De Granada".**

Manuela Martínez Jiménez

*Salvemos la Vega - Vega Educa*

### **Abstract**

The Salvemos la Vega - Vega Educa initiative represents a multi-stakeholder Nature-Based Solutions (NBS) approach aimed at preserving and restoring the socio-ecological landscape of the “Vega de Granada”, in the south of Spain. Through its “Activism and Society” area, the platform mobilizes citizens, educational institutions, and local governments to promote ecological stewardship, cultural heritage, and sustainable land use. At the core of these efforts is the annual “Week of the Vega,” a community-wide campaign that combines cultural programming, environmental education, and participatory events to strengthen public awareness and place-based identity.

Salvemos la Vega - Vega Educa also implements targeted ecological actions grounded in NBS principles, including “Tree Acupuncture” for urban climate resilience, “Biodiversity Hedges” to enhance agroecological connectivity, and the protection and rehabilitation of traditional irrigation systems such as the Acequia del Albaricoque. These interventions are co-designed and co-executed with institutional partners, reinforcing collaborative governance and ensuring long-term impact. Salvemos la Vega - Vega Educa exemplifies how cross-sector collaboration, cultural engagement, and ecological restoration can converge in effective NBS to address land degradation, biodiversity loss, and socio-environmental disconnection in peri-urban landscapes.

**Keywords:** Nature-Based Solutions (NBS), civic engagement, ecological restoration, environmental education, agroecological landscape, inter-institutional collaboration,

## **Paludiculture - Silver Bullet Solution For Landscape-Level Nbs (Bridging the Agricultural-Conservation Divide)**

Doug McMillan

*Green Restoration Ireland Cooperative Society Ltd*

### **Abstract**

Irish peatlands have been subjected to drainage for centuries, firstly as a source of fuel and secondly after reclamation for agricultural land. As this process started from the edges this has resulted in an outer zone typically reclaimed for agriculture, a second zone of 'cutover' bog used for fuel (but not reclaimed for agriculture) and an inner zone of semi-intact peatland. Restoration work has concentrated on the most intact areas but through its work pioneering Ireland's first on-farm Paludiculture trials, Green Restoration Ireland has identified a 'silver bullet' opportunity in the regeneration of damaged areas of cutover by implementation of appropriate crops for wetter agriculture or forestry.

This will create new areas of restored and novel peatland habitat in these areas of cutover so resolving all the environmental issues of drained peat i.e. avoiding GHG emissions, sequestering carbon (depending on the 'crop'), enhancing biodiversity and water quality and increasing water storage, both in the blocked drains and in the rewetted peat soils. This will diversify income by generating carbon income and increasing the area of cultivable land which can be sown with potentially high value crops.

In addition, even without specific interventions this reclamation by paludiculture will help restore the remnant inner area of semi-degraded peatland and also regulate the supply of water to the surrounding farmlands. Lastly, this will familiarise farmers with the new methods required for successful implementation of these new farming practices making them more amenable to raising the water table for their existing farmed areas of peatland. This is significant as these are the highest emitters of GHGs for any current land use.

**Keywords:** Paludiculture, Raising Water Table, Peatlands, Wetter Farming

# **UR3: Nature based solutions for restoration of urban water cycle**

## Improved Modeling of Tree Rainfall Interception in Urban Hydrology: Quantifying the Stormwater Reduction by Birch (*Betula Pendula* Roth.) and Pine (*Pinus Nigra* Arnold) Trees

Mark Bryan Alivio, Matej Radinja, Mojca Šraj and Nejc Bezak

*University of Ljubljana, Faculty of Civil and Geodetic Engineering, 1000 Ljubljana, Slovenia*

### Abstract

There is renewed interest in incorporating trees into urban areas as part of nature-based solutions, creating a demand for more advanced urban hydrology models capable of simulating their ecosystem services, particularly in terms of stormwater runoff reduction. Urban trees provide an important pathway for stormwater management by routing the rainfall into various components of the hydrologic cycle. However, tree canopy hydrological processes (i.e., rainfall interception) are rarely represented and simulated in detail by existing stormwater models. In this study, we evaluated the capability of the updated SWMM with the added tree canopy module (Zi et al., 2021) in simulating the rainfall interception process in birch (*Betula pendula* Roth.) and pine (*Pinus nigra* Arnold) trees. Further, the model was then used to quantify the stormwater reduction potential of birch and pine trees in three scenarios (i.e., birch, pine, mixed-species planting) on a storm event basis. The interception routine implemented within the canopy module of the SWMM model effectively captured the temporal evolution of throughfall + stemflow (TF+SF) under both trees in different phenoseasons. There is also a strong correlation between the simulated and observed TF+SF ( $r = 0.97-0.99$ ) and interception values ( $r = 0.72$ ) across all storm events. Thus, the model tends to overestimate TF+SF, particularly for the pine tree, resulting in an underestimation of canopy interception by 3.1% for the birch and 19.6% for the pine. The event-based reduction in runoff volume and peak flow across all scenarios and phenoseasons ranges from 20-25% and 16-25%, respectively, depending on the scenarios and storm events. The mixed-species tree planting scenario generally provide greater reduction benefits for both runoff volume and peak flow than the single-species scenarios. Water balance analysis further emphasizes the relative contribution of canopy interception in the runoff reduction benefits of urban trees, particularly during the leafed season, small to moderate storm events, and when trees are in directly connected impervious areas. This underscores the importance of considering rainfall interception as a critical hydrological process, especially when modeling nature-based solutions in urban environments. Moreover, infiltration and storage in the soil play a dominant mechanism in managing net rainfall under the tree canopy before it contributes to runoff, accounting for over 20% of the water balance. Importantly, the findings from our study offer valuable insights and guidance for urban planners and stormwater engineers on appropriately crediting the stormwater reduction benefits of urban trees within urban planning frameworks and policy development.

**Keywords:** birch, pine, heavy rainfall, rainfall interception, runoff, stormwater, SWMM, tree canopy, urban greening, urban trees

**References**

Zi, T., Whipple, A., Kauhanen, P., Spotswood, E., Grenier, L., Grossinger, R., Askevold, R. (2021). Trees and Hydrology in Urban Landscapes. SFEI Contribution No. 1034. San Francisco Estuary Institute: Richmond, CA. <https://www.sfei.org/projects/healthy-watersheds-resilient-baylands>

**Acknowledgments:** This study was supported by the P2-0180 research program through the Ph.D. grant to the first author, which is financially supported by the Slovenian Research and Innovation Agency (ARIS). Moreover, this study was also carried out within the scope of the ongoing research projects J6-4628, J2-4489, and N2-0313 supported by the ARIS and SpongeScapes project (Grant Agreement ID No. 101112738) and NATURE-DEMO (Grant Agreement IDNo. 101157448), which are supported by the European Union's Horizon Europe research and innovation programme.

# **NH2: Forest fires: Their impact on land and their restoration strategies. A scientific and stakeholder approach**

## **Carbon Stock Modeling For Better Understanding Forest Ecosystems Through Soil Information System (Case of Tunisia)**

Attia Rafla<sup>1,\*</sup>, Mohamed Naoufel Ben Haha<sup>1</sup>, Mounir sellami<sup>1</sup>, Taoufik Hermassi<sup>2</sup>, Ayda Ben RHOUMA<sup>1</sup> and Sana Dridi<sup>1</sup>

<sup>1</sup>*Ministry of Agriculture Tunisia*

<sup>2</sup>*National Institute for Rural Engineering, Water and Forests-Tunisia University of Carthage*

### **Abstract**

Forests play an important role in the carbon cycle, biodiversity and climate change mitigation. Improve knowledge related to forests, pastures and olive groves, their management and the factors that influence land use and land cover change. This is achieved through the integration of the field inventory. The national assessment of soil organic carbon in Tunisia is developed as part of the National Forestry, Pastoral and Olive Inventory "integrated landscape management". Provide information on the state of forest, pastoral and olive resources to facilitate long-term monitoring of resources natural. Assist national-scale management planning, policy decisions and international reporting including commitments on carbon stocks and REDD +; Identify the links between the use of natural resources and their states to assist in the assessment of ecosystem services; Support sustainable management objectives for different ecosystems. National assessment of soil organic carbon in forests, olive groves and rangelands by developing a database on soil carbon stock to produce a national map of soil organic carbon. Characterization of forest, rangeland and olive grove soils through the collection and analysis of 1000 soil samples throughout the territory. Have a database on soil organic carbon useful for monitoring soil condition and identifying degraded areas. Assessment of the impact of forestry, pastoral and olive resource management practices on soil organic carbon. Forest ecosystems contain more carbon per unit area than any other land use type global models of carbon dynamics or indicators of carbon stock stability make it possible to improve predictions of the evolution of soil organic carbon stocks. The use of data by modeling (interpolation), statistical processing makes it possible to establish thematic and factorial maps. A national map of soil organic carbon and indicators that reflect the characterization of soils in the different agro-ecological zones. Use this cartography in planning and land use. Modeling of SOC content and density in 2022 as part of the showed an average SOC density of 15.96 t ha<sup>-1</sup> in 2022. Three scenarios of improved soil management practices), under business as usual in 2040 increases with an additional increase in organic carbon sequestration of 5, 10 and 20%. Croplands, grasslands and forests have the potential to sequester carbon in soils and there is a great need for cultural practices that can increase soil carbon storage and productivity. Any change in the management of such ecosystems induces major changes

in carbon dynamics, resulting in lower stocks than in the original forest. Forms of management involve slash-and-burn agriculture, deforestation, reforestation and agroforestry.

**Keywords:** Keywords Carbon , Biodiversity , Climat Change , Forest

### **References**

Friedlingstein et al., 2006; IPCC, 2014a; Wieder et al., 2015: Potential impact of climate change mitigation by the forest sector TCP RAB 3802 FAO Project Birdsey et al., 2013 Land use and land change and climate and environmental change. Baldock and Skjemstad, 2000 SOC role in aggregation dynamics Tremley et al. model (2002) Andriulo, Mary, and Guérif model, 1999 Hénin-Dupuis model (1945) MOMO'S model (Pansu et al., 1994)

# **AN1: Soil and water conservation for sustainable land management**

## **Froof Biotech Code of Good Regenerative Agricultural Practices**

Katarina Kostic and Asso Lankots

*FROOF BIOTECH*

### **Abstract**

Soil and water conservation are fundamental to sustainable land management, particularly in the face of accelerating land degradation caused by unsustainable agricultural practices and climate change. The increasing pressure on natural resources demands systemic solutions that harmonize productivity with ecosystem restoration. FROOF Biotech has developed the Code of Good Regenerative Agricultural Practices ("The Code"), a science-based framework that integrates biodiversity restoration, soil regeneration, and water conservation into agricultural landscapes. This presentation will introduce The Code and its application across diverse farming systems, demonstrating its potential to reverse land degradation and enhance agroecosystem resilience by establishing a regenerative value chain—supporting all stakeholders from soil to table.

The Code is built on the core philosophy: Healthy SOIL - Healthy FOOD - Healthy PEOPLE. It provides a structured approach to regenerative agriculture, emphasizing soil organic carbon sequestration, agroforestry, habitat restoration, mycology-driven soil remediation, and biofertilizers. By leveraging cutting-edge regenerative agriculture techniques and on-farm trials, The Code functions as an audit blueprint, establishing practical guidelines for farmers, land managers, and policymakers. The Code focuses on mitigating erosion, improving water retention, and fostering biodiversity while maintaining economically viable agricultural production. Its implementation is adaptable to various environmental and socio-economic conditions, ensuring applicability in both industrialized and developing countries.

Our work aligns with this conference's theme by addressing systemic approaches to improving soil and water conservation in rainfed and deficit-irrigated cropping systems, as well as in grazing and forested landscapes. We will present case studies from ongoing projects across southern Europe, where The Code has been successfully applied to design biodiversity-supporting cover crops, native flowering field margins, and agroforestry systems that enhance pollinator habitats and soil health. These initiatives demonstrate how locally adapted regenerative practices can combat desertification, improve water cycles, and create sustainable food production models.

Furthermore, our approach integrates precision agriculture and carbon farming technologies. By combining the audit results with on-farm soil and biodiversity metrics, we provide measurable indicators of land restoration success, ensuring evidence-based decision-making for stakeholders. Attendees will gain insight into how The Code serves as a scalable model for holistic land management and contributes to food security and

climate resilience.

We invite researchers, practitioners, and policymakers to explore The Code's methodologies and join us in fostering agricultural landscapes that sustain both people and the planet. The Code is available at: <https://froofbio.tech/froof-code-of-regeneration/>.

**Keywords:** Regenerative Supply Chain, Biodiversity-Driven Agribusiness, Standards and Audits, Ecosystem-Based Value Creation

### **References**

<https://froofbio.tech/>;

[https://environment.ec.europa.eu/news/nature-restoration-law-enters-force-2024-08-15\\_en#:~:text=The%20law%20sets%20in%20motion,2030%20at%20the%20EU%20level.](https://environment.ec.europa.eu/news/nature-restoration-law-enters-force-2024-08-15_en#:~:text=The%20law%20sets%20in%20motion,2030%20at%20the%20EU%20level.)

**Acknowledgments:** EIT FOOD and Project CREDIBLE (European Commission)

## Land Use Planning (Lup) Tool to Achieve Land Degradation Neutrality (Ldn): Tunisia Case Study

Attia Rafla<sup>1,\*</sup> and Claudio Zucca<sup>2</sup>

<sup>1</sup>Ministry of Agriculture Tunisia

<sup>2</sup>Centre for Sustainable Management of Soil and Landscape (SMSL), Università degli Studi di Sassari, Viale

### Abstract

Abstract—In Tunisia, landscape change and land degradation are critical issues for landscape conservation, management and planning. Landscapes are undergoing crucial environmental problems made evident by soil degradation and desertification. Human improper uses of land resources (e.g., unsuitable land uses, unsustainable crop intensification, and poor rangeland management) and climate change are the main factors leading to the landscape transformation and desertification affecting high proportions of the Tunisian lands. Land use planning (LUP) to achieve Land Degradation Neutrality (LDN) must be supported by methodologies and technologies that help identifying best solutions and practices and designing context-specific sustainable land management (SLM) strategies. Such strategies must include restoration or rehabilitation efforts in areas with high land degradation, as well as prevention of degradation that could be caused by improper land use (LU) and land management (LM). The geoinformatics Land Use Planning for LDN (LUP4LDN) tool has been designed for this purpose. Its aim is to support national and sub-national planners in i) mapping geographic patterns of current land degradation; ii) anticipating further future land degradation expected in areas that are unsustainably managed; and iii) providing an interactive procedure for developing participatory LU-LM transitional scenarios over selected regions of interest and timeframes, visualizing the related expected levels of impacts on ecosystem services via maps and graphs. The tool has been co-developed and piloted with national stakeholders in Tunisia. The piloting implementation assessed how the LUP4LDN tool fits with existing LUP processes and the benefits achieved by using the tool to support land use planning for LDN.

**Keywords:** Keywords—LUS = LAND USE SYSTEM, LC = LAND COVER, SLM = SUSTAINABLE LAND MANAGEMENT, LUP4 LDN = LAND USE PLANNING FOR LAND DEGRADATION NEUTRALITY

### References

Reference [1] Antje Hecheltjen (GIZ): Overview of GEO-LDN Technology Competition [2] Geo Week 2022 Global Action for Local Impact <https://www.earthobservations.org/geoweek2022.php> Pythagoras Karampiperis (SCiO): LUP4LDN methodology and design [3] <https://lup4ldn.scio.services/> [4] Tatenda Lemann (University of Bern): Interlinkage of LUP4LDN with WOCAT Global SLM Database Pythagoras Karampiperis (SCiO): Live

demonstration/walkthrough of LUP4LDN Taoufik Hermassi (INRGREF): Experiences from LUP4LDN pilot in Tunisia [remote talk] Boundia Thiombiano (Université Nazi Boni): Experiences from LUP4LDN pilot in Burkina Faso [remote talk] [6]. Panagiotis Zervas (SCiO): Evolution plans for LUP4LDN and digital support for LDN [5]  
<https://www.wocat.net/en/projects-and-countries/projects/land-use-planning-land-degradation-neutrality-lup4ldn>

## Emerging Contaminants in Soil Ecosystems: Microbial Disruption and Antimicrobial Resistance From a One Health Perspective

Lyudmyla Symochko<sup>1,\*</sup>, Olena Demyanyuk<sup>2</sup> and Nazaré Coelho Pinheiro<sup>3</sup>

<sup>1</sup>Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Martim de Freitas Str., 3000-456, Coimbra, Portugal; Uzhhorod National University, Voloshyna Str.32, 88000 Uzhhorod, Ukraine; Institute of Agroecology and Environmental Management, Metrologichna Str. 12, 03143 Kyiv, Ukraine

<sup>2</sup>Institute of Agroecology and Environmental Management, Metrologichna Str. 12, 03143 Kyiv, Ukraine

<sup>3</sup>Polytechnic University of Coimbra, 3030-199 Coimbra, Portugal; CERNAS—Research Centre for Natural Resources, Environment and Society, Polytechnic University of Coimbra, Bencanta, 3045-601 Coimbra, Portugal

### Abstract

The presence of emerging contaminants, particularly antibiotics and their residues, in soil ecosystems poses significant environmental and public health risks. Among these, the proliferation of antimicrobial resistance (AMR) and the development of a soil resistome are critical concerns. Soils, which sustain approximately 98.8% of global food production, serve as key reservoirs and transmission pathways for AMR through complex interactions within the soil microbiome. Antibiotic concentrations in environmental matrices such as manure, sewage sludge, biosolids, and agricultural soils vary considerably depending on antibiotic type, metabolic fate, and treatment regimes. Notably, tetracyclines and fluoroquinolones are frequently detected at elevated levels in manure, raising alarms about their persistent environmental presence. In this study, we investigated the long-term impact of fluoroquinolone contamination on the functional structure of soil microbiome and the prevalence of AMR across diverse agroecosystems over five years. Soil samples were collected from agroecosystems cultivating *Capsicum annum*, *Vitis vinifera*, *Rubus idaeus* L., and *Petroselinum crispum*, all fertilized with organic manure. Enrofloxacin levels in manure were quantified using High-Performance Liquid Chromatography (HPLC), and microbiological analyses were provided according to the standard protocols. Results revealed that antibiotic residues significantly altered soil microbial communities, reducing nitrogen-fixing bacteria and promoting a shift toward oligotrophic and pedotrophic populations. Furthermore, a 2.28-fold increase in antibiotic-resistant bacteria was observed, alongside a 2.21-fold proliferation of clinically relevant ESKAPE pathogens (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter spp.*). These findings highlight the urgent need for enhanced monitoring and sustainable soil management practices to curb the spread of antibiotic resistance. Addressing the

ecological impacts of emerging contaminants in soil is essential for safeguarding both environmental integrity and public health.

**Keywords:** Soil, Microbiome, Emerging contaminants, Antimicrobial resistance, One health

# **AN3: Climate-Resilient Land Management: Integrating Nature-Based Solutions for Sustainable Land Use in a Changing Climate**

## **Sponge Measures in Agricultural Landscapes: Results From Implementing Nature-Based Solutions in the Upper Thames Catchment, Uk**

Alejandro DUSSAILLANT, Neeraj SAH, James BLAKE and Gareth OLD

*UK Centre for Ecology & Hydrology*

### **Abstract**

Floods and droughts pose significant threats to both human communities and natural landscapes. The EU Horizon SpongeScapes project ([www.spongescapes.eu](http://www.spongescapes.eu) 2023-2027) aims to enhance landscape resilience against these hydrometeorological extremes by exploring "landscape sponge functions" - the natural ability of landscapes to absorb, store, and gradually release water. This project investigates various nature-based solutions (NBS) across diverse European sites with varying climates, geographies, and soil conditions, to address three main questions: (i) what is the longer-term effectiveness of sponge measures (and what indicators/metrics are more adequate); (ii) what is the overall effect of all sponge measures in a catchment (i.e. sponge strategies); (iii) what are the main co-benefits and tradeoffs of sponge measures and strategies. Here we will present results from implementing Sponge Measures in agricultural fields water retention capacity in the river Thames basin where research has been ongoing since 2017. These sites include several farms where regenerative agricultural practices (RAPs) have been followed to improve soils, surface and ground water resilience to hydro-climatic extremes of floods and droughts. Results will be presented and discussed based on ongoing field investigations, including analyses based on survey data for soil bulk density, water retention functions, infiltration and hydraulic conductivity for the agricultural fields, as well as interrogating longer-term datasets in sites monitored for 10 years or more.

**Keywords:** sponge, nature-based solutions, regenerative agriculture, floods, droughts

# **AN5: Innovative Solutions for Sustainable Andalusian Agriculture: Showcasing AEI Operational Groups**

## **Soil Carbon (Soc) Prediction Using Remote Sensing and Artificial Intelligence.Remote. Case of Andalusia.**

Adolfo Peña Acevedo, Valeri Cubero and Antonio Miguel Gámiz

*University of Córdoba*

### **Abstract**

Soil organic carbon (SOC) is an essential component of terrestrial ecosystems and a key indicator of soil health and carbon sequestration. Its accurate quantification and monitoring is critical for assessing agricultural sustainability and its role in climate change mitigation. Traditional methods, based on field sampling and laboratory analysis, are costly and unrepresentative on a large scale. Therefore, remote sensing, satellite data and machine learning modelling emerge as a viable alternative to estimate the spatial distribution of SOC more accurately. This study aimed to generate a predictive SOC model for Andalusia in order to establish baselines and facilitate access to voluntary carbon markets.

The LUCAS 2018 database was used, selecting 471 sampling points in Andalusia. The information from these points was combined with satellite images and environmental data, including variables such as vegetation indices (NDVI, NDWI), surface temperature (LST), topography, climate and soil physical characteristics. Five machine learning algorithms were evaluated: Random Forest, Support Vector Machines (SVM), Gradient Boosting, linear regression and Cubist. Hyperparameter fitting was performed by k-fold cross-validation, and performance was evaluated with RMSE and  $R^2$  on the test set.

The results showed that the mean SOC in Andalusia is 14.46 g/kg. Forest areas (>30 g/kg) and fallow land/cereal mixtures (23 g/kg) showed significantly higher values. Andalusian olive groves averaged 13.75 g/kg, while traditional olive groves in Jaén reached 15.82 g/kg, 15% higher than the regional average for olive groves. In the model comparison, SVM showed the best performance with  $R^2 = 0.40$  and RMSE = 16.56, with a more concentrated distribution of residual errors around zero. It was followed by lineal regression ( $R^2 = 0.33$ ) and Random Forest ( $R^2 = 0.32$ ). SVM and Cubist were the most robust models in cross-validation.

This model facilitates the definition of baselines for accessing voluntary carbon markets, supporting sustainable agricultural practices aligned with the Common Agricultural Policy.

**Keywords:** soil organic carbon, machine learning, carbon farming, remote sensing

## **NH3: Human impact on erosion and connectivity in agricultural land**

## **Assessment of Soil Erosion and Redistribution in Steep Slope Vineyards by Sedimentological and Temporal Analysis**

Laura Cambronero<sup>1,\*</sup>, Manuel Seeger<sup>2</sup>, Jesús Rodrigo-Comino<sup>1</sup> and Johannes B. Ries<sup>2</sup>

<sup>1</sup>*Department of Regional Geographic Analysis and Physical Geography, Faculty of Filosofía y Letras, University Campus of Cartuja, University of Granada, 18071, Granada, Spain*

<sup>2</sup>*Department of Physical Geography, Trier University, D-54286 Trier, Germany.*

### **Abstract**

Vineyards are the second most important crop in Europe and are recognized as one of the agricultural system most severely affected by soil erosion, particularly on steep slopes. A combination of natural and anthropogenic factors contributes to this process, such as slopes, lithological properties, the passage of machinery and human trampling, the direction of the crop and the age of the vines. Knowing and understanding these sediment flows derived from the erosion process is a key aspect to developing more effective soil management, planning and conservation strategies, especially in vulnerable agroecosystems such as vineyards. Despite growing awareness of the issue, seasonal and spatial variability in erosion rates remains poorly understood, particularly in relation to key vineyard management practices such as planting, harvesting and tillage. In this context, the present study aims to analyze the long-term evolution of erosion processes in two vineyards of different ages and steep slopes, located in Waldrach (Ruwer-Mosel valley, Germany), in order to identify patterns in soil redistribution and grain-size composition. The study will be based on data collected using Gerlach collectors over a 15-year period (2010-2025), combined with granulometric analysis of the eroded sediments. Through this methodology, we aim to explore how soil loss rates fluctuate over time in relation to both land use practices and topographic conditions, and to detect possible trends in grain size selectivity. The expected findings will contribute to a better understanding of soil erosion dynamics in sloping vineyards and support the development of site-specific soil conservation strategies tailored to both environmental conditions and the developmental stage of the vineyard.

**Keywords:** soil erosion, Gerlach trough, steep slopes, grain size distribution, vineyards.

# **AN5: Innovative Solutions for Sustainable Andalusian Agriculture: Showcasing AEI Operational Groups**

## **Implementation of Innovative Practices For the Reduction of the Alcohol Content of Andalusian Biologically Aged Wines**

Lourdes Vega Espinar<sup>1,\*</sup>, Rogelio. Borrego lópez<sup>2</sup>, Victor Manuel Palacios<sup>1</sup>, Jesus Manuel Cantoral Fernandez<sup>2</sup>, Gustavo Cordero Bueso<sup>2</sup> and Cristina Lasanta Melero<sup>1</sup>

<sup>1</sup>*Department of Chemical Engineering and Food Technology, Faculty of Science, University of Cádiz, 11510, Puerto Real (Spain).*

<sup>2</sup>*Department of Biomedicine, Biotechnology and Public Health, Institute of Marine Research (INMAR), University of Cadiz, 11510, Puerto Real (Spain).*

### **Abstract**

Current market trends point towards a consumption of wine with a lower alcohol content. The organic crianza wines of the appellation of origin 'Jerez-Xérez-Sherry and Manzanilla de Sanlúcar' stand out for their typicity and organoleptic characteristics that differentiate them from other types of wine. These wines, which are made under 'velo de flor' in a stage known as biological ageing, have an alcohol content that current regulations establish between 15% and 17% ethanol, although the typical range usually varies between 15 and 15.5% in bottled wines, as this has traditionally been established as necessary to guarantee their microbiological stability.

This alcoholic strength is obtained by the addition of alcohol or fortification once fermentation is complete, and usually needs to be replenished during or after the ageing process, due to the consumption of ethanol by the flor yeast. However, recent studies suggest that these types of wines could be made with a slightly lower alcohol content.

The main objective of the Inofino operational group is to improve the sustainability of these traditional Andalusian wines by means of a series of innovations and scientific-technical studies that can lead to a reduction in the alcohol content of organically aged wines while preserving the quality of the product and adapting them to current market demands.

In this context, the analysis and monitoring of these biologically aged wines is being carried out, including physicochemical, microbiological and sensory analyses, in order to culminate in a protocol of good practices that will allow these modifications to be applied on a winery scale.

In the final stage of this project and with the data obtained so far, we can establish as a preliminary conclusion the possibility of producing these wines with a reduction in alcohol content without significantly affecting their stability and quality, maintaining their organoleptic characteristics and typicity.

**Keywords:** Keywords: Traditional Andalusian Wines, Biological Ageing, Microbiology, Innovation.

## **Social-Agri: Digital Innovation and Collaboration For Sustainable Agriculture**

Alejandro Alonso Conde<sup>1,\*</sup>, David Mostaza Colado<sup>1</sup>, Francisco Muñoz Torrero<sup>1</sup>, José Marín<sup>2</sup>  
and Pedro Mauri Ablanque<sup>1</sup>

<sup>1</sup>IMIDRA

<sup>2</sup>Areaverde MG Projects S.L.

### **Abstract**

The SOCIAL-AGRI (Integrating diSruptive technOLogies and CIizens in digitAL transition of AGRiculture for rural and urban communities) subproject, in the framework of the AGRICULTURE 6.0 project, aims to promote the development of a platform for monitoring and digitizing agriculture, which will act as a Woody Crop Observatory to reach sustainability and competitiveness of the sector while bringing the process of primary production closer to digital society.

SOCIAL-AGRI represents a key initiative in the digital transformation of the agri-food sector towards a more sustainable, efficient and inclusive model. Its primary objective is to promote the implementation of advanced digital technologies (IoT, Big Data, Artificial Intelligence) in small and medium-scale farms, also integrating collaborative management tools to strengthen territorial cohesion and social sustainability in rural areas.

The proposal is based on a clear diagnosis: despite the growing development of technological solutions in the agri-food sector, there is a significant gap in their effective adoption by small farmers, in many cases due to a lack of training, economic access or technical support. SOCIAL-AGRI goals are to address this issue through a strategy of co-creation and participatory technology transfer. This strategy involves collaboration between farmers, cooperatives, research centres, technology companies and public administrations.

During the project's development phase, it has yielded open digital platforms, user-friendly control panels and personalised advice protocols, all of which are based on real farm data. It has also promoted training and meeting spaces to facilitate the appropriation of the tools by end users. Preliminary results a strengthening of cooperation networks between rural actors.

SOCIAL-AGRI is in line with the objectives of the European strategy for the digitisation of rural areas, and can serve as a replicable model for other regions. Its multi-actor and territorially rooted approach positions it as an outstanding experience within the ecosystem of agricultural innovation.

**Keywords:** agriculture 6.0, digitisation, sustainability, cooperation,

**Acknowledgments:** Grant TED2021-131040B-C2 funded by MCIN/AEI/ 10.13039/501100011033

and by the "European Union NextGenerationEU/PRTR"

## Approach to a Potential Strategy For Improving Agricultural Soil Quality Through the Use of Pig Slurry in Olive and Cereal Crops

Margarita Sepúlveda García<sup>1,\*</sup>, Benjamín Galacho Jiménez<sup>1</sup>, Francisco Javier Lima Cueto<sup>2</sup>, Rafael Blanco Sepúlveda<sup>2</sup>, Javier González Pérez<sup>3</sup> and José Damián Ruiz Sinoga<sup>1</sup>

<sup>1</sup>*Institute of Habitat, Territory and Digitalization. Department of Geography. University of Malaga*

<sup>2</sup>*Department of Geography. University of Malaga*

<sup>3</sup>*Institute of Habitat, Territory and Digitalization*

### Abstract

This study analyzes the improvement of soil quality through the use of pig slurry as an organic fertilizer using an experimental approach developed on a representative agricultural holding in the municipality of Campillos (Malaga), an area with a high concentration of pig farms (Vadillo et. al., 2016). Slurry management in this region presents a significant environmental problem due to the volume generated and the risk of soil and aquifer contamination through leaching (Marín and García, 2009). This research offers an alternative perspective that transforms slurry, traditionally seen as polluting waste, into a valuable resource within a circular economic strategy (Domínguez and Faz, n.d). The main objective is to design a scientific methodology based on technologies applied to precision agriculture to generate intelligent information. The specific objectives are to determine the optimal conditions for slurry application as fertilizer, develop a system for analysis and evaluation in olive and cereal farms, and establish procedures adapted to various agricultural scenarios (Carneiro et al., 2011). The methodology involves physiographic and edaphological characterization of the experimental plots, chemical and morphological soil analyses, controlled slurry applications, and monitoring through successive samplings. Drones are used to observe the response of soil and crops, complementing the statistical analysis of the results using tools as SPSS. Additionally, the research complies with current regulations regarding organic fertilization and livestock by-product management. The expected results include identifying optimal fertilization doses tailored to the specific needs of soil and crops, modeling ideal application conditions, and assessing the environmental viability of using slurry. The objective is not only to enhance crop yields but also to provide sustainable solutions for local farmers dealing with a long-standing problem. This project constitutes a major contribution to sustainable agriculture in Andalusia by offering a technically, legally, and environmentally viable approach that promotes resource efficiency and the integration of circular economy principles into the agricultural and livestock sectors.

**Keywords:** Pig slurry, Organic Fertilizers, Soils, Circular Economy, Sustainability

## References

Carneiro, J.P., Coutinhob, J., and Trindadec, H. (2011). Nitrate leaching from a maize×oats double-cropping forage system fertilized with organic residues under Mediterranean conditions. *Agriculture, Ecosystems and Environment*, 160: 29-39.

Domínguez, S. G., & Faz, A. (s.f.). Utilización sostenible de purines de cerdo, con y sin tratamiento, como enmienda orgánica en cultivos de almendro. Universidad Politécnica de Cartagena, Grupo de Investigación: Gestión, Aprovechamiento y Recuperación de Suelos y Aguas, Departamento de Ciencia y Tecnología Agraria.

Marín, C., & García, R. (2009). Tratamiento de purines de ganado porcino en España para minimizar la contaminación de suelos y su impacto ambiental. *Avances en estudios sobre desertificación*, 2009-01-01, ISBN 978-84-8371-888-9, pags. 673-676.

Vadillo, I., Candela, L., Jiménez, P., Urresti, B., & Corada, C. (2016). Estudio de contaminantes emergentes en acuíferos detríticos de la cuenca hidrográfica del río Guadalhorce (Málaga). Universidad de Málaga.

**Acknowledgments:** DCOOP and Cooperativas Agroalimentarias de Andalucía

## **Gososviti: Innovation in Viticulture Through an Integrated Dss (Decision Support System) For Soil and Water Conservation**

Laura Cambroner, Alicia M. Arredondo and Jesús Rodrigo-Comino

*Departamento de Análisis Geográfico Regional y Geografía Física, Facultad de Filosofía y Letras, Campus Universitario de Cartuja, Universidad de Granada, 18071 Granada, Spain.*

### **Abstract**

The development of a Decision Support System (DSS) for sustainable soil management in vineyards represents a key opportunity to link scientific knowledge and social demands. The Operational Group project 'GOSOSVITI - Creación de una herramienta de DSS (Decision Supporting System) para el manejo sostenible del suelo en viticultura' is approached as a research proposal whose objective is to build an innovative tool capable of translating scientific information into practical applications, thereby supporting farmers in making informed decisions that balance productivity with environmental stewardships. By integrating indicators such as soil health, climatic conditions and management practices allow the DSS to focus on sustainable viticulture. This initiative, carried out in an experimental vineyard plot in Granada (Spain), is structured around four key objectives: i) development of a DSS focused on soil and water conservation in vineyards; ii) creation of an open-access database integrating environmental factors and diverse methodologies; iii) active involvement of farmers to ensure usability and relevance; iv) implementation of hydrological models calibrated with in situ experimental data. The methodological approach combines environmental monitoring with UAVs and satellite data, social perception análisis, digital platform development, and strategic dissemination and knowledge transfer. The proposal highlights the fundamental role of knowledge transfer, making collaboration with agri-food cooperatives, winegrowers' associations and wineries as stakeholders. In this way, it aims to address environmental and social challenges through an innovative tool that promotes a competitive, resilient and sustainable agricultural model aligned with circular economy and enhances the profitability of the sector.

**Keywords:** Viticulture, Decision Support System (DSS), Soil conservation, Social innovation

**Acknowledgments:** We would like to thank the owners of Bodegas Calvente, in the Villamena municipality (Granada, Spain) and colleagues that helped us to conduct this research in the field. This work was produced with the support of a 2021 Leonardo Grant for Researchers and Cultural Creators and BBVA Foundation and is gratefully acknowledged. Also, we want to thank the Projects granted by the University of Granada within the Plan Propio: i) PP2022.EI-01 Caracterizando la degradación ambiental en el viñedo granadino. Un enfoque multidisciplinar a largo plazo utilizando parcelas experimentales y muestreos poblacionales; ii) PPJIA2022-58 Caracterización hídrica del suelo en viñedos para la optimización de recursos agrícolas y ambientales; and c) Proyectos Innovadores 2022-2025 de Grupos Operativos AEI-agri (andalucía):

Creación de una herramienta DSS (Decision Support System) para el manejo sostenible del suelo en viticultura.

## **Perception and Use of Precision Agriculture Technologies in Viticulture: Preliminary Results From the Go Sosviti Project**

González-Vivar, Jesús<sup>1,\*</sup>, Sobczyk, Rita<sup>2</sup>, Caballero-Calvo, Andrés<sup>1</sup>, Serrano-Montes, Jose Luis<sup>3</sup>, Serrano-Bernardo, Francisco<sup>4</sup> and Rodrigo-Comino, Jesús<sup>5</sup>

<sup>1</sup>*Department of Regional Geographic Analysis and Physical Geography, University of Granada, 18071 Granada, Spain*

<sup>2</sup>*Department of Sociology, Faculty of Political Science and Sociology, University of Granada, C/ Rector López Argüeta s/n, 18071 Granada, Spain*

<sup>3</sup>*Department of Human Geography, University of Granada, 18071 Granada, Spain*

<sup>4</sup>*Department of Civil Engineering, University of Granada, Granada 18071, Spain*

<sup>5</sup>*Department of Regional Geographic Analysis and Physical Geography, University of Granada, 18071 Granada, Spain & Andalusian Research Institute in Data Science and Computational Intelligence, DaSCI, University of Granada, 18071. Granada, Spain*

### **Abstract**

As part of the GO SOSVITI operational group, which focuses on promoting sustainability and technological innovation in viticulture, a mixed-methods study has been developed to analyze the perception and adoption of precision agriculture technologies in the province of Granada. The methodology includes semi-structured interviews and 105 surveys conducted with various professional profiles in the sector: DOP wineries, agronomists, oenologists, and technicians. In this phase of the study, a selection of 38 surveys is analyzed, chosen based on territorial criteria (one per wine-producing municipality linked to the Granada DOP) and professional criteria (the respondent with the highest level of training and experience in each location). The aim is to explore the concerns, expectations, and level of familiarity of these professionals with technologies or digital decision-support tools. The analysis focuses on understanding the current vineyard management practices in the different regions of Granada, including decision-making based on technology and whether or not data is used to support such decisions. The goal is to identify whether there is a basic technological foundation on which to build toward digitalization or if, on the contrary, vineyard management still relies on traditional experience. A specific section of the study addresses perceptions regarding the development of a digital application to support winegrowers in improving vineyard performance. The survey explores whether respondents would be willing to use such a tool, what functionalities they would find useful, and what type of recommendations they would value the most. This line of work aligns with one of the main objectives of the GO SOSVITI project: to design a Decision Support System (DSS) tailored to the real conditions of viticulture in Granada—accessible, practical, and grounded in the concrete needs and demands of the sector.

**Keywords:** precision agriculture, surveys, APP, digitalization

**Acknowledgments:** We would like to thank the owners of Bodegas Calvente, in the Villamena municipality (Granada, Spain) and colleagues that helped us to conduct this research in the field. This work was produced with the support of a 2021 Leonardo Grant for Researchers and Cultural Creators and BBVA Foundation and is gratefully acknowledged. Also, we want to thank the Projects granted by the University of Granada within the Plan Propio: i) PP2022.EI-01 Caracterizando la degradación ambiental en el viñedo granadino. Un enfoque multidisciplinar a largo plazo utilizando parcelas experimentales y muestreos poblacionales; ii) PPJIA2022-58 Caracterización hídrica del suelo en viñedos para la optimización de recursos agrícolas y ambientales; iii) Proyectos Innovadores 2022-2025 de Grupos Operativos AEI-agri (andalucía): Creación de una herramienta DSS (Decision Support System) para el manejo sostenible del suelo en viticultura and iv) SOSVITI project under the Marie Curie Staff Exchange.

# **AN1/2/3: Climate-Resilient Soil and Water Conservation: Integrating Nature-Based Solutions for Sustainable Land Management in Grazing Systems**

## Mapping Soil Erodibility by Means of Machine Learning Models in a Semi-Arid Watershed

Shamsollah Ayoubi<sup>1</sup>, Artemi Cerdà<sup>2,\*</sup>, Mohammad Sajjad Ghavami<sup>1</sup>, Zhou Na<sup>1</sup> and Salman Naimi Marandi<sup>1</sup>

<sup>1</sup>Department of Soil Science, College of Agriculture, Isfahan University of Technology, Isfahan, 8415683111, Iran

<sup>2</sup>Soil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain Artemio.cerda@uv.es

### Abstract

To determine the optimal estimation of K factor at this scale in this study two approaches were implemented and compared using machine learning (ML) models. I: spatial modeling of K factor in one hundred points while K factor was already calculated by the soil properties in each point, and II: spatial modeling of soil properties by ML and then integration of prepared maps for determination of K factor. The findings of the study indicated that digital soil mapping by machine learning and the use of easily available ancillary covariates like topographic attributes, thematic maps, and remotely sensed maps could successfully predict the K factor at the watershed scale. The prediction was more reliable in approach II ( $R^2 = 0.48$ , nRMSE = 11.89%) as compared to approach I ( $R^2 = 0.32$ , nRMSE = 11.89%). Our results revealed that implementation of approach II for estimating K factor improved the accuracy of K prediction about 51.4% as compared to approach I. The findings of the variable important analysis exhibited amongst the remotely sensed indices, some original bands, Carbonate index(CI), and Ratio vegetation index (RVI), and amongst the topographic features, elevation, multi-resolution of ridge top flatness index (MRRTF), and among the thematic maps, land use map were recognized as the furthestmost covariates for estimating the K factor. The resulting map has a substantial consequence in predicting and modeling soil loss and supports soil protection measures.

**Keywords:** Machine learning, Soil, Erodibility, Watershed, Iran

### References

- Adhikary, P. P., Tiwari, S. P., Mandal, D., Lakaria, B. L., & Madhu, M. (2014). Geospatial comparison of four models to predict soil erodibility in a semi-arid region of Central India. *Environmental earth sciences*, 72, 5049-5062.
- Alaboz, P., Dengiz, O., Demir, S., & Şenol, H. (2021). Digital mapping of soil erodibility factors based on decision tree using geostatistical approaches in terrestrial ecosystem. *Catena*, 207, 105634.
- Ghavami, M. S., Ayoubi, S., Mosaddeghi, M. R., & Naimi, S. (2023). Digital mapping of soil physical and mechanical properties using machine learning at the watershed scale. *Journal of Mountain Science*, 20(10), 2975-2992.
- Gu, Z., Huang, Y., Feng, D., Duan, X., Xue, M., Li, Y., & Li, Y. (2021). Towards mapping large scale soil erodibility by using pedological knowledge. *Archives of Agronomy and Soil Science*, 67(6),

809-821. Gupta, S., Borrelli, P., Panagos, P., & Alewell, C. (2024). An advanced global soil erodibility (K) assessment including the effects of saturated hydraulic conductivity. *Science of the Total Environment*, 908, 168249. Panagos, P., Meusburger, K., Alewell, C., & Montanarella, L. (2012). Soil erodibility estimation using LUCAS point survey data of Europe. *Environmental Modelling & Software*, 30, 143-145. Vaezi, A. R., Sadeghi, S. H. R., Bahrami, H. A., & Mahdian, M. H. (2008). Modeling the USLE K-factor for calcareous soils in northwestern Iran. *Geomorphology*, 97(3-4), 414-423.

**Acknowledgments:** This work has received funding from REACT4MED: Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean. The REACT4MED Project (grant agreement 2122) is funded by PRIMA, a program supported by Horizon 2020.

# **Enhancing Climate-Resilient Irrigation For Fruit Production Through Reference Evapotranspiration Calibration and Nature-Based Solutions in Bosnia and Herzegovina**

Nataša Čereković

*Scientific Associate*

## **Abstract**

Nataša Čereković 1, Sretenka Srdić 2, Zorica Srđević 3, Ružica Stričević 4, Pavel Benka 3, Nada Rudan 5, Milica Rajić 3, Mladen Todorović 6

1Centre for Development and Research Support, Institute for Genetic Resources, University of Banja Luka, Bulevar vojvode Petra Bojovića 1A, 78000 Banja Luka, Bosnia and Herzegovina

2System Office, Colorado State University, 4817 National Western Dr., Denver, CO 80216, USA

3Department of Water Management, Faculty of Agriculture, University of Novi Sad, Trg Dositeja Obradovića 8, 21000 Novi Sad, Serbia

4Department of Soil and Water Management, Faculty of Agriculture, University of Belgrade, Nemanjina 6, 11080 Belgrade, Serbia

5Republic Hydrometeorological Institute, Put banjalučkog odreda bb, 78000 Banja Luka, Bosnia and Herzegovina

6CIHEAM-Bari, Via Ceglie 9, 70010 Valenzano, Italy

Efficient water management is critical for sustainable fruit production in Bosnia and Herzegovina, where climate variability and increasing water scarcity threaten productivity. Nature-Based Solutions (NBS), such as agroforestry, soil conservation techniques, and green infrastructure, offer sustainable approaches to water retention and soil moisture preservation. However, optimizing these strategies requires accurate reference evapotranspiration ( $ET_0$ ) estimation to align irrigation needs with climate-adaptive land and crop management. This study assesses drought index and nine  $ET_0$  models during vegetation period to enhance irrigation scheduling for fruit production and support NBS implementation. Using meteorological data we estimated drought index for three climatic zones over two periods (2000-2005; 2018-2024), and compared the FAO Penman-Monteith (FAO-PM) model with alternative empirical approaches to refine water use strategies.

Our findings indicate a clear trend of drought stress contributing to a shift from moisture sub-humid to dry sub-humid zones in three municipalities (Bugojno, Gacko and Sarajevo) and from dry sub-humid to semi-arid in one municipality (Bijeljina). However, three municipalities, such as Trebinje, Višegrad, and Banja Luka, remained classified as moisture sub-humid. This suggests that a longer observation period is necessary to

confirm any definitive climatic transitions in these regions. Additionally, the occurrence of intense but short-duration rainfall events, a known consequence of climate change, may have contributed to the climatic stability observed in these areas despite overall drying trends.

Results reveal substantial variability in  $ET_0$  estimates due to regional climatic differences and model selection. While FAO-PM remains the benchmark, temperature-based models exhibited notable discrepancies, underscoring the need for localized calibration. The calibrated Hargreaves-Samani (HC) model demonstrated the highest accuracy across all zones, with an average root mean square error (RMSE) of  $0.67 \text{ mm day}^{-1}$  in the semi-arid zone,  $0.49 \text{ mm day}^{-1}$  in the dry sub-humid zone, and  $0.50 \text{ mm day}^{-1}$  in the moist sub-humid zone. In contrast, the uncalibrated Hargreaves-Samani (HS) model overestimated  $ET_0$  by up to 18% in the moist sub-humid zone, leading to inefficient water allocation.

The total  $ET_c$  is depending of the fruit management, cultivars and climate. This work additionally provides an analysis of crop evapotranspiration ( $ET_c$ ) and crop coefficient ( $K_c$ ) in strawberry cultivation under different growing system (open field, with and without mulch, greenhouses and plastic tunnels) elaborating the difference between the water needs.

By integrating  $ET_0$  predictions with NBS, irrigation strategies can be optimized to enhance soil moisture retention, minimize water waste, and strengthen fruit resilience to drought. This research provides actionable insights for policymakers, farmers, and agronomists to develop climate-resilient irrigation decision support system and irrigation scheduling that support sustainable land and crop management.

**Keywords:** Keywords: Evapotranspiration, fruit production, irrigation optimization, climate-resilient agriculture, FAO Penman-Monteith, Hargreaves-Samani, sustainable water management, nature-based solutions, Bosnia and Herzegovina.

**Acknowledgments:** The funding of the research was supported by the Ministry of Civil Affairs Bosnia and Herzegovina.

## **Farm Dams as Climate-Smart Adaptations For Agricultural Water Storage in Sweden.**

Melissa Reidy and Jennie Barron

*Swedish University of Agricultural Sciences*

### **Abstract**

Agricultural production in Sweden is increasingly vulnerable to unstable and extreme weather conditions. Precipitation regimes have already become highly variable, leading to more frequent and severe dry and wet spells throughout the annual production cycle. In light of these shifts, there is a growing need for agricultural water infrastructure to be better adapted for production, environmental and climate resilience. Sweden has historically invested in single-purpose agricultural water infrastructure. The turn of the 20th century saw widespread landscape drainage as a move towards increasing national food security through crop land expansion. A growing awareness of the effects of diffuse agricultural pollution led to a second phase emphasizing implementation of a range of 'best management practises' in crop soil and land resources to improve fresh and marine water quality under the Water Framework Directive (2000). At the same time, the notion of Nature Based Solutions (NBS) have gained attention and momentum, while the paradigm shifts to one of climate resilience and adaptation. Yet, there remains a mismatch between landscape and farm infrastructure needs, and what is perceived as functional, especially for agricultural water infrastructure, including drainage and storage solutions. Farm dams are a relatively new adaptation in the Swedish agricultural landscape however have received less research attention and support than other NBS, such as agricultural wetland restoration. Here we present our investigation into the range and scale of farm dam typologies that have emerged across three agricultural regions of southern Sweden since 2015 as landholders address water storage needs. We ask whether farm dams are a climate-smart water storage solution to secure agricultural productivity, and if these structures also provide other ecosystem benefits., specifically nutrient recirculation potential and hydrological regulation. By viewing farm dams through a multi-functional lens, we aim to address whether the water storage needs of the production sector can be merged with current NBS approaches to build greater resilience within Sweden's agricultural regions.

**Keywords:** agriculture, water storage, Sweden

# **Flood Risk Communication Infrastructure For Risk Reduction and Resilience**

Muhammad Inam Ul Haq

*National University of Sciences and Technology (NUST), Islamabad, Pakistan*

## **Abstract**

Effective risk communication is essential for reducing flood risk and enhancing community resilience. Many studies have been done on structural measures, but very few have focused on non-structural measures for flood risk reduction and community resilience. This study aims to explore and evaluate the existing flood risk communication infrastructure in the River Swat Region of District Swat. By assessing the existing communication strategies and their effectiveness, this study highlights the strength of the current communication infrastructure and identifies areas for improvement of flood risk reduction. It focuses on the clarity, timeliness, and accessibility of flood risk information dissemination, ensuring that the community is well-informed and prepared for flood events. The findings of this study also highlight the critical role of community engagement and the integration of advanced communication strategies that contribute to better preparedness and resilience. This research provides valuable insights into existing communication strategies and infrastructure and recommendations for future improvements for policy makers, practitioners, and stakeholders involved in flood risk management.

**Keywords:** communication strategies, community resilience, flood risk communication, non-structural measures, preparedness and engagement

## Assessment of Nature-Based Agricultural Practices For Soil and Water Conservation Using Swat+

Piroska Kassai<sup>1</sup>, Péter Braun<sup>2</sup>, Ronald András Kolcsár<sup>1</sup>, Kinga Farkas-Iványi<sup>1</sup>, János Mészáros<sup>1</sup>, Zoltán Tóth<sup>3</sup>, Michael Strauch<sup>4</sup>, Christoph Schürz<sup>5</sup>, Natalja Čerkasova<sup>6</sup>, Svajūnas Plungė<sup>7</sup>, Mikołaj Piniewski<sup>7</sup> and Brigitta Szabó<sup>1,\*</sup>

<sup>1</sup>*Institute for Soil Sciences, HUN-REN Centre for Agricultural Research, Budapest, 1116, Hungary; National Laboratory for Water Science and Water Safety, Budapest, 1116, Hungary*

<sup>2</sup>*Marine Research Institute, Klaipeda University, Klaipėda, 92294, Lithuania*

<sup>3</sup>*Georgikon Campus, Hungarian University of Agriculture and Life Sciences, Keszthely, 8360, Hungary*

<sup>4</sup>*Department of Computational Landscape Ecology, Helmholtz Centre for Environmental Research GmbH - UFZ Leipzig, 04318, Germany*

<sup>5</sup>*Division of Environment and Natural Resources, Norwegian Institute of Bioeconomy Research, Ås, 1431, Norway*

<sup>6</sup>*Texas A&M AgriLife, Blackland Research and Extension Center, Temple, TX, 76502, USA; Marine Research Institute, Klaipeda University, Klaipėda, 92294, Lithuania*

<sup>7</sup>*Department of Hydrology, Meteorology and Water Management, Warsaw University of Life Sciences (SGGW), Warsaw, 0-653, Poland*

### Abstract

Agricultural systems are increasingly vulnerable to the intensifying extremes of water availability brought about by climate change. Addressing these challenges requires the implementation of integrated practices that not only enhance drought resilience and restrain soil erosion but also preserve soil quality and ensure sustainable food production. This research investigates the performance of a range of nature-based small water retention measures and agricultural management practices promoted under the European Union's Common Agricultural Policy (CAP). The evaluation was conducted within the Felső-Válicka catchment area in Hungary, utilizing the Soil Water Assessment Tool (SWAT+) hydrological modelling software for scenario analysis. Each modelled practice was parameterized according to classifications and guidelines of the Hungarian CAP Strategic Plan. For this study, we selected the practices of no-till farming, reduced tillage, the use of cover crops, perennial leguminous forage crops, and green cover, such as the conversion of arable land to grassland, implementation of grass and shrub riparian buffers, and grass and shrub erosion control strips. To assess the hydrological impact of these measures, key environmental indicators were analysed, including streamflow, soil moisture content, and soil loss rates. The analysis also considered potential trade-offs in terms of reducing the availability of arable land for crop production. Our results show that no-till farming has the most beneficial impact at the study site, with a significant increase in soil moisture content (exceeding 40%) and a significant reduction in erosion (up to -70%) compared to the status quo management, all without reducing the available

arable land. Reduced tillage also resulted in a notable increase in soil moisture content (~25%). Where erosion control is a priority, the use of perennial leguminous forage crops (e.g., alfalfa), and cover crops can be an effective solution. Conversely, riparian buffers and erosion control strips showed limited large-scale hydrological benefits, instead providing more localized water and soil conservation benefits.

**Keywords:** agricultural management practices, soil moisture content, soil erosion, Soil Water Assessment Tool

**Acknowledgments:** This work was supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 862756, project OPTAIN, and the Széchenyi Plan Plus program, supported by the RRF-2.3.1-21-2022-00008 project.

# Past Herbivore Grazing Pressure on Highly Diverse Open Ecosystems in Central-Eastern Europe: a View From Coprophilous Fungal Spores

Angelica Feurdean<sup>1,\*</sup> and Roxana Grindean<sup>2</sup>

<sup>1</sup>*Department of Physical Geography, Goethe University, Frankfurt am Main, Germany*

<sup>2</sup>*Babes Bolyai University*

## Abstract

Grazing by herbivores impacts vegetation distribution and dynamics and maintains vegetation in a more open state worldwide. The magnitude of herbivores' impact largely depends on their density, body size, and dietary preference. Wild herbivores, particularly megafauna, have declined in abundance, diversity, and body size over the past 15 ka years, associated with an increase in the abundance of domestic herbivores with more intensive, localized herbivory pressure. Understanding the effect of grazing by domestic herbivores in sustaining more open ecosystems is particularly critical when livestock is introduced for grassland management and restoration. Coprophilous fungal spores are widely used to reconstruct past grazing activity, yet their potential for assessing grazing pressure remains underexplored. Here, we first analyze coprophilous fungal spores' composition in modern soil and dung samples across diverse habitats in Romania, CE Europe, home to remnants of highly diverse open ecosystems, including grasslands and forest-steppe, to improve the interpretation of CFS signals of livestock biomass and type. We then used paleoecological records of coprophilous spores and those for vegetation derived from pollen, with information on herbivore population dynamics and dietary habits derived from archaeological records from CE Europe to infer past grazing regimes and their impact on open ecosystems. Finally, we highlight avenues for further research into herbivore grazing intensity and ecosystem dynamics in palaeoecological records.

**Keywords:** Coprophilous fungal spores, pollen, past herbivore, grazing pressure, grasslands

## Multi-Objective, Stakeholder-Oriented Planning of Nature-Based Small Water Retention Measures in an Agricultural Catchment

Ronald András Kolcsár<sup>1,\*</sup>, Piroska Kassai<sup>1</sup>, Péter Braun<sup>2</sup>, Kinga Farkas-Iványi<sup>1</sup>, János Mészáros<sup>1</sup>, Michael Strauch<sup>3</sup>, Cordula Wittekind<sup>3</sup>, Christoph Schürz<sup>4</sup>, Natalja Čerkasova<sup>5</sup> and Brigitta Szabó<sup>1</sup>

<sup>1</sup>*Institute for Soil Sciences, HUN-REN Centre for Agricultural Research, Budapest, 1116, Hungary; National Laboratory for Water Science and Water Safety, Budapest, 1116, Hungary*

<sup>2</sup>*Institute for Soil Sciences, HUN-REN Centre for Agricultural Research, Budapest, 1116, Hungary; Marine Research Institute, Klaipeda University, Klaipėda, 92294, Lithuania*

<sup>3</sup>*Department of Computational Landscape Ecology, Helmholtz Centre for Environmental Research GmbH - UFZ Leipzig, 04318, Germany*

<sup>4</sup>*Division of Environment and Natural Resources, Norwegian Institute of Bioeconomy Research, Ås, 1431, Norway*

<sup>5</sup>*Marine Research Institute, Klaipeda University, Klaipėda, 92294, Lithuania; Texas A&M AgriLife, Blackland Research and Extension Center, Temple, TX, 76502, USA*

### Abstract

The growing frequency of extreme weather events, such as droughts and heavy rainfall, has made water retention a critical challenge in agriculture and environmental protection. Nature-based small water retention measures (NSWRMs) have emerged as key tools to improve soil moisture, groundwater recharge, water quality, reduce runoff and erosion, and enhance landscape resilience.

The aim of this study was to determine the optimal placement of four NSWRMs - no-till with cover crops, cropland-to-grassland conversion, forested riparian buffers, and hedges - within the catchment of Tetves stream, located in the Southern Transdanubia region of Hungary. The catchment area covers 79 km<sup>2</sup>, with cropland accounting for 26% of the total area. A genetic algorithm for Constrained Multi-objective Optimization of Land use Allocation (CoMOLA), implemented as a Python script in conjunction with an R-based model processor, was used to identify the best possible combination of these measures within the study area. Four objectives were simultaneously considered in the optimisation process: nitrogen load at the catchment outlet (average annual sum in kg N) - to be minimized, soil moisture content in cropland (average annual value in mm) - to be maximized, implementation and maintenance costs of the NSWRM (average annual sum in EUR) - to be minimized, and agricultural production (average annual sum in grain units) - to be maximized. Input data preparation, model setup, verification, calibration, and validation, as well as NSWRM scenario implementation, were carried out following the OPTAIN modelling protocol (<https://doi.org/10.5281/zenodo.7463395>). The optimization resulted in 192 Pareto optimal solutions, which represent trade-offs where

improving one objective would lead to a decline in at least one other objective. These solutions were analysed using an R-based application, ParetoPick-R, which allowed for the identification of distinct solutions, each with different advantages and disadvantages in terms of their impact on the selected environmental and economic objectives. One solution that has been found to be very effective in reducing nitrogen load suggests applying no-till management with cover crops on 45% of the cropland (~920 ha) and converting an additional 13% (~262 ha) to grassland. Forested riparian buffer strips should be established along 16% of the Tetves stream (~5.9 km), ideally on both sides. While optimal for reducing nitrogen load, this solution may not be feasible for farmers due to the grassland conversion. The ParetoPick-R app helps to visualize, filter and navigate through the set of Pareto optimal solutions, explore trade-offs and synergies between optimization objectives, enable in-depth analysis and stakeholder discussions, compare sector-specific advantages and disadvantages of selected solutions and identify the most acceptable ones.

**Keywords:** water and nutrient retention, sustainable agriculture, multi-objective optimization, CoMOLA, ParetoPick-R

**Acknowledgments:** This work was supported by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 862756, project OPTAIN.

## **Exploring the Roman Centuriation Northeast of Padua as a Historical Nature-Based Solution For Better Flood and Drought Resilience**

Tanja Kremenec

*Department of Historical and Geographic Sciences and the Ancient World (Geography Section),  
University of Padua, 35141 Padova, Italy*

### **Abstract**

In response to the growing impact of climate change-induced extreme events, solution strategies increasingly draw on the revival of historical and "traditional" practices — approaches that historically aligned human activity more closely with natural processes. In this context, this study examines historical water management techniques in a Roman agrarian landscape northeast of Padua (Italy), specifically a well-preserved centuriation system. Its orthogonal network of watercourses was originally designed to support agricultural productivity by facilitating drainage in accordance with the area's hydrogeomorphological conditions. The resilience of this hydraulic system is evidenced by its persistence over two millennia. However, recent field observations indicate that its functionality is gradually being reduced: many channels have been enclosed in narrow concrete pipes or left unmanaged, largely as a result of ongoing urban development and the simplification of agricultural landscapes. This research explores the potential of this historical land division as a nature- and culture-based solution to contemporary environmental challenges, particularly the rising frequency of flood events and prolonged droughts driven by climate change. Two key landscape features — water ditches and hedgerows — were selected for detailed cartographic analysis due to their hydraulic and ecological significance. An initial review of their presence in current urban planning frameworks was followed by a series of GIS-based operations. These included the digitisation of features using available orthophotography, LiDAR data, and derived DEM models, enabling the quantification of changes in the extent of ditches and hedgerows from 2008 to 2022. In addition, GIS tools were used to estimate the potential storage capacity of the water ditch network (expressed in cubic metres), calculating the theoretical volume of water that could be retained or drained as needed. The results present quantitative metrics of landscape change and estimates of current hydraulic storage capacity. Finally, the study reflects on governance challenges affecting the reintegration of historical green-blue infrastructure into contemporary environmental planning and highlights the importance of interdisciplinary approaches to landscape and water management that value historical knowledge while addressing current and future climatic risks.

**Keywords:** water ditches, hedgerows, historical rural landscapes, NBS, climate change

**Acknowledgments:** Other authors: Mauro Varotto (mauro.varotto@unipd.it), Francesco Ferrarese (francesco.ferrarese@unipd.it)

## **Spatial Patterns of Soil Bacterial Communities in Mediterranean Agrosilvopastoral System**

Jesús Barrena González<sup>1,\*</sup>, Eva Lloret<sup>2</sup>, Raúl Zornoza<sup>3</sup>, J. Francisco Lavado Contador<sup>1</sup> and Manuel Pulido Fernández<sup>1</sup>

<sup>1</sup>*Instituto Universitario de Investigación para el Desarrollo Territorial Sostenible (INTERRA), Universidad de Extremadura, 10071 Cáceres, España*

<sup>2</sup>*Instituto de Biotecnología Vegetal (IBV), Campus Muralla del Mar, Edificio I+D+I, Universidad Politécnica de Cartagena, 30202, Cartagena, Spain*

<sup>3</sup>*Sustainable Use, Management and Reclamation of Soil and Water Research Group, Department of Agricultural Engineering, Universidad Politécnica de Cartagena, Paseo Alfonso XIII, 48, 30203 Cartagena, Spain*

### **Abstract**

Soil microbial communities play a key role in ecosystem functioning, yet their spatial patterns in Mediterranean grazing systems remain insufficiently explored. This study examines how dominant copiotrophic and oligotrophic bacterial phyla respond to different grazing regimes and landscape positions in an agrosilvopastoral setting of Southwest Spain. We analysed 71 soil samples collected across five management types: occasional grazing, holistic management, organic farming, conventional rangeland, and conventional grassland, and three topographic positions (hilltops, mid-slopes, and valley bottoms). Using 16S rRNA metabarcoding, we found that both grazing intensity and topography significantly influenced microbial diversity and composition. Holistic management supported higher bacterial richness than more conventional systems. Copiotrophic taxa, such as Proteobacteria and Actinobacteriota, were more abundant in upper slopes and areas with greater grazing pressure, whereas oligotrophic Verrucomicrobiota was more common in valley bottoms and under lower disturbance. Random Forest and structural equation models revealed that vegetation indices, soil organic matter, and animal stocking rate were key predictors of  $\beta$ -diversity. These findings underscore the spatial complexity of microbial responses to land use and highlight the ecological benefits of diversified and adaptive grazing strategies in maintaining soil biodiversity.

**Keywords:** Dehesa/Montado, microbial diversity, land management, soil mapping

**Acknowledgments:** This work was made possible thanks to funding from the Consejería de Economía, Ciencia y Agenda Digital de la Junta de Extremadura and from the European Regional Development Fund of the European Union through reference grant IB16052. On the other hand, this study is part of the Complementary Biodiversity Plan from MICIU with funding from European Union NextGenerationEU/PRTR-C17.I1 and Junta de Extremadura.

## **Biochar as a Nature-Based Solution in Runoff and Soil Erosion Control: Plot-Scale Measurements Under Natural Rainfall**

Ataollah Kavian<sup>1,\*</sup>, Gilda Moafi<sup>1</sup>, Leila Gholami<sup>1</sup> and Hosein Kheirfam<sup>2</sup>

<sup>1</sup>*Sari Agricultural Sciences and Natural resources University*

<sup>2</sup>*Urmia University*

### **Abstract**

The sustainable management of soil and water resources is essential for ensuring global food security and enhancing environmental quality. Biochar, a material derived from various biological sources, has recently gained attention as a nature-based solution to conserve soils. Understanding its behavior, reactions, and its short- and long-term impacts on soil-water is crucial for sustainable agricultural practices. This study examines the influence of biochar on runoff, soil erosion, and sediment yield in abandoned rain-fed plots after eight effective rainfall events that produced surface runoff. Biochar derived from the branches of *Populus nigra* was applied at a rate of 32.5 t ha<sup>-1</sup> in 40 m<sup>2</sup> soil erosion plots situated on the Urmia Lake watershed slopes. The runoff volume was measured after the end of the rainfall in the end tanks, and then the collected samples were analyzed in the lab with different methods. Normality Shapiro-Wilk test, paired t-test, and multivariate analysis of variance using the GLM method were used to investigate the effectiveness of biochar. The findings revealed that biochar significantly reduced runoff volume and soil erosion, with statistical significance observed at the 99 % confidence level and the reductions of 20, 24, and 8 % in runoff volume, soil erosion, and sediment concentration, respectively, compared to the control. These results underscore the potential of biochar derived from *Populus nigra* branches to serve as an effective nature-based solution for soil and water conservation in abandoned rain-fed semi-arid areas. Longer time measurements and changes in soil properties are highly recommended.

**Keywords:** soil conservation, biochar, Natural Rainfall, USLE Plots

## **Biogas Residues in the Battle For Terrestrial Carbon Sequestration in the Grassland Soils of the Greater Region**

Bella Tsachidou

*Luxembourg Institute of Science and Technology*

### **Abstract**

The recycling of biogas residues resulting from the anaerobic digestion of organic waste on agricultural land is among the means to reduce chemical fertilizer use and combat climate change. In this in sacco decomposition study we investigate (1) the potential of the granulated biogas residue fraction to provide nutrients and enhance soil carbon sequestration when utilized as exogenous organic matter in grassland soils, and (2) the impact of different nitrogen fertilizers on the organic matter decomposition and nutrient release processes. The experiment was conducted in two permanent grasslands of the Greater Region over one management period using rooibos tea as a comparator material. The decomposition and chemical changes of the two materials after incubation in the soil were assessed by measuring the mass loss, total carbon and nitrogen status, and fibre composition in cellulose, hemicellulose and lignin. Granulated biogas residue demonstrated resilience and a higher response uniformity when exposed to different nitrogen fertilizers, as opposed to the comparator material of rooibos tea. However, the magnitude of fertilizer-type effect varied, with ammonium nitrate and the combinatorial treatment containing urea leading to the highest organic matter loss. The findings of this study suggest that granulated biogas residue is a biofertilizer with the potential to supply nutrients to soil biota over time, and promote carbon sequestration in grassland soils, and thereby advance agricultural sustainability while contributing to climate change mitigation.

**Keywords:** anaerobic digestion, carbon sequestration, climate change

## **Using Policy Innovation to Scale Biochar as a Nature-Based Solution For Climate-Resilient Land Management: Insights From Ireland**

Lena Grobusch<sup>1</sup>, Aleksandra Goldys<sup>2</sup>, Denyse Julien<sup>2</sup>, Katarzyna Balucka-Debska<sup>2</sup>, Stewart Gee<sup>2</sup>, Marlene Zanier<sup>2</sup> and Saskia M. Visser<sup>2</sup>

<sup>1</sup>*Aleksandra.Goldys@climate-kic.org*

<sup>2</sup>*Climate KIC, Plantage Middenlaan 45, 1018 DC, Amsterdam, Netherlands*

### **Abstract**

Climate-resilient land management demands integrated approaches that address both adaptation and mitigation and are embedded into policy frameworks that create favorable conditions for financing and implementation by local stakeholders. Biochar is a promising yet lesser-known nature-based solution (NbS) that can play a crucial role in land-agri-food system transformations. Biochar can be produced from a range of different feedstocks via a process called pyrolysis. It can be used as a soil amendment and improves soil health through improving the soil biome, nutrient retention, water management, and agricultural productivity leading to increased resilience in the face of extreme weather events and environmental stressors. However, the use of biochar as an NbS is still underutilized. Understanding the role of policy innovations in mobilizing funding and providing suitable conditions to test local-level implementation can reveal key enabling factors for scaling up the use of biochar as an NbS for climate-resilient land management. In this presentation, we discuss insights from Climate KIC's Ireland Deep Demonstration initiative. We discuss how our policy impact lab approach leverages in-depth multi-level policy analysis, sensemaking, interviews, and co-production with diverse local stakeholders to explore how policy innovation can support the scaling up of the use of biochar in Ireland, while considering wider national and EU-level policy developments. The multi-stakeholder approach that is central to our policy innovation work captures perspectives from businesses and collaboratives, academia, national and local level government, and NGOs. These diverse perspectives reveal contrasting spaces of synergy and tension and showcase that stakeholders' positions in the supply chain inform their viewpoints and priorities on biochar. Based on the multi-stakeholder inputs, we chart a path for the scaling up of biochar as an innovative and implementable NbS that is anchored in a process dedicated to co-creating innovative policy solutions that enable scaling, provide favorable market and investment conditions, and encourage future-oriented, science and practice-based decision-making. As the EU strives for a just transition while achieving its Green Deal, Competitiveness, and Common Agricultural Policy Agendas, balancing the political, social, economic, and environmental is more crucial than ever. Let's actively involve all stakeholders to keep the social dividend fair for everyone - and recognize that thinking outside of the box when it comes

to the types of NbS that are desirable and feasible is vital. Future research will feed our findings into the design of a framework for resilient and sustainable food systems.

**Keywords:** Policy Innovation, Biochar, Nature-based Solution, Climate Resilient Land Management, Land-Agri-Food Transition

# **Principles For the Assessment of Natural Source Zone Depletion Based on Temperature Measurements in the Subsoil**

Daniel Díaz

ARCADIS

## **Abstract**

### Background / objective

For decades, biological processes have been considered to be a significant pathway for attenuation of the subsoil impacts. In fact, these processes have been evidenced in a wide variety of sites for different types of contaminants.

In the case of petroleum hydrocarbons (TPH, BTEX, etc) these processes are well-known and have been widely used as the final stage of the remediation phase, mainly for dissolved compounds or plume areas.

However, evidence shows that these processes are also given in the source areas. Specifically, the so called Natural Source Zone Depletion (NSZD) processes involve a combination of biological reactions and physical processes which preferentially occur in the non-saturated area, and stimulates the attenuation of the subsoil impacts via two pathways:

- On one hand, it allows the removal of the mass contaminant and
- on the other hand, a change of the composition, by increasing to amount of less readily available compounds.

Just as for natural attenuation processes in dissolved phases, the quantitative and qualitative assessment of NSZD is addressed by the monitoring of a number of indicators or lines of evidence. One of these pathways is based on the temperature increase arising from the subsoil as a result of hydrocarbon biodegradation.

### Approach / Activities

Overall, NSZD begins with methanogenic fermentation reactions (CO<sub>2</sub> intake and methane emission) in areas where most severe impact are present (i.e. capillary zone at areas where LNAPL has been identified). The generated methane diffuses through shallow layers of the vadose area (high oxygen content) where its aerobic oxidation occurs together with the hydrocarbons of the upper horizons, if still present.

Hydrocarbon aerobic oxidation processes, specifically for the case of methane, generates a considerable quantity of heat, proportional to the amount of hydrocarbon biodegradation, which in turn implies an increase of the subsoil temperature.

The monitoring of the temperature increase together with site-specific thermal subsoil properties, allows the quantification of the hydrocarbon biodegradation rates.

### Results

The proposed approach includes a tiered assessment of the NSZD. The preliminary assessment requires one simple temperature profile monitoring round, in former installed monitoring wells (both in source and background area). The information gathered, along with bibliographic data regarding thermal soil properties, enable the identification whether biodegradative processes are being produced as well as its preliminary estimation.

A further detailed assessment requires a mid-term (months/years) monitoring, of the temperature in different areas and at different depths. This enables a reasonable precise quantification of NSZD processes (site specific soil thermal parameters) throughout different periods of the year.

**Keywords:** Natural Source Zone Depletion, Natural Based Solutions, Biodegradation

## Soil Erosion in New Citrus Plantations. Rainfall Simulation Experiments. Montesa Experimental Station, Eastern Iberian Peninsula

Artemi Cerdà<sup>1,\*</sup>, Antonio Giménez Morera<sup>2</sup>, Enric Terol<sup>3</sup>, Shamsollah Ayoubi<sup>4</sup>, Ana Pérez Albarracín<sup>5</sup>, Ioannis Daliakopoulos<sup>6</sup> and Saskia Deborah Keesstra<sup>7</sup>

<sup>1</sup>*Soil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain. Artemio.cerda@uv.es*

<sup>2</sup>*Departamento de Economía y Ciencias Sociales, Universitat Politècnica de València, Cami de Vera S/N, 46022 València, Spain.*

<sup>3</sup>*Department of Cartographic Engineering, Geodesy and Photogrammetry, Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain.*

<sup>4</sup>*Department of Soil Science, College of Agriculture, Isfahan University of Technology, 8415683111, Isfahan, Iran.*

<sup>5</sup>*Soil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain*

<sup>6</sup>*Department of Agriculture, Hellenic Mediterranean University, 71410 Heraklion, Greece.*

<sup>7</sup>*imate-Kic Holding B.V. Plantage Middenlaan 45, Amsterdam, the Netherlands*

### Abstract

Spain is severely affected by soil degradation and high soil erosion rates. In Spain, agriculture has been the cause of onsite soil degradation on arable land and the source of the sediments that reach rivers, reservoirs, and wetlands (Taguas and Gómez, 2015; Bayat et al., 2019). This is due to the steep slopes, poor soils, heavy rains, and the eradication of all vegetation other than the crop itself (García Ruiz, 2010). Until the 1960s, the plow affected soil structure and facilitated the mineralization of organic matter. Since then, the use of high-horsepower tractors has caused soil disturbance deeper in the profile causing compaction and even more organic matter depletion than traditional ploughing. In recent years, herbicide use has increased in non-irrigated crops, which has led to less vegetation cover and soil surface crusting and compaction (Keesstra et al., 2019). This practice provides the right conditions to generate high rates of soil erosion. Casalí et al., (1999) measured soil losses of 13.3 Mg ha<sup>-1</sup> year<sup>-1</sup> on gullied agricultural land in Navarre, Rodríguez Martínez-Conde (1998) measured a high erosion rate in Galicia, where 17.58 Mg ha<sup>-1</sup> year<sup>-1</sup> in 1996 and 15.81 Mg ha<sup>-1</sup> year<sup>-1</sup> in 1997 were registered. Martínez Casanovas et al., (2002) reported a 207 Mg ha<sup>-1</sup> soil loss in Lérida after a 205 mm rainfall event in 135 minutes. Studies at the Pyrenean Institute of Ecology demonstrated that the greatest soil loss (15 Mg ha<sup>-1</sup> year<sup>-1</sup>) was from fallow fields that were ploughed but not sown after 2- or 3-years years of crop production, a practice that is traditionally done in the Mediterranean Region (García Ruiz, 1996). Soil erosion in agriculture land is high. New citrus plantations shown high erosion rates. The

removal of vegetation cover by herbicides, the soil compaction and rugged terrain contribute to high erosion rates. We measured by means of rainfall simulation experiments the soil erosion rates in one hour of a thunderstorm with 5 years return period. A rainfall event of 55 mmh<sup>-1</sup> over one hour was produced in each of the 100 plots. Runoff was collected each minute and samples transported to the laboratory to determine the sediment concentration and later calculate the soil erosion. The results show that Ponding (Tp) and Runoff generation (Tr and Tro) was fast (71', 101', and 122' for Tp, Tr, and Tro). The mean runoff discharge was 54.56 %. Mean soil erosion reached 8.96 Mg ha<sup>-1</sup> h<sup>-1</sup>. The laboratory measurements by dissection of the runoff samples show a sediment concentration from 10.7 g l<sup>-1</sup>. The results show that runoff is very fast, abundant and with a high content of sediments. The soil erosion rates in citrus plantations are as high as in other regions of the world such as China. The literature review show the need to find new and alternative managements to the herbicides to control the spontaneous vegetation and reduce soil and water losses.

**Keywords:** Citrus, Montesa, Spain, Erosion, Runoff

### References

- Bayat, F., Monfared, A. B., Jahansooz, M. R., Esparza, E. T., Keshavarzi, A., Morera, A. G., ... & Cerdà, A. (2019). Analyzing long-term soil erosion in a ridge-shaped persimmon plantation in eastern Spain by means of ISUM measurements. *Catena*, 183, 104176
- Casali, J., López, J. J., & Giráldez, J. V. 1999. Ephemeral gully erosion in southern Navarra (Spain). *Catena*, 36(1-2), 65-84.
- García Ruiz, J.M., Lasanta, T., Ortigosa, L., Ruiz Flaño, P., Martí, C. & González, C. 1995. Sediment yield under different land-uses in the Spanish Pyrenees. *Mountain Research and Development*, 15 (3), 229-240.
- García-Ruiz, J. M. 2010. The effects of land uses on soil erosion in Spain: a review. *Catena*, 81(1), 1-11.
- García-Ruiz, J. M., Lasanta, T., Nadal-Romero, E., Lana-Renault, N., & Álvarez-Farizo, B. 2020. Rewilding and restoring cultural landscapes in Mediterranean mountains: Opportunities and challenges. *Land Use Policy*, 99, 104850.
- Keesstra, S. D., Rodrigo-Comino, J., Novara, A., Giménez-Morera, A., Pulido, M., Di Prima, S., & Cerdà, A. (2019). Straw mulch as a sustainable solution to decrease runoff and erosion in glyphosate-treated clementine plantations in Eastern Spain. An assessment using rainfall simulation experiments. *Catena*, 174, 95-103.
- Keesstra, S., Mol, G., De Leeuw, J., Okx, J., De Cleen, M., & Visser, S. 2018. Soil-related sustainable development goals: Four concepts to make land degradation neutrality and restoration work. *Land*, 7(4), 133.
- Lasanta, T. & Sobrón, I. 1988. Influencia de las prácticas de laboreo en la evolución hidrogeomorfológica de suelos cultivados con viñedo. *Cuadernos de Investigación Geográfica*, 14, 81-97.
- López-Vicente, M., Calvo-Seas, E., Álvarez, S., & Cerdà, A. 2020. Effectiveness of cover crops to reduce loss of soil organic matter in a rainfed vineyard. *Land*, 9(7), 230.

Rodríguez Sousa, A. A., Barandica, J. M., & Rescia, A. J. 2019. Estimation of Soil Loss Tolerance in Olive Groves as an Indicator of Sustainability: The Case of the Estepa Region (Andalusia, Spain). *Agronomy*, 9(12), 785.

Taguas, E. V., & Gómez, J. A. 2015. Vulnerability of olive orchards under the current CAP (Common Agricultural Policy) regulations on soil erosion: a study case in Southern Spain. *Land Use Policy*, 42, 683-692.

**Acknowledgments:** This work has received funding from REACT4MED: Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean. The REACT4MED Project (grant agreement 2122) is funded by PRIMA, a program supported by Horizon 2020. The “MANEJOS AGRÍCOLAS SOSTENIBLES PARA EL CONTROL DE LA EROSIÓN DEL SUELO EN PLANTACIONES DE CÍTRICOS (CONERO)” research project funded by Ministerio de ciencia e innovación PID2023-151431OB-I00 contributed to the field and laboratory work.

## Soil Erosion in Agriculture Land in Spain: a Review

Artemi Cerdà<sup>1,\*</sup>, Antonio Giménez Morera<sup>2</sup>, Enric Terol<sup>3</sup>, Shamsollah Ayoubi<sup>4</sup>, Ana Pérez Albarracín<sup>5</sup>, Ioannis Daliakopoulos<sup>6</sup> and Saskia Deborah Keesstra<sup>7</sup>

<sup>1</sup>*Soil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain Artemio.cerda@uv.es*

<sup>2</sup>*Departamento de Economía y Ciencias Sociales, Universitat Politècnica de València, Cami de Vera S/N, 46022 València, Spain*

<sup>3</sup>*Department of Cartographic Engineering, Geodesy and Photogrammetry, Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain*

<sup>4</sup>*Department of Soil Science, College of Agriculture, Isfahan University of Technology, 8415683111, Isfahan, Iran*

<sup>5</sup>*Soil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain*

<sup>6</sup>*Department of Agriculture, Hellenic Mediterranean University, 71410 Heraklion, Greece.*

<sup>7</sup>*limate-Kic Holding B.V. Plantage Middenlaan 45, Amsterdam, the Netherlands*

### Abstract

The pioneering work of Lasanta and Sobrón (1984) on traditional plowing practices in the vineyards of La Rioja showed soil erosion rates  $< 1 \text{ Mg ha}^{-1} \text{ year}^{-1}$ . López Bermúdez (2002) reported ploughed fields averaged  $1.84 \text{ Mg ha}^{-1} \text{ year}^{-1}$  of soil loss in Murcia, but values were lower when cereal crops were planted (barley -  $1.04 \text{ Mg ha}^{-1} \text{ year}^{-1}$ ), and very low on scrubland ( $0.05 \text{ Mg ha}^{-1} \text{ year}^{-1}$ ). This demonstrates that vegetation cover is the key factor that controls soil loss and explains the soil loss reductions found by Francis (1990) and Ruiz Flaño et al., (1992) in the north and south-eastern Spain after land abandonment. In Andalucía, Cuadros et al., (1993) measured soil losses of  $10.9 \text{ Mg ha}^{-1} \text{ yr}^{-1}$  in citrus orchards using traditional ploughing methods, while soil loss was reduced to  $2.9 \text{ Mg ha}^{-1} \text{ yr}^{-1}$  under non-tillage conditions. De Alba (1998) found soil losses of  $2.4 \text{ Mg ha}^{-1} \text{ year}^{-1}$  when cereal fields in the Castilla-La Mancha region are fallow,  $0.48 \text{ Mg ha}^{-1} \text{ year}^{-1}$  when a crop is present,  $0.67 \text{ Mg ha}^{-1} \text{ yr}^{-1}$  when no-tillage is applied, and only  $0.17 \text{ Mg ha}^{-1} \text{ year}^{-1}$  on abandoned land. Bienes and Torcal (1997) found similar results in Central Spain. The available data confirm that agricultural lands contribute to soil exhaustion (Lasanta et al., 2001). In addition, soil erosion rates on agricultural land in Mediterranean environments depend on the type of crop that is grown. Giráldez et al., (1989) used the Universal Soil Loss Equation to show that no-tillage practices reduced the soil losses in all crops they studied (sunflower, wheat, sugar beet, beans) except in olive orchards. However, no-tillage practices aimed to reduce soil losses are not always the most sustainable land management system. Francia et al., (2000) found that no-tillage increased the soil erosion rates ( $5.2 \text{ Mg ha}^{-1} \text{ year}^{-1}$ ), as compared to traditional tillage ( $1.3 \text{ Mg ha}^{-1} \text{ year}^{-1}$ ), and areas with vegetation cover ( $0.41 \text{ Mg ha}^{-1} \text{ year}^{-1}$ ). Martínez-Raya et al., (2001) also found a no-tillage strategy for an Andalucía olive orchard

increased the soil losses to 28.03 Mg ha<sup>-1</sup> year<sup>-1</sup>, as compared to traditional plowing of 9.08 Mg ha<sup>-1</sup> year<sup>-1</sup>, and 1.56 Mg ha<sup>-1</sup> year<sup>-1</sup> in soil with vegetation cover. Soil losses are usually low or negligible where vegetation cover is present or surface mulches are used (Bienes et al., 2000). The latest research findings on soil erosion for agricultural land in Spain show that non-sustainable soil losses are widespread (Gómez et al., 2004; Arnáez et al., 2006; De Santisteban et al., 2006) and more research is necessary on control of soil erosion by water and tillage. The non-sustainable soil erosion rates in Spain found by the pioneers mentioned here were confirmed along the last decades by many other researchers such as Sastre et al. (2017); Rodrigo-Comino et al. (2018); Merchán et al. (2019); Rodríguez Sousa et al. (2019) and Zuazo et al. (2020). The review of the literature show that soil erosion in agriculture land is high in comparison to forest land, included the fire affected areas. This show the need to research new strategies to control the non-sustainable soil erosion rates.

**Keywords:** Soil, Erosion, Spain, Sustainability, Agriculture

### References

- Arnáez, J., Lasanta, T., Ruiz-Flaño, P. & Ortigosa, L. 2007. Factors affecting runoff and erosion under simulated rainfall in Mediterranean vineyards. *Soil & Tillage Research*, 93, 324-334.
- Borrelli, P., Robinson, D. A., Panagos, P., Lugato, E., Yang, J. E., Alewell, C., ... & Ballabio, C. 2020. Land use and climate change impacts on global soil erosion by water (2015-2070). *Proceedings of the National Academy of Sciences*, 117(36), 21994-22001.
- Calatrava, J., & Franco, J. A. 2020. Diffusion of soil erosion control practices in the olive orchards of the Alto Genil Basin (Granada, Spain). *Studies of Applied Economics*, 29(1), 359-384.
- Casali, J., López, J. J., & Giráldez, J. V. 1999. Ephemeral gully erosion in southern Navarra (Spain). *Catena*, 36(1-2), 65-84.
- Cerdà, A. & Doerr, S.H. 2007. Soil wettability, runoff and erodibility of major dry-Mediterranean land use types on calcareous soils. *Hydrological Processes*, 21, 2325. 2336.
- Cerdà, A. & Jurgensen, M.F. 2008. The influence of ants on soil and water losses from an orange orchard in eastern Spain. *Journal of Applied Entomology-Zeitschrift für Angewandte Entomologie*. 132, 306-314. doi 10.1111/j.1439-0418.2008.01267.x
- Cerdà, A., Jurgensen, M.F. & Bodí, M.B. 2009. Effects of ants on water and soil losses from organically-managed citrus orchards in eastern Spain. *Biologia*, 3, 527-531. DOI: 10.2478/s11756-009-0114-7.
- De Santisteban, L. M., Casali, J., & López, J. J. 2006. Assessing soil erosion rates in cultivated areas of Navarra (Spain). *Earth Surface processes and landforms: The Journal of the British Geomorphological Research Group*, 31(4), 487-506.
- Duan, J., Liu, Y. J., Yang, J., Tang, C. J., & Shi, Z. H. 2020. Role of groundcover management in controlling soil erosion under extreme rainfall in citrus orchards of southern China. *Journal of Hydrology*, 582, 124290. Chichester,331-338.
- García Ruiz, J.M., Lasanta, T., Ortigosa, L., Ruiz Flaño, P., Martí, C. & González, C. 1995. Sediment yield under different land-uses in the Spanish Pyrenees. *Mountain Research and Development*, 15 (3), 229-240.

- García-Ruiz, J. M. 2010. The effects of land uses on soil erosion in Spain: a review. *Catena*, 81(1), 1-11.
- García-Ruiz, J. M., Lasanta, T., Nadal-Romero, E., Lana-Renault, N., & Álvarez-Farizo, B. 2020. Rewilding and restoring cultural landscapes in Mediterranean mountains: Opportunities and challenges. *Land Use Policy*, 99, 104850.
- Giráldez, J.V., Laguna, A. & González, P. 1989. Soil conservation under minimum tillage techniques in mediterranean dry farming. En Schwertmann, U. Rickson, R.J., Auerswald, K. (Eds.) *Soil erosion protection measures in Europe. Soil Technology series*, 139-148.
- Guerra, C. A., Rosa, I. M., Valentini, E., Wolf, F., Filipponi, F., Karger, D. N., ... & Eisenhauer, N. 2020. Global vulnerability of soil ecosystems to erosion. *Landscape Ecology*, 1-20.
- Guillaume, T., Holtkamp, A. M., Damris, M., Brümmer, B., & Kuzyakov, Y. (2016). Soil degradation in oil palm and rubber plantations under land resource scarcity. *Agriculture, Ecosystems & Environment*, 232, 110-118.
- Hondebrink, M. A., Cammeraat, L. H., & Cerdà, A. 2017. The impact of agricultural management on selected soil properties in citrus orchards in Eastern Spain: A comparison between conventional and organic citrus orchards with drip and flood irrigation. *Science of the Total Environment*, 581, 153-160.
- Kamau, S., Barrios, E., Karanja, N. K., Ayuke, F. O., & Lehmann, J. 2017. Soil macrofauna abundance under dominant tree species increases along a soil degradation gradient. *Soil Biology and Biochemistry*, 112, 35-46.
- Katra, I. 2020. Soil Erosion by Wind and Dust Emission in Semi-Arid Soils Due to Agricultural Activities. *Agronomy*, 10(1), 89.
- Keesstra, S. D., Rodrigo-Comino, J., Novara, A., Giménez-Morera, A., Pulido, M., Di Prima, S., & Cerdà, A. (2019). Straw mulch as a sustainable solution to decrease runoff and erosion in glyphosate-treated clementine plantations in Eastern Spain. An assessment using rainfall simulation experiments. *Catena*, 174, 95-103.
- Keesstra, S., Mol, G., De Leeuw, J., Okx, J., De Cleen, M., & Visser, S. 2018. Soil-related sustainable development goals: Four concepts to make land degradation neutrality and restoration work. *Land*, 7(4), 133.
- Kuzyakov, Y., & Zamanian, K. 2019. Reviews and syntheses: Agropedogenesis-humankind as the sixth soil-forming factor and attractors of agricultural soil degradation. *Biogeosciences*, 16(24), 4783-4803.
- Liu, Y., Zhao, L., & Yu, X. (2020). A sedimentological connectivity approach for assessing on-site and off-site soil erosion control services. *Ecological Indicators*, 115, 106434.
- López-Vicente, M., Calvo-Seas, E., Álvarez, S., & Cerdà, A. 2020. Effectiveness of cover crops to reduce loss of soil organic matter in a rainfed vineyard. *Land*, 9(7), 230.
- Nearing, M. A., Xie, Y., Liu, B., & Ye, Y. 2017. Natural and anthropogenic rates of soil erosion. *International Soil and Water Conservation Research*, 5(2), 77-84
- Niu, Y. H., Li, X., Wang, H. X., Liu, Y. J., Shi, Z. H., & Wang, L. 2020. Soil erosion-related transport of neonicotinoids in new citrus orchards. *Agriculture, Ecosystems & Environment*, 290, 106776.

Panagos, P., Ballabio, C., Poesen, J., Lugato, E., Scarpa, S., Montanarella, L., & Borrelli, P. (2020). A Soil Erosion Indicator for Supporting Agricultural, Environmental and Climate Policies in the European Union. *Remote Sensing*, 12(9), 1365

Rodrigo-Comino, J., da Silva, A. M., Moradi, E., Terol, E., & Cerdà, A. 2020. Improved Stock Unearthing Method (ISUM) as a tool to determine the value of alternative topographic factors in estimating inter-row soil mobilisation in citrus orchards. *Spanish Journal of Soil Science*, 10(1).

Rodrigo-Comino, J., Keesstra, S., & Cerdà, A. 2018. Soil erosion as an environmental concern in vineyards: the case study of Celler del Roure, Eastern Spain, by means of rainfall simulation experiments. *Beverages*, 4(2), 31

Rodríguez Martínez-Conde, R., Puga, J.M., Vila, R. & Cibeira, A. 1998. Comportamientos de la escorrentía en un medio oceánico y de uso agrícola (Galicia, España). V Reunión Nacional de Geomorfología, Granada, 547-556.

Rodríguez Sousa, A. A., Barandica, J. M., & Rescia, A. J. 2019. Estimation of Soil Loss Tolerance in Olive Groves as an Indicator of Sustainability: The Case of the Estepa Region (Andalusia, Spain). *Agronomy*, 9(12), 785.

van Leeuwen, C. C., Cammeraat, E. L., de Vente, J., & Boix-Fayos, C. 2019. The evolution of soil conservation policies targeting land abandonment and soil erosion in Spain: A review. *Land Use Policy*, 83, 174-186.

Xu, H., Qi, S., Gong, P., Liu, C., & Wang, J. 2018. Long-term monitoring of citrus orchard dynamics using time-series Landsat data: a case study in southern China. *International Journal of Remote Sensing*, 39(22), 8271-8292.

Yang, J., Mo, M. H., Song, Y. J., & Chen, X. A. 2012. Hydro-ecological effects of citrus land under vegetation measures of soil and water conservation in red-soil slope. *Resources and Environment in the Yangtze Basin*, 21(8), 994-999.

Zhang, N., Zhang, Q., Li, Y., Zeng, M., Li, W., Chang, C., ... & Huang, C. 2020. Effect of groundcovers on reducing soil erosion and non-point source pollution in citrus orchards on red soil under frequent heavy rainfall. *Sustainability*, 12(3), 1146.

Zuazo, V. H. D., Rodríguez, B. C., García-Tejero, I. F., Ruiz, B. G., & Tavira, S. C. 2020. Benefits of organic olive rainfed systems to control soil erosion and runoff and improve soil health restoration. *Agronomy for Sustainable Development*, 40(6), 1-15.

**Acknowledgments:** This work has received funding from REACT4MED: Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean. The REACT4MED Project (grant agreement 2122) is funded by PRIMA, a program supported by Horizon 2020. The “MANEJOS AGRÍCOLAS SOSTENIBLES PARA EL CONTROL DE LA EROSIÓN DEL SUELO EN PLANTACIONES DE CÍTRICOS (CONERO)” research project funded by Ministerio de ciencia e innovación PID2023-151431OB-I00 contributed to the field and laboratory work.

## **Soil Erosion Control in Citrus Plantations. the Use of Chipped Pruned Branches in Sloping Terrain as a Mulch.**

Artemi Cerdà<sup>1,\*</sup>, Antonio Giménez Morera<sup>2</sup>, Enric Terol<sup>3</sup>, Shamsollah Ayoubi<sup>4</sup>, Ioannis Daliakopoulos<sup>5</sup>, Ana Pérez Albarracín<sup>6</sup> and Saskia Deborah Keesstra<sup>7</sup>

<sup>1</sup>*Soil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain. Artemio.cerda@uv.es*

<sup>2</sup>*Departamento de Economía y Ciencias Sociales, Universitat Politècnica de València, Cami de Vera S/N, 46022 València, Spain*

<sup>3</sup>*Department of Cartographic Engineering, Geodesy and Photogrammetry, Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain*

<sup>4</sup>*Department of Soil Science, College of Agriculture, Isfahan University of Technology, 8415683111, Isfahan, Iran*

<sup>5</sup>*Department of Agriculture, Hellenic Mediterranean University, 71410 Heraklion, Greece.*

<sup>6</sup>*Soil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain*

<sup>7</sup>*imate-Kic Holding B.V. Plantage Middenlaan 45, Amsterdam, the Netherlands*

### **Abstract**

Soil erosion in citrus plantation in Eastern Spain is high. The soil erosion losses range from 10 to 100 Mg ha<sup>-1</sup>y<sup>-1</sup> and it is necessary to control them to achieve a sustainable management for agriculture land. To reduce soil losses there are different techniques: geotextiles, catch crop, cover crops, mulches and also chipped pruned branches. We studied in by means of rainfall simulation experiments the soil losses in citrus plantations under chipped pruned branches mulches and bare soils.

At the soil erosion experimental station of Montesa we developed an experiment with 25 plots covered with chipped pruned branches (CPB Mulch) and 25 plots in an area without (Burnt chipped pruned branches). Both plots, Burnt and Mulch, used tillage to remove the weeds. A rainfall event of 55 mmh<sup>-1</sup> over one hour was produced in each of the 50 plots (25 Burnt and 25 Mulch covered) and runoff was collected each minute and samples transported to the laboratory to determine the sediment concentration and later calculate the soil erosion. The results show that Ponding (Tp) and Runoff generation (Tr and Tro) were faster in the Burnt plots (66', 99', and 1420' for Tp, Tr, and Tro) than on the Mulch treated plots (140', 394', and 892' for Tp, Tr and Tro, respectively). The mean runoff discharge was 50.50 % and 19.59 % for the Burnt and Mulch plots. Mean soil erosion reached 5.6 Mg ha<sup>-1</sup> h<sup>-1</sup> and 0.71 Mg ha<sup>-1</sup>h<sup>-1</sup>, respectively. The results show a reduction in sediment concentration from 11.7 gl<sup>-1</sup> to 3.14 gl<sup>-1</sup>. The use of chipped pruned branches is very positive to achieve a sustainable agriculture management in citrus plantations.

**Keywords:** Citrus, Soil, Erosion, Management, Control

## References

- Cerdà, A., & Jurgensen, M. F. (2011). Ant mounds as a source of sediment on citrus orchard plantations in eastern Spain. A three-scale rainfall simulation approach. *Catena*, 85(3), 231-236.
- Cerdà, A., Ackermann, O., Terol, E., & Rodrigo-Comino, J. (2019). Impact of farmland abandonment on water resources and soil conservation in citrus plantations in eastern Spain. *Water*, 11(4), 824.
- Cerdà, A., Morera, A. G., & Bodí, M. B. (2009). Soil and water losses from new citrus orchards growing on sloped soils in the western Mediterranean basin. *Earth Surface Processes and Landforms: The Journal of the British Geomorphological Research Group*, 34(13), 1822-1830.
- Cerdà, A., Novara, A., & Moradi, E. (2021). Long-term non-sustainable soil erosion rates and soil compaction in drip-irrigated citrus plantation in Eastern Iberian Peninsula. *Science of the Total Environment*, 787, 147549.
- Cerdà, A., Rodrigo-Comino, J., Giménez-Morera, A., & Keesstra, S. D. (2018). Hydrological and erosional impact and farmer's perception on catch crops and weeds in citrus organic farming in Canyoles river watershed, Eastern Spain. *Agriculture, Ecosystems & Environment*, 258, 49-58.
- Chen, L., Bao, Y., He, X., Yang, J., Wu, Q., & Lv, J. (2025). Nature-based accumulation of organic carbon and nitrogen in citrus orchard soil with grass coverage. *Soil and Tillage Research*, 248, 106419.
- de Souza, F. G., Silva, J. V., Sampaio, T. I., de Morais, J. T., Moura, V., de Lima, A. F. L., ... & Campos, M. C. C. (2023). Soil erodibility in areas under citrus (*Citrus sinensis* L. Osbeck) and forest in Rondônia, Brazil. *Revista de agricultura neotropical*, 10(4), e7683-e7683.
- Gao, Z., Xu, Q., Si, Q., Zhang, S., Fu, Z., & Chen, H. (2022). Effects of different straw mulch rates on the runoff and sediment yield of young citrus orchards with lime soil and red soil under simulated rainfall conditions in southwest China. *Water*, 14(7), 1119.
- García-Ruiz, J. M. (2010). The effects of land uses on soil erosion in Spain: A review. *Catena*, 81(1), 1-11.
- Keesstra, S. D., Rodrigo-Comino, J., Novara, A., Giménez-Morera, A., Pulido, M., Di Prima, S., & Cerdà, A. (2019). Straw mulch as a sustainable solution to decrease runoff and erosion in glyphosate-treated clementine plantations in Eastern Spain. An assessment using rainfall simulation experiments. *Catena*, 174, 95-103.
- Keesstra, S., Pereira, P., Novara, A., Brevik, E. C., Azorin-Molina, C., Parras-Alcántara, L., ... & Cerdà, A. (2016). Effects of soil management techniques on soil water erosion in apricot orchards. *Science of the Total Environment*, 551, 357-366.
- Nadal-Romero, E., & García-Ruiz, J. M. (2025). Market as a factor in soil erosion: the expansion of new and old crops into marginal Mediterranean lands. *Regional Environmental Change*, 25(1), 16.
- Niu, Y. H., Li, X., Wang, H. X., Liu, Y. J., Shi, Z. H., & Wang, L. (2020). Soil erosion-related transport of neonicotinoids in new citrus orchards. *Agriculture, Ecosystems & Environment*, 290, 106776.
- Niu, Y. H., Wang, L., Wan, X. G., Peng, Q. Z., Huang, Q., & Shi, Z. H. (2021). A systematic review of soil erosion in citrus orchards worldwide. *Catena*, 206, 105558.

Tu, A., Xie, S., Zheng, H., Li, H., Li, Y., & Mo, M. (2021). Long-term effects of living grass mulching on soil and water conservation and fruit yield of citrus orchard in south China. *Agricultural Water Management*, 252, 106897.

Wang, L., Tang, L., Wang, X., & Chen, F. (2010). Effects of alley crop planting on soil and nutrient losses in the citrus orchards of the Three Gorges Region. *Soil and Tillage Research*, 110(2), 243-250.

Cerdà, A., Rodrigo-Comino, J., Giménez-Morera, A., Novara, A., Pulido, M., Kapović-Solomun, M., & Keesstra, S. D. (2018). Policies can help to apply successful strategies to control soil and water losses. The case of chipped pruned branches (CPB) in Mediterranean citrus plantations. *Land use policy*, 75, 734-745.

Wu, J., Li, Q., & Yan, L. (1997). Effect of intercropping on soil erosion in young citrus plantation—a simulation study. *Chinese Journal of Applied Ecology*, 8(2), 143.

**Acknowledgments:** This work has received funding from REACT4MED: Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean. The REACT4MED Project (grant agreement 2122) is funded by PRIMA, a program supported by Horizon 2020. The “MANEJOS AGRÍCOLAS SOSTENIBLES PARA EL CONTROL DE LA EROSIÓN DEL SUELO EN PLANTACIONES DE CÍTRICOS (CONERO)” research project funded by Ministerio de ciencia e innovación PID2023-151431OB-I00 contributed to the field and laboratory work.

## **Soil Erosion Control in Citrus Plantations. the Case of Cover Crops in the Montesa Experimental Station**

Artemi Cerdà<sup>1,\*</sup>, Ana Pérez Albarracín<sup>2</sup>, Shamsollah Ayoubi<sup>3</sup>, Antonio Giménez Morera<sup>4</sup>,  
Enric Terol<sup>5</sup>, Ioannis Daliakopoulos<sup>6</sup> and Saskia Deborah Keesstra<sup>7</sup>

<sup>1</sup>*oil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain Artemio.cerda@uv.es*

<sup>2</sup>*Soil Erosion and Degradation Research Group Departament de Geografia. Universitat de València. Blasco Ibàñez, 28, 46010-Valencia. Spain*

<sup>3</sup>*Department of Soil Science, College of Agriculture, Isfahan University of Technology, 8415683111, Isfahan, Iran*

<sup>4</sup>*Departamento de Economía y Ciencias Sociales, Universitat Politècnica de València, Cami de Vera S/N, 46022 València, Spain*

<sup>5</sup>*Department of Cartographic Engineering, Geodesy and Photogrammetry, Universitat Politècnica de València, Camino de Vera, s/n, 46022 Valencia, Spain*

<sup>6</sup>*Department of Agriculture, Hellenic Mediterranean University, 71410 Heraklion, Greece.*

<sup>7</sup>*Climate-Kic Holding B.V. Plantage Middenlaan 45, Amsterdam, the Netherlands*

### **Abstract**

Due to the fact that Soil erosion in citrus plantation is non-sustainable, the Soil Erosion and Degradation Research Group of the University of València research strategies to reduce the soil losses. Within the experimental station we are measuring the impact of geotextiles, catch crop, cover crops, mulches and also chipped pruned branches. We measure by means of rainfall simulation experiments the runoff and sediment yield in plots under cover of cover crops and bare soils.

We selected 25 plots covered with Cover Crops (C) and 25 plots in an area without (B). Both plots, Bare and Covered, used tillage to remove the weeds. A rainfall event of 55 mmh<sup>-1</sup> over one hour was produced in each of the 50 plots and runoff was collected each minute and samples transported to the laboratory to determine the sediment concentration and later calculate the soil erosion. The results show that Ponding (Tp) and Runoff generation (Tr and Tro) were faster in the Bare plots (46', 59', and 124' for Tp, Tr, and Tro) than on the Cover treated plots (110', 294', and 472' for Tp, Tr and Tro, respectively). The mean runoff discharge was 52.52 % and 21.65 % for the B and C plots. Mean soil erosion reached 8.6 Mg ha<sup>-1</sup> h<sup>-1</sup> and 0.91 Mg ha<sup>-1</sup> h<sup>-1</sup>, respectively. The results show a reduction in sediment concentration from 10.7 gl<sup>-1</sup> to 2.98 gl<sup>-1</sup>. The use of chipped pruned branches is very positive to achieve a sustainable agriculture management in citrus plantations.

**Keywords:** Soil, Erosion, Spain, Sustainability, Cover crops

### **References**

Chen, L., Rejesus, R. M., Aglasan, S., Hagen, S. C., & Salas, W. (2022). The impact of cover crops on soil erosion in the US Midwest. *Journal of Environmental Management*, 324, 116168.

Kaspar, T. C., & Singer, J. W. (2011). The use of cover crops to manage soil. *Soil management: Building a stable base for agriculture*, 321-337.

Langdale, G. W., Blevins, R. L., Karlen, D. L., McCool, D. K., Nearing, M. A., Skidmore, E. L., ... & Williams, J. R. (1991). Cover crop effects on soil erosion by wind and water. *Cover crops for clean water*, 15-22.

De Baets, S., Poesen, J., Meersmans, J., & Serlet, L. (2011). Cover crops and their erosion-reducing effects during concentrated flow erosion. *Catena*, 85(3), 237-244.

Malik, R. K., Green, T. H., Brown, G. F., & Mays, D. (2000). Use of cover crops in short rotation hardwood plantations to control erosion. *Biomass and Bioenergy*, 18(6), 479-487.

Haruna, S. I., Anderson, S. H., Udawatta, R. P., Gantzer, C. J., Phillips, N. C., Cui, S., & Gao, Y. (2020). Improving soil physical properties through the use of cover crops: A review. *Agrosystems, Geosciences & Environment*, 3(1), e2010

Koudahe, K., Allen, S. C., & Djaman, K. (2022). Critical review of the impact of cover crops on soil properties. *International Soil and Water Conservation Research*, 10(3), 343-354.

Sharma, P., Singh, A., Kahlon, C. S., Brar, A. S., Grover, K. K., Dia, M., & Steiner, R. L. (2018). The role of cover crops towards sustainable soil health and agriculture—A review paper. *American Journal of Plant Sciences*, 9(9), 1935-1951.

López-Vicente, M., Calvo-Seas, E., Álvarez, S., & Cerdà, A. (2020). Effectiveness of cover crops to reduce loss of soil organic matter in a rainfed vineyard. *Land*, 9(7), 230.

Novara, A., Gristina, L., Saladino, S. S., Santoro, A., & Cerdà, A. (2011). Soil erosion assessment on tillage and alternative soil managements in a Sicilian vineyard. *Soil and Tillage Research*, 117, 140-147.

**Acknowledgments:** This work has received funding from REACT4MED: Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean. The REACT4MED Project (grant agreement 2122) is funded by PRIMA, a program supported by Horizon 2020. The “MANEJOS AGRÍCOLAS SOSTENIBLES PARA EL CONTROL DE LA EROSIÓN DEL SUELO EN PLANTACIONES DE CÍTRICOS (CONERO)” research project funded by Ministerio de ciencia e innovación PID2023-151431OB-I00 contributed to the field and laboratory work.

## **The Effect of Biochar From Pruning Wastes on Co2 Emissions, Hydrophysical and Soil Biological Properties**

Victoria Bernasconi<sup>1</sup>, Gabriel Gascó<sup>1</sup>, Patricia Almendros<sup>2</sup> and Ana Méndez<sup>3</sup>

<sup>1</sup>*Department of Agricultural Production. Agronomic. Food and Biosystems Engineering School. Universidad Politécnica de Madrid. 28040 Madrid. Spain*

<sup>2</sup>*Department of Chemistry and Food Technology. Agronomic. Food and Biosystems Engineering School. Universidad Politécnica de Madrid. 28040 Madrid. Spain.*

<sup>3</sup>*Department of Geological and Mining Engineering. Mines and Energy School. Universidad Politécnica de Madrid. Madrid. 28003. Spain. email: p.almendros@upm.es*

### **Abstract**

Pyrolysis of biomass have attracted a great attention as valuable waste management methods. Biochar is the carbon-rich solid product obtained from pyrolysis of organic matter. It differs from other solid products of biomass pyrolysis in that its main objective is the long-term carbon storage in soils rather than creation of feedstock for processing industries or fuels (Mašek et al., 2013). In addition, chemical, physical and biological soil properties could be improved if biochar is used as soil amendment (Paz-Ferreiro et al., 2012) as cation exchange capacity, pH, water holding capacity, porosity or microorganism activity. The properties of the biochar and its effect greatly depend on raw material and pyrolysis temperature (Song and Guo, 2012). The use of biochar as soil amendment is a double strategy against climate change. First, the use of biochar is a mitigation strategy due to its application to soil, reduce CO<sub>2</sub> emissions with respect to the application of the raw material due to its high recalcitrant organic matter content. Secondly, the application of biochar is an adaptive strategy due to its use can increase the soil water holding capacity reducing the effect of precipitation changes.

The objective of this work is to study the effect of two biochars prepared from vine pruning remains at 2 temperatures (300 and 500°C) in the CO<sub>2</sub> soil emissions, water holding capacity and microorganism activity. For this reason, an incubation experiment was designed and CO<sub>2</sub> emissions was determined during 60 days. Results shown that there was not differences in CO<sub>2</sub> emissions between soil amended with biochars, microbial biomass increased between 290-139% and that biochars increased the field capacity compared to control soil.

**Keywords:** biochar, water holding capacity, CO<sub>2</sub> emissions

## Assessing Climate Impact in Vineyards of Bodegas Calvente (Padul, Granada) Through Advanced Data Processing and Bioclimatic Indices

Chytis, Thodoris Maximilianos<sup>1,\*</sup>, Cuenca-Moreno, Lucía<sup>2</sup> and Rodrigo-Comino, Jesús<sup>3</sup>

<sup>1</sup>*School of Chemical and Environmental Engineering, Technical University of Crete, Chania, Greece*

<sup>2</sup>*Department of Regional Geographic Analysis and Physical Geography, Faculty of Philosophy and Letters, Cartuja University Campus, University of Granada, 18071 Granada, Spain. Andalusian Research Institute in Data Science and Computational Intelligence (DaSCI), University of Granada, 18071 Granada, Spain. Medialab UGR - Research Laboratory for Digital Culture and Society, University of Granada, Granada, 18012, Spain.*

<sup>3</sup>*Department of Regional Geographic Analysis and Physical Geography, Faculty of Philosophy and Letters, Cartuja University Campus, University of Granada, 18071 Granada, Spain. Andalusian Research Institute in Data Science and Computational Intelligence (DaSCI), University of Granada, 18071 Granada, Spain. RNM-197 Research Group.*

### Abstract

Reliable climate analysis requires high-quality, consistent meteorological data. In this work, a robust data processing pipeline is presented for climate impact assessment in the area of Padul, Granada, Spain, specifically focused on vineyards in Bodegas Calvente, integrating raw datasets from different stations and time periods. The workflow begins with comprehensive data cleaning, including harmonization of column names, handling of missing values through climatological and statistical imputation, and correction of outliers and inconsistencies. Exploratory data analysis (EDA) is performed to characterize temporal patterns, variability, and relationships among key climate variables such as temperature, humidity, wind speed, solar radiation, and precipitation. Feature engineering steps include aggregation of daily, monthly, and seasonal statistics, as well as the creation of lagged variables, to support downstream analyses. Additionally, several bioclimatic indices—such as the Huglin, Cool Night, Hydrothermic, and Dryness indices—are computed to provide further insight into agroclimatic conditions relevant for regional impact studies.

The analysis reveals distinct temporal trends in climate indicators as periods with increased frequency of extreme events, such as heatwaves, frost days, tropical nights, and episodes of low humidity or high wind speeds, are identified. Seasonal aggregation of growing degree days and drought indices highlights seasons with heightened agroclimatic stress, providing quantitative insight for risk assessment. Correlation analyses and time series decomposition uncover underlying relationships and seasonal patterns, while rigorous outlier detection ensures the robustness of the dataset.

The processed dataset and pipeline can serve as a foundation for advanced applications,

including the development of machine learning and deep learning models, to predict future climate trends and assess the risk of extreme events such as droughts, heatwaves, and frost days. This, in turn, supports hazard forecasting as well as the derivation of adaptation and decision-making strategies in agriculture and regional planning.

**Keywords:** climate data, data cleaning, exploratory data analysis, bioclimatic indices, climate impact

## Assessing the Impact of Afforested Species on Carbon Sequestration in the Green Zones of an Industrial Site Located in Arid Regions of Iran

Mojtaba Taghizadeh Ganji<sup>1</sup>, Fatemeh Roustaei<sup>1</sup>, Mostafa Shirmardi<sup>2</sup>, Shamsollah Ayoubi<sup>3,\*</sup> and Artemi Cerdà<sup>4</sup>

<sup>1</sup>Faculty of Natural Resources, Department of Nature Engineering, Ardakan University, Ardakan, Iran

<sup>2</sup>Department of Horticultural Science, Faculty of Agriculture and Natural Resources, Ardakan University, P.O. Box 184, Ardakan, Iran

<sup>3</sup>Department of Soil Science, College of Agriculture, Isfahan University of Technology, Isfahan 84156-83111, Iran

<sup>4</sup>Soil Erosion and Degradation Research Group, Department of Geography, University of Valencia, Valencia, Spain

### Abstract

In arid environments where industrial operations intensify carbon emissions, the intentional selection of plant species for green spaces can play a pivotal role in enhancing carbon sequestration and meeting environmental regulations. This study assesses the carbon sequestration capacity of six commonly cultivated species—*Olea europaea*, *Nerium oleander*, *Pinus eldarica*, *Punica granatum*, *Eucalyptus camaldulensis*, and *Acacia saligna*—within the arid, industrial landscape of Iran's Ghadir Iron and Steel Company in Central Iran. Carbon stocks in biomass and soil (down to 50 cm) were evaluated under uniform growing conditions across 15-year-old trees. Measurements included carbon stored in plant components (stems, roots, litter) and soil organic carbon (SOC) beneath the canopy. Results revealed clear species-specific differences: *Eucalyptus* recorded the highest total carbon sequestration (232.07 Mg/ha), largely due to its extensive shoot biomass (112.9 Mg/ha) and root mass (29.92 Mg/ha), whereas *Punica granatum* had the lowest (73.83 Mg/ha). SOC levels in the topsoil (0-25 cm) were highest under *Punica granatum* (1.197%) and *Eucalyptus* (1.04%), reflecting litter accumulation and root activity. Biomass contributed between 58.6% and 90.9% of total carbon storage for most species, except for *Punica granatum*, where soil accounted for 41.4%. Notably, *Nerium oleander* and *Eucalyptus* enhanced SOC in deeper layers (25-50 cm). Overall, the findings highlight *Eucalyptus* and *Nerium oleander* as particularly effective choices for green space development in arid industrial zones, offering a dual benefit of rapid biomass growth and soil carbon enrichment. This research provides practical guidance for industries in arid regions seeking to offset carbon emissions through informed species selection, in alignment with climate mitigation goals and regulatory green space requirements.

**Keywords:** Carbon sequestration, Arid industrial zones, Soil organic carbon, Biomass carbon storage, Climate change mitigation

## References

- Abdelrhman, A.A., Sayed, Y.A., Fadl, M.E., Casucci, C., Drosos, M., Scopa, A. and Moftah, H., 2025. Impact of Aggregate-Associated Carbon on Soil Mechanical Properties: Stability and Compaction Indices in Pomegranate Orchards of Different Ages. *Soil Systems*, 9(1), p.20.
- Alonso-Serra, J., 2021. Carbon sequestration: counterintuitive feedback of plant growth. *Quantitative plant biology*, 2, p.e11.
- Alonso-Serra, J., 2021. Carbon sequestration: counterintuitive feedback of plant growth. *Quantitative plant biology*, 2, p.e11.
- Bhattacharyya, S.S., Mondaca, P., Shushupti, O. and Ashfaq, S., 2023. Interplay between plant functional traits and soil carbon sequestration under ambient and elevated CO<sub>2</sub> levels. *Sustainability*, 15(9), p.7584.
- Chavan, S.B., Dhillon, R.S., Sirohi, C., Saleh, I.A., Uthappa, A.R., Keerthika, A., Jinger, D., Halli, H.M., Pradhan, A., Kakade, V. and Morade, A., 2024. Optimizing planting geometries in eucalyptus-based food production systems for enhanced yield and carbon sequestration. *Frontiers in Sustainable Food Systems*, 8, p.1386035.
- Fareed, A.G., Khoja, A.H., De Felice, F., Petrillo, A., Sultan, M.A., Jalalzai, Z.K. and Daood, S.S., 2023. Underground geological sequestration of carbon dioxide (CO<sub>2</sub>) and its effect on possible enhanced gas and oil recovery in a fractured reservoir of Eastern Potwar Basin, Pakistan. *Science of the Total Environment*, 905, p.167124.
- Galán-Martín, Á., del Mar Contreras, M., Romero, I., Ruiz, E., Bueno-Rodríguez, S., Eliche-Quesada, D. and Castro-Galiano, E., 2022. The potential role of olive groves to deliver carbon dioxide removal in a carbon-neutral Europe: Opportunities and challenges. *Renewable and Sustainable Energy Reviews*, 165, p.112609.
- Garosi, Y., S. Ayoubi, Madlene Nussbaum, Mohsen Sheklabadi. 2022. Effects of different sources and spatial resolutions of environmental covariates on predicting soil organic carbon using machine learning in a semi-arid region of Iran. *Geoderma Regional*. e00513.
- Haseeb, M., Tahir, Z., Mehmood, S.A., Gill, S.A., Farooq, N., Butt, H., Iftikhar, A., Maqsood, A., Abdullah-Al-Wadud, M. and Tariq, A., 2024. Enhancing carbon sequestration through afforestation: Evaluating the impact of land use and cover changes on carbon storage dynamics. *Earth Systems and Environment*, 8(4), pp.1563-1582.
- Huang, W.Q., Xu, B., Chen, F.S., Zong, Y.Y., Duan, X.Q., Zhang, G.X., Wu, Z.J. and Fang, X.M., 2023. The effects of vegetation type on ecosystem carbon storage and distribution in subtropical plantations. *Frontiers in Forests and Global Change*, 6, p.1149799.
- Jin, S., Zhang, E., Guo, H., Hu, C., Zhang, Y. and Yan, D., 2023. Comprehensive evaluation of carbon sequestration potential of landscape tree species and its influencing factors analysis: Implications for urban green space management. *Carbon Balance and Management*, 18(1), p.17.
- Kalankesh, L.R., Rodriguez-Couto, S., Alami, A., Khosravan, S., Meshki, M., Ahmadov, E., Mohammadpour, A. and Bahri, N., 2022. Socio-Environmental Determinants and Human Health Exposures in Arid and Semi-Arid Zones of Iran—Narrative Review. *Environmental Health Insights*, 16, p.11786302221089738.
- Lei, Z., Yu, D., Zhou, F., Zhang, Y., Yu, D., Zhou, Y. and Han, Y., 2019. Changes in soil organic carbon and its influencing factors in the growth of *Pinus sylvestris* var. *mongolica* plantation in Horqin Sandy Land, Northeast China. *Scientific Reports*, 9(1), p.16453.
- Li, H., Van den Bulcke, J., Mendoza, O., Deroo, H., Haesaert, G., Dewitte, K., De Neve, S. and Sleutel, S., 2022. Soil texture controls added organic matter mineralization by regulating soil moisture—evidence from a field experiment in a maritime climate. *Geoderma*, 410, p.115690.
- Lopez-Bellido, P.J., Lopez-Bellido, L., Fernandez-Garcia, P., Muñoz-Romero, V. and Lopez-Bellido, F.J., 2016. Assessment of carbon sequestration and the carbon footprint in olive groves in Southern Spain. *Carbon Management*, 7(3-4), pp.161-170.
- Naghipour Borj, A.A., Radnezhad, H. and Matinkhah, S.H., 2014. The impact of afforestation on soil carbon sequestration and plant biomass in arid areas (case study: Bakhtiardasht forest park, Isfahan). *Iranian Journal of Forest and Poplar Research*, 22(1), pp.99-108.
- Olmedo, G.F., Guevara, M., Gilabert, H., Montes, C.R., Arellano, E.C., Barriá-Knopf, B., Gárate, F., Mena-Quijada, P., Acuña, E., Bown, H.E. and Ryan, M.G., 2020. Baseline of carbon stocks in *Pinus radiata* and *Eucalyptus* spp. plantations of Chile. *Forests*, 11(10), p.1063.
- Ribeiro, F.P., Gatto, A., Oliveira, A.D.D., Pulrolnik, K., Valadão, M.B.X., Araújo, J.B.C.N., Carvalho, A.M.D. and Ferreira, E.A.B., 2023. Carbon storage in different

compartments in Eucalyptus stands and native cerrado vegetation. *Plants*, 12(14), p.2751. Sdejo, R. and Sohngen, B. 2012. Carbon sequestration in forests and soils. *Annual Review of Resource Economics*. *Ann. Rev. Resour. Econ.* 4, 127-144. Villat, J. and Nicholas, K.A., 2024. Quantifying soil carbon sequestration from regenerative agricultural practices in crops and vineyards. *Frontiers in Sustainable Food Systems*, 7, p.1234108. Wilding, L.P. (1985). Spatial variability: Its documentation, accommodation, and implication to soil surveys. In D.R. Nielsen, & J. Bouma (Eds.), *Soil Spatial Variability*. Pudoc, Wageningen, The Netherlands. Zhong, J., Pan, P., Xiao, S. and Ouyang, X., 2022. Influence of eucalyptus plantation on soil organic carbon and its fractions in severely degraded soil in Leizhou Peninsula, China. *Forests*, 13(10), p.1606.

## Soil Erosion Dynamics in Rehabilitated Apple Orchards, Hilly Region, Central Iran (Use of Magnetic Susceptibility and Cs-137 Techniques)

Shamsollah Ayoubi<sup>1,\*</sup>, Artemi Cerdà<sup>2</sup> and Ameneh Mohammadi<sup>1</sup>

<sup>1</sup>Department of Soil Science, College of Agriculture, Isfahan University of Technology, 8415683111, Isfahan, Iran

<sup>2</sup>1- Soil Erosion and Degradation Research Group, Department of Geography, University of Valencia, Valencia, Spain

### Abstract

Understanding how land-use changes—particularly the introduction of orchards—impact soil quality and redistribution on steep slopes is crucial for improved land management. This study focuses on rangeland degradation, dryland farming, and land rehabilitation via apple orchard cultivation across varying slope positions in a semiarid area of central Iran. The main objectives were to: i) assess the effects of land-use change and orchard cultivation on selected chemical, physical, and magnetometric soil properties across slope positions; ii) evaluate soil redistribution due to land-use change using the <sup>137</sup>Cs technique; and iii) investigate the relationship between soil properties and the extent of redistribution as indicated by <sup>137</sup>Cs in southern Isfahan Province. Seventy-two soil samples were collected from three land uses—natural rangelands, dryland farms, and apple orchards—at four slope positions (shoulder, backslope, footslope, toeslope) within the 0–30 cm layer. Soil properties were analyzed alongside <sup>137</sup>Cs-based redistribution estimates. Results showed that rangeland degradation followed by rainfed cultivation significantly reduced soil quality (SOM, TN, Kava, Pava) and heightened soil loss, as confirmed by <sup>137</sup>Cs data. In contrast, transforming drylands into contour-planted apple orchards improved soil quality ( $p < 0.05$ ) and reduced erosion. Both slope position and land-use type strongly influenced soil characteristics and redistribution. The most severe soil loss ( $185.3 \text{ t ha}^{-1} \text{ y}^{-1}$ ) and sedimentation ( $182.5 \text{ t ha}^{-1} \text{ y}^{-1}$ ) were recorded at the shoulder and footslope of drylands, respectively. A multiple regression model found pb, CCE, and Pava explained 98% of the variation in <sup>137</sup>Cs. Additionally, strong correlations between <sup>137</sup>Cs and low-frequency magnetic susceptibility ( $\chi_{lf}$ ) support magnetic parameters as cost-effective proxies for assessing soil movement. Overall, the findings indicate that orchard-based land rehabilitation can enhance soil quality and mitigate erosion in semiarid regions—though continued research is necessary to explore broader environmental consequences.

**Keywords:** Soil rehabilitation, <sup>137</sup>Cs technique, magnetic susceptibility, multiple linear regression, soil nutrients.

### References

Afshar, F.A., Ayoubi, S., Jalalian, A., 2010. Soil redistribution rate and its relationship with soil organic carbon and total nitrogen using <sup>137</sup>Cs technique in a cultivated complex hillslope in western Iran. *J. Environ. Radioact.* 101, 606-614. Baranian Kabir, E., Bashari, H., Bassiri, M., Mosaddeghi M.R., 2020. Effects of land-use/cover change on soil hydraulic properties and pore characteristics in a semi-arid region of central Iran. *Soil Till. Res.* 197, 104478. Bouhlassa, S., Bouhsane, N., 2019. Assessment of areal water and tillage erosion using magnetic susceptibility: the approach and its application in Moroccan watershed. *Environ. Sci. Pollu. Res.* 26, 25452-25466. Burst, M., Chauchard, S., Dambrine, E., Dupouey, J., 2020. Distribution of soil properties along forest-grassland interfaces: Influence of permanent environmental factors or land-use after-effects? *Agriculture, Ecosys. Environ.* 289, 106739. Carter, M.R., E.G. Gregorich, (Eds.), 2006. *Soil Sampling and Methods of Analysis*. Second Edition. Canadian Society of Soil Science. Taylor & Francis Group, LLC. ISBN-10: 0-8493-3586-8. Fujiyoshi, R., Sawamura, S., 2004. Mesoscale variability of vertical profiles of environmental radionuclides (<sup>40</sup>K, <sup>226</sup>Ra, <sup>210</sup>Pb and <sup>137</sup>Cs) in temperate forest soil in Germany. *Sci. Total. Environ.* 408, 2543-2548. Gee, G.W., Bauder, J.W., 1979. Particle Size Analysis by Hydrometer: A Simplified Method for Routine Textural Analysis and a Sensitivity Test of Measurement Parameters<sup>1</sup>. *Soil Sci. Soc. Am. J.* 43, 1004-1007. Göl, C., Dengiz, O., 2008. Effect of modifying land cover and longterm agricultural practices on the soil characteristics in native forest-land. *J. Environ. Biol.* 29(5), 667-682. Guan, Y., Zhou, W., Bai, Z., Cao, Y., Huang, Y., Huang, H., 2020. Soil nutrient variations among different land use types after reclamation in the Pingshuo opencast coal mine on the Loess Plateau, China. *Catena.* 188, 104427. Kızılkaya, R, Dengiz., O.2010. Variation of land use and land cover effects on some soil physico-chemical characteristics and soil enzyme activity. *Zemdirbyste-Agric* 97,15-24. Kooch, Y., Moghimian, N., Wirth, S., Noghre, N., 2020. Effects of grazing management on leaf litter decomposition and soil microbial activities in northern Iranian rangeland. *Geoderma.* 361. 114100. Li, B., Tang, H., Wu, L., LI, Q, Zhou, C., 2012. Relationships between the soil organic carbon density of surface soils and the influencing factors in differing land uses in Inner Mongolia. *Environ Earth Sci.* 65,195-202. Liu, H.H., Zhang, T.Y., Liu, B.Y., Liu, G., Wilson, G.V., 2013. Effects of gully erosion and gully filling on soil depth and crop production in the black soil region, Northeast China. *Environ Earth Sci.* 68,1723-1732. Liu, L., Zhang, K., Zhang, Z., Qiu, Q., 2015. Identifying soil redistribution patterns by magnetic susceptibility on the black soil farmland in Northeast China. *Catena.* 129, 103-111. Lopez-Granados, F., Jurado-Exposito, M., Atenciano, S., Garcia-Ferrer, A., De la Orden, M.S., Garcia-Torres, L., 2002. Spatial variability of agricultural soil parameters in southern Spain. *Plant Soil* 246: 97-105. Menshov O, Kruglov O, Vyzhva S, Nazarok P, Pereira P, Pastushenko T. 2018. Magnetic methods in tracing soil Erosion, Kharkov Region, Ukraine. *Studia Geophys. Geodact.* 62:681-696. Renard, K.G., Laflen, J.M., Foster, G.R., McCool, D.K., 1994. RUSLE revisited: status questions, answers and the future. *J. Soil Water Cons.* 49, 213-220. Sac, M.M., Ugur, A., Yener, G., Ozden, B., 2008. Estimate of soil erosion using Cs-137 tracer models. *Environ. Monit. Assess.* 136, 461-467. Sadiki A, Faleh A, Navas A, Bouhlassa S., 2009. Using magnetic susceptibility to assess soil degradation in the Eastern Rif, Morocco. *Earth Surf. Process. Landf.* 34, 2057-2069. Walling, D.E., He, Q., Appleby, P.G., 2002. Conversion Models for Use in Soil-erosion, Soil-redistribution and Sedimentation Investigations. In: Zapata, F. (Ed.). Yuan, Y., Zhao, Z., Niu, S., Li, X., Wang, Y., Bai, Z., 2018. Reclamation promotes the succession of the soil and vegetation in opencast coal mine: A case study from Robinia pseudoacacia reclaimed forests, Pingshuo mine, China. *Catena* 165, 72-79. Zhou, W., Yang, K., Bai, Z., Cheng, H., Liu, F., 2017. The development of topsoil properties under different reclaimed land uses in the Pingshuo opencast coalmine of Loess Plateau of China. *Ecol. Eng.* 100, 237-245.

## **Proposing a Soil Quality Index For Cereal Croplands in Campo De Cámara (Málaga, Spain)**

José Carvajal<sup>1</sup>, Jack Cuneo<sup>2</sup>, Víctor Hugo Durán-Zuazo<sup>3</sup>, Dara Park<sup>2</sup> and Jesús Rodrigo-Comino<sup>4</sup>

<sup>1</sup>*University of Granada*

<sup>2</sup>*University of Clemson*

<sup>3</sup>*IFAPA*

<sup>4</sup>*University of Granada and DaSCI*

### **Abstract**

Understanding and monitoring soil quality is crucial for sustainable agricultural management, especially in regions prone to degradation. This study proposes the development of a comprehensive Soil Quality Index (SQI) tailored for experimental cereal croplands in the Campo de Cámara region of Málaga, Spain. The research aims to establish a robust framework for assessing soil health, reflecting the integrated effects of various physical, chemical, and biological properties over time. Soil samples were collected from five different experimental plots at multiple key growth stages throughout the year, allowing for the capture of seasonal variations in soil properties. A range of critical soil parameters were measured, including water holding capacity, aggregate stability, organic matter content, carbonates, pH, and electrical conductivity. These indicators were selected due to their significant influence on soil function and crop productivity in Mediterranean agroecosystems. The proposed SQI will integrate these diverse parameters using a weighted scoring system, where individual indicators are normalized and assigned weights based on their relative importance to overall soil health and their sensitivity to management practices. This index will provide a single, easily interpretable value reflecting the current state of soil quality. Such a tool will be invaluable for: 1) identifying areas with declining soil health, 2) evaluating the effectiveness of different agricultural management practices, and 3) guiding decision-making towards more sustainable land use in cereal-producing areas. This research contributes to a better understanding of soil dynamics in experimental settings and offers a practical method for long-term soil quality monitoring.

**Keywords:** Cereals, soil quality indicators, soil digital mapping, soil properties

## **Connected Cities - Strengthening Green Infrastructure Through Data and Collaboration**

Miglena Zhiyanski and Maria Glushkova

*Forest Research Institute - Bulgarian Academy of Sciences*

### **Abstract**

Urban areas have a strong environmental impact due to high population density resulting in a high demand for ecosystem services (ES) including nature-based recreation, local climate regulation and clean air (Newman 2006; Baró et al. 2015). Urban green infrastructure can significantly improve the quality of life through providing important ES thus reducing the environmental impact of cities and should therefore be more systematically incorporated into urban planning and policy, to ensure a more sustainable local development (Rall et al. 2015).

In this study we chose a small city, rich of surrounding natural forests, but with low level of urban green spaces in central Bulgaria and raise the important policy questions: 1. Are the green spaces in Karlovo Municipality characterized with good ecological condition in order to continue supplying the variety of ecosystem services? 2. How should the green spaces be maintained to have the greatest impact on the environment and human well-being? and 3. What are the potential effects of urban green infrastructure (UGI) and ecosystem services on agricultural and climate policy as well as disaster risk reduction at local and regional level?

The assessment of ecosystem condition in urban ecosystems and green infrastructure of the city is measured by the set of indicators, based on the concept of ecosystem integrity. The following assessment of the key elements of green infrastructure condition was performed through an integrated application of in-situ observation and remote sensing. The final step was the assessment of selected ecosystem services provided by green infrastructure in Karlovo at local and regional levels. Close cooperation with the local authorities was realized and aimed at providing direct assistance in defining measures to improve the condition of green spaces and to integrate the assessment and mapping of some ES in the spatial planning.

The in-depth analysis of green spaces dynamics within the landscape system allowed identifying the drivers and barriers influencing adaptive green spaces management and governance. As a final result mapping and assessment of ES provided by urban and peri-urban green spaces was demonstrated and accepted as a policy support system and relevant decision making tools by the city authorities.

The results are a good basis to promote adaptive management at local and regional level and to implement the ES concept into the municipal development plans and relevant policy for agriculture, forestry and climate change to maintain biodiversity and to mitigate the impact of the natural hazards across Europe.

**Keywords:** green infrastructure, ecological condition, ecosystem services, mapping, adaptive management

## **Projection of Drought Tendencies in the Horné Pohronie Region (Central Europe - Slovakia) For the Period 2025-2050**

Jaroslav Vido<sup>1</sup> and Paulína Nalevanková<sup>2</sup>

<sup>1</sup>*1. Department of Natural Environment, Faculty of Forestry, Technical University in Zvolen, Zvolen, 960 01, Slovak Republic, 2. Department of Forest Botany, Dendrology and Geobiocoenology, Faculty of Forestry and Wood Technology, Mendel University in Brno, Brno, 613 00, Czech Republic*

<sup>2</sup>*Department of Natural Environment, Faculty of Forestry, Technical University in Zvolen, Zvolen, 960 01, Slovak Republic*

### **Abstract**

Drought is among the most critical threats to forest ecosystems in Central Europe, with projections indicating further intensification under future climate conditions. This case study presents a prognostic assessment of drought development in Horné Pohronie region of Slovakia for the period 2025–2050. The evaluation employed the Standardized Precipitation Evapotranspiration Index SPEI (Vicente-Serrano et al., 2010) for 1-month and 12-month accumulation periods, calculated using modeled average air temperature and precipitation totals from the MRI-AGCM3-2-S climate model (Yukimoto et al., 2019) with a 20 km resolution. SPEI values were computed for four elevation levels (300, 600, 900, and 1200 m a.s.l.) selected to represent various forest vegetation zones (2nd to 7th LVS). While the 1-month SPEI indicated a significant increase in drought frequency only at the lowest elevation, the 12-month SPEI revealed a statistically significant increasing trend across all elevation zones. This suggests that cumulative water balance deficits—indicative of prolonged droughts—are likely to intensify throughout the region during the forecast period. Monthly analysis revealed that May and July to December are expected to be the driest months, while January, February, and June may show positive water balances. March and April exhibited no clear tendencies. The data suggest that even the highest elevation forests will not be spared from the impacts of intensifying droughts. These trends are likely driven by anticipated shifts in atmospheric circulation patterns over Central Europe (Faranda et al., 2020), rather than by local geographic factors. The findings underscore the urgent need for forward-looking adaptation strategies in forestry, silviculture, and landscape management that take into account future, not current, climatic and hydrological stressors.

**Keywords:** Climate change, Drought, Slovakia, Hron river

### **References**

Vicente-Serrano, S. M., Beguería, S., & López-Moreno, J. I. (2010). A multiscalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index. *Journal of*

climate, 23(7), 1696-1718. Yukimoto, S., Kawai, H., Koshiro, T., Oshima, N., Yoshida, K., Urakawa, S., ... & Ishii, M. (2019). The Meteorological Research Institute Earth System Model version 2.0, MRI-ESM2. 0: Description and basic evaluation of the physical component. *Journal of the Meteorological Society of Japan. Ser. II*, 97(5), 931-965.

## The Impact of Historical Land Cover Change on Soil Organic Carbon in Malagasy Open Grassy Ecosystems : a Stable Isotope Approach

Lovafitia Ratovoarimanana<sup>1,\*</sup>, Nandrianina Ramifehiarivo<sup>1</sup>, Nasandratra Ravonjiarison<sup>1</sup>, Andry Andriamananjara<sup>1</sup>, Steven Bouillon<sup>2</sup> and Herintsitohaina Razakamanarivo<sup>1</sup>

<sup>1</sup>Laboratoire des Radioisotopes, University of Antananarivo Madagascar

<sup>2</sup>Department of Earth & Environmental Sciences, KU Leuven, Belgium

### Abstract

In Madagascar, a key debate remains whether open grassy ecosystems, covering 65% of the country's land area, are primarily natural ecosystems, or the result of historical forest degradation. However, their potential to soil organic carbon (SOC) sequestration remains largely unexplored, despite its significance for climate change mitigation. Since SOC content and its stable carbon isotope composition (variations in  $^{13}\text{C}/^{12}\text{C}$ , expressed as  $\delta^{13}\text{C}$  values) along soil profiles are sensitive to land cover change, and can serve as indicator reflecting shifts in carbon inputs and soil carbon turnover. This study investigates how historical land-use changes have shaped SOC trends. We hypothesized that SOC stocks (SOCs) are not only determined by current land cover, but are also strongly influenced by land cover change history.

A total of 153 soil profiles were collected across open ecosystems and reference forest sites as reference in three Malagasy bioclimatic zones: the subhumid central highlands, dry northwest, and subhumid southeast. SOCs were assessed at five depth intervals (0-10, 10-20, 20-30, 50-60, and 80-90 cm), and  $\delta^{13}\text{C}$  values were analyzed to distinguish C<sub>3</sub>- and C<sub>4</sub>-derived carbon.

Firstly, the combined use of carbon content and  $\delta^{13}\text{C}$  profiles reveals three distinct origins of those open grassy ecosystems : (i) treeless natural grasslands (previous C<sub>4</sub>), (ii) grasslands derived from deforestation (previous C<sub>3</sub>), and (iii) those from woody vegetation with grassy understories (Mixed C<sub>3</sub> and C<sub>4</sub>), shaped by long-term human activity. Secondly, SOCs varied most by sampling site ( $p < 0.001$ ), with former vegetation showing also a significant effect ( $p = 0.01$ ), whereas current vegetation did not. We found that SOCs were consistently higher in soils originally covered by C<sub>3</sub> vegetation (i.e., forest), irrespective of their current vegetation cover. Lastly, the contribution of C<sub>3</sub>-derived carbon to SOCs followed a clear gradient from stable C<sub>3</sub> > C<sub>3</sub>\_Mixed > C<sub>3</sub>\_C<sub>4</sub> > Mixed > Mixed\_C<sub>4</sub> > to natural C<sub>4</sub> systems, indicating strong legacy effects of past vegetation. Systems that transitioned from C<sub>3</sub> vegetation still retain substantial C<sub>3</sub>-derived carbon in deeper layers, as remnants of past forest vegetation, though this contribution progressively declines — higher in C<sub>3</sub> to mixed transitions than in C<sub>3</sub> to C<sub>4</sub> conversions.

Overall, combining SOC profiles with  $\delta^{13}\text{C}$  analysis and C<sub>3</sub>/C<sub>4</sub> source partitioning

provides a robust tool to reconstruct vegetation history. Recognizing the historical context of Malagasy landscapes is crucial for climate-resilient conservation. This approach supports targeted reforestation and land management strategies to enhance carbon sequestration and ecosystem restoration.

**Keywords:** C3-derived carbon, former land use, transition,  $\delta^{13}\text{C}$

## Exploring the Saprolite Horizons as Proxies For Enhanced Rock Weathering in Tropical Soil.

Thairís Gomes dos Santos, Juliana Costa do Nascimento, Luis Vieira and Antonio Carlos de Azevedo

*Department of Soil Science. Luiz de Queiroz College of Agriculture - University of São Paulo (Esalq-USP)*

### Abstract

Como uma tecnologia emergente, o Intemperismo Aprimorado de Rochas enfrentou o obstáculo da lenta taxa de ocorrência e das pequenas alterações correspondentes nos minerais dos pós-rocha, dificultando uma quantificação clara do intemperismo por métodos de rotina. Experimentos de longo prazo, especialmente em ambientes tropicais, forneceram resultados mais sólidos, mas ainda são raros. Para investigar as mudanças no pó de rocha aplicado a um solo tropical, amostramos uma rocha de diabásio e os horizontes de saprolito sobrepostos, naturalmente intemperizados, Cr1, Cr2 e Cr3. Em seguida, cominuímos e misturamos 0 e 10 t ha<sup>-1</sup> desses materiais em um Latossolo tropical de textura média. O saprolito foi classificado como Saprolito Háptico (Juileret et al., 2016). Usamos os materiais de saprolito como proxies de diferentes estágios de intemperismo da rocha no solo, aumentando de Cr3 (menos intemperizado) para Cr1 (mais intemperizado). Após mistura completa, alíquotas de misturas de solo+saprólito foram amostradas e evidenciadas para análise química total por digestão ácida e fusão de metaborato de lítio para determinação elementar por ICP-OES e ICP-MS foi realizada. A perda por ignição (LOI) foi determinada pela calcinação das amostras a 1000 °C. Os materiais de referência certificados foram usados para controle de qualidade (OREAS46 e SG\_092 para óxidos, OREAS460 e SG\_142 para oligoelementos e SG\_241 para LOI). A interpretação preliminar mostrou padrão semelhante para as cátions básicas (Ca, Mg, K e Na) aumentando de R para Cr3 para Cr2 e trazendo em Cr1. Elementos de baixa mobilidade como Fe tiveram o mesmo padrão, mas não Al, indicando potencial contribuição de respostas redox e/ou biociclagem. O aumento na concentração de elementos pode ser o resultado de vários mecanismos. Pode estar relacionado à perda de outros elementos e ao acúmulo residual de minerais ricos em bases. O silênio foi o elemento mais abundante no sistema solo+rocha ou saprolito e teve comportamento oposto, indicando que esse mecanismo de aumento residual na concentração de bases está, pelo menos parcialmente, relacionado à perda de Si pelo sistema. Isso também pode ser devido à posição desses horizontes no solo, que recebe o aporte de elementos lixiviados dos horizontes superiores. O aumento na concentração dos elementos majoritários, quando ocorreu, ficou entre 0,1 a 1%. Os valores de Zr e Zn foram aproximadamente constantes, atestando a utilidade desses elementos como padrões internos para balanços geoquímicos, enquanto a titânio provocava maior variação. A

análise de DRX não foi capaz de capturar mudanças na fase sólida do mineral. As amostras serão submetidas à análise térmica.

**Keywords:** Element mobility, Weathering indicators, Rock alteration, Rock powder, Diabase

### **References**

JUILLERET, Jérôme; DONDEYNE, Stefaan; VANCAMPENHOUT, Karen; DECKERS, Jozef; HISSLER, Christophe. Mind the gap: A classification system for integrating the subsolum into soil surveys. *Geoderma*, [S.l.], v. 264, p. 332-339, 2016. DOI: 10.1016/j.geoderma.2015.08.031.

**Acknowledgments:** I would like to thank the “Luiz de Queiroz” College of Agriculture - University of São Paulo (ESALQ/USP) for the institutional and academic support throughout this research. My gratitude also goes to the Coordination for the Improvement of Higher Education Personnel (CAPES) for the financial support through a scholarship, which was essential for the development of this work. I am also thankful to the Grantham Foundation for supporting this scientific research and encouraging studies related to sustainability and climate change.

## **An Integrated Multi-Process Evaluation of Land Degradation in Europe**

Remus PRĂVĂLIE<sup>1,\*</sup>, Pasquale BORRELLI<sup>2</sup>, Nicușor NECULA<sup>3</sup>, Georgeta BANDOC<sup>1</sup> and  
Cristian PATRICHE<sup>4</sup>

<sup>1</sup>*University of Bucharest, Faculty of Geography, 1 Nicolae Bălcescu Street, 010041, Bucharest, Romania; Academy of Romanian Scientists, 54 Splaiul Independentei Street, 050094, Bucharest, Romania*

<sup>2</sup>*Department of Science, Roma Tre University, Rome, Italy; Department of Environmental Sciences, University of Basel, Basel, 4056, Switzerland*

<sup>3</sup>*Alexandru Ioan Cuza University of Iasi, Faculty of Geography and Geology, Department of Geography, 20A Carol I Street, 700505, Iasi, Romania*

<sup>4</sup>*Romanian Academy, Iasi Divison, Geography Department, 8 Carol I Street, 700505, Iasi, Romania*

### **Abstract**

Land systems (soils, vegetation and inland water resources) are dramatically degrading throughout pan-European (and global) agricultural environments, threatening climate stability, crop production, food security and the economic development of the continent. The impact of land degradation is proportionally amplified by the number of degradative processes operating across the continent, for which no integrated spatial inventory, at multiple spatial scales, has been undertaken yet. This work integrates and evaluates 12 land degradation processes (water erosion, wind erosion, soil organic carbon loss, soil salinization, soil acidification, soil compaction, soil nutrient imbalances, soil pollution via pesticides, soil pollution via heavy metals, vegetation degradation, groundwater decline and aridity), which affect the agricultural environments of 38 European countries. Using complex data and modelling schemes, which were processed / applied based on Geographic Information System techniques, we mapped and evaluated the complex spatial pattern of multiple degradative pathways, as a detailed multi-scale (continental to sub-regional) inventory of agricultural land degradation in Europe. The complex cartographic results can facilitate the implementation and spatial prioritization of various measures designed to combat the degrading conditions of agricultural lands, in order to increase their agroecological potential and their sustainable use across Europe, in the coming years.

**Keywords:** multiple land degradation processes, agricultural landscapes, integrated evaluation, multiple spatial scales, Europe.

## Optimal Soil Management For Carbon Sequestration

Ruben Dümmer<sup>1\*</sup>, Kika Lewak<sup>1</sup>, Christian de Kleijn<sup>2</sup>, Mark Smits<sup>3</sup>, Gera van Os<sup>2</sup>, Karin Pepers<sup>2</sup>, Frank van der Helm<sup>4</sup>, Marjoleine Hanegraaf<sup>5</sup> and Emiel Elferink<sup>1</sup>

<sup>1</sup>*Van Hall Larenstein*

<sup>2</sup>*Aeres*

<sup>3</sup>*HAS Green Academy*

<sup>4</sup>*InHolland*

<sup>5</sup>*B.U. Field Crops*

### Abstract

Soil organic matter (OM), a critical component of soil health and carbon sequestration, consists of 45–60% carbon and is commonly reported as a single total value. However, OM comprises various fractions, notably Particulate Organic Matter (POM) and Mineral-Associated Organic Matter (MAOM), which behave differently in the soil and respond uniquely to management practices. Understanding these fractions provides greater insight into long-term carbon storage potential. As part of the "Koolstof Als Kans" ("Carbon as an Opportunity") project, the four agricultural universities of applied sciences (HAOs) in the Netherlands developed a method, based on (literature) research and testing, to separate and quantify POM and MAOM based on particle size. POM is defined as the organic fraction between 53  $\mu\text{m}$  and 2 mm, while MAOM is  $<53 \mu\text{m}$  and typically bound to mineral surfaces. This method was applied to soil samples from 85 fields (18 sand, 43 loam, 24 clay), with additional data collected from Eurofins analyses and field management records obtained through farmer surveys and the "Boer en Bunder" database. POM and MAOM responded differently to total organic matter levels. POM increased linearly with total OM, whereas MAOM showed signs of saturation, even when total OM continued to increase. This saturation suggests physical and chemical limits to MAOM accumulation, potentially due to mineral adsorption capacity related to clay content, iron/aluminum oxides, or calcium-mediated binding mechanisms. POM demonstrated stronger correlations with soil chemical parameters than MAOM, indicating its greater sensitivity to soil conditions. When looking at management practices, only permanent grassland significantly influenced POM and MAOM levels, with grass-based rotations resulting in higher POM concentrations. In contrast, MAOM remained unaffected. Tillage, fertilization, and green manure-regime had no impact on either fraction. Focusing on POM and MAOM fractions instead of total organic matter is essential because total OM masks underlying dynamics that determine soil carbon stability and responsiveness to management. Both fractions are important and play a different role in the soil. Steering on the POM fraction will focus more on nutrients released, while steering on the MAOM fraction ensures long term carbon storage. In this study it is found that while POM is strongly correlated to soil (chemical) properties,

MAOM has the same but weaker trend. Permanent grassland and grass-rich rotations emerge as key strategies for enhancing POM and overall organic matter input.

**Keywords:** Organic Matter, POM, MAOM, carbon sequestration

# NH1: Innovative solutions for increasing resilience to water-related hazards and soil erosion in agricultural areas

Valerio Vivaldi

*Department of Earth and Environmental Sciences, University of Pavia, Pavia, 27100, Italy*

Valentina Vaglia

*Department of Earth and Environmental Sciences, University of Pavia, Pavia, 27100, Italy*

Chiara Toffanin

*Department of Electrical, Computer and Biomedical Engineering, University of Pavia, Via Ferrata 3, Pavia, 27100, Italy*

Fabio Dell'Acqua

*Department of Electrical, Computer and Biomedical Engineering, University of Pavia, Via Ferrata 3, Pavia, 27100, Italy*

Natural hazards, such as slope instabilities, floods and droughts continue to pose significant threats to communities worldwide, especially in agro-ecosystems. These processes, exacerbated by the current soil management practices, are particularly relevant in semi-arid zones such as the agricultural areas (e.g. olive groves and vineyards) under Mediterranean climatic conditions. Since climate changes are increasing the frequency and intensity of these events, it becomes necessary to explore innovative and sustainable approaches to mitigate their impact on the environment. This proposed session is under the frame of the PNRR-NODES project (funded from the Italian MUR) and aims to shed light on the fundamental role of nature-based solutions (NbS) in mitigating the impact of water-related hazards in agroecosystems. The session invites contributions in the context of agronomical, geological, engineering and hydrogeological topics. Furthermore, any contribution about the different applications of NbS and sustainable practices to water-related hazard and soil erosions reduction with multidisciplinary approaches is welcome: a) proximal and remote sensing for measurement and monitoring the effects of NbS in agro-ecosystem (e.g. satellite observation, in-situ meteorological, hydrological, agronomical measurements, geophysical surveys, laboratory samples-test); b) numerical and physical (e.g. machine learning models) simulation of the effects of NbS and climate changes in different agro-ecosystems. Scientific applications include earth and environmental sciences topics such as climate changes, landslide hazards, soil water content measurements, water management, early warning systems and atmospheric circulation, as well as the influences of agricultural management on slope instabilities and plant health (e.g. NDVI correlations). By the end of this session, farmers and policymakers will gain a comprehensive understanding of the potential of nature-based solutions in building resilience against water-related hazards agro-ecosystems. The session will conclude by discussing the implications of integrating nature-based solutions into water-related disaster risk reduction strategies e.g. the use of innovative management strategies of ground covers or cover crops in vineyards to avoid soil erosion. This conference session proposal is part of the project NODES which has received funding from the MUR - M4C2

1.5 of PNRR funded by the European Union - NextGenerationEU (Grant agreement no. ECS00000036).

# Spaceborne Monitoring of Vineyards: Optical and Multipolarized Radar-Based Indices Tested on a Wine-Producing Area in Northern Italy in the Context of the Nodes Project

Andrea Bergamaschi<sup>1,\*</sup>, Abhinav Verma<sup>2</sup>, Avik Bhattacharya<sup>2</sup> and Fabio Dell'Acqua<sup>1</sup>

<sup>1</sup>*University of Pavia, Pavia, Italy*

<sup>2</sup>*Indian Institute of Technology Bombay, Mumbai, India*

## Abstract

Multi-polarized Synthetic Aperture Radar (SAR) technology has gained increasing attention in agriculture, offering unique capabilities for monitoring vegetation dynamics thanks to its all-weather, day-and-night operation and high revisit frequency. This study explores the use of an innovative radar vegetation index that leverages the polarimetric potential of SAR data for vineyard monitoring. Specifically, the dual-polarimetric radar vegetation index (DpRVI) [1] is applied, for the first time, to vineyards—a crop characterized by a non-isotropic response due to row orientation.

The research investigates the relationship between DpRVI and optical vegetation indices, demonstrating the complementary nature of their information. The lack of significant correlation suggests that radar and optical indices capture different aspects of vineyard development. Additionally, an analysis of DpRVI as a descriptor of vineyard biomass indicates a parabolic trend over the growing season, with a potential link to biomass estimated using the Winkler Index [2]. This suggests that while optical indices typically relate to vegetative activity, DpRVI is more directly associated with biomass growth, likely corresponding to different vineyard phenological phases. Furthermore, preliminary results indicate the potential of DpRVI as a parameter for distinguishing vineyards from other crops.

This research aligns with the objectives of the PNRR-NODES project, which promotes nature-based solutions (NbS) for sustainable vineyard management. The application of DpRVI for monitoring vineyards is part of the integration of remote sensing techniques into broader climate change adaptation and risk reduction strategies, emphasizing the role of innovative SAR-based monitoring in sustainable agriculture.

**Keywords:** Vineyards, dual-pol radar, satellite, monitoring

## References

[1] Mandal, D., Bhattacharya, A., Rao, Y.S. (2021). Radar Vegetation Indices for Crop Growth Monitoring. In: Radar Remote Sensing for Crop Biophysical Parameter Estimation. Springer Remote Sensing/Photogrammetry. Springer, Singapore.

[https://doi.org/10.1007/978-981-16-4424-5\\_7](https://doi.org/10.1007/978-981-16-4424-5_7) [2] Winkler, A. J. (1974). General viticulture. Univ of California Press.

**Acknowledgments:** Funded by the European Union - NextGenerationEU, Mission 4 Component 1.5 - ECS00000036 - CUP F17G22000190007

## Temporal Analysis of Dual-Pol Scattering Powers Over Wet and Dry Sown Rice Fields: a Case Study in Northern Italy

Ashmitha Nihar<sup>1</sup>, Abhinav Verma<sup>1</sup>, Fabio Dell'Acqua<sup>2</sup> and Avik Bhattacharya<sup>1</sup>

<sup>1</sup>*Microwave Remote Sensing Lab (MRSLab), Indian Institute of Technology Bombay, Mumbai, India*

<sup>2</sup>*Dpt. of Electrical, Computer, Biomedical Engineering, University of Pavia, Pavia, Italy*

### Abstract

Monitoring rice phenology is crucial, as timely interventions like irrigation and fertilization during key growth stages significantly influence yield. Synthetic Aperture Radar (SAR) data is invaluable in phenology monitoring, as it is sensitive to crop water content and geometrical properties. While dual-polarimetric (dual-pol) SAR data has traditionally been limited to backscatter coefficients (such as  $\sigma_{0VV}$  and  $\sigma_{0VH}$  in Sentinel-1) due to reduced polarimetric detail, a dual-pol decomposition technique introduced in [1] enables extraction of physically meaningful scattering powers such as surface-like ( $P_{s-1}$ ), dihedral-like ( $P_{d-1}$ ), and unpolarized ( $P_u$ ) components that correspond to crop morphology across phenological stages.

This study analyzes the temporal variations of scattering powers derived from Sentinel-1 dual-pol SAR data over rice fields in Parasacco and Zeccone, near Pavia, Italy, to monitor phenological changes in wet- and dry-sown rice. Early growth stages show distinct differences, with wet-sown fields displaying low backscatter due to specular reflections from standing water, whereas dry-sown fields exhibit strong  $P_{d-1}$  powers from rough, moist soils. As tillering advances, the  $P_{d-1}$  component becomes increasingly prominent in wet fields due to stem and water column interactions, while for dry sown fields, the  $P_{s-1}$  component is dominant. Concurrently, the  $P_u$  component steadily rises in both field types as the canopy density increases. With the transition into the reproductive phase, both cases show decreasing total power, with the  $P_u$  component becoming dominant as the crop canopy turns highly depolarizing. In the ripening phase, the  $P_u$  component remains dominant and is accompanied by a notable rise in  $P_{d-1}$  power.

Apart from these major phenological stages, the scattering powers revealed distinct signatures at specific growth phases, such as a sudden peak in  $P_{d-1}$  power at the onset of the ripening stage and the drop in  $P_u$  in the reproductive phase which can aid as markers for crop monitoring. These consistent patterns reflect changes in crop structure, highlighting the potential of dual-pol scattering powers to track phenological evolution. This physically grounded approach enhances the interpretation of SAR data and offers a better understanding than traditional dual-pol backscatter coefficient-based methods, and is especially valuable for large-scale missions like Sentinel-1. As an added benefit, monitoring phenological phases through the considered scattering powers offers insights about different water management strategies in paddy fields. This is relevant to assessing

levels and patterns of agricultural water consumption at a large scale, which constitute important factors in environmental resource management.

**Keywords:** Scattering power components, Dual-pol decomposition, Sentinel-1, Rice monitoring, Crop phenology

### **References**

[1] A. Verma, A. Bhattacharya, S. Dey, A. Marino, and P. Gamba, "Target characterization and scattering power components from dual-pol Sentinel-1 SAR data," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 62, pp. 1-19, 2024.

**Acknowledgments:** The authors wish to thank Dr. David Marzi for providing ground reference information about the rice paddy fields considered in the case study. This publication was partly funded by the European Union - NextGenerationEU, Mission 4 Component 1.5 - ECS00000036 - CUP F17G22000190007".

## Analysis of Tomato Yield Predictions With Sentinel-2 and Uav-Based Ndvi: a Case Study in Northern Italian Farms

Avinash Kafle<sup>1</sup>, Andrea Caporrella<sup>2</sup>, Federica Carmagnola<sup>2</sup>, Giuseppe Caporrella<sup>2</sup> and Fabio Dell'Acqua<sup>3</sup>

<sup>1</sup>*Department of Environmental and Earth Sciences - University of Pavia, Pavia, Italy*

<sup>2</sup>*Innova-Tech-Agro*

<sup>3</sup>*Department of Electrical, Computer, Biomedical Engineering - University of Pavia, Pavia, Italy*

### Abstract

This study presents a technique for assessing the Sentinel-2 and UAV-derived NDVI competence in monitoring and predicting yield in three different tomato fields of Northern Italy: "Castello" (29.15 hectares) in the province of Piacenza, "Andrea" (4.47 hectares) and "CEO" (2.67 hectares) in the province of Alessandria.

Sentinel-2 Level-2A tiles were used to derive spaceborne NDVI on the concerned fields. Additionally, a DJI MAVIC 3M UAV equipped with a multispectral sensor at  $2 \times 2$  m<sup>2</sup> resolution was used to create airborne-NDVI maps of the fields from the day of the anticipated top vegetative stage and from the day before harvest. Nine different  $2 \times 2$  m<sup>2</sup> grids at each field, three each from low-, medium- and high-NDVI field zones were selected to conduct yield sampling. In-depth relations between the NDVI of the sample grid and the sample grid yield were extracted using both remotely sensed data from July to September 2024.

Coefficient of determination (Adj. R<sup>2</sup>), Root mean square error (RMSE) and Relative root mean square error (RRMSE) were computed as cost functions of prediction techniques. NDVI values from specific dates that had achieved the best Adj. R<sup>2</sup> to yield were selected to create a linear regression for yield prediction at the sample level. That same relation was then used to predict yield at the field level. Relating sample yield with predicted sample yield and total field yield with predicted field yields, Relative Root Mean Square Error (RRMSE) was calculated to define comparative prediction accuracy at sample and field level.

It was found that, for all three fields, both spaceborne- and airborne-NDVI yield prediction scored Adj R<sup>2</sup> above 50 % from the early flowering to the late fruiting stage, confirming that NDVI is a good indicator of yield during this period. Specifically, the "Castello" field featured the best spaceborne-NDVI-to-yield relationship 30 days prior to harvest; then, tomatoes were harmed by excessive rainfall during the harvesting stage. This unexpected factor resulted in an overprediction of 5.68% at sample level and 16.07% at field level as measured by RRMSE. This significant inaccuracy reflected the damage caused to tomatoes by excess rainfall. Fields "Andrea" and "CEO", which didn't suffer late rainfall damage, had best spaceborne-NDVI-to-yield relation at 22 and 15 days before harvest, respectively, with more accurate predictions: on "Andrea" the overprediction of

yield was measured by a RRMSE of 4.89% at the sample level and 10.13% at the field level, while for “CEO” it was 12% at sample level and 9.36% at field level. At the same time, it was found that airborne-NDVI caused underprediction of yield at all three experimental fields and performed better than spaceborne-NDVI only for “CEO”. Here, UAV underpredicted the yield by RRMSE of 6.05% at the sample level and 7.85% at the field level. It was found RRMSE derived from airborne data sources was smaller and more consistent between sample to field level, 6.05% at sample level and 7.85% at the field level to spaceborne data source, 12% at sample level and 9.36% at field level. “Andrea” and “Castello” reported higher RRMSE and less consistence with spaceborne data.

In conclusion, this study reveals some error patterns due to inherent limitations of each data source: scarce spatial resolution for Sentinel-2 and scarce temporal resolution for UAV. In general, Sentinel-2 data lead to overprediction and greater inconsistency with respect to UAV data. However, more frequent UAV campaigns would be advisable to increase accuracy. Still, relationship between NDVI and yield remained strong between early flowering to late fruiting stage, and the ideal time window to anticipate tomato yield is between 15 to 30 days prior to harvest.

**Keywords:** Yield prediction, tomatoes, multispectral data, airborne sensing, spaceborne sensing, NDVI

**Acknowledgments:** This publication was partly funded by the European Union - NextGenerationEU, Mission 4 Component 1.5 - ECS00000036 - CUP F17G22000190007”

# Water as a Foundation For Climate Resilience: Integrating Energy Production and Agricultural Sustainability at Cascina Vialone

Nadia Bertolino

*University of Pavia*

## Abstract

Water has historically served as the foundational element shaping rural landscapes in the Po Valley, providing the essential conditions for agricultural development, settlement patterns, and the ecological balance between human and non-human life. Traditional rural typologies such as the cascina — compact courtyard-based farmsteads — exemplify a spatial organization intrinsically linked to water management. These settlements fostered a symbiotic relationship between humans, animals, crops, and wetlands, with water availability dictating their location, architecture, and long-term viability (Cosgrove & Petts, 1990; Schama, 1995; Iovino, 2012).

Today, this historical relationship faces unprecedented stress. Climate change-induced alterations in precipitation patterns, increasing drought frequency, soil erosion, and extreme flood events pose critical risks to agricultural productivity and landscape stability in lowland regions. In this context, the pilot project at Cascina Vialone in Sant'Alessio con Vialone (PV) proposes a contemporary reinterpretation of traditional water-land dynamics to address the urgent need for resilient agricultural systems.

Situated within a matrix of rice fields, historical irrigation canals, and protected wetlands (Cavallo, 2014), Cascina Vialone integrates conventional water infrastructures with decentralized renewable energy systems — notably micro-hydropower installations and photovoltaic arrays — to create a multifunctional water landscape. Water flows are carefully managed and optimized not only for irrigation but also for energy generation, contributing to farm energy autonomy and effective biowaste management. In this closed-loop system, agricultural runoff and organic waste are treated on-site, reducing environmental contamination risks and enhancing soil quality, thereby directly mitigating soil erosion processes.

The project advances the concept of energy landscapes (Stremke, 2010; Nadai & Labussière, 2017), while also addressing the experiential dimension of water systems as highly valued and preferred elements of rural space (Herzog, 1985). Water is framed both as a generative and regulating agent — a dual role that enables new synergies between food production, ecological conservation, and climate adaptation strategies. Through real-time monitoring and automation, water resources are allocated efficiently according to seasonal variability, contributing to drought resilience while maintaining the ecological functions of adjacent wetlands.

By drawing from historical land-use models and combining them with contemporary

sustainable technologies, Cascina Vialone demonstrates how rural territories can transform water-related hazards into opportunities for integrated landscape regeneration. The project advocates for a systemic approach in which water management becomes a catalyst for rural sustainability, fostering a new generation of multifunctional agricultural landscapes capable of withstanding environmental pressures and supporting intensive yet ecologically sound food production.

**Keywords:** Water resilience, energy landscapes, cascina architecture, climate adaptation, circular agriculture, sustainable rural development, soil erosion mitigation.

### References

- Cavallo, F. (Ed.). (2014). *Wetlandia. Tradizioni, valori, turismi nelle zone umide italiane*. Padova: CEDAM.
- Cosgrove, D., Petts, G. (1990). *Water, Engineering and Landscape: Water Control and Landscape Transformation in the Modern Period*. London: Belhaven Press.
- Herzog, T. R. (1985). A cognitive analysis of preference for waterscapes. *Journal of Environmental Psychology*, 5, 225-241. [https://doi.org/10.1016/S0272-4944\(85\)80024-3](https://doi.org/10.1016/S0272-4944(85)80024-3)
- Iovino, S. (2012). Restoring the imagination of place: Narrative reinhabitation and the Po Valley. In Lynch, T., Glotfelty, C., Armbruster, K. (Eds.), *The Bioregional Imagination: Literature, Ecology, and Place* (pp. 100-117). Athens: University of Georgia Press.
- Nadaï, A., Labussière, O. (2017). *Energy Landscapes in a Crowded World: A Spatial Perspective*. Cham: Springer.
- Schama, S. (1995). *Landscape and Memory*. New York: Knopf.
- Stremke, S. (2010). Designing sustainable energy landscapes: concepts, principles and procedures. *Renewable and Sustainable Energy Reviews*, 14(9), 2200-2211. <https://doi.org/10.1016/j.rser.2010.03.001>
- Visentin, F. (2018). Liquid Conclusions. Towards a Humanistic Hydrology. In Vallerani, F., Visentin, F. (Eds.), *Waterways and the Cultural Landscapes* (pp. 244-256). London: Routledge.

**Acknowledgments:** This conference paper is part of the project NODES which has received funding from the MUR - M4C2 1.5 of PNRR with grant agreement no. ECS00000036.

## Evaluation and Innovative Study of the Vine According to New Agronomic Scenarios For Oltrepò Pavese, Italy

Giovanni Marchese<sup>1,\*</sup>, Sohail Anwar<sup>2</sup>, Chiara Toffanin<sup>2</sup>, Marta Debolini<sup>3</sup>, María José Marqués Pérez<sup>4</sup> and Valentina Vaglia<sup>1</sup>

<sup>1</sup>*Department of Earth and Environmental Sciences, University of Pavia, Via S. Epifanio 14, 27100 Pavia, Italy*

<sup>2</sup>*Department of Electrical, Computer And Biomedical Engineering, University of Pavia, Via Ferrata 3, 27100 Pavia, Italy*

<sup>3</sup>*Institute for Climate Resilience (ICR), IAFES Division, CMCC*

<sup>4</sup>*Geology and Geochemistry Department, Universidad Autónoma de Madrid, Calle Francisco Tomás y Valiente, 7, 28049 Madrid, Spain*

### Abstract

Climate change (CC) introduces complex environmental, economic, and social challenges, particularly threatening food security and agricultural sustainability. As a high-value crop sensitive to climatic variations, grapevine cultivation demands adaptive strategies to maintain yield, quality, and market stability. This is especially relevant in the Oltrepò Pavese wine region, where enhancing the economic resilience of local viticulture is a priority. In this context, a PhD project—co-funded by Confagricoltura Pavia, Sezione Vino, and supported by the PNRR project NODES Spoke 6 VINO—was initiated to explore innovative methodologies for sustainable vineyard management. The project pursues several objectives, including the assessment of land suitability for vineyards, the identification of abandoned vineyards for potential replanting, and the monitoring of grapevine phenology using remote sensing technologies. Methods applied span multiple disciplines and foster collaboration between experts in agronomy, geology, engineering, and spatial planning. Key activities include: (i) a systematic literature review of methodologies for vineyard suitability assessment, (ii) the development of a novel approach using the YOLOv8 model for detecting abandoned vineyards as potential sites for redevelopment. The research also involves an international collaboration with Universidad Autónoma de Madrid, where the developed detection methodologies are being adapted for olive groves. This phase focuses on evaluating soil management practices (tillage vs. cover cropping) by analyzing soil organic carbon, moisture, and NDVI metrics from remote sensing data. The project is currently ongoing (2025–2026), with promising preliminary outcomes and the potential for broader application in sustainable land use planning for agriculture, in particular the YOLO model achieved optimal performance with 90% recall for abandoned vineyard detection. Final results are expected to contribute to decision-support tools for viticultural adaptation in the face of climate change, offering a scalable vineyard monitoring framework beyond Oltrepò Pavese.

**Keywords:** Viticulture, abandonment, Climate Change Adaptation, Remote Sensing, YOLOv8  
Object Detection

# **Hydrogeological Characterization of Steep Vineyard Slopes Through a Combined Approach For Shallow Slope Failures Susceptibility Estimation**

Valerio Vivaldi, Massimiliano Bordoni, Patrizio Torrese and Claudia Meisina

*Department of Earth and Environmental Sciences, University of Pavia*

## **Abstract**

Vineyards located on steep slopes are widespread worldwide and often represent both a defining feature of the landscape and a key economic activity in many regions. However, these vineyards are vulnerable to several issues, including shallow slope instabilities, which can be triggered by intense storms or prolonged heavy rainfall events. Such shallow landslides can severely damage vineyards, also leading to a loss of soil fertility and biodiversity.

To reduce these risks, it's essential to analyze the characteristics of the slopes where vineyards are planted. This helps assess the likelihood of slope failure and understand how different inter-row soil management practices can influence slope stability.

This study introduces a multidisciplinary approach to evaluate the susceptibility of steep vineyard slopes to shallow landslides.

The method involves several main steps:

- 1) Preliminary slope characterization, including geological and geomorphological analysis through UAV surveys, soil trenches, and monitoring of soil moisture using in-situ sensors (TDR, tensiometers).
- 2) Hydrogeological assessment of the slope using geophysical methods such as Electrical Resistivity Tomography (ERT).
- 3) Evaluation of grapevine root density and root reinforcement in inter-rows managed with different soil practices (e.g., conventional tillage vs. sustainable methods).

The approach was applied to different test sites in the Oltrepò Pavese area, located in the northern Apennines of Italy and representing a significant wine-producing region that faces both water stress and slope instability. The study's findings contribute to a better understanding of the factors that lead to shallow landslides in steep vineyards and emphasize the role of sustainable soil management in improving slope stability, especially in the context of climate change.

This conference abstract is part of the project NODES which has received funding from the MUR - M4C2 1.5 of PNRR funded by the European Union - NextGenerationEU (Grant agreement no. ECS00000036).

**Keywords:** ERT, Hydrological characterisation, Vineyards, Shallow Landslides

## **References**

VIVALDI V., TORRESE P., BORDONI M., MEISINA C. (2024) - " ERT-based experimental integrated approach for soil hydrological characterization in rainfall-induced shallow landslides prone areas". Bull Eng Geol. Environ 83, 167. <https://doi.org/10.1007/s10064-024-03627-8>.

BORDONI M., CORRADINI B., LUCCHELLI L., VALENTINO R., BITTELLI M., VIVALDI V. AND MEISINA C. (2019) - "Empirical and Physically Based Thresholds for the Occurrence of Shallow Landslides in a Prone Area of Northern Italian Apennines." Water 2019, 11, 2653; doi:10.3390/w11122653.

CRUDEN D.M. & VARNES D. J. (1996) -" Landslide types and processes." In: TURNER A.K. & SCHUSTER R.L. (eds) - "Landslide: Investigation and Mitigation. Transportation Research Board", Special Report 247, National Academy Press, pp. 36-75, Washington D.C.

WHITELEY J. S., CHAMBERS J. E., UHLEMANN S., WILKINSON P. B., KENDALL J. M. (2019) - "Geophysical Monitoring of Moisture-Induced Landslides: A Review." Reviews of Geophysics, 57. doi.org/10.1029/2018RG000603

**Acknowledgments:** This conference abstract is part of the project NODES which has received funding from the MUR - M4C2 1.5 of PNRR funded by the European Union - NextGenerationEU (Grant agreement no. ECS00000036).

## Nature-Based Solutions in Vineyards of Oltrepò Pavese (Northern Italy): Effects on Land Degradation

Antonio Gambarani<sup>1,\*</sup>, Alberto Vercesi<sup>2</sup>, Massimiliano Bordoni<sup>1</sup>, Matteo Giganti<sup>1</sup>, Valerio Vivaldi<sup>1</sup>, Matteo Gatti<sup>2</sup> and Claudia Meisina<sup>1</sup>

<sup>1</sup>University of Pavia

<sup>2</sup>Università Cattolica del Sacro Cuore di Piacenza

### Abstract

Climate change, with its increasing frequency and intensity of extreme weather events, exacerbates land degradation phenomena such as soil erosion and shallow landslides. This leads to soil and fertility loss, posing a major threat to agroecosystems, especially on sloped terrains like vineyards and olive groves, and often results in land abandonment. Agricultural practices, particularly soil tillage, also play a crucial role: if mismanaged, they can accelerate degradation processes.

To address these issues, effective Disaster Risk Reduction (DRR) strategies that are also biodiversity-friendly and economically viable for farmers are essential. Nature-based Solutions (NbS)—such as agroforestry and cover cropping—funded by international bodies like the EU and UN, offer a sustainable alternative. They help mitigate climate risks, reduce pesticide and fertilizer use, and promote biodiversity. However, NbS remain underutilized, as local governments and farmers often prefer gray infrastructure measures, which are frequently limited in scale and ineffective in achieving land degradation neutrality.

The study area is a sector of Oltrepò Pavese (Northern Italy), a region heavily dedicated to viticulture, where over 2,000 shallow landslides have occurred in the past 15 years due to intense rainfall. These events have affected more than 40% of the vineyard-covered terrain. Since 2021, two demo farms in the area have been equipped with hydrometeorological stations that record soil moisture every 10 minutes down to 90 cm depth.

Monitoring focuses on different Nature-based Solutions (NbS), including various cover crops (spontaneous grasses, cereal-based, and legume-based mixtures) and management practices (green manuring, between-row mulching, and piling grass under the row).

This study aims to present an overview of the applied NbS and analyze hydrological data to identify seasonal variations in soil water content. These insights help assess differences in water stress and vulnerability to land degradation across practices.

The work is a PNRR-funded PhD project in partnership with seven municipalities, focusing on identifying technically and economically viable NbS for the area. The scientific outcomes will be incorporated into municipal planning and rural police regulations to prevent shallow landslides.

**Keywords:** Nature-based Solutions, Land degradation, Soil Water Content monitoring, Shallow landslides, Viticulture

## Environmental Factors Regulating the Fire Effects on Soil Organic Carbon Across Malagasy Ecosystems

Lovafitia Ratovoarimanana<sup>1,\*</sup>, Nandrianina Ramifehiarivo<sup>1</sup>, Andry Andriamananjara<sup>1</sup>, Tantely Razafimbelo<sup>1</sup>, Nasandraatra Ravonjjarison<sup>1</sup>, Steven Bouillon<sup>2</sup>, Tiphaine Chevallier<sup>3</sup>, Adam Devenish<sup>4</sup> and Herintsitohaina Razakamanarivo<sup>1</sup>

<sup>1</sup>Laboratoire des Radioisotopes, University of Antananarivo Madagascar

<sup>2</sup>Katholieke Universiteit Leuven, Belgium

<sup>3</sup>UMR Eco&Sols, IRD, France

<sup>4</sup>Royal Botanic Gardens, Kew, United Kingdom

### Abstract

Frequent fire with well-known effects on the aboveground biomass (AGB) of tropical ecosystem can affect carbon dynamics and, subsequently, ecosystem functioning. However, fire impact on soil organic carbon (SOC), a key indicator of soil health, remains unclear, as does the role of environmental factors in shaping soil resilience to fire. This study explores how environmental factors such as land cover, topography and pedoclimatic conditions influence SOC responses to varying fire frequencies. We assume that soil responses to fire are driven by these environmental factors and their complex interactions controlling SOC levels, rather than a simple decline with more frequent fires. AGB carbon and SOC stocks were assessed across 307 plots in three bioclimatic zones: the subhumid central highlands, dry northwest, and subhumid southeast of Madagascar. Soil samples were taken from the 0-30 cm topsoil at 10 cm intervals. The study design captured the combined effects of key environmental drivers, including land cover, bioclimatic conditions, soil type, topography, with fire frequency—defined as the number of burn events over multiple years—ranging from unburned to annually burned areas. Soils store far more carbon than AGB in all forests, shrublands, grasslands and reforestation sites. SOC levels under forests and shrublands declined significantly—as the AGB carbon—with increasing fire frequency. Under reforestation, however, SOC stocks were primarily shaped by the age of reforestation, the species planted, and prevailing climatic conditions—rather than fire occurrence. In grasslands, fire frequency alone did not significantly affect SOC stocks, although significant interactions with environmental factors were observed. Furthermore, fire effects extended throughout the entire 30 cm soil profile, not just the top 10 cm layer as commonly assumed. Ferruginous soils were more vulnerable to SOC depletion (–22 %) under high fire frequency compared to Ferrallitic soils (–3 %). In grasslands, SOC decreased with increasing fire frequency, by up to 27 % under annual burning below 500 m elevation, while it showed a slight increase between 1000-1500 m in the subhumid central highlands, but no clear trend in other zones at the same elevation range. Frequent fires can increase SOC under specific environmental conditions, challenging the assumption of consistent SOC

depletion. These findings show the strong influence of environmental factors on soil resilience to fire, leading to varied patterns in topsoil. Understanding these interactions can improve fire management strategies, enhance carbon sequestration outcomes, and support sustainable land management and restoration in Malagasy fire-prone ecosystem.

**Keywords:** fire frequency, interaction, land cover, pedo-climatic condition, topography

## Mechanical Behavior of Clayey Soil Treated With *Trichoderma Asperellum*

Ali Hajian<sup>1,\*</sup>, Kimia Saber Sichani<sup>1</sup>, Solveig Tosi<sup>2</sup>, Massimiliano Bordoni<sup>3</sup>, Valerio Vivaldi<sup>3</sup>,  
Laura Pedretti<sup>3</sup> and Claudia Meisina<sup>3</sup>

<sup>1</sup>MSc student, Faculty of Engineering, University of Pavia

<sup>2</sup>Mycology Laboratory, Department of Earth and Environmental Sciences, University of Pavia, via S. Epifanio 14, 27100 Pavia, Italy and National Biodiversity Future Center, Piazza Marina 61, 90133 Palermo, Italy

<sup>3</sup>Department of Earth and Environmental Sciences, University of Pavia, via Ferrata 1, 27100 Pavia, Italy

### Abstract

Nowadays, due to climate change and human activities, the risks associated with water-related hazards, such as slope instability, flooding, and erosion, are increasing significantly. Traditional mitigation methods are often costly, environmentally harmful, and unsustainable. These approaches are generally unsuitable for agricultural fields because of their negative impact on ecosystems and the potential damage they can cause to the land.

Nature-Based Solutions (NBS) offer promising alternatives for risk mitigation. Over the past few decades, these methods have gained considerable attention and are now widely applied in practices such as reforestation, afforestation, cover cropping and bio-based treatments. NBS promote sustainability, enhance resilience to climate change, conserve soil and water, and support pest management and biodiversity. Their implementation is also often cost-effective in the long term, especially when compared to conventional engineering approaches. Moreover, the integration of NBS into land management strategies can help restore ecological balance and improve the overall health of agroecosystems.

The soil used in this study was collected from agricultural land in the northeastern part of Oltrepò Pavese, located on the northern termination of the Italian Apennines, at a depth of 0 to 60 cm from the surface. For laboratory testing, the soil was disturbed and remolded. The fungus used in this study was *Trichoderma asperellum*, a non-pathogenic and saprophytic organism. To retrieve geotechnical parameters, such as soil friction angle, soil cohesion, and soil compressibility, direct shear and oedometer tests were conducted. To examine the internal structure of the soil, scanning electron microscopy (SEM) was also performed. Additionally, suction stress was calculated based on soil water retention curves for three different sample preparation methods: mixing, surface treatment, and injection. Furthermore, the treated samples were compared with control samples to observe the differences.

This research demonstrates that fungal treatment offers an eco-friendly method for soil

improvement and aligns with sustainable management practices for the future by enhancing soil structure, improving its mechanical properties, and promoting the adhesion of soil particles.

**Keywords:** Soil improvement, Bio-inspired techniques, Fungal treatment, *Trichoderma asperellum*

**Acknowledgments:** Claudia Meisina

## Effect of Fungal Treatment With *Penicillium Chrysogenum* on Mechanical Properties of a Clayey Soil

Kimia Saber Sichani<sup>1,\*</sup>, Ali Hajian<sup>1</sup>, Solveig Tosi<sup>2</sup>, Massimiliano Bordoni<sup>3</sup>, Valerio Vivaldi<sup>3</sup>, Laura Pedretti<sup>3</sup> and Claudia Meisina<sup>3</sup>

<sup>1</sup>MSc student, Faculty of Engineering, University of Pavia

<sup>2</sup>Mycology Laboratory, Department of Earth and Environmental Sciences, University of Pavia, via S. Epifanio 14, 27100 Pavia, Italy, and National Biodiversity Future Center, Piazza Marina 61, 90133 Palermo, Italy

<sup>3</sup>Department of Earth and Environmental Sciences, University of Pavia, via Ferrata 1, 27100 Pavia, Italy

### Abstract

The management and mitigation of land degradation processes (e.g. landslides, soil erosion) have become increasingly important due to the rising frequency and intensity of natural hazards. These challenges significantly contribute to soil loss and slope instability, particularly in sensitive and cultivated terrains. As a result, the exploration of innovative, eco-friendly, and cost-effective approaches is essential. Bio-inspired methods involving the use of microorganisms are gaining increasing attention as nature-based solutions (NbS) for enhancing soil resilience.

This research investigates the impact of fungal treatments on the mechanical behavior of clayey soils by focusing on the specific kind of fungi, *Penicillium chrysogenum*. The soil samples were collected from a field in the Northern Italian Apennines, a region prone to landslides and severe soil erosion, especially in vineyards. The aim is to evaluate how fungal application influences soil strength and stability. The proposed experimental approach involves geotechnical and hydrological characterization by means of Direct Shear Tests, Oedometer Tests, Shrinkage Limit Analysis, Suction Stress Measurements, and mineralogical analysis through Scanning Electron Microscopy (SEM). All samples treated with *Penicillium chrysogenum* were compared with untreated control samples under the same test conditions.

The findings highlight the potential of fungal-based treatments as a sustainable strategy to mitigate erosion and slope instability in vulnerable agricultural landscapes. These treatments not only improve soil structure but also promote long-term ecological balance. Fungal hyphae can bind soil particles together, potentially enhancing cohesion and modifying the soil's hydromechanical behavior. This study contributes to the broader application of NbS in reducing water-related hazards and enhancing soil management practices. Furthermore, understanding the interaction between fungal structures and soil matrices can offer new insights into the design of bio-mediated geotechnical solutions.

**Keywords:** *Penicillium Chrysogenum*, fungal treatment, soil improvement

**Acknowledgments:** Claudia Meisina

## **A Probabilistic Approach For the Analysis of Susceptibility to Shallow Landslides in Different Soil Managements**

Matteo Giganti<sup>1,\*</sup>, Antonio Gambarani<sup>1</sup>, Alessia Giarola<sup>2</sup>, Claudia Meisina<sup>1</sup> and Massimiliano Bordonì<sup>1</sup>

<sup>1</sup>*Department of Earth and Environmental Sciences, University of Pavia, Via Ferrata 1, 27100, Pavia, Italy*

<sup>2</sup>*Institut für Geographie, Leopold-Franzens-Universität Innsbruck, Innrain 52f, 6020, Innsbruck*

### **Abstract**

In recent decades, climate change has heightened slope instabilities, namely soil erosion and shallow landslides, in agricultural areas, and crop fields. This research, part of the UNDER- VINE project, aims to identify the most effective management practices for water retention in vineyards while minimizing soil erosion and shallow landslide risks. The study focuses on the Oltrepò Pavese area, a part of the northern Apennines in Northern Italy.

In order to identify the proneness of the soils with different soil management practices (grass cover, legume-based mixture, cereal-based mixture, between and under-the-row mulching) to shallow landslides, several properties of the terrain (soil friction angle, slope angle, soil effective cohesion, root reinforcement provided by plant roots in the soil, soil unit weight, depth below ground level in which a potential sliding surface could develop and suction stress) were collected and field measurements and historical data on shallow landslides occurrence were also taken into account. These data were used to calculate the safety factor (SF) for every cell of the digital elevation model, with one meter of resolution.

To achieve this, a probabilistic model was used, utilizing a Python script that assigns to each parameter a value from a specified range and then calculates SF for every cell. The results are presented as a series of raster images depicting SF variations across the study sites.

Ultimately, the model aims to determine which land-use types are most prone to shallow slope instabilities and whether different management practices can help in mitigating these phenomena.

**Keywords:** landslides susceptibility, soil managements

## Participatory Mapping For Wildfire Prevention: a Stakeholder-Based Approach in Sardinia (Italy)

Michela Bazzoni<sup>1,\*</sup>, Valentina Bacciu<sup>2</sup>, Alessandro Fadda<sup>1</sup>, Alessio Menini<sup>1</sup>, Grazia Pellizzaro<sup>2</sup>, José Costa-Saura<sup>3</sup> and Costantino Battista Sirca<sup>3</sup>

<sup>1</sup>*IAFES DIVISION- CMCC Foundation, Sassari, 07100, Italy*

<sup>2</sup>*CNR-IBE, Sassari, 07100, Italy*

<sup>3</sup>*IAFES DIVISION-CMCC Foundation, Sassari, 07100, Italy; Department of Agriculture, University of Sassari, Sassari, 07100, Italy*

### Abstract

Forest fires are an increasing threat to Mediterranean landscapes, driven by climate change, land abandonment, and fragmented land-use policies. In this context, prevention strategies must go beyond ecological measures by integrating stakeholder knowledge and territorial governance. This contribution presents a case study from The HuT project (Human-Tech Nexus - Horizon Europe, 2022-2026), which aims to reduce climate-related risks across ten European demonstration areas. In Sardinia, the Demo Area addresses wildfire risk in Ogliastra by co-developing fire-smart solutions through fire modelling and participatory approaches. The interdisciplinary research design involves ongoing stakeholder consultations and social science methods throughout the project to align activities with socio-cultural realities. As part of this effort, Participatory Mapping was performed during the second local workshop (February 2025) as a method for knowledge co-production and stakeholder engagement. The workshop involved diverse local actors, including farmers, institutional representatives, and civil society, who worked in groups using printed base maps and spatial tools. They addressed three guiding questions: (1) Which areas are most valuable? (2) What stories and meanings are attached to these places? (3) What actions are needed to reduce wildfire risk and bring benefits to these areas? In total, participants identified 38 key areas, including 19 natural green areas, 16 WUIs (Wildland-Urban Interface) and 3 critical infrastructures. The mapping activities were accompanied by open discussions on barriers and enablers for wildfire prevention. The process generated spatially explicit insights based on lived experience and local knowledge. It enabled the collaborative identification of both high-value and high-risk areas, while building consensus among stakeholders on priority objectives and preferred land management strategies. The participatory approach brought several benefits: it enabled the spatialization of local knowledge that is often overlooked by conventional surveys; fostered trust and dialogue among citizens, experts, and institutions; and promoted shared ownership of both problems and solutions. These insights will now be combined with wildfire risk models developed by researchers, enabling an alignment between scientific analysis and stakeholder-defined priorities, and will serve as a foundation for the upcoming consultation events. Looking ahead, this method supports

the development of context-sensitive and socially legitimate prevention strategies, within a cultural pyrogeography perspective, including the restoration of traditional land-use practices. It shows how participatory GIS tools can support territorial planning, strengthen community resilience, and be replicated in other The HuT sites to address climate risks through co-creation and local empowerment.

**Keywords:** Risk Perception, Co-production of Knowledge, Stakeholder Engagement, Climate Adaptation

## **Green Horizons Farmers Network: Supporting Farmers Towards Sustainability and Resilience**

Saskia Keesstra, Stelios Dristas, Pernille Martiny Modvig, Thanh-Tam Le and Saskia Visser

*Climate-Kic Foundation*

### **Abstract**

The Green Horizons Farmers' Network is a Europe-wide initiative that empowers forward-thinking farmers to adapt to climate change through sustainable, climate-smart agricultural practices. Designed for those ready to innovate but facing real barriers, our network provides practical tools, a platform for sharing knowledge between farmers, tailored guidance, and a powerful voice in shaping the future of agriculture.

The network helps these farmers transition to sustainable, climate-smart agricultural practices while also providing a way for their voices and experiences to shape better agricultural policy. The network offers training modules focused on sustainability transitions. These are developed to equip farmers with practical knowledge and skills they can apply directly on their farms. At the same time, the network works closely with farmers to co-develop transition pathways—tailored strategies that reflect different farming sectors and climate conditions—helping them move towards regenerative and resilient practices.

A key element of the network is the creation of collaborative spaces where farmers can connect, learn, and share. Through a mix of in-person workshops, study visits, and regular online or hybrid sessions, farmers will have access to up-to-date policy information, advice on funding instruments, opportunities to test new innovations, and a chance to engage in real-life pilot cases. These interactions aim to build trust and collaboration, both within local communities and across the wider farming network.

Farmers will also be given a platform to express their needs and concerns, while gaining foresight into upcoming policy developments. This feedback will be used to generate insights that can help shape future policies, ensuring they are grounded in the realities of farming life.

Climate-KIC will act as the host for the Green Horizons Farmers' Network. It will support the initiative through targeted webinars and training sessions, a solution database that shares results from innovation projects, and efforts to continually gather insights into farmers' experiences. The network will serve as a platform for farmers to connect with EU projects with the aim to participate directly in funded projects, allowing them to contribute to and benefit from innovation.

**Keywords:** transition, sustainable agriculture, co-creation

# **MET1/2/4: Advances and Best Practices in Ecosystem Restoration and Environmental Remediation: Integrating Remote Sensing, Machine Learning, and In Situ Technologies**

Ioannis Louloudakis

*Department of Agriculture, Hellenic Mediterranean University Heraklion, 71410, Greece*

Ioannis Daliakopoulos

*Department of Agriculture, Hellenic Mediterranean University Heraklion, 71410, Greece*

Anna Brook

*University of Haifa, Israel*

Marco Micotti

*SoftWater, Italy*

Today, land ecosystem restoration actions are among the proven solutions to reverse anthropogenic and climate-driven land degradation and desertification. Such actions have multiple advantages such as supporting ecosystem resilience (Ellison & Ifejika Speranza, 2020; Sacande et al., 2021), increasing carbon sequestration (Dixon et al., 2016), restoring hydrological catchment characteristics (Anderson et al., 2010; Carrick et al., 2019), etc. Thus, ecosystem restoration actions are a global priority (Robinson et al., 2023). Indicative of this is that UN named years 2021-2030 as the “Decade on Ecosystem Restoration” (Waltham et al., 2020), while the EU incorporates such policies in the “Green Deal” (Gann et al., 2019) and has announced action like the “3 billion additional trees pledge”. Although restoration actions do take place, too few of these are monitored thereafter (Nadal-Romero et al., 2023). Monitoring methods based on remote sensing could be a viable alternative to high-cost and labor-intensive conventional ones (de Almeida et al., 2020). Meanwhile, Machine Learning has a great advantage in dealing with the nonlinear ecological relationships (Guo et al., 2023). In this session we aim to explore:

- State of the art and advances in land ecosystem monitoring using RS
- Artificial intelligence and automated monitoring for assisting conservation and restoration of land ecosystems
- Decision support tools for land ecosystem restoration
- Bridging space-time scale gaps and tackling uncertainties
- Novel datasets and indicators from RS and/or for training AI systems
- Ground truthing methods for RS

This session is supported by PRIMA - REACT4MED

## **Full-Scale Application in Italy of an Erd Technology For the Treatment of an Aquifer Impacted With Chlorocarbons Near a Salt Pond Ecosystem**

Alberto Leombruni

*Evonik Operation GmbH*

### **Abstract**

#### Background/Objectives.

The site is in a highly and historical industrialized area of Italy where groundwater is contaminated with a large dilute plume including tetrachloroethylene (PCE; >10 ppb), trichloroethylene (TCE; >10 ppb) and, to a lesser extent, dichloroethylene and vinyl chloride (<1 ppb). The target area is up to 14000 m<sup>2</sup> with a typical vertical interval of approximately 13 m bgl. The aquifer presented challenges in terms of contaminant distribution and permeability due to the presence of silty-clay layers that made the saturated soil very heterogenous. Little DHC microbial activity has been detected occurring naturally in groundwater. Moreover, low remedial goals along with a rapid treatment timeline made this site a challenge. After a detailed assessment, the ELS™ Microemulsion technology (ELS®) was selected as the preferred remedy. ELS® deploys Enhanced Reductive Dichlorination (ERD) mechanisms for treatment of impacted groundwater and, it is comprised of a controlled-release food-grade carbon in the form of lecithin. ELS® is specially designed for easy on-site handling and addition to the subsurface via existing wells, hydraulic injection networks, or direct push technology. The addition of organic carbon electron donor in a saturated zone is widely known to promote conventional enzymatic reductive dichlorination reactions. As bacteria ferment the ELS Microemulsion component, they release a variety of volatile fatty acids (VFAs) such as lactic, propionic and butyric acids, which diffuse from the site of fermentation into the groundwater plume and serve as electron donors for other bacteria including dehalogenators. Lecithin itself is primarily composed of phospholipids, with both hydrophilic and hydrophobic properties at different positions of the molecular structure. Further, phospholipids support remediation by providing essential nutrients (carbon, nitrogen, phosphorus) to bacteria.

#### Approach/Activities.

In 2022, pilot was successfully performed in a small part of the contaminated aquifer showing rapid and full treatment of the chlorinated mass. Afterwards, application of the ELS™ Microemulsion remedial reagent was performed via direct push DPT injection system in approximately 500 injection points distributed in a triangular grid mode in the most impacted areas nearby a salt pond ecosystem. Treatment interval was in the shallow aquifer between 2 m and 15 m b.g.l. where a grey clay layer represents the bottom.

#### Results/Lessons Learned.

Less than 12 months after injection of ELS™ Microemulsion into the main contaminated areas, concentrations of PCE and TCE contaminants were rapidly reduced up to 95% in the main monitoring locations compared to pre-treatment levels. Main field parameters in the ERD treatment areas included: i) increase of Mn & Fe(II) in solution as anaerobic cometabolites, ii) decrease of DO (mg/L) and sulphate (mg/L) - competing electron acceptors pH stable in the neutral range, and iii) negative Redox around -150 mV. These conditions along with black precipitates as FeS confirmed also ongoing biogeochemical treatment. Consequently, no substantial accumulation of daughter products such as DCE and VC has been observed. Site-specific remedial target values were reached in most of the main monitoring piezometers of the treatment areas.

**Keywords:** Bioremediation, aquifer, chlorinated solvents, dechlorination

## **Hazardous Elements and Pharmaceuticals in Soils of a Mediterranean Wetland (L'albufera De Valencia, Spain). Possible Interactions.**

Vicente Andreu Pérez

*CIDE-CSIC*

### **Abstract**

There is scarce information about several toxic elements widely used in agriculture and industry. These so called elements "of emerging concern" have not been studied, mainly regarding their environmental effects or relationships in soils. As study case, we have selected an important area in Spain that is affected by high anthropogenic pressures.

The target area of study the alluvial plain between the rivers Turia and Júcar (Valencia, SPAIN), with an extension of 486 km<sup>2</sup>, which is characterized by its dense network of channels and ravines for irrigation one of the most productive agricultural areas of Spain. This area includes a wide zone of rice farming and a Natural Park (L'Albufera). In this study area, 33 sampling zones were selected covering the different water sources and agricultural types, to monitor the distribution of the levels of 15 hazardous metals.

Total concentrations of the selected metals (Al, As, B, Be, Bi, Co, Fe, Li, Mo, Se, Rb, Sr, Ti, Tl and V) were determined. Standard analytical methods were used to measure soil physical and chemical properties. Total content of the twelve heavy metals, in soil samples, were extracted by microwave acid digestion and determined by ICP-OES. In the same zones, 32 pharmaceuticals were also studied. soil samples were extracted by pressurized liquid extraction (SPE). and determined by liquid-chromatography tandem mass spectrometry (LC-MS/MS).

Maximum average values were determined for Ti, Sr and Rb with 466.36, 263.16 and 63.62 mg/kg, respectively. Highest values for B, Li and Tl were 76.05, 70.91 and 56.37 mg/kg, respectively. The Northern part of the Albufera lake, devoted to rice farming, concentrated the highest values of almost all the selected elements. From the 32 studied pharmaceuticals, 29 were detected being the most frequent Bisphenol A, Caffeine and Tramadol. Maximum values were observed for Alprazolam (67.28 ng/g), Ibuprofen (76.11 ng/g) and Lorazepam (62.02 ng/g).

The interactions between metals and pharmaceuticals, and from both with soil characteristics and the influence of environmental factors were also studied.

More research is needed to establish their toxic levels and effects, or even their average concentrations in soils of these elements, very scarcely studied in the majority of them.

**Keywords:** Emerging contaminants, pharmaceuticals, heavy metals, Mediterranean wetlands, soils

**Acknowledgments:** This work has been supported by the ThinkInAzul programme by MCIN with

funding from the European Union Next Generation EU (PRTR-C17.I1) and the Generalitat Valenciana. And by Generalitat Valenciana also through the project CIPROM/2021/032.

# Google Earth Engine-Based Land Use/Land Cover Mapping in Granada, Spain Using Sentinel-2 and Machine Learning Techniques

Sinan DEMİR

*Isparta University of Applied Sciences*

## Abstract

This study aims to demonstrate the potential of combining seasonal satellite observations with machine learning techniques to improve the accuracy and scalability of land use classification at regional levels, providing valuable insights for sustainable land management and environmental monitoring. This study evaluates the performance of three supervised machine learning algorithms—Decision Tree (CART), Random Forest (RF), and Support Vector Machine (SVM)—for land use classification in the Granada region of Spain. Using Sentinel-2 time series data and 2018 LUCAS Copernicus polygon-based ground truth samples (171 training, 55 testing), 36 spectral variables were derived from seasonal composites representing spring, summer, and autumn of 2024. These composites were created in Google Earth Engine to capture seasonal variability in land surface reflectance. The RF model achieved the highest accuracy (96.36% validation), followed by CART (100% but with signs of overfitting) and SVM (58.18%). Feature importance analysis highlighted specific Sentinel-2 bands (e.g., B7, B11\_2, and B7\_1) as key predictors. The results demonstrate the effectiveness of integrating seasonal remote sensing data and ensemble learning methods for regional-scale land use mapping. In conclusion, future research could focus on advanced regularization methods, additional data sources, and broader regional applications to enhance model accuracy and generalizability.

**Keywords:** Land Use/Land Cover Classification, Sentinel-2, LUCAS 2018, Random Forest, Google Earth Engine, Seasonal Composites, Granada

## References

- Demir, S. (2024). Determination of suitable agricultural areas and current land use in Isparta Province, Türkiye, through a linear combination technique and geographic information systems. *Environment, Development and Sustainability*, 1-39.
- Demir, S., & Başayığıt, L. (2024). Digital Mapping Burn Severity in Agricultural and Forestry Land over a Half-Decade Using Sentinel Satellite Images on the Google Earth Engine Platform: A Case Study in Isparta Province. *Trees, Forests and People*, 100520.
- Demir, S., Dedeoğlu, M., & Başayığıt, L. (2024). Yield prediction models of organic oil rose farming with agricultural unmanned aerial vehicles (UAVs) images and machine learning algorithms. *Remote Sensing Applications: Society and Environment*, 33, 101131.
- GEE (2024). Google Earth Engine Data Catalog, Granada, Spain. <https://developers.google.com/earth-engine/datasets/> (accessed 23 April 2025).



## “Fertile Islands From Above”: Utilizing Uav Photogrammetry to Map Fertile Forest Patches in a Unesco Biosphere Reserve

Engelmann, Lars<sup>1,\*</sup>, Marzloff, Irene<sup>2</sup>, Kirchhoff, Mario<sup>1</sup>, Seeger, Manuel<sup>1</sup> and Ries, Johannes B.<sup>1</sup>

<sup>1</sup>Trier University, Department 6 Spatial and Environmental Science, Behringstraße 21, 54296 Trier, Germany

<sup>2</sup>Goethe University, Institute of Physical Geography, Altenhöferallee 1, 60438 Frankfurt am Main, Germany

### Abstract

*Argania spinosa*, endemic to southern Morocco, forms sparse forest in an area of approximately 1,000,000 ha (Alba-Sánchez et al., 2015). As a keystone species, the trees accumulate soil organic matter and nutrients compared to their rather barren surroundings (Kirchhoff et al., 2021). The emerging rich vegetation patches can be described as “fertile islands” and provide the basis for a silvo-pastoral land use practice (Garner and Steinberger., 1989). Socio-economically induced overexploitation through grazing threatens the stability of the system. Previous studies based on satellite imagery have shown that Argan forests lack regrowth and remain stable in a severely degraded state (Kirchhoff et al., 2022; Le Polain de Waroux and Lambin, 2012). While such approaches can help monitoring forest degradation, their limited spatial resolution is not sufficient to retrieve detailed information on tree geometry and the extent of “fertile islands”. Considering the strong interlink between plant and soil health this is, however, an important part of the system dynamic in the area.

The work presented in this talk leverages unmanned aerial vehicle (UAV) imagery to bridge this gap and map “fertile island” patterns in *Argania spinosa* forests. Seven one-hectare test sites, comprising 501 trees, were surveyed under indirect illumination conditions to generate photogrammetric 3D point clouds and conventional orthophotos. These data were used to obtain information on tree geometries such as crown volume and tree height. In addition, the vegetation was removed from the point clouds, and ground-only orthophotos were created. Based on the two types of orthophotos, the extent of the tree-crown area and the extent of the ground area influenced by trees were mapped. The size and position of the two areas were then compared. Trends in their interaction were analyzed, taking into account tree properties retrieved from the UAV data and field observations.

Preliminary results show that *Argania spinosa* trees affect soil conditions across an area roughly twice the size of their canopy cover, with this influence shifted predominantly in a north-eastern direction. Interestingly, this directional bias appears independent of slope inclination and exposition, suggesting a decoupling from hydrogeomorphic processes. Alternative factors such as the prevailing wind direction and shading effects,

possibly interlinked with mineralization conditions, are currently being evaluated. This application of UAV photogrammetry provides new insight into plant-soil interactions in *Argania spinosa* forests. Our results could inform conservation efforts, especially when combined with additional soil sampling campaigns in the future.

**Keywords:** fertile islands, *Argania spinosa*, UAV

### References

- Alba-Sánchez, F., Lopez-Sáez, J. A., Nieto-Lugilde, D., Svenning, J.-C. 2015. Long-term climate forcings to assess vulnerability in North Africa dry argan woodlands. *Appl. Vegetation Sci.* 18(2), 283-296. <https://doi.org/10.1111/avsc.12133>.
- Garner, W., Steinberger, Y., 1989. A proposed mechanism for the formation of 'Fertile Islands' in the desert ecosystem. *J. Arid Environ.* 16(3), 257-262. [https://doi.org/10.1016/S0140-1963\(18\)30941-8](https://doi.org/10.1016/S0140-1963(18)30941-8).
- Kirchhoff, M., Marzloff, I., Stephan, R., Seeger, M., Ait Hssaine, A., Ries, J.B., 2022. Monitoring dryland trees with remote sensing. Part B: Combining tree cover and plant architecture data to assess degradation and recovery of *Argania spinosa* woodlands of South Morocco. *Front. Environ. Sci.* 10. <https://doi.org/10.3389/fenvs.2022.896703>.
- Kirchhoff, M., Engelmann, L., Zimmermann, L.L., Seeger, M., Marzloff, I., Ait Hssaine, A., Ries, J.B., 2019. Geomorphodynamics in argan woodlands, South Morocco. *Water* 11(10), 2193. <https://doi.org/10.3390/w11102193>.
- Le Polain de Waroux, Y., Lambin, E.F., 2012. Monitoring degradation in arid and semi-arid forests and woodlands: The case of the argan woodlands (Morocco). *Appl. Geogr.* 32(2), 777-786. <https://doi.org/10.1016/j.apgeog.2011.08.005>.

**Acknowledgments:** This work received funding from the German Research Foundation (funding number RI 835/24-1 and MA 2549/6-1).

## Deriving Forest Cover Rates From Map Sources: a Contribution to Official Statistics and Environmental Reporting

Alessia D'Agata and Luca Salvati

*Sapienza University of Rome*

### Abstract

While forest statistics are currently released at NUTS-1 (macro-regions) or NUTS-2 (administrative regions) levels, advancements in remote sensing technology may improve their accuracy at smaller spatial units. To explore the potential contribution of remote sensing in downscaling forest cover rates to finer administrative levels, we run a quantitative analysis of the statistical relationship between selected indicators of forest cover derived from 16 independent (wall-to-wall) map-sources and 4 probabilistic sampling surveys (land cover/forest inventories) with the aim at verifying the consistency of their statistical distribution at the regional scale in Italy. The empirical results indicate that, given current technological capabilities and the standard land cover classifications used in each survey, only a limited number of map-based (local-scale) sources align with official sampling sources provided at large (regional) scale. Specifically, indicators from EFI, FAO, FROM, JRCLU and the JRC20 dataset exhibit compatibility with EFI and JRCLU, standing out as particularly reliable for spatial downscaling of sample-based forest indicators, being not affected by the Modifiable Areal Unit Problem. Forest cover rates derived from these sources can serve as valuable ancillary variables in spatial downscaling procedures of official (sample-based) forest estimates provided at a large scale, thus representing a reliable source of information for the routine production of official statistics at the level of small-area administrative units.

**Keywords:** environmental indicators, land cover, remote sensing, forest inventory, Italy

### References

- Avitabile, V., Camia, A., 2018. An assessment of forest biomass maps in Europe using harmonized national statistics and inventory plots. *For. Ecol. Manag.* 409, 489–498. Barbati, A., Marchetti, M., Chirici, G., Corona, P., 2014. European Forest types and Forest Europe SFM indicators: tools for monitoring progress on forest biodiversity conservation. *For. Ecol. Manag.* 321, 145–157. Biswas, J., Jobaer, M.A., Haque, S.F., Islam Shozib, M.S., Limon, Z.A., 2023. Mapping and monitoring land use land cover dynamics employing Google earth engine and machine learning algorithms on Chattogram, Bangladesh. *Heliyon* 9 (11), e21245. Bontemps, J.D., Bouriaud, O., Vega, C., Bouriaud, L., 2022. Offering the appetite for the monitoring of European forests a diversified diet. *Ann. For. Sci.* 79 (1), 1–9. Borrelli, P., Modugno, S., Panagos, P., Marchetti, M., Schütt, B., Montanarella, L., 2014. Detection of harvested forest areas in Italy using Landsat imagery. *Appl. Geogr.* 48, 102–111. Carfagna, E., Gallego, F.J., 1999. Thematic maps and statistics. In: *Land*

Cover and Land Use Information Systems for European Union Policy Needs. Office for Official Publications of the European Communities, Luxembourg, pp. 219–228. Cavalli, A., Francini, S., Cecili, G., Coccozza, C., Congedo, L., Falanga, V., Spadoni, G., Maesano, M., Munafo, M., Chirici, G., Scarascia Mugnozza, G., 2022. Afforestation monitoring through automatic analysis of 36-years Landsat best available composites. *iForest-Biogeosci. Forest.* 15 (4), 220–228. Coluzzi, R., Bianchini, L., Egidi, G., Cudlin, P., Imbrenda, V., Salvati, L., Lanfredi, M., 2022. Density matters? Settlement expansion and land degradation in Peri-urban and rural districts of Italy. *Environ. Impact Assess. Rev.* 92, 106703. Corona, P., Alivernini, A., 2024. Forests for the world. *Ann. Silvicult. Res.* 49, 80–81. Corona, P., Marchetti, M., 2007. Outlining multi-purpose forest inventories to assess the ecosystem approach in forestry. *Plant Biosyst.* 2, 243–251. Corona, P., Barbati, A., Tomao, A., Bertani, R., Valentini, R., Marchetti, M., Fattorini, L., Perugini, L., 2012. Land use inventory as framework for environmental accounting: an application in Italy. *iForest* 5, 204–209. Corona, P., Di Stefano, V., Mariano, A., 2023. Knowledge gaps and research opportunities in the light of the European Union regulation on deforestation-free products. *Ann. Silvicult. Res.* 48, 87–89. Costa, H., Almeida, D., Vala, F., Marcelino, F., Caetano, M., 2018. Land cover mapping from remotely sensed and auxiliary data for harmonized official statistics. *ISPRS Int. J. Geo Inf.* 7 (4), 157. D’Agata, A., Cudlin, P., Vardopoulos, I., Schinaia, G., Corona, P., Salvati, L., 2024. Assessing the spatial coherence of forest cover indicators from different data sources: a contribution to sustainable development reporting. *Ecol. Indic.* 158, 111498. D’Amico, G., Vangi, E., Francini, S., Giannetti, F., Nicolaci, A., Travaglini, D., Chirici, G., 2021. Are we ready for a National Forest Information System? State of the art of forest maps and airborne laser scanning data availability in Italy. *iForest-Biogeosci. Forest.* 14 (2), 144. Ferrara, A., Kelly, C., Wilson, G.A., Nol`e, A., Mancino, G., Bajocco, S., Salvati, L., 2016. Shaping the role of ‘fast’ and ‘slow’ drivers of change in forest-shrubland socioecological systems. *J. Environ. Manag.* 169, 155–166. Ferrara, C., Carlucci, M., Grigoriadis, E., Corona, P., Salvati, L., 2017. A comprehensive insight into the geography of forest cover in Italy: exploring the importance of socioeconomic local contexts. *Forest Policy Econ.* 75, 12–22. Ferretti, M., Marchetto, A., Arisci, S., Bussotti, F., Calderisi, M., Carnicelli, S., Cecchini, G., Fabbio, G., Bertini, G., Matteucci, G., de Cinti, B., Salvati, L., Pompei, E., 2014. On the tracks of nitrogen deposition effects on temperate forests at their southern European range—an observational study from Italy. *Glob. Chang. Biol.* 20 (11), 3423–3438. Francaviglia, R., Di Bene, C., Farina, R., Salvati, L., Vicente-Vicente, J.L., 2019. Assessing “4 per 1000” soil organic carbon storage rates under Mediterranean climate: a comprehensive data analysis. *Mitig. Adapt. Strateg. Glob. Chang.* 24, 795–818. Gessler, A., Schaub, M., Bose, A., Trotsiuk, V., Valbuena, R., Chirici, G., Buchmann, N., 2024. Finding the balance between open access to forest data while safeguarding the integrity of National Forest Inventory-derived information. *New Phytol.* 242 (2), 344–346. Gschwantner, T., Alberdi, I., Bauwens, S., Bender, S., Borota, D., Bosela, M., Tomter, S. M., 2022. Growing stock monitoring by European National Forest Inventories: historical origins, current methods and harmonisation. *For. Ecol. Manag.* 505, 119868. Kosmas, C., Detsis, V., Karamesouti, M., Kounalaki, K., Vassiliou, P., Salvati, L., 2015. Exploring long-term impact of grazing management on land degradation in the socio-ecological system of Asteroussia Mountains, Greece. *Land* 4 (3), 541–559. Loepfe, L., Lloret, F., Roman-Cuesta, R.M., 2012. Comparison of burnt area estimates derived from satellite products and national statistics in Europe. *Int. J. Remote Sens.* 33 (12), 3653–3671. Lorenz, M., Fischer, R., 2013. Pan-European forest monitoring: an overview. *Develop. Environ. Sci.* 12, 19–32. Mancino, G., Nol`e, A., Salvati, L., Ferrara, A., 2016. In-between forest expansion and cropland decline: a revised USLE model for soil erosion risk under land-use change in a Mediterranean region. *Ecol. Indic.* 71, 544–550. Moharir, K.N., Baliram Pande, C., Kumar Gautam, V., Sandeep Dash, S., Pratap Mishra, A., Kumar Yadav, K., Darwish, H.W., Pramanik, M., Elshahabi, M., 2025. Estimation of land surface temperature and LULC changes impact on groundwater resources in the semi-arid region of Madhya Pradesh, India. *Adv. Space Res.* 75 (1), 233–247. Nesha, M.K., Herold, M., De Sy, V., Duchelle, A.E., Martius, C., Branthomme, A., Pekkarinen, A., 2021. An assessment of data sources, data quality and changes in national forest monitoring capacities in the global Forest resources assessment 2005–2020. *Environ. Res. Lett.* 16 (5), 054029. Pekkarinen, A., Reithmaier,

L., Strobl, P., 2009. Pan-European forest/non-forest mapping with Landsat ETM+ and CORINE land cover 2000 data. *ISPRS J. Photogramm. Remote Sens.* 64 (2), 171–183. Quaranta, G., Salvia, R., Salvati, L., Paola, V.D., Coluzzi, R., Imbrenda, V., Simoniello, T., 2020. Long-term impacts of grazing management on land degradation in a rural community of southern Italy: depopulation matters. *Land Degrad. Dev.* 31 (16), 2379–2394. Quaranta, G., Salvia, R., Cudlin, P., Salvati, L., 2023. Evaluating the spatial coherence of composite indexes of land degradation at small administrative units. *Environ. Impact Assess. Rev.* 103, 107226. Sallustio, L., Munafo, M., Riitano, N., Lasserre, B., Fattorini, L., Marchetti, M., 2016. Integration of land use and land cover inventories for landscape management and planning in Italy. *Environ. Monit. Assess.* 188, 1–20. Sallustio, L., Pettenella, D., Merlini, P., Romano, R., Salvati, L., Marchetti, M., Corona, P., 2018. Assessing the economic marginality of agricultural lands in Italy to support land use planning. *Land Use Policy* 76, 526–534. Salvati, L., Zitti, M., 2009. Substitutability and weighting of ecological and economic indicators: exploring the importance of various components of a synthetic index. *Ecol. Econ.* 68 (4), 1093–1099. Salvati, L., Tombolini, I., Perini, L., Ferrara, A., 2013. Landscape changes and environmental quality: the evolution of land vulnerability and potential resilience to degradation in Italy. *Reg. Environ. Chang.* 13, 1223–1233. Salvati, L., Mavrakis, A., Colantoni, A., Mancino, G., Ferrara, A., 2015. Complex adaptive systems, soil degradation and land sensitivity to desertification: a multivariate assessment of Italian agro-forest landscape. *Sci. Total Environ.* 521, 235–245. Sawant, S., Garg, R.D., Meshram, V., Mistry, S., 2023. Sen-2 LULC: land use land cover dataset for deep learning approaches. *Data Brief* 51, 109724. Schuck, A., Paivinen, R., Hame, T., Van Brusselen, J., Kennedy, P., Folving, S., 2003. Compilation of a European forest map from Portugal to the Ural mountains based on earth observation data and forest statistics. *Forest Policy Econ.* 5 (2), 187–202. Seebach, L.M., Strobl, P., San Miguel-Ayanz, J., Gallego, J., Bastrup-Birk, A., 2011. Comparative analysis of harmonized forest area estimates for European countries. *Forestry* 84 (3), 285–299. Tomao, A., Quatrini, V., Corona, P., Ferrara, A., Laforteza, R., Salvati, L., 2017. Resilient landscapes in Mediterranean urban areas: understanding factors influencing forest trends. *Environ. Res.* 156, 1–9. Tomppo, E., Olsson, H., Ståhl, G., Nilsson, M., Hagner, O., Katila, M., 2008. Combining national forest inventory field plots and remote sensing data for forest databases. *Remote Sens. Environ.* 112 (5), 1982–1999. Vega, C., Renaud, J.P., Sagar, A., Bouriaud, O., 2021. A new small area estimation algorithm to balance between statistical precision and scale. *Int. J. Appl. Earth Obs. Geoinf.* 97, 102303. Vizzarri, M., Chiavetta, U., Chirici, G., Garfi, V., Bastrup-Birk, A., Marchetti, M., 2015. Comparing multisource harmonized forest types mapping: a case study from central Italy. *i-Forest* 8 (1), 59–66. Zhang, K., Fiwa, L., Kurata, M., Okazawa, H., Luweya, K.A.B., Mandal, M.S.H., Sakai, T., 2024. Precise LULC classification of rural area combining elevational and reflectance characteristics using UAV. *Scientific Afr.* 26, e02431.

**Acknowledgments:** PRIN 2020 - Research Projects of National Relevance funded by the Italian Ministry of University and Research entitled “Multi-scale observations to predict Forest response to pollution and climate change” (MULTIFOR, prot. 2020E52THS).

# Land Restoration Effectiveness Assessed by Satellite-Based Remote Sensing Technologies as a New Monitoring Approach

Ghadir Zbedat and Anna Brook

*Spectroscopy and Remote Sensing Laboratory, School of Environmental Science, University of Haifa, Israel*

## Abstract

The Mediterranean region requires effective land restoration monitoring methods to face increasing land degradation, desertification, and climate change threats. Traditional assessments are often time-consuming and subjective. This study addresses this need by focusing on two sites in Israel: the restored food forest in Beit Lehem of the Galilee and the adjacent Alonie Aba natural forest. Within Beit Lehem of Galilee, we compare the restored food forest to a non-restored area where traditional farming practices remain. By comparing these sites, the study aims to assess how well the restored area mimics the ecological functions of a natural forest and how it contrasts with areas under continued traditional agriculture. This assessment leverages satellite-based remote sensing, specifically Sentinel-2 and Sentinel-1 data, to provide a comprehensive and objective approach to monitoring restoration initiatives. Sentinel-2 high-resolution multispectral imagery enables detailed tracking of vegetation health through indices like SAVI, PSRI, and NDWI.

Additionally, Sentinel-1 SAR data offers insights into microtopography changes and soil moisture monitoring. Our comparative analysis of the restored and natural forest areas, alongside the non-restored agricultural areas, reveals significant improvements in vegetation health, soil moisture, and microtopographic stability in restored sites.

Furthermore, this work employs a Hidden Markov Model (HMM) to examine the temporal dynamics of restoration indicators such as SAVI, PSRI, and NDWI. The HMM models the observed satellite-derived indices as emissions. These emissions originate from underlying hidden states, representing different ecosystem conditions (e.g., degraded, transition, restored). We estimate the transition probabilities between these states over time by training the model on multi-temporal satellite data. This probabilistic approach allows us to predict the likelihood of restoration success by estimating transition probabilities between states, identifying stable restoration trajectories, and detecting potential regression or stagnation.

The HMM thus provides a robust, interpretable, and scalable framework for long-term monitoring and decision support in restoration planning.

This study offers a detailed assessment of long-term restoration processes in the Mediterranean region, contributing to sustainable land management and ecosystem restoration practices.

**Keywords:** Restoration actions, Mediterranean, Land Degradation, Satellite Imagery

**Acknowledgments:** REACT4MED Project (Grant Agreement No. 2122) is funded by PRIMA, the Partnership for Research and Innovation in the Mediterranean Area, a Programme supported by Horizon 2020, the European Union's Framework Programme for Research and Innovation.

## **Ai-Generated Landscape Imagery: Towards a Comprehensive Assessment**

Phoebe Koundouri<sup>1</sup> and Fivos Papadimitriou<sup>2</sup>

<sup>1</sup>*Athens University of Economics and Business*

<sup>2</sup>*Ae4ria Alliance of Excellence for Research and Innovation on Aephoria*

### **Abstract**

It is more than likely that no other form of computer creativity has attracted as much interest in the last years as visual forms created by Generative AI. Amidst the volumes of images created by GANs and other GenAI technologies, those depicting urban or rural landscapes, present particular interest due to the wide range of possible approaches that can be adopted to create and to assess them in cultural, aesthetic, or even ecological contexts. Evaluating the aesthetic forms and styles of such fictitious landscape imagery (that is derived from different GenAI providers) is an issue of its own; assessing their usefulness as sources of inspiration for real-world interventions in urban or rural landscapes is another: it is precisely these intertwined research problems that this paper aims to tackle. To formulate evaluation criteria and to explore the usefulness of the AI-generated imagery, this research proceeded in the following steps: a) examination of the GenAI technologies (i.e. text-to-image, image-to-image) used to create these landscapes, b) formation of a broad set of criteria for the evaluation of such AI-generated imagery, c) assessment of its usefulness as a source of inspiration for devising scenarios for future landscapes. The conclusions of this research highlight the role of technological biases imposed by the restrictions of the imagery datasets, the diversity of visual outputs depending on the GenAI system that is used, the usefulness of such imagery for education and training and for deriving ideas for sustainable landscape management.

**Keywords:** Generative AI, Landscapes, Future Landscapes

## **Meo-Carbon: a Decision-Support Tool to Identify Critical Areas and Guide Ecosystem Restoration**

Sfaksi Nafissa and Ezzeddine Abbessi

*MEOSS*

### **Abstract**

Ecosystems are increasingly pressured by human activities and climate-related disturbances, compromising their capacity to provide essential ecosystem services. In this context, the implementation of integrated land management solutions has become crucial to maintaining biodiversity, ensuring food security, and strengthening socio-ecological resilience in the face of global change. It is therefore essential to rely on spatial assessment tools that quantify the impact of land use dynamics on carbon sequestration and other regulatory functions, in order to guide land-use decisions toward trajectories aligned with planetary ecological boundaries.

MEO-Carbon is a decision-support tool designed to assist territorial stakeholders in developing land-use strategies that are compatible with local ecological capacities, particularly with respect to carbon sequestration. By combining high- and very-high-resolution satellite data (Sentinel-2, Pléiades), thematic datasets, and the ALDO model developed by ADEME, MEO-Carbon generates carbon-oriented land cover maps and converts them into spatialized maps of carbon stocks and fluxes. These maps help identify current land dynamics, highlight areas with high additional sequestration potential—such as hedgerows, plots suited to agroforestry, or land favorable to cover cropping—as well as areas of concern where carbon loss is likely, for example, agricultural land converted into impervious surfaces. By offering an integrated view of carbon-related spatial dynamics, MEO-Carbon facilitates the understanding of underlying processes, the detection of carbon loss risks, and the prioritization of interventions. The tool supports land-use policies that are nature-based, contributing to the transition toward sustainable and resilient territorial management aligned with long-term climate goals.

The use case in the French department of Mayenne illustrates the tool's value in prospective planning toward carbon neutrality. MEO-Carbon was successfully deployed there in a forward-looking planning initiative, combining insights from a territorial carbon diagnosis with customized development scenarios. This approach enabled the refinement of modeling assumptions and the alignment of action levers with the territory's biophysical, socio-economic, and operational realities.

The tool stands out for its ability to integrate and highlight the diversity of territorial components, whether natural—such as forests, wetlands, and open environments—or anthropogenic, including grasslands, croplands, and artificial surfaces. By providing detailed spatial data on carbon stocks and fluxes associated with each land cover type,

MEO-Carbon supports the development of differentiated and realistic strategies that leverage the strengths of each component.

This integrated approach gives priority to the preservation of high ecological value areas, the restoration of degraded ecosystems, and the strengthening of territorial resilience to climate change. It enables the design of ambitious yet feasible pathways tailored to local specificities and implementable by territorial actors. By rooting scenarios in local realities, the tool also enhanced stakeholder ownership of the results and reinforced their capacity to turn strategic orientations into concrete actions. It played a key role as a tool for awareness-raising, knowledge dissemination, and dialogue, making carbon-related issues more accessible and mobilizing stakeholders around a topic that is both technically complex and politically critical.

Thanks to its modular and adaptable structure, MEO-Carbon can support a wide range of actors in steering land use decisions toward nature-based solutions that are aligned with climate objectives and grounded in the ecological realities of each territory. It thus contributes to resilient, sustainable planning that respects planetary boundaries

**Keywords:** Remote sensing, Carbon sequestration, Ecosystem restoration, Landcover, ALDO

## **Can Soil Water Repellency Impact the Function and Efficiency of Bioretention Cells?**

Jack Cuneo, Debabrata Sahoo and Dara Park

*Clemson University*

### **Abstract**

Bioretention cells (BRCs) are engineered stormwater best management practices (BMPs), commonly found in urban and suburban areas, that treat contaminants in stormwater runoff before the water is discharged to natural surface waters, both in the U.S. and globally. BRCs are designed to retain contaminants in the media and support plant growth. The media provides slow infiltration rates and longer hydraulic retention time to make BRCs effective in managing contaminants. BRCs can prevent excess phosphorus, nitrogen, heavy metals, oils and suspended solids from entering local waterways; yet their performance and efficacy vary significantly, with the underlying mechanisms and factors influencing these differences remaining incompletely understood. The variability in contaminant removal efficiency observed in bioretention cells (BRCs) may be partly due to climatic factors, with extreme weather conditions (such as increased temperatures and more intense droughts anticipated under climate change), potentially impacting BRC function and efficacy. Soil water repellency (SWR), a condition where soils resist water infiltration, is exacerbated by high temperatures and dry conditions and is closely linked to organic matter decomposition. SWR leads to uneven water infiltration, increased surface runoff, preferential flow pathways where water and contaminants can be lost to deep percolation, and reduced plant performance, all of which can compromise BRC effectiveness. To better understand and address this variability, it is critical to evaluate factors such as BRC age, organic matter content, plant species selection, root zone media composition, and topdressing maintenance, as these may all influence SWR.

**Keywords:** Bioretention cell (BRC), Best management practice (BMP), Soil water repellency (SWR)

## Comparative Assessment of Enriched Compost and Biochar Application in an Olive Orchard in Crete

T. Manios<sup>1</sup>, F. Galliou<sup>1,\*</sup>, A. Maragkaki<sup>1</sup>, C. Bouki<sup>1</sup>, G. Daskalakis<sup>1</sup>, I. Daliakopoulos<sup>1</sup> and E. Kokkinelis<sup>2</sup>

<sup>1</sup>*Department of Agriculture, Hellenic Mediterranean University, Heraklion, Crete, 71410, Greece*

<sup>2</sup>*Seven Olea Extra Virgin Olive Oil of Crete, Arkalochori, Municipality of Minoa Pediados, 70300, Heraklion, Crete Greece*

### Abstract

Sustainable soil fertility management in Mediterranean perennial cropping systems, such as olive orchards, requires innovative, low-input strategies that close organic matter loops and enhance agroecosystem resilience. This study evaluates the agronomic and environmental performance of two locally produced soil amendments, namely enriched compost and biochar derived from the same olive orchard's pruning residues, applied to a mature olive grove in Crete, Greece. The enriched compost was produced on-site through aerobic composting, in windrows, from the olive pruning residues, to which olive mill wastewater (OMWW) was gradually added to regulate windrow moisture and enhance nutrient content. In parallel, the biochar that was used, was obtained via slow pyrolysis of the coarser pruning olive tree pruning ( $\geq 2$  cm diameter) under limited-oxygen conditions at  $\sim 450$  °C, creating a carbon-rich, porous material. Both amendments embody circular practices by valorizing locally available agricultural by-products. This is the 1st period of the field trial, three treatments were carried out: (i) untreated control, (ii) compost amendment, and (iii) biochar application. Soil physicochemical and biological parameters were measured, including pH, soil organic carbon (SOC), available N, P, K, cation exchange capacity (CEC) and microbial biomass. The enriched compost significantly improved short-term nutrient availability, microbial biomass, and tree vigor. Biochar contributed to gradual increases in soil pH, water-holding capacity, and SOC, with longer-term benefits in soil structure and buffering capacity. The two amendments displayed complementary effects: compost supported immediate biological fertility, while biochar enhanced long-term soil resilience and carbon sequestration potential. Olive tree performance is expected to be evaluated within the next period. This study highlights the viability of fully localized, on-farm amendment production for sustainable soil management. By closing organic loops and recycling olive pruning residues and OMWW into value-added soil inputs, the system reduces external inputs, mitigates waste disposal issues, and supports climate-smart olive production. These findings align with existing evidence supporting the synergistic use of compost and biochar in Mediterranean agriculture (Bernal et al., 2009; Lehmann & Joseph, 2015).

**Keywords:** biochar, compost, olive pruning, olive mill wastewater, circular agriculture, Mediterranean agroecosystems, soil fertility

**References**

Bernal, M. P., Albuquerque, J. A., & Moral, R. (2009). Composting of animal manures and chemical criteria for compost maturity assessment: A review. *Bioresource Technology*, 100(22), 5444-5453. <https://doi.org/10.1016/j.biortech.2008.11.027> Lehmann, J., & Joseph, S. (2015). *Biochar for Environmental Management: Science, Technology and Implementation* (2nd ed.). Routledge.

## Revealing Land Management Practices Effects on Ecosystem Recovery Using Ndvi

Ioannis Louloudakis<sup>1,\*</sup>, Ioannis Daliakopoulos<sup>1</sup>, Dimitrios Papadimitriou<sup>1</sup>, Ioanna Panagea<sup>2</sup> and Thrassyvoulos Manios<sup>1</sup>

<sup>1</sup>*Hellenic Mediterranean University, Department of Agriculture, Heraklion, Greece*

<sup>2</sup>*Institute for Agricultural and Fisheries Research, 9820 Merelbeke-Melle, Belgium*

### Abstract

Soil degradation and desertification represent major challenges for Mediterranean ecosystems. A clear example is found in the marginal maquis shrublands of Messara, Crete (Greece), where unsustainable land management practices and particularly overgrazing have altered vegetation structure and density, accelerating soil erosion and desertification processes (Alexakis et al., 2017; Daliakopoulos et al., 2017; Jucker Riva et al., 2017). Because of that, ecosystem restoration projects have become established, adopting strategies such as livestock exclusion and revegetation. However, the effectiveness of these interventions has not been adequately assessed. For this reason, we applied Landscape Function Analysis (LFA), a widely recognized methodology (Maestre & Puche, 2009), in conjunction with remote sensing index analysis to evaluate the effectiveness of 2 different ecosystem restoration practices, foresting and fencing, compared to "business as usual" management. Three such plots were located per management practice, in Messara valley, in the Island of Crete, Greece, where "Foresting" and "Fencing" took place in 2003 as a pastureland recovery practice. LFA assessment was conducted using two 30 m transects per plot, while remote sensing assessment was conducted using the Normalized Difference Vegetation Index (NDVI). NDVI values for the plots during the period 01/01/85 to 27/06/25 were obtained using Google Earth Engine (GEE). The process involved combining data from Landsat 4, 5, 7, 8, 9 and Sentinel-2 sensors and pixel level cloud masking to filter low quality data. Monthly commutative NDVI values per plot were analysed with double mass curve and Pettitt's test, using package *trend* in the R programming environment. Results from the LFA assessment show no statistically significant differences between management practices for soil "Infiltration" and "Nutrient cycling", but statistically significant differences in soil "Stability" with 67.7% score from "Forested" plots. On the other hand, commutative NDVI values shows a break point from the business as usual, for both management practices in late spring of 2005, 3 years after the ecosystem restoration actions were implemented with the "Forested" plots exhibiting a fast recovery.

**Keywords:** LFA, landscape function analysis, NDVI

### References

Alexakis, D. D., Mexis, F. D. K., Vozinaki, A. E. K., Daliakopoulos, I. N., & Tsanis, I. K. (2017). Soil

moisture content estimation based on Sentinel-1 and auxiliary earth observation products. A hydrological approach. *Sensors* (Switzerland), 17(6). <https://doi.org/10.3390/s17061455>

Daliakopoulos, I. N., Panagea, I. S., Tsanis, I. K., Grillakis, M. G., Koutroulis, A. G., Hessel, R., Mayor, A. G., & Ritsema, C. J. (2017). Yield Response of Mediterranean Rangelands under a Changing Climate. *Land Degradation & Development*, 28(7), 1962-1972. <https://doi.org/10.1002/ldr.2717>

de Almeida, D. R. A., Stark, S. C., Valbuena, R., Broadbent, E. N., Silva, T. S. F., de Resende, A. F., Ferreira, M. P., Cardil, A., Silva, C. A., Amazonas, N., Zambrano, A. M. A., & Brancalion, P. H. S. (2020). A new era in forest restoration monitoring. *Restoration Ecology*, 28(1), 8-11. <https://doi.org/10.1111/rec.13067>

Jucker Riva, M., Daliakopoulos, I. N., Eckert, S., Hodel, E., & Liniger, H. (2017). Assessment of land degradation in Mediterranean forests and grazing lands using a landscape unit approach and the normalized difference vegetation index. *Applied Geography*, 86, 8-21. <https://doi.org/10.1016/j.apgeog.2017.06.017>

Maestre, F. T., & Puche, M. D. (2009). Indices based on surface indicators predict soil functioning in Mediterranean semi-arid steppes. *Applied Soil Ecology*, 41(3), 342-350. <https://doi.org/10.1016/j.apsoil.2008.12.007>

Nadal-Romero, E., Cammeraat, E., Pérez-Cardiel, E., & Lasanta, T. (2016). Effects of secondary succession and afforestation practices on soil properties after cropland abandonment in humid Mediterranean mountain areas. *Agriculture, Ecosystems & Environment*, 228, 91-100. <https://doi.org/10.1016/j.agee.2016.05.003>

Zhou, T., Geng, Y., Chen, J., Pan, J., Haase, D., & Lausch, A. (2020). High-resolution digital mapping of soil organic carbon and soil total nitrogen using DEM derivatives, Sentinel-1 and Sentinel-2 data based on machine learning algorithms. *Science of the Total Environment*, 729. <https://doi.org/10.1016/j.scitotenv.2020.138244>

**Acknowledgments:** This work has received funding from REACT4MED: Inclusive Outscaling of Agro-Ecosystem Restoration Actions for the Mediterranean. The REACT4MED Project (grant agreement 2122) is funded by PRIMA, a program supported by Horizon 2020.

# **MET3: Social Innovation Labs: A Collaborative Space for Co-creation and Social Transformation**

## **How Living Labs Can Support Lasting Transformation**

Sonia Pietosi

*EIT Food South*

### **Abstract**

Climate change is significantly impacting agricultural soils in the EU, particularly in the Mediterranean region, which is warming 20% faster than the global average. Without mitigation, crop yields in southern EU could decline by up to 50% by 2050. While agriculture contributes 13% of the EU's total GHG emissions, it also has great potential to mitigate climate change. Carbon Farming emerges as a key solution, improving soil health and sustainability by sequestering carbon in soils.

The project LILAS4SOILS - Living Labs for soil health - aims to contribute to climate change mitigation by fostering Carbon Farming Practices (CFPs) in the Mediterranean region through a Living Lab approach. Over five years, LILAS4SOILS will develop five Living Labs (LLs) across six countries, involving 24 organisations, more than 80 farmers and 125 stakeholders. The project will test CFPs on 100 sites in diverse farming systems and pedoclimatic zones.

Living Labs bring stakeholders with different backgrounds and areas of expertise together to co-create and test a solution in real-world setting. What motivates stakeholders to engage in a Living Lab? how can Living Labs create impact and contribute to long-term systemic transformation? In our intervention, we will share recent lessons learned from our first co-creation workshops and ecosystem gathering.

**Keywords:** Carbon Farming, Living Labs

## **Soil Living Labs as Tools For Sustainable Land Management: a Conceptual and Operational Framework Based on a Systematic Review**

González-Moreno María Teresa<sup>1,\*</sup>, Rodrigo-Comino Jesús<sup>2</sup> and Romero-Frías Esteban<sup>3</sup>

<sup>1</sup>*Departamento de Análisis Geográfico Regional y Geografía Física, Facultad de Filosofía y Letras, Campus Universitario de Cartuja, Universidad de Granada, 18071 Granada, Spain; Andalusian Research Institute in Data Science and Computational Intelligence, University of Granada, Granada, 18016, Spain; Medialab UGR - Research Laboratory for Digital Culture and Society, University of Granada, Granada, 18012, Spain*

<sup>2</sup>*Departamento de Análisis Geográfico Regional y Geografía Física, Facultad de Filosofía y Letras, Campus Universitario de Cartuja, Universidad de Granada, 18071 Granada, Spain; Andalusian Research Institute in Data Science and Computational Intelligence, University of Granada, Granada, 18016, Spain*

<sup>3</sup>*Medialab UGR - Research Laboratory for Digital Culture and Society, University of Granada, Granada, 18012, Spain*

### **Abstract**

The health of European soils is currently under serious threat. Scientific findings reveal that 60-70% of soils across Europe are experiencing degradation, primarily due to unsustainable land management practices and pollution. This alarming situation has prompted the European Union to take significant action, providing substantial funding to a wide range of projects that directly or indirectly address soil-related challenges. One such EU-funded initiative is the SOILCRATES project, which aims to improve soil health through the design and implementation of innovative and sustainable soil management practices, as well as by raising awareness of soil as a vital resource. A key component of the project is the establishment of four “Soil Living Labs” (SLLs): open innovation ecosystems dedicated to developing solutions for sustainable soil management. These SLLs follow a quadruple-helix model, involving collaboration among public authorities, businesses, academia, and civil society. They also include the funding of pilot projects where soil characteristics are monitored and best practices are tested. The four SLLs are located in the Netherlands, France, Ireland and Spain. This study focuses on the creation of a database derived from a systematic review of projects related to Soil Living Labs. Projects have been classified into three categories: (1) those explicitly focused on SLLs, (2) projects that support the development of SLLs, and (3) soil-related initiatives with potential links to SLLs. The review includes sources from the EU CORDIS platform, academic publications, and general web searches. Collected data cover aspects such as project themes, stakeholders involved, targeted population sectors, goals, and practices or analyses related to soil health. This review and its analysis aim to clarify the concept of SLLs and assess their current status, as well as the broader initiatives emerging from concerns over soil health, which directly impact environmental quality. Additionally, the

study will examine whether a shared understanding and implementation of the SLL model exists. Ultimately, this research seeks to contribute to the theoretical framing and practical deployment of Soil Living Labs.

**Keywords:** Soil Living Labs (SLL), soil health, sustainable land management, project database, systematic review

**Acknowledgments:** This work has been carried out in the framework of the SOILCRATES project, funded by the European Union's Horizon Europe programme. Views and opinions expressed are however, those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA) Neither the European Union nor the granting authority can be held responsible for them.

## **Implementing Nbs Solutions to Enhance Regional Climate Resilience Through the Co-Creation Approach of the Natalie Transformations Labs**

Beatriz Medina<sup>1,\*</sup>, Alexandra Spyropoulou<sup>2</sup>, Teresa Pastor<sup>1</sup> and Georgia Tseva<sup>2</sup>

<sup>1</sup>*WE&B, Water Environment and Beyond, SCCL*

<sup>2</sup>*Department of Civil Engineering, University of Thessaly*

### **Abstract**

Addressing climate resilience necessitates a transformative shift towards a just transition in our societies. Nature-based solutions (NBS) have been gaining increasing attention globally as a means to address environmental challenges while providing multiple benefits to society. However, despite their promise, several key issues and considerations still need to be addressed mainly related to the translation of NBSs - into practical and sustainable on-the-ground solutions, while also taking into consideration the -broader socio-political and socio-technical environment (content ?).

A key aspect of overcoming these challenges -lies in enhancing -integration and collaboration among stakeholders across various- sectors. Recent literature on NBSs suggests that - involving a diverse range of stakeholders throughout project lifecycle multiple benefits arise.

The NATALIE project (Accelerating and mainstreaming transformative NATure-bAsed solutions to enhance resiliENCE to climate change for diverse bio-geographical European regions) project, funded by Horizon Europe research and innovation program is focusing on knowledge creation and sharing to boost the adoption of NBS for enhancing climate resilience in vulnerable communities and regions. The NATALIE project establishes Transformation Labs (TLs) as an open innovation mechanism to integrate local knowledge from stakeholders and facilitate the co-creation of solutions across eight diverse Demonstration Sites. The co-creation process is structured into the 4 following phases, each comprising at least certain necessary workshops: Phase 1- Diagnosis, Phase 2- Design&Visioning, Phase 3-Developing, and a transversal Phase 5- Participatory assessment for social transformation. The process developed is based on inputs from Dushkova & Kuhlicke, 2024; European Commission. Directorate General for Research and Innovation., 2023; Meister Broekema et al., 2022; Sillak et al., 2021.

The TL process is anchored in the fundamental principles of balancing power dynamics, promoting democratic practices, engaging in context-specific actions, fostering mutual learning, and employing suitable tools and techniques .Through this approach, the framework for implementing Nature-Based Solutions (NBS) is co-created to effectively mitigate climate change hazards. The TLs have been established in Greece, Romania, Latvia, Spain (Gran Canaria), Belgium (Flanders), France, Iceland, and Italy to empower

communities, improve resilience, and facilitate the co-creation of sustainable and locally tailored solutions. Here we share lessons learned from the project, drawn from experiences across these eight European countries.

The co-creation process has been structured within a comprehensive framework consisting of five phases. This structured approach ensures an integrated transformation within local communities, facilitating scalability and contributing to a more climate-resilient society.

Moreover, it facilitates the scalability and replicability of successful interventions across different contexts, ultimately contributing to the development of more climate-resilient, socially cohesive, and sustainable societies

**Keywords:** co-creation, NBS, climate resilience, transformation labs

### References

- Dushkova, D., & Kuhlicke, C. (2024). Making co-creation operational: A RECONNECT seven-steps-pathway and practical guide for co-creating nature-based solutions. *MethodsX*, 12, 102495.
- European Commission. Directorate General for Research and Innovation. (2023). Guidelines for co-creation and co-governance of nature-based solutions: Insights from EU funded projects. Publications Office. <https://data.europa.eu/doi/10.2777/157060>
- Meister Broekema, P., Horlings, L. G., & Bulder, E. A. M. (2022). Understanding the value of co-creation for social innovation interpretations of social innovation and co-creation in European policy-related documents between 1995 and 2018. *Innovation: The European Journal of Social Science Research*, 35(2), 291-308. <https://doi.org/10.1080/13511610.2021.1909464>
- Sillak, S., Borch, K., & Sperling, K. (2021). Assessing co-creation in strategic planning for urban energy transitions. *Energy Research & Social Science*, 74, 101952. <https://doi.org/10.1016/j.erss.2021.101952>

**Acknowledgments:** NATALIE has received funding from the European Union's under Horizon Europe programme under the Grant agreement n° 101112859. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Climate, Infrastructure and Environment Executive Agency (CINEA). Neither the European Union nor the granting authority can be held responsible for them.

## A Soil Database For the Province of Granada to Support Pedoclimatic Modelling and Environmental Degradation Assessment

Lucía Moreno Cuenca<sup>1,\*</sup>, Esteban Romero Frías<sup>2</sup>, Irene Ortiz Bernad<sup>3</sup>, Manuel Sierra Aragón<sup>3</sup>, Ana Romero Freire<sup>3</sup>, Victor Hugo Durán Zuazo<sup>4</sup>, Jesús Fernández Gálvez<sup>5</sup> and Jesús Rodrigo Comino<sup>6</sup>

<sup>1</sup>*Department of Regional Geographic Analysis and Physical Geography, Faculty of Philosophy and Letters, Cartuja University Campus, University of Granada, 18071 Granada, Spain. Andalusian Research Institute in Data Science and Computational Intelligence (DaSCI), University of Granada, 18071 Granada, Spain. Medialab UGR - Research Laboratory for Digital Culture and Society, University of Granada, Granada, 18012, Spain.*

<sup>2</sup>*Medialab UGR - Research Laboratory for Digital Culture and Society, University of Granada, Granada, 18012, Spain.*

<sup>3</sup>*Department of Soil Science and Agricultural Chemistry, Faculty of Sciences, University of Granada, 18071 Granada, Spain.*

<sup>4</sup>*Instituto de Investigación y Formación Agraria y Pesquera (IFAPA), Centro "Camino de Purchil", Granada, Spain.*

<sup>5</sup>*Department of Regional Geographic Analysis and Physical Geography, Faculty of Philosophy and Letters, Cartuja University Campus, University of Granada, 18071 Granada, Spain.*

<sup>6</sup>*Department of Regional Geographic Analysis and Physical Geography, Faculty of Philosophy and Letters, Cartuja University Campus, University of Granada, 18071 Granada, Spain. Andalusian Research Institute in Data Science and Computational Intelligence (DaSCI), University of Granada, 18071 Granada, Spain. <sup>3</sup>RNM-197 Research Group.*

### Abstract

The generation of knowledge about soils is essential to understand their dynamics and to promote sustainable management strategies. This knowledge plays a key role in supporting European initiatives such as the Soil Living Labs—experimental platforms designed to co-develop and test soil-related solutions with stakeholders—and particularly SOILCRATES (Horizon Europe 2021–2027), a project focused on creating a harmonized framework to assess and enhance soil health across diverse European landscapes. However, at the regional scale, soil databases are often incomplete or outdated, missing opportunities to integrate this information with climate-related and environmental degradation data.

This work presents the first phase in the development of a soil database for the province of Granada, integrating: i) data from the LUCDEME project, which identified southeastern Spain as one of the European regions at highest risk of desertification; ii) a meta-analysis of soil-related publications with georeferenced data available through Scopus and Web of Knowledge; and iii) personal datasets developed by contacted researchers, providing standardized soil classifications and laboratory analyses of

physical and chemical properties.

This database will combine physical, chemical, and biological soil properties with an analysis of pedoclimatic gradients, using climatic records and spatial modelling based on advanced geostatistical techniques. This integrated approach aims to support future research and evidence-based policy making, enabling sustainable land use strategies and enhancing territorial resilience in the face of increasing climatic and environmental challenges.

**Keywords:** soil classification, province of Granada, geomatics, climate, environmental degradation.

**Acknowledgments:** This work has been carried out within the framework of the SOILCRATES project, funded by the European Union's Horizon Europe programme. The views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Executive Agency (REA). Neither the European Union nor the granting authority can be held responsible for them.

## **AN6: Nature-based solutions for water quality and quantity in Agricultural land**

## **Hydrogeological Experiments on Mar Efficiency in Oaxaca, Mexico**

Roel Dijkma<sup>1,\*</sup>, Evi Derks<sup>2</sup> and Britt Basel<sup>3</sup>

<sup>1</sup>*Wageningen University*

<sup>2</sup>*Vitens*

<sup>3</sup>*Ecothropic*

### **Abstract**

In the Central Valleys of Oaxaca, rural communities were experiencing increasingly declining water tables and water scarcity, likely as a result of upstream deforestation and gullying (Basel et al., 2021; Basel et al., in press). In response, local community members formed associations including the 'Unión de Ejidos y Comunidades Buin Dannis, de la cordillera central Ocotlán-Tlacolula', or in short Buin Dannis (Basel et al., 2021). The main objective was to self-organize and collectively implement small scale Managed Aquifer Recharge (MAR) to increase the infiltration of seasonal rainwater runoff, and enhance recharge of the aquifer system. Local livelihoods depend on groundwater for milpa subsistence agriculture, agave for producing mezcal, and minimal greenhouse production for export. Local water users reported that MAR increased water availability for agricultural and household use. In 2024 a short intense field campaign, from April 1 to July 15, 2024, was conducted to quantify the impact of MAR on the water availability, especially for agricultural purposes.

The timing of the field campaign aligned with the transition from the dry season (Oct - April) to wet season (May - Sept). The local geology was studied to measure the thickness of weathered cover and the aquifer system. Pressure transducers were used to measure temporal water level changes in private wells and upstream of leaky dams. From these measurements, aquifer transmissivities were calculated and estimates were made on the infiltration capacity of retenes.

It was found that the hydraulic conductivity of the regolith varied from 0.1 to 50 m d<sup>-1</sup>, so ranging from poorly permeably to highly permeable (Derks, 2024). The aquifer depth increased downhill, leading to an increased transmissivity from uphill to downhill. The specific yield of the aquifer ranged from 0.03 in the mountainous regions to 0.2 lower in the valley. This implied that the highest storage capacity can be expected lower in the valleys. This was also found in the reaction of groundwater levels on the start of the wet season. The wells at higher elevations reacted rapidly after the first rain event, where the wells lower in the valley showed a slower response, but with a higher quantity of water stored. This proved the occurrence of groundwater storage capacity and groundwater flow in the region.

As MAR structures are located on hillslopes, where they are successfully reducing direct runoff, however, situated on lower specific storage areas, not reaching full potential of

recharging the available aquifer.

**Keywords:** MAR, Hydraulic conductivity, field campaign, regolith

**References**

Basel, B., Hernández Quiroz, N., Velasco Herrera, R., Santiago Alonso, C., Hoogesteger, J., 2021. Beemietii rak rkabni nis (the people know how to seed water): A zapotec experience in adapting to water scarcity and drought. *Climate and Development* 13, 792-806. doi:10.1080/17565529.2020.1855100. Basel, B., Hoogesteger, J., Piemontese, L., Castelli, G., Bresci, E., Derks, E., Dijkma, R., Velasco Herrera, R. (in press). Community-led small-scale Managed Aquifer Recharge in Oaxaca, Mexico: A sociohydrological approach to attenuating meteorological drought. *Hydrogeology Journal*. Derks, E, 2024. Assessing managed aquifer recharge in a mountainous watershed, a field study in Oaxaca, Mexico. MSc thesis, Wageningen University, the Netherlands

## Integrating Hydrogeological and Agronomical Sciences to Assess Agmar Suitability in North Indian Region

Kartik Jadav and Basant Yadav

*Department of Water Resources Development and Management, Indian Institute of Technology Roorkee, Roorkee-247667, Uttarakhand, India*

### Abstract

Globally, north Indian regions are known as groundwater guzzlers due to issues like climate change, intensive agricultural practices, industrial activity, and land use and land cover change (Rodella et al., 2023). Notably, India is an agriculture-dominated country that relies heavily on groundwater resources and extracts 25 % of total global groundwater (United Nations, 2022). In this context, Agricultural Managed Aquifer Recharge (AgMAR) emerges as a nature-based solution that integrates hydrogeological and agronomic principles for long-term groundwater sustainability. Ag-MAR entails intentional recharge by using floodwater, stormwater, and treated wastewater to support various ecosystem functions such as agricultural, industrial and domestic water supply, maintenance of environmental base flow in the river, protection of seawater intrusion, and enhanced groundwater quantity and quality (Levintal et al., 2022). However, AgMAR implementation in India requires the assessment of various site-specific conditions such as the availability of excess water, cropping patterns, soil and aquifer heterogeneity, fate and transport of contaminants, climate change and socioeconomic feasibility. Therefore, this study presents a preliminary multidisciplinary investigation for AgMAR feasibility considering the assessment of hydrological conditions, agronomic practices and subsurface characterization in the Hindon River basin, India. To identify potential AgMAR zones, we employed a GIS-based MCDA approach that considered rainfall patterns, post-monsoon water level, land use type, aquifer hydraulic conductivity, and canal network distribution (Jadav and Yadav, 2023). Moreover, North Indian regions cultivate waterlogged susceptible crops such as sugarcane, paddy, and poplar trees, which may offer practical opportunities for integrating AgMAR (Patle et al., 2017; Jadav and Yadav, 2023; Casas et al., 2025). Therefore, agronomic suitability was also assessed using agro-hydrological models that considered biophysical and hydrogeological factors. The results indicate that upstream and midstream regions exhibit high potential for AgMAR implementation, specifically for sugarcane fields during their grand growth stage, which can increase potential recharge up to 545 mm/year. The developed conceptual framework also discusses risks associated with regions-specific contaminant transport during recharge events, specifically under the influence of pesticide-laden runoff and discharge of un or partially treated wastewater. This preliminary analysis provides a guide for AgMAR site selection and highlights how AgMAR can be tailored to semiarid agrarian settings like northern India. The comprehensive insights gained from

this study contribute to a growing body of research advancing AgMAR, provide future research directions for Indian conditions and highlight the need for robust collaboration among local stakeholders to implement Ag-MAR strategies effectively.

**Keywords:** AgMAR, agro-hydrological modeling, GIS-based MCDA, northern India, nature-based solutions

### References

1. Casas, J. D. H., Escalante, E. F., Richard-Cerda, J. C., & Ayuga, F. (2025). A NATURE-BASED SOLUTION TO ENHANCE AQUIFER RECHARGE: COMBINING TREES AND INFILTRATION BASINS. *Groundwater for Sustainable Development*, 101436.
2. Jadav, K., & Yadav, B. (2023). Identifying the suitable managed aquifer recharge (MAR) strategy in an overexploited and contaminated river basin. *Environmental Monitoring and Assessment*, 195(8), 1014.
3. Levintal, E., Kniffin, M. L., Ganot, Y., Marwaha, N., Murphy, N. P., & Dahlke, H. E. (2022). Agricultural managed aquifer recharge (Ag-MAR)—a method for sustainable groundwater management: A review. *Critical Reviews in Environmental Science and Technology*, 1-24. <https://doi.org/10.1080/10643389.2022.2050160>.
4. Patle, G. T., Singh, D. K., Sarangi, A., & Sahoo, R. N. (2017). Modelling of groundwater recharge potential from irrigated paddy field under changing climate. *Paddy and water environment*, 15, 413-423.
5. Rodella, Aude-Sophie, Esha Zaveri, and François Bertone (2023). *The Hidden Wealth of Nations: The Economics of Groundwater in Times of Climate change*. Washington, DC: World Bank. License: Creative Commons Attribution CC BY 3.0 IGO.
6. United Nations, *The United Nations World Water Development Report 2022: Groundwater: Making the invisible visible*. UNESCO, Paris.

**Acknowledgments:** The authors acknowledge the support provided by the Prime Minister Research Fellowship (PMRF) grant (Grant Number: PM-31-22-751-414) by the Ministry of Education, Government of India.

## **Territorial Center For Nature-Based Solutions (Nbs): an Inclusive Mechanism to Bridge Policy, Science, and Local Action in Southern Mauritania**

Almamy Soumaré

*SER/UNDRR ARISE & MRC2030/ICLEI/NBS Community/Commune of Wompou/Ets Bouga Té AgriServices*

### **Abstract**

The Guidimakha region, located at the crossroads of Mauritania, Mali, and Senegal, is one of the most climate-vulnerable and socially fragile areas in the Sahel. With more than 60% of its population living in poverty and exposed to increasing environmental degradation, floods, and loss of agro-pastoral livelihoods, the region reflects the complexity of systemic risks faced by territories in ecological and social transition. Decades of fragmented interventions have left communities disillusioned, with projects often duplicating efforts in the same villages while critical zones remain neglected. In this context, we propose the creation of a Territorial Center for Nature-based Solutions (NbS), an inclusive, adaptive, and co constructed mechanism aimed at addressing the fragmentation, duplication, and inefficiency of current responses. The Center is not a classic "project," but a transversal and evolving interface that connects national institutions, scientific knowledge, local communities, youth, and decentralized authorities to co-produce solutions tailored to local realities.

This initiative focuses on:

- Implementing NbS as integrated responses to land degradation, urban sprawl, disaster risks, and socio-economic vulnerability, prioritizing community-validated approaches like agroforestry systems blending food crops and native trees;
- Enhancing institutional capacities through collaborative learning, participatory monitoring, and updated local planning tools co-designed with village councils;
- Supporting livelihood diversification through community-led ecosystem restoration, climate advisory services, and access to green job pathways such as sustainable non-timber forest product value chains;
- Facilitating multi-stakeholder coordination to prevent overlaps and reduce conflict over land and resources, guided by traditional conflict-resolution frameworks. The approach is grounded in recent local diagnostics, lessons from humanitarian response failures, and demands from communities who increasingly reject externally imposed projects. Field observations reveal that projects lacking community ownership often collapse post-funding, reverting systems to pre-intervention states. It aims to reverse top-down planning and enable a territorial transition from rural to urban contexts, in anticipation of rapid urbanization and displacement dynamics. This presentation will outline the conceptual model, early field evidence, and potential pathways for scaling this approach

across similar fragile zones in the Sahel. By centering NbS as tools for social cohesion, the initiative seeks to transform cycles of failure into durable resilience. It calls for dialogue between practitioners, scientists, and policy-makers to reimagine NbS as a vector of inclusive governance and territorial resilience.

**Keywords:** Nature-based Solutions, Climate Vulnerability, Sahel Resilience, Inclusive Governance, Participatory Monitoring,

### **References**

UCN (2020). Global Standard for Nature-based Solutions. FAO (2021). Farmer Field School Guidance Document. UNEP (2021). State of Finance for Nature: Tripling Investments in Nature-based Solutions by 2030. IPCC (2022). Sixth Assessment Report - Climate Change Impacts and Adaptation. UNDRR (2019). Words into Action Guidelines - Ecosystem-based Disaster Risk Reduction. UNEP/PEDRR (2022). Nature-based Solutions for Disaster and Climate Resilience. SDG Academy. World Bank (2023). Environmental and Social Framework (ESF). Open Learning Campus; Stratégie de Croissance Régionale Accélérée et de Prospérité Partagée du Guidimakha - Volume II : Plan d'Action 2022-2025. Plan de Contingence de la Région du Guidimakha - Octobre 2024.

**Acknowledgments:** We gratefully acknowledge the contributions of local communities in Guidimakha, municipal councils, and youth organizations who participated in early consultations. Special thanks to grassroots organizations and regional experts whose field insights shaped the design of this territorial innovation. We also recognize the invaluable support of international networks, global training programs, and knowledge platforms (e.g., FAO, UNEP, IUCN, World Bank, PEDRR, UNDRR AISE), which have guided my professional transition and strengthened the foundations of this initiative

## **Learning to See the Invisible - Experimental Approach to Understanding Microplastic Pollution Processes in Vineyard Soils**

Manuel Seeger and Feras Youssef

*Trier University, Fac. Environmental and Spatial Sciences, Physical Geography, Trier (Germany)*

### **Abstract**

For approaching NBS to tackle environmental problems, these have to be identified and understood. Experiments have shown to be an excellent tool for generation of knowledge, for transmission of knowledge, and for enhancing student's interests and scientific skills. Microplastic (MP) particles are emerging into the focus of science, because of their ubiquitous appearance in all ecosystems and geographical zones of the earth, as well as due to the increased ability to analyze them. Their effect on the functioning of geo-ecosystems is still under debate, as well as the paths they take to spread. Understanding them is crucial for designing NBS to reduce and mitigate pollution with MP.

Recent investigations have shown that vineyard soils in Central Europe contain a number of MPs higher than the average of agricultural soils, and the results indicate that they are transported within the soil profile and along the slope. Thus, soils may not only act as sinks for MPs, but also as non-point sources into different ecosystems, e.g. rivers. For designing NBS we need to know not only the input paths into the agricultural systems, but especially the dynamics of MP in and on soils. And on the other hand, we need to increase the awareness of students (and the public in general) for this issue.

Herein, we will present the experiment designed within a research training course for students in BSc Geography and MEd Geography at Trier University. Their aim was to design an experiment for understanding soil erosion related pathways of MP particles in typical vineyard soils of the Mosel vineyard region. The results obtained led to first insight into experiment design methodology, and processes involved in MP transportation. But they also raised additional questions that were addressed in following individual BSc-Thesis projects.

With this, in a common effort, we managed to increase knowledge and methodological skills, show still unanswered questions, and raise the awareness of future professionals for a still overseen environmental issue.

**Keywords:** microplastics, experiments, vineyard soils, education

## Effect of Hedgerows and Vegetation Cover as Decentralized Flood Protection Measures on the Drainage Behaviour of Arable Soil With a Historical Plough Pan

Mathias Jackel and Tobias Schuetz

*Trier University, Hydrology Department, Trier, 54296, Germany*

### Abstract

Pluvial flash floods and surface runoff events triggered by intense rainfall are increasingly causing damage. Research to date has predominantly focused on urban areas, even though approximately 80% of Germany's land surface is used for agricultural or forestry purposes. This highlights the need to investigate surface runoff generation on such soils. On agricultural land, specific conditions promote the formation of saturation overland flow (SOF), particularly because of conventional tillage. This practice increases the density of the soil matrix in the Ap horizon (0–30 cm depth) and frequently reduces vertical macroporosity. In addition, a plough pan often forms as a compacted, nearly impermeable layer. Water infiltrating above this layer may accumulate, leading to rapid saturation of the upper soil and increasing the risk of SOF. This study investigates the influence of vegetation cover and slope-parallel hedge strips as decentralized flood mitigation measures, and the impact of a historically compacted plough pan, on runoff behaviour in an agricultural setting near Trier-Filsch (Germany). Since autumn 2023, two field sites with slopes of 6.8° and 12.8° have been established. Each site includes two 2 × 6 m plots differing in land use (vegetated vs. bare soil). Each plot contains a hedge strip equipped with FDR sensors at depths of 15, 30, and 45 cm for continuous soil moisture monitoring. Additional sensors were placed upslope and downslope of the hedge strips at the same depths. A total of 68 FDR sensors were used to generate time series at multiple depths. Using peak separation, drainage behaviour was characterized for different soil depths and plot zones, separately for periods of high and low global radiation to assess the effects of transpiration from hedge strips and vegetation cover. To evaluate drainage functions, the empirical water retention model of Brooks and Corey (1964) was applied and optimized for approximately 35 (15 cm) and 25 (30 cm and 45 cm) drainage events during the low-radiation winter period, and for summer conditions about 20 (15 cm) and 10 (30 cm and 45 cm) events. The clearest effects were observed in the sensors below the hedge strips. Drainage at 15 cm and 30 cm depth was consistently stronger than in all other plots. At 45 cm depth, this effect was found only below the hedge strip, suggesting a potential root-induced breakthrough of the plough pan. In the next phase of the study, infiltration dynamics beneath the hedge strip will be analysed.

**Keywords:** Pluvial flash floods, Decentralized Flood Protection, Plough Pan, Soil Moisture Monitoring, Vegetation Effects on Drainage

**References**

Brooks, R.H. and Corey, A.T. (1964) Hydraulic Properties of Porous Media. Hydrology Paper, Vol. 3, Colorado State University, Fort Collins.

**Acknowledgments:** Funded by the Deutsche Hydrologische Gesellschaft (DHG)

## Short-Term Influence and Potential Long-Term Impacts of Cover Crops on the Health of Southern United States Inceptisols

Dara Park<sup>1,\*</sup>, Payton Davis<sup>1</sup>, Brook Russell<sup>2</sup> and Debabrata Sahoo<sup>3</sup>

<sup>1</sup>*Plant and Environmental Sciences, Clemson University*

<sup>2</sup>*Department of Mathematical Sciences, Clemson University*

<sup>3</sup>*Department of Agricultural Sciences, Clemson University*

### Abstract

Protecting and improving soil health is a key priority for agricultural stakeholders, prompting a transition from conventional to conservation-based on-farm management strategies. Among these, cover cropping has emerged as a prominent practice due to its demonstrated benefits, including erosion control, improved soil structure, weed suppression, and enhanced carbon sequestration. Despite these advantages, the effects of live cover crops, their biomass, and residues on short and long-term soil hydrodynamics, particularly in Inceptisols, remain understudied. In particular, no research investigates how cover crops may impact the development of soil water repellency (SWR). SWR is a globally recognized phenomenon that can disrupt soil hydrology, compromise crop productivity, and threaten food security and farmer livelihoods. To address this knowledge gap, a field experiment was conducted in the Southern Piedmont region of South Carolina, USA. Treatments included various cover crop species and a fallow control. Monthly assessments of SWR were performed, while infiltration rates and aggregate stability were measured before, in the middle of, and after the cover crop growing season. Biomass hydrophobicity was evaluated at cover crop termination and as residue four weeks post-termination. Results indicate that both cover crop biomass at termination and four week old residues exhibited hydrophobic properties, suggesting that the integration of cover crops into cropping systems may influence SWR development over time. Notably, crimson clover residues displayed the highest degree of water repellency at termination. Short-term effects on infiltration rates were inconsistent, whereas aggregate stability generally improved throughout the cover crop growing season. These findings suggest that, under current favorable growing conditions, cover crops may have minimal immediate impact on soil water dynamics. However, the observed hydrophobicity of cover crop residues and improvements in aggregate stability raise concerns that, as regional climates become warmer and drought events more frequent and intense, certain cover crops could contribute to increased SWR severity. This research highlights the need for further investigation into the long-term hydrological implications of cover crop (and cash crop) management in changing climates.

**Keywords:** cover crops, southern Piedmont, soil health, soil water repellency, hydrophobicity, aggregate stability

# **MET5/6: Nature-based solutions for transformation journeys**

## **Disentangling the Green, Grey, and Hybrid in a Complex Nature-Based Framing**

Pavel Raška et al.

*J. E. Purkyně University in Ústí nad Labem*

### **Abstract**

Nature-based solutions (NbS) have made their way to dominate both international frameworks and national strategies. While this growing visibility signals a welcome shift toward sustainable thinking, it also raises some important questions. One of the pressing concerns is how the popularity of NbS may be shaping the way funding decisions are made; thus potentially pushing other viable options out of view. This presentation has two main aims. First, we take a closer look at the current funding landscape in Europe and beyond to understand how NbS have risen to dominate practical discussions around managing hydrometeorological hazards, and their mitigation. Then, turning to the implementation perspective, we present findings from a public survey carried out in Slovenia, Czechia, and the Netherlands. The survey focused on the perception of the effectiveness, feasibility, and acceptability of different measures, namely green, grey, and hybrid (i.e. those combining green and grey features). Our results suggest that preferences vary not only across countries but also within different groups of the population, influenced by sociodemographics. Most importantly, our results point to a need of bringing the public into the conversation in more meaningful ways, especially when designing complex risk mitigation projects in urban settings.

**Keywords:** hydrometeorological hazards, nature-based solutions, public perception

**Acknowledgments:** The study was conducted in the scope of the lead agency project “Evaluation of hazard-mitigating hybrid infrastructure under climate change scenarios” funded by Czech Science Foundation and Slovenian Research and Innovation Agency (J6-4628) (ARIS).

## Making Monitoring Work: Addressing Implementation Challenges in Nature-Based Solutions

Pilar Andrés<sup>1,\*</sup>, Angela Ribas<sup>2</sup>, Stefania Mattana<sup>3</sup>, Aleix Valls<sup>4</sup>, Moisès Guardiola<sup>5</sup>, Juana María Hallat<sup>4</sup>, Gia Caruso<sup>4</sup>, Catarina Meireles<sup>6</sup>, Mariana Machado<sup>7</sup>, Beatriz Romão<sup>8</sup>, Carlos José Pinto-Gomes<sup>9</sup>, Taxiarihis Seintos<sup>10</sup>, Evangelos Statiris<sup>10</sup> and Tadej Stepisnik<sup>10</sup>

<sup>1</sup>CREAF. Edifici C, Campus de Bellaterra (UAB). 08193, Cerdanyola del Vallès, Barcelona. Spain

<sup>2</sup>CREAF. Edifici C, Campus de Bellaterra (UAB). 08193, Cerdanyola del Vallès, Barcelona. Spain & Department of Animal and Plant Biology and Ecology, Edifici C, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain.

<sup>3</sup>Department of Agri-Food Engineering and Biotechnology, Universitat Politècnica de Catalunya, Campus Baix Llobregat, Castelldefels, Spain

<sup>4</sup>CREAF. Edifici C, Campus de Bellaterra (UAB). 08193, Cerdanyola del Vallès, Barcelona. Spain.

<sup>5</sup>Department of Animal and Plant Biology and Ecology, Edifici C, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain.

<sup>6</sup>MED—Mediterranean Institute for Agriculture, Environment and Development. University of Évora. Évora, Portugal & CHANGE—Global Change and Sustainability Institute, School of Science and Technology, University of Évora, Évora, Portugal

<sup>7</sup>MED—Mediterranean Institute for Agriculture, Environment and Development. University of Évora. Évora, Portugal & CHAIA—Art History and Artistic Research Centre. Department of Landscape, Environment and Planning (DPAO), School of Science and Technology; University of Évora. Évora, Portugal.

<sup>8</sup>MED—Mediterranean Institute for Agriculture, Environment and Development. University of Évora. Évora, Portugal

<sup>9</sup>MED—Mediterranean Institute for Agriculture, Environment and Development. University of Évora. Évora, Portugal & CREATE—Center for Sci-Tech Research in Earth System and Energy; Department of Landscape, Environment and Planning (DPAO), University of Évora. Évora, Portugal.

<sup>10</sup>Department of Water Resources and Environmental Engineering, National Technical University of Athens. Athens 15780, Greece

### Abstract

Monitoring the effects of Nature Based Solutions (NBS) on human and natural environment is fundamental for many different reasons, including assessing the real effect of our actions, making progress towards improving techniques and, not least important, providing transparency and credibility to our interventions. Monitoring frameworks are abundant, and many lists of indicators are available from academic and technical literature. This surplus wealth of knowledge makes the almost complete absence of monitoring results all the more frustrating. Among the most important barriers to obtaining reliable databases on the success or failure of NBS are the non-inclusion of monitoring costs in the budget of the projects, and the lack of legal

responsibility for the continuity of monitoring after the completion of the project. There are also some weaknesses in scientific knowledge concerning the most adequate indicators to be used for monitoring NBS effects on some compartments of the natural environment, to define a desired reference scenario and to predict the expected progression of the indicators over time. In the CARDIMED project (<https://cordis.europa.eu/project/id/101112731>), we have struggled to produce monitoring programs tailored to 19 study cases and covering a variety of NBS addressing common threats to the Mediterranean Basin. Most of these NBS are aimed at improving water use efficiency in industries and cities, at reducing flood risk, at mitigating erosion and at making cities and food production resilient to climate change. We will describe in this presentation how we have co-designed viable monitoring plans in close cooperation with the implementers of the NBS of CARDIMED, with the aim of making monitoring viable in the practice. We will also explain how we have applied this methodology to two study cases in the Alentejo region (Portugal) and in the Lesvos island in the region of North Aegean (Greece). In Alentejo, the ecological structure of the landscape is being repaired by reforesting degraded riparian forests and also the agroforestry matrix of “montados”; in Lesvos, treated urban wastewater is being reused for fertirrigation to produce food and aromatic plants. We will concentrate on the methods that we are following to assess the baseline, the reference scenario and the expected evolution of the indicators concerning soil health and food production.

**Keywords:** NBS, monitoring plans, soil indicators, fertirrigation, agroforestry

**Acknowledgments:** This work has been funded by the CARDIMED project (EC Horizon. Climate, Energy and Mobility program)

## Forests and Forest Management as Nbs: Lessons Learned From Co-Creation Processes in the Upper Allgäu (Germany)

Gerd Lupp

*Chair for Strategic Landscape Planning and Management, TUM School of Life Sciences, Technical University of Munich, Munich, Germany*

### Abstract

The Upper Allgäu (EU-NUTS3) covers pre-alpine and alpine areas stretching from 630 m to 2600 m above sea level. Forests in the region often play a vital role in providing numerous ecosystem services and the aspect of reducing the risks of natural hazards such as landslides, avalanches, rockfall and flooding being one of the most important ones. Many forests are planted Norway Spruce (*Picea Abies*) stands established around 150 years ago as a result of changing farming practices and, to some extent, also to reduce risks caused by natural hazards, often in combination with technical measures such as torrent control. Nowadays, many forests are in a poor condition and threatened by climate change. A large share of forests privately owned, small scale, scattered and often located in steep terrain. An increasing number of forest owners lost interest or do not have skills, abilities or means to manage them. To change the situation, the “Mountain Forest Initiative” was started as a collaborative approach of forest administration to enhance the situation of the forests. Widely recognized being a success story, it serves as a good practice case to identify success factors for co-creation of NBS, shift of governance models and establishing new human-nature relations with nature.

The main objectives are to adapt forests to climate change to secure multiple ecosystem services that are very important service of forests in mountains, especially to reduce risks from natural hazards through creating mixed, structured well maintained forests. From a governance perspective, an interesting aspect is the changing role of forest administration shifting from a sovereign role to partners meeting on equal ground to co-create solutions collaboratively with all stakeholders. With pioneering activities in the 1990s, systematic interventions started in 2008 with more than 2.000 activities, 1.100 ha of forests covered with activities and more than 220.000 trees were planted. Analyzing success factors, key elements are: external facilitation and mediation; clear rules for collaboration and decision-making; an Advisory Board with embedded and anchored in the local society members; strong inclusion of policy and decision makers in the process; transparent planning and monitoring; provision of incentives and funding; good communication to make success stories visible; the role of “champions” as forerunners; engaging youth; competitions; and on-site excursions, hands on and good practice examples. Finally, a part of the success is based on a large network of partners and supporters and the importance of celebrating achievements together.

**Keywords:** NBS Co-Creation, Forestry, Multifunctional Forest Management, Case Study

**Acknowledgments:** TRANS-lighthouses has received funding from the European Union's Horizon Europe Framework Programme for Research and Innovation under Grant Agreement No. 101084628. The authors would like to thank the Office of Food, Agriculture and Forestry Kempten as well as Martin Wenzel, Simon Östreicher and Ulrich Sauter for their support.

## Balancing Urban Densification and Climate Resilience With Nature-Based Solutions: Insights Into 3D Spatial Patterns and Cooling Effects Via Remote Sensing

Karolina Zięba-Kulawik<sup>1,\*</sup>, Konrad Skoczylas<sup>1</sup>, Piotr Wężyk<sup>2</sup> and Hichem Omrani<sup>1</sup>

<sup>1</sup>Luxembourg Institute of Socio-Economic Research (LISER), Department of Urban Development and Mobility, L-4366 Esch-sur-Alzette / Belval, Luxembourg

<sup>2</sup>University of Agriculture in Krakow, Faculty of Forestry, Department of Forest Resource Management, 31-425 Krakow, Poland

### Abstract

Urban population growth is accelerating both horizontal and vertical densification, exerting increasing pressure on green infrastructure (GI)—a vital element for ensuring urban livability. GI contributes to improved air quality, biodiversity, public health, and mitigates the urban heat island effect. However, conventional two-dimensional (2D) urban analyses often overlook the vertical dimension of vegetation (e.g. Normalized Difference Vegetation Index - NDVI) and built structures, limiting our understanding of GI cooling potential under densification. This study addresses this gap by employing advanced three-dimensional (3D) analysis to examine the spatial relationships between vegetation volume, urban 3D structure, and land surface temperature (LST). The specific aims were to: (1) estimate vegetation volume (VV) using voxel-based methods and building volume (BV) through mesh modelling; (2) investigate the spatial distribution of LST; and (3) analyze the correlations between the 3D indices and LST. Using Airborne Laser Scanning (LiDAR) data and Landsat 8 thermal imagery (NASA), we developed 3D indices (Vegetation 3D Density Index - V3DI; and Building 3D Density Index - B3DI) and spatial distribution of land surface temperatures. The results show that the vegetation volume is weakly negatively correlated with the building volume and the population count (coefficients equal to -0.39 and -0.29, respectively). The total VV (> 1.0 m above ground) was about 2 billion m<sup>3</sup>. The value of V3DI reached a level of 0.76 m<sup>3</sup>/m<sup>2</sup>. The volume of buildings across the country is about 330 million m<sup>3</sup>, achieving a low B3DI = 0.13 m<sup>3</sup>/m<sup>2</sup>. In the capital, the B3DI reaches 1.09 m<sup>3</sup>/m<sup>2</sup> indicating a significant density of development. On one of the hottest days of the summer in 2019 (23 August), LST ranged from 19°C to 52°C. Higher LST values were observed in the southern regions, including Luxembourg City, primarily due to rapid urban expansion and reduced vegetation cover. The northern region exhibited lower LST values, attributable to the predominance of agricultural areas and forests. Areas with the highest VV values exhibited the lowest temperatures within the study area, a trend more pronounced in the VV data than in the NDVI data alone. The combined use of NDVI and VV improved the explanatory power of the model ( $R^2 = 0.7$ ), compared to NDVI alone. These findings demonstrate that 3D vegetation structure provides a more robust indicator for urban heat mitigation than 2D

metrics alone, offering valuable insights for climate-resilient spatial planning and the strategic implementation of nature-based solutions in urban environments.

**Keywords:** urban densification, green infrastructure, land surface temperature, remote sensing, GIS

# Moroccan Vernacular Knowledge: the Genius of Durability and Adaptivity

Youssra ELMARINI and Sahib Nada

*National School of Architecture of Rabat, Morocco*

## Abstract

Moroccan vernacular architecture is a reference in terms of sustainability and adaptation to climate change. It faces the various climatic challenges while preserving its cultural and social heritage. The ancestral methods on which it is based give it ecological properties thanks to the use of bio-sourced, sustainable and biodegradable materials, such as wood and plant fibers. This approach, which is closely linked to nature, must be adapted to local specificities and the immediate cultural and environmental context. This reflection aims to unveil how the Moroccan vernacular could inspire contemporary solutions in response to current environmental and social issues, more specifically in the context of climate change. The pragmatic and contextual responses offered by traditional techniques, in particular ventilation systems, natural light (Central Patio) and hydraulic drainage (khattara), demonstrate remarkable thermal performance and energy efficiency, thus allowing the optimization and reduction of the ecological footprint of buildings. From the constructive unit to the urban scale, the integration of these principles can contribute to the birth of urban ecological models that blend naturally into their natural ecosystem. This multiscale approach investigates in a granular and holistic way the different forms of natural inspiration such as biomimicry and bionics. This approach is not limited to the study of natural form but focuses on intuitive ingenuity, the multi-scale algorithm of nature and ancestral methods. The paths of reconciliation between the city and nature can draw on the living heritage offered by Moroccan architecture. The promotion of nature-based solutions (NBS) leads us to reconsider ecological balance, sustainability and integration into the local context. The integration of Moroccan vernacular architecture can only enrich this reflection to meet the urban and social challenges of our era.

**Keywords:** Vernacular architecture, adaptation, bio-based materials, natural ecosystem, Nature-based solutions.

## **Scaling Soil-Based Farm Management: an Action Perspective on Carbon Sequestration and Agricultural Transition**

Jennie van der Kolk

*Mrs*

### **Abstract**

Agriculture in Europe stands at a crossroads, facing urgent challenges related to climate change and biodiversity loss. There is a growing consensus among farmers, policymakers, and researchers that healthy soils are fundamental to a sustainable agriculture. This awareness signifies more than just technical adjustments—it reflects a deeper cultural shift from maximizing yields to embracing responsible stewardship of the land. In this context, carbon sequestration should play a key role in Nature-Based Solutions (NbS), which call for systemic change, including adjustments in soil management practices and farmer motivation.

Within the Dutch research program Smart LandUse, we explore the needs of farmers and assess the impact of strategic approaches to scale up carbon sequestration. The effects of various farm-level measures on carbon stocks are examined through both Long-Term Experiments and real-world farm practices. However, the success of the transition depends on more than technical potential alone. Intrinsic motivation, farmer pride, and regionally embedded networks form the backbone of successful initiatives.

At the same time, institutional and economic barriers—as well as gaps in farmer knowledge—can hinder progress. These challenges include fragmented regulations, short-term incentives, and limited support for local experimentation.

During the session, we will present the findings from the Smart LandUse program.

**Keywords:** carbon sequestration, measures, transition

# **Circularity and Interconnectivity of Sustainable Bioeconomy and Agriculture - Optimisation of Approaches to the Nature-Based Solutions.**

Lena Madden

*CircAB group, LIFE Institute, Technological university of the Shannon, Moylish Park, Ireland.*

## **Abstract**

For national economy to fully achieve its bio-based potential, an integrated pathway to market for new technologies, processes and products is needed. There is an increased drive from European and National governments for academia, SMEs and large industry to come together for process development & scale-up of biobased products, to re-processes renew and re-use resources, enabling conversion of renewable feedstocks into bio-based chemicals, bio-based materials, food ingredients, biofuels, fertilisers and other bioproducts. These products start their journey from natural environment through agriculture, forestry, fisheries and other primary production and the key of any sustainable bioeconomy is to return the remaining resources back to the environment to replenish the nature back to it's original strength.

Many of sustainable processes are primarily explored in laboratory and small pilot-scale level that is often not replicable in the real life scenario, hence a different approach required to bring the best outcomes of bio-based process development into a real life scenario. Through this presentation we will discuss the interconnectedness of biobased industries in Ireland on examples of deep demonstrations, and their integration with living labs to achieve a maximum impact on the journey to circularity and sustainability.

Human capital is another key part of sustainable bioeconomy path. The lack of knowledge and support data from the large scale trials are often results in a rejection of sustainable technologies in both biotechnology and agriculture. Therefore, we will further discuss the pathways, the support and acceleration of the development of bio-based processes in Ireland through: interdisciplinary and intersectoral collaborations, that drive new business opportunities for the just transition from a fossil to a biobased economy. Provision of robust operational data at an appropriate scale that enables industries to technically and economically assess opportunities and inform strategic decisions on new products, and services. Establishment of a research, training and educational facilities for bio-based industries needs, including access to finance expertise and financial actors, to meet short, medium- and long-term strategic needs of industry, RPOs, entrepreneurs, farmers, cooperatives and other stakeholders that are seeking to advance sustainability in biotechnology and agriculture.

**Keywords:** Bioprocessing, zero-effluent, deep demonstrations, Living Labs

## **Making Nbs Work For Transformational Adaptation at the Local Level: What Can We Learn From Comparative Approaches?**

Lena C. Grobusch<sup>1</sup>, Mohsen Soleymani<sup>1</sup>, Saskia Keesstra<sup>1</sup>, Laurene Lebelt<sup>1</sup>, Yawei Wang<sup>2</sup>, Rutger Dankers<sup>2</sup>, Joske Houtkamp<sup>2</sup>, Sverre van Klaveren<sup>2</sup>, Joris Gort<sup>2</sup>, Annemarie Groot<sup>2</sup> and Parveen Kumar<sup>2</sup>

<sup>1</sup>*Climate KIC, Plantage Middenlaan 45, 1018 DC, Amsterdam, Netherlands.*

<sup>2</sup>*Wageningen Environmental Research, Wageningen University & Research, Wageningen, Netherlands.*

### **Abstract**

The EU Mission on Adaptation to Climate Change strives for 150 communities across the EU to achieve climate resilience by 2030. Nature-based Solutions (NbS) have significant potential to serve as effective climate change adaptation measures: potentially enhancing local climate resilience to a range of climate hazards and simultaneously generate multiple co-benefits, including improved ecosystem health, carbon sequestration, and enhanced community well-being. However, despite growing awareness and an increasing number of NbS efforts reported in publications and online databases, evidence mapping of NbS implementation across the EU remains fragmented and inconsistent. Current NbS knowledge bases are not designed to understand what enables some regions to be comparatively more successful than others at implementing NbS, how NbS policies and funding mechanisms can be effectively designed at the local level, and how learnings and best practices can be translated to other regions. This fragmented knowledge base makes it challenging to synthesize if, whether, how, and under what conditions transformational adaptation is occurring and whether it can be effectively scaled across diverse geographies, socio-ecological contexts, risk profiles, and governance arrangements. To address this gap, the ESPON-funded project “Re-Naturing Territorial Development for Climate Risk Adaptation (ReAdapt)” deploys a comparative case study approach across eight European regions. The aim is to deepen our understanding of the enabling conditions, design features, and institutional dynamics that determine the effectiveness of NbS in delivering transformational adaptation at the local level. This presentation outlines the design of our comparative case study approach. It focuses on three key components: 1) mapping and analysis of the existing NbS knowledge base by synthesizing information from diverse resources and databases to identify EU-wide NbS case studies and highlight knowledge gaps relevant for comparative research; 2) design of a multi-criteria matrix for selecting case studies that can generate transferable insights to inform policymaking and practical implementation; and 3) development of a robust case study template to guide data collection, aimed at supporting policymakers in enhancing the adaptive capacity of their territories through context-specific, place-based

NbS interventions. The outcomes of ReAdapt allow for a timely discussion about how NbS can effectively be implemented for regional level transformational adaptation, and how approaches can be scaled to meet local, regional, national and EU-level adaptation and resilience objectives. Next, we will conduct a comprehensive study of the selected regions, the tangible results of which will directly inform future policy development and more effective NbS implementation.

**Keywords:** Transformational climate change adaptation, Nature-based Solutions, comparative case study approach, EU regions

## Dendrogeomorphology in Intertropical Mountain Environments: Case of El Rosario, Michoacán.

Violeta Rangel-Velarde<sup>1,\*</sup>, Manuel E. Mendoza<sup>2</sup>, José Villanueva Díaz<sup>3</sup>, Genaro Gutiérrez-García<sup>4</sup> and Brent Ward<sup>5</sup>

<sup>1</sup>*Centro de Investigaciones en Geografía Ambiental, Universidad Nacional Autónoma de México, Morelia, México, ORCID: <https://orcid.org/0009-0003-5621-987X>*

<sup>2</sup>*Instituto de Geofísica, Unidad Michoacán, Universidad Nacional Autónoma de México, Morelia, México; Centre for Natural Hazard Research, Simon Fraser University, , ORCID: <https://orcid.org/0000-0003-1310-9702>. Corresponding author.*

<sup>3</sup>*Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Durango, México. ORCID: <https://orcid.org/0000-0001-8211-1203>*

<sup>4</sup>*Departamento de Botánica, Instituto de Biología, Universidad Nacional Autónoma de México. Ciudad Universitaria, Ciudad de México. ORCID: <https://orcid.org/0000-0003-2299-1194>*

<sup>5</sup>*Department of Earth Science, Simon Fraser University, Vancouver, Canada. ORCID: <https://orcid.org/0000-0001-6482-7283>*

### Abstract

Mass wasting processes (MWP), such as landslides, are geomorphological hazards driven by gravity and often triggered by hydrometeorological or seismic events. These phenomena involve the downslope movement of substantial volumes of soil, water, and rock debris. Understanding their historical and present-day dynamics is frequently hindered by the scarcity of chronological data, limited archival records, and challenges in accurately dating such events. In recent decades, dendrogeomorphology—a multidisciplinary approach combining dendrochronology and geomorphology—has gained prominence for its capacity to reconstruct past events and assess variability across spatial and temporal scales. However, research has predominantly focused on temperate zones, with comparatively few studies conducted in intertropical regions, particularly in Latin America.

In Mexico, hydrometeorological events have historically caused the greatest number of disasters and economic losses (notably in 2010), followed by geological events (e.g., in 2017). One such hydrometeorological disaster is under investigation within the Monarch Butterfly Biosphere Reserve, located in the municipality of Ocampo, Michoacán. This area, situated in the Trans-Mexican Volcanic Belt, is marked by its volcanic origins and active tectonics—conditions that generate a highly hazardous geomorphic setting. A significant portion of central Mexico's population inhabits this region, underscoring the critical intersection of natural hazards and societal vulnerability.

In late January 2010, a sequence of storms and two cold fronts impacted the region, producing hailstorms and intense rainfall. The combination of saturated soils and steep slopes triggered numerous landslides, and debris flows across multiple municipalities. The disaster had severe consequences: human casualties, infrastructure damage,

disruption of tourism, forest degradation, and forced displacement of entire communities. To reconstruct this event, a tree-ring chronology was developed using samples from seven stumps and eight reference trees of *Abies religiosa*, yielding 33 usable cores out of 39 analyzed. Analysis via the CDendro program produced a high inter-series correlation of 0.90 (P2YrsLCorrC algorithm), a T-Test value of 18.2, and a Chi-square value of 41.5, indicating a strong and coherent growth signal among the sampled trees. Ring-width series were detrended using a negative exponential function. Tree ages ranged from 28 to 107 years (1911–2017), with a mean age of 64.7 years.

Evidence of disturbance and traumatic resin ducts (TRDs) pointed to probable event years in 2010, 2004, and 1985. This study adopts a multiproxy approach, integrating dendrogeomorphological indicators, growth ring eccentricity, the Schröder index, and precipitation anomalies derived from CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) for February. Additionally, drainage patterns were analyzed using a high-resolution LiDAR-derived digital elevation model. Notably, results revealed an anomalous rainfall pattern totaling 95.464 mm over three days, supporting the identification of 2010 as a likely trigger year for MWPs.

This research demonstrates the value of dendrogeomorphological methods in intertropical mountain systems and highlights the potential for broader applications in hazard assessment and historical reconstruction of geomorphic processes in understudied regions.

**Keywords:** Dendrogeomorphology, mass wasting processes, extreme hydrometeorological phenomena, landslides..

**Acknowledgments:** Project: “Dendrogeomorphology: Development and implementation of a scheme for mapping and assessing geomorphological hazards in intertropical mountainous areas of Mexico”. Funded by DGAPA-PAPIIT IN110222. SECIHTI PhD Scholarship and Graduate Studies Support Program (PAEP-UNAM).

# **NH3/4: Scaling and Integrating Nature-Based Solutions for Climate Action: Frameworks for Classification**

## Enhancing Regional Climate Resilience: a Comprehensive Evaluation Framework From the Natalie Project

Jesús Soler Martin<sup>1</sup>, Sonia Siauve<sup>2</sup> and lydia vamvakeridou-lyroudia<sup>3</sup>

<sup>1</sup>*Aquatec*

<sup>2</sup>*Oieau*

<sup>3</sup>*KWR*

### Abstract

This abstract introduces the methodologies and tools in the NATALIE project to evaluate the performance of NBS to adapt to climate change impacts and support the planning and implementation of interventions for enhancing climate resilience of regions and communities. The project proposes a streamlined framework that includes modelling, cost benefit analysis and participatory multi-criteria decision process. This framework aims to engage local regional/communities to better manage climate related hazards under a wide range of climatic and socioeconomic scenarios.

Nature-Based Solutions (NBS) have been regarded a multifunctional approach that not only mitigates climate hazards, but more importantly, also contributes to habitat restoration, biodiversity conservation, improving environmental quality, social justice and cohesion, health and wellbeing and green economy (European Commission, 2021; Stafford et al., 2021). The NATALIE (Accelerating and mainstreaming transformative NATure-bAsed solutions to enhance resiliEence to climate change for diverse bio-geographical European regions) project, funded by Horizon Europe research and innovation program is focusing on knowledge creation and sharing to boost the adoption of NBS for enhancing climate resilience in vulnerable communities and regions. To achieve this goal, adequate methodologies and tools will be developed to evaluate the performance of NBS for implementing interventions to support climate resilient communities.

A set of tailored tools will be utilised to evaluate the consequences of climate/weather hazards on urban, peri-urban and rural environment and assessing the performance of NBS. The tools include hydrological and water quality modelling, geohazards simulations, urban subsurface analysis, temperature regulation, biodiversity, ecosystem and social system analysis, wellbeing, economic benefits assessment. The tools will simulate not only the consequences of individual hazards, but also their combinations (compound events) and the cascading effects under various climate change and socioeconomic scenarios, in a multi-hazard analysis to evaluate the impact of the NBS in the resilience of the systems.

Tools will also be developed to enable participatory multi-criteria decision making with

stakeholders in the co-creation of specific NBS deployment pathways (sequences of actions and interventions in time). These pathways will be dynamic in nature, constrained by the specificities of the situation at hand, and will leverage emerging opportunities depending on ecosystem type, geography and country and match them to enhance the mitigation and adaptation potential of NBS.

**Keywords:** Nature-based solutions, climate resilience,

### **References**

European Commission (2022). «Nature-Based Solutions», Stafford, R., Chamberlain, B., Clavey, L., Gillingham, P. K., McKain, S., Morecroft, M. D., Morrison-Bell, C., & Watts, O. (Eds.) (2021). Nature-based solutions for climate change in the UK: A report by the British Ecological Society. Retrieved from [www.britishecologicalsociety.org/nature-based-solutions](http://www.britishecologicalsociety.org/nature-based-solutions),

**Acknowledgments:** NATALIE has received funding from the European Union's Horizon Europe research and innovation program under grant agreement n° 101112859.

## Comparative Analysis of Yolo Models For Vineyard Abandonment Detection in Oltrepò Pavese

Sohail Anwar<sup>1,\*</sup>, Giovanni Marchese<sup>2</sup>, Valentina Vaglia<sup>2</sup> and Chiara Toffanin<sup>1</sup>

<sup>1</sup>Department of Electrical, Computer and Biomedical Engineering, University of Pavia, Via Ferrata 5, 27100 Pavia, Italy

<sup>2</sup>Department of Earth and Environmental Sciences, University of Pavia, Via S. Epifanio 14, 27100 Pavia, Italy

### Abstract

Climate change poses significant threats to agriculture, particularly impacting viticulture by altering grape phenology and challenging traditional wine-growing regions such as Northern Italy's Oltrepò Pavese. Abandoned vineyards intensify problems related to phytoplasma diseases like *flavescence dorée*, an incurable disease spread by the insect vector *Scaphoideus titanus*. The persistence of abandoned vineyards thus threatens not only vineyard health but also regional economic stability and agricultural sustainability. However, detecting abandoned vineyards efficiently remains challenging due to legal hurdles and the impractical nature of manual inspections.

To address this challenge, our study undertakes a comprehensive comparative analysis of YOLO (You Only Look Once) deep learning models to differentiate active vineyards from abandoned ones using orthophoto imagery sourced from Google Earth Pro. The dataset includes 882 annotated vineyard images (472 abandoned, 410 active) captured in October across the years 2014, 2015, and 2018. Images are pre-processed including resizing, adaptive histogram equalization, strategic cropping, and data augmentation on the training set to maximize the training accuracy of the models.

This study extends our previous research on YOLO-based vineyard abandoned detection in Oltrepo Pavese [1]. In this study, multiple YOLO versions are compared in terms of their performance specially YOLOv5, YOLOv6, YOLOv8, YOLOv9, YOLOv10, YOLOv11, and YOLOv12 were tested with nano and small models with varying batch sizes of 8,16, and 32. Preliminary results indicate that YOLOv8 with batch size of 32 achieves a highest recall 90% specially on the abandoned vineyard class as the primary objective of the study is to detect abandoned vineyards. These findings underline the feasibility and effectiveness of applying machine learning technique in managing vineyard health and sustainability. This work is supported by PNRR's NODES to make important contributions toward preserving the viticultural heritage, promoting sustainable agricultural management, and enhance economic resilience in the Oltrepò Pavese region. The practical applications of these models can significantly streamline the monitoring process, improve management decisions, and aid in mitigating risks associated with vineyard abandonment.

**Keywords:** satellite observation, machine learning, object detection, YOLO, PNRR-NODES

**References**

Anwar, S., Marchese, G., Toffanin, C., and Vaglia, V.: Vineyard condition detection method using Google Earth Images and the YOLOv8 model in Northern Italy, EGU General Assembly 2025, Vienna, Austria, 27 Apr-2 May 2025, EGU25-981, <https://doi.org/10.5194/egusphere-egu25-981>, 2025.

**Acknowledgments:** This work was funded by the European Union - NextGenerationEU, Mission 4 Component 1.5 - ECS00000036 - CUP F17G22000190007.

# Mainstreaming Nature-Based Solutions in Practice Across Coastal and Riverine Areas of Europe

Geert J.M. van der Meulen, Jurre J. de Vries and Ralph Schielen

*The Netherlands Ministry of Infrastructure and Water Management, Rijkswaterstaat*

## Abstract

Nature-based solutions (NbS) offer a holistic approach to address environmental challenges and are capable of delivering ecological and socio-economical co-benefits. Despite a growing NbS evidence-base, development of adaptation strategies for resilience and mitigation which would enable widespread integration and scaled-up implementation of NbS is still a process in transition with outstanding questions. Manabas Coast and ResiRiver are two EU Interreg programs focusing on mainstreaming (and upscaling) of NbS, for coastal and riverine systems respectively, by means of practical experience gained at (~25) physical study cases spread around the North Sea and across Northwest European Regions. Insights from both programs, case studies, and affiliated responsible authorities contribute to developing a mutual understanding of the diversity of perceptions, activities, and objectives of NbS mainstreaming within Europe. An enabler-based integrated system perspective (Van Eekelen and Bouw, 2020) is presented to distinguish NbS mainstreaming activities in the governance, natural, and societal systems (Van der Meulen et al., 2025). These three systems correspond to theories on up-, out-, and deep-scaling (Moore et al., 2015; Salafsky et al., 2021) of NbS, respectively. Connecting activities from ongoing NbS practice to established theory facilitates identifying aspects related to NbS processes requiring attention, as well as distributing roles and tasks in NbS mainstreaming (Adams et al., 2023). By means of the 'Theory of Change' (Van Es et al., 2015), the regional and national coastal and river management authorities involved are guided in aligning such NbS activities and outputs around a case study to foreseen outcomes and the desired mainstreaming objectives. By also inventorising and mapping the network of relations to stakeholders in NbS processes in 'circles of influence' (Van Es et al., 2015), relevant existing or feasible new alliances can be identified for the listed activities and outputs which are deemed necessary for the formulated NbS mainstreaming objectives. As such, the programs deliver key components for developing meaningful strategies by building upon existing theoretical frameworks of mainstreaming in alignment with practice to enhance actionable NbS mainstreaming processes in the context of European coastal and riverine systems.

**Keywords:** Mainstreaming, Scaling, Nature-based solutions, Strategies, Theory of change

## References

Adams, C., Frantzeskaki, N., Moglia, M. (2023). Mainstreaming nature-based solutions in cities: A systematic literature review and a proposal for facilitating urban transitions. *Land Use Policy*, 130,

106661.; Moore, M.L., Riddell, D., Vocisano, D. (2015). Scaling Out, Scaling Up, Scaling Deep. In: McIntosh, M., Waddell, S., Waddock, S., Cornell, S., Dentoni, D., McLachlan, M. (Eds.). Large Systems Change: An Emerging Field of Transformation and Transitions. London, England: Routledge.; Salafsky, N., Suresh, V., Bierbaum, R., Clarke, E., Smith, M.S., Whaley, C., Margoluis, R. (2021). Taking Nature-Based Solutions Programs to Scale. Bethesda, MD: Foundation of Success.; Van der Meulen, G.J.M., De Vries, J.J., Van Well, L., Kannekens, F.A. (2025). Towards a Common Language for Mainstreaming Nature-Based Solutions Through Coastal Systems in the North Sea Region. *Journal of Marine Science and Engineering*, 13(3), 509.; Van Eekelen, E., Bouw, M. (2020). Building with Nature. Creating, Implementing, and Upscaling Nature-Based Solutions. Rotterdam, The Netherlands: nai010 Publishers.; Van Es, M., Guijt, I., Vogel, I. (2015). Theory of change thinking in practice. The Hague, The Netherlands: Hivos.

**Acknowledgments:** EU Interreg programs Manabas Coast and ResiRiver

# Mapping Soil Erosion in Vineyards to Create the First National Database: the Isum Web-Based Approach

Alejandro Florido<sup>1,\*</sup>, Artemi Cerdá<sup>2</sup> and Jesús Rodrigo-Comino<sup>1</sup>

<sup>1</sup>*University of Granada*

<sup>2</sup>*University of Valencia*

## Abstract

Monitoring soil erosion is critical for sustainable viticulture, and engaging students in this process can foster valuable scientific literacy. This project introduces a novel approach to visualize and analyze soil erosion data from vineyards, leveraging the Improved Stump Grafting Method (ISUM) as a bioindicator. We propose a national study of vineyard health in Spain, utilizing a standardized methodology across ten representative wine regions to enable future comparisons of management practices both nationally and internationally.

This abstract focuses on creating an interactive web-based platform to present experimental soil erosion data. We demonstrate this approach through a detailed case study of the Marls vineyard in Moixent, Valencia, Spain, where we analyze an 8-year comprehensive dataset. This specific example serves as a representative model that illustrates our methodology, which we then systematically apply to the other vineyards in our study. Our objective is to build an interface that displays location maps, 2D and 3D views of the vineyard to illustrate erosion patterns, real photographs, and a statistical analysis of the vineyard's data.

The interactive interface is developed using HTML for the webpage structure and Python for data processing and visualization. Key Python libraries utilized include pandas, numpy, matplotlib, plotly, geopandas, leafmap, and shapely, with Jupyter Notebook facilitating real-time code development and visualization. Basic knowledge of CSV file format and QGIS/ArcGIS for handling shapefiles is beneficial for understanding the data. A critical step involves correcting potential slight variations in vineyard coordinates when exploited to a .shp file to ensure accurate real-world positioning. This project demonstrates how students can actively participate in mapping soil erosion processes and contribute to an open-access database, making valuable viticultural data accessible to a broader audience.

**Keywords:** Soil erosion, vineyards, Spain, mapping, geomatics

# **UR: Upscaling and effects of nature-based solutions in urban regions and metropolises**

# **Developing a Comprehensive Framework For Upscaling Nature-Based Solutions For Wastewater Treatment in Urban India: a Case of Kachchh, Gujarat**

Aswin S Kumar<sup>1,\*</sup> and Siddh Doshi<sup>2</sup>

<sup>1</sup>*Student, faculty of planning, CEPT University, Ahmedabad, 380009, India*

<sup>2</sup>*Doctoral Scholar and Visiting Faculty, faculty of planning, CEPT University, Ahmedabad, 380009, India*

## **Abstract**

India's rapid urbanization has intensified the need for efficient and sustainable wastewater treatment facilities. Conventional methods used within the treatment facilities are often energy-intensive, costly, and environmentally unsustainable. This research explores Nature-based Solutions (NbS) as an eco-centric method for wastewater treatment facilities in India. The research seeks to develop a comprehensive framework for implementing NbS in wastewater treatment facilities, which will inform decisions on adopting NbS as a process.

The study employs an exploratory approach, combining primary and secondary research methods. It begins with a literature review of reports, journals, and articles to scope and define NbS for wastewater treatment. Analysis of global and national case studies, including 35 shortlisted Indian cases, emphasizes that comprehensive knowledge of NbS for wastewater treatment is crucial for informed decision-making. From 11 initial papers, four were selected after review to form the basis for developing a comprehensive framework. The framework was validated and tested at two sites in Gujarat's Kachchh district through field visits, which included photographic documentation, stakeholder interviews, and focus group discussions. Field assessments indicated the need for a thorough review of India's wastewater treatment regulations, which was conducted by examining existing policies, acts, and programs.

The study produced three main outcomes: a comprehensive framework for implementing and scaling NbS, identification of opportunities to integrate NbS into India's wastewater treatment using current schemes, and evidence-based recommendations for improving NbS implementation in Indian wastewater treatment landscape. These outcomes lay the groundwork for informed decision-making and effective implementation of NbS in wastewater treatment across diverse Indian contexts.

**Keywords:** Wastewater treatment, Nature-based Solutions, Wastewater Regulations, Comprehensive Framework

## **References**

Bassi, N. S. (2023). Reuse of Treated Wastewater in India: Market Potential and Pointers for Strengthening Governance. New Delhi: Council on Energy, Environment and Water. Brix, H.

(1995). Use of constructed wetlands in water pollution control: historical development, present status, and future perspectives. *Water Science & Technology*, 30(8):209-223. CEPT University.

(2016). *Moving Bhuj towards Water Security*. Ahmedabad: EPT University.

Cohen-Shacham, E. W. (2016). *Nature-based Solutions to address global societal challenges*. Gland, Switzerland: IUCN.

Crites, R. W. (2004). *Small and Decentralized Wastewater Management Systems*. International Water Association. EMC. (2020, 8 5). *Understanding And Addressing Water Stress - A Science Based Approach*. Retrieved from Environment Management Centre: <https://emcentre.com/2020/08/05/understanding-and-addressing-water-stress-a-science-based-approach/>

GoG. (2017). *Policy for Reuse of Treated Waste Water*. Gandhinagar: Government of Gujarat (GoG).

IWA. (2021). *Nature-Based Solutions for Wastewater Treatment*. London: IWA Publishing.

Kabisch, N. F. (2016). Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. *Ecology and Society*. *Ecology and Society*, 39.

Lena Breitenmoser, G. C. (2022). Perceived drivers and barriers in the governance of wastewater treatment and reuse in India: Insights from a two-round Delphi study. *Resources Conservation and Recycling*, 10. Metcalf & Eddy. (2003). *Wastewater engineering: Treatment and resource recovery*. Taiwan, China: McGraw-Hill Education.

MoHUA. (2021). *Atal Mission for Rejuvenation and Urban Transformation 2.0*. New Delhi: MoHUA.

MoHUA. (2021). *Swachh Bharat Mission - Urban 2.0 Operational Guidelines*. New Delhi: MoHUA.

MoJS. (2022). *National Framework on Safe Reuse of Treated Water*. Namami Gange, Ministry of Jal Shakti. Delhi: National Mission for Clean Ganga. Retrieved from [https://nmcg.nic.in/writereaddata/fileupload/32\\_SRTW%20Framework\\_Final\\_23\\_11\\_2021%20\(1\).pdf](https://nmcg.nic.in/writereaddata/fileupload/32_SRTW%20Framework_Final_23_11_2021%20(1).pdf)

Nesshöver, C. A. (2016). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. *The Science of The Total Environment*, 579, 1215-1227. NITI Ayog.

(2022). *Urban Wastewater Scenario in India*. New Delhi: NITI Ayog.

NITI Ayog. (2023). *Reuse of Treated Wastewater in Urban/Peri-Urban Agriculture in India*. Delhi: National Institution for Transforming India (NITI) Aayog.

Seddon, N. C. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. *Philosophical Transactions of the Royal Society. Phil. Trans. R. Soc. B*, 12.

Shealy, S. (2017). Retrieved from *The Caravan*: <https://caravanmagazine.in/reportage/the-last-artisans-of-ajrakhpur>

UNEP. (2023, 06 23). *United Nations Environmental Programme*. Retrieved from [www.unep.org](http://www.unep.org): <https://www.unep.org/news-and-stories/press-release/down-drain-lies-promising-climate-and-nature-solution-un-report#:~:text=Today%2C%20only%2011%20per%20cent,volume%20of%20wastewater%20being%20produced.>

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2023). *The United Nations World Water Development Report 2023: Partnerships and Cooperation for Water*. Paris: United Nations. UN-Water. (2018). *The United Nations World Water Development Report 2018: Nature-Based Solutions for Water*. Paris: UNESCO.

Water JPI. (2022). *Nature-Based Solutions for Water Management in the Peri-Urban: Linking Ecological, Social and Economic Dimensions (NATWiP)*. Stellenbosch, Stockholm: NATWiP Project.

WEF. (2022, 10 19). *World Economic Forum*. Retrieved from [www.weforum.org](http://www.weforum.org): <https://www.weforum.org/agenda/2022/10/wastewater-corporations-climate-goals/>

WHO. (2019). *National systems to support drinking-water, sanitation and hygiene: global status report*. UN-Water global analysis and assessment of sanitation and drinking water (GLAAS) report. Geneva: World Health Organisation.

WRI. (2015, 2 26). *3 Maps Explain India's Growing Water Risks*. Retrieved from *World Resource Institute*: <https://www.wri.org/insights/3-maps-explain-indias-growing-water-risks>

**Acknowledgments:** The copyright for this research shall remain equally with the authors and CEPT University. The research has been funded by Global Sanitation Graduate School.

## **Rejuvenating India'S Water Bodies: Nature-Based Solutions For Sustainable Water Security**

Ankit Kumar, Shahbaz Anwar, Dr. Nidhi Pundhir and Dr. Santanu Basu

*HCLFoundation*

### **Abstract**

Over the past four decades, global water consumption has increased by 1% annually and is projected to continue this trend until 2050, primarily due to population growth and changing consumption patterns. In India, approximately 70% of water usage comes from groundwater, making it the largest extractor globally, surpassing both China and the United States. India is rich in finite natural resources, including various traditional water bodies such as ponds, tanks, and lakes. The National Wetland Inventory and Assessment report (2011) identifies 555,557 small water bodies across the country. The rejuvenation of these water bodies is crucial for water security and climate resilience, serving as biodiversity hotspots and supporting various Sustainable Development Goals (SDGs).

Our study focuses on Gautam Buddha Nagar district in Uttar Pradesh, where around 217 out of 1,018 ponds have been encroached upon due to rapid urbanization. Water quality assessments show significant pollution, with low Dissolved Oxygen levels, high Total Suspended Solids, and silt accumulation linked to dairy businesses. Community attitudes toward these ponds are also shifting. Using a mixed-method approach, we analyzed water quality and conducted surveys with 100 community members.

The findings indicated broad support for pond rejuvenation initiatives and identified shared responsibilities among stakeholders. Post-intervention results showed significant improvements in water quality, with reduced TSS and increased Dissolved Oxygen levels in several ponds. The ecological, social, and economic contributions of these ponds were assessed across various ecosystem services. Notably, supporting services, such as biodiversity preservation, scored highest, while provisioning services received the lowest score. This suggests a growing interest in ecological conservation within the community. Community engagement was vital for the success of our NbS interventions. Despite 57.1% of respondents noting a lack of cleaning efforts, 98.5% recognized external organizational support, with over 76% participating in cleanliness initiatives. These results highlight the importance of community involvement as an integral part of the rejuvenation process. In conclusion, our study confirms that Nature-based Solutions can effectively restore water bodies, improve water quality, and enhance ecosystem resilience, emphasizing the need for ongoing support for these initiatives.

**Keywords:** Water security, Climate resilience, Nature based Solutions, Ecosystem services

## References

1. National Wetland Inventory and Assessment Report. National Wetland Inventory and Assessment Report, 2011.
2. Agarwal, A.; Narain, S. *Making Water Everybody's Business: Practice and Policy of Water Harvesting*; Centre for Science and Environment: New Delhi, 1999.
3. Biggs, J.; von Fumetti, S.; Kelly-Quinn, M. The Importance of Small Water Bodies for Biodiversity and Ecosystem Services: Implications for Policy Makers. *Hydrobiologia* 2017, 793 (1), 3–39.
4. Central Ground Water Board. *Groundwater Yearbook 2019-20: India*; Ministry of Jal Shakti, Government of India, 2020.
5. Cohen-Shacham, E.; Walters, G.; Janzen, C.; Maginnis, S. *Nature-Based Solutions to Address Global Societal Challenges*; IUCN: Gland, Switzerland, 2016.
6. Hassall, C. The Ecology and Biodiversity of Urban Ponds. *Wiley Interdiscip. Rev. Water* 2014, 1 (2), 187–206.
7. Iyer, R.; Srinivasan, V.; Sundaresan, J. Pond Restoration and Sustainable Water Management: A Review from India. *Water Policy* 2019, 21 (6), 1247–1262.
8. Kumar, P.; Purohit, P. Challenges in Implementing Nature-Based Solutions for Urban Water Management. *J. Environ. Manage.* 2018, 216, 36–44.
9. Mukherjee, S.; Shah, T.; Verma, S. Small Water Bodies and Sustainable Groundwater Management: A Pathway to Resilience. *Int. J. Water Resour. Dev.* 2020, 36 (5), 783–795.
10. Ramsar Convention. *The Global Wetland Outlook: State of the World's Wetlands and Their Services to People 2018*; Ramsar Secretariat, 2018.
11. Seddon, N.; Chausson, A.; Berry, P., et al. Understanding the Value and Limits of Nature-Based Solutions to Climate Change and Other Global Challenges. *Philos. Trans. R. Soc., B* 2020, 375 (1794).
12. Singh, V.; Singh, S. *Water Bodies and Ecosystem Services: Perspectives from Rural India*; Springer: New Delhi, 2021.
13. UN-Water. *The United Nations World Water Development Report 2021: Valuing Water*; UNESCO: Paris, 2021.
14. World Bank. *Groundwater Management and Policies in India: Sustaining the Future*; World Bank, 2018.

## Green Walls For Water and Waste Circularity in Urban Water-Scarce Environments

Estefanía Aguirre-Álvarez, Liliana Lizárraga-Mendiola, Claudia Coronel-Olivares, J. Andrés Tavizón-Pozos and Gabriela A. Vázquez-Rodríguez

*Universidad Autónoma del Estado de Hidalgo*

### Abstract

Light greywater (LGW) is the domestic wastewater derived from personal hygiene activities and washing clothes. Particularly, LGW from washing clothes has low concentrations of pollutants, and given that it accounts for more than 50% of the wastewater volume generated by households, it is considered a well-suited source for reuse and, consequently, is at the center of the circular economy efforts at the domestic level (Ghaitidak and Yadav, 2013). Another critical waste is that generated by the construction industry, which represents about 30% of solid waste worldwide. Besides being cumbersome, official sites for the disposal of construction and demolition waste (CDW) are scarce in some regions, and it often ends up in unauthorized sites.

This study proposes a nature-based solution, a CDW packed-green wall, for LGW treatment to reuse the infiltrated water and contribute to the CDW circularity. Three types of crushed CDW (concrete aggregates, permeable concrete, and bricks) and a natural zeolite as reference material were packed separately in containers. In each container, layers of granular activated carbon, one type of CDW, and soil were successively placed. One module was integrated by four containers packed with the same CDW and working in series, so three modules were set up for testing each CDW, while another module was packed with the zeolite. In one module, each container was planted with one vascular species in the following order: *Chrysopogon zizanioides*, *Portulaca grandiflora*, *Tradescantia pallida*, and *Nephrolepis oblitterata*. Each module was fed one liter of real LGW weekly for eight weeks. Turbidity, pH, chemical and biological oxygen demand (COD and BOD<sub>5</sub>, respectively), nutrients (N-NH<sub>4</sub><sup>+</sup> and orthophosphates), and *Escherichia coli* were measured in the LGW through standard methods at the input and output of each module.

The module filled with concrete aggregates had the best performance concerning effluent quality, exhibiting on average turbidity removal efficiencies of 52%, ammonia nitrogen (N-NH<sub>4</sub><sup>+</sup>) of 65%, orthophosphates of 68%, COD of 72%, BOD<sub>5</sub> of 80.7%, and 100% for *E. coli*. The quality of the effluents of the module packed with concrete aggregates complied with Mexican regulations regarding pH, COD, and *E. coli* contents. This infiltrated water is suitable for reuse in the irrigation of green areas, in other types of irrigation, or for on-site domestic activities. Overall, the work demonstrated that green walls integrating CDW for LGW treatment could contribute to the circular economy of water-scarce areas by using these wastes as filter materials.

**Keywords:** light grey water, construction and demolition waste, water reuse, circular economy

**References**

Ghaitidak, D.M., Yadav, K.D. (2013) Characteristics and treatment of greywater—a review. *Environ. Sci. Pollut. Res.* 20, 2795–2809 (2013)

## Free the Wai

Dr Matthew Bradbury and Nikolay Popov

*Unitec Institute of Technology*

### Abstract

The trajectory of 19th-century colonial urban planning, including the suppression of natural water systems through the draining of wetlands and the piping of streams, was a long and fraught process. The founders and bureaucrats of these cities in the Americas and Australasia spent much time, effort, and treasure on this endeavour. However, in the 21st century, with the environmental effects of climate change becoming more pressing, especially pluvial flooding, the indigenous landscape of wetlands and rivers has been revealed as the original waterways find their paths to the sea regardless of the roads, pipes, or housing that has been built.

This paper explores this history by discussing the suburban development of Tāmaki Makaurau/ Auckland, Aotearoa, New Zealand, particularly the effects of a recent catastrophic flood on Anniversary Day, January 2023. The paper then looks at a case study, the master planning of a sizeable 35-ha site in Tāmaki Makaurau that flooded badly. The paper concludes with a speculative proposal for a regional-based strategy to daylight and re-naturalise Tāmaki Makaurau hidden awa (streams) and ripo (wetlands).

The case study investigation focuses on the Avondale racecourse, a 35-hectare site in the centre of an early 20th-century suburb in Tāmaki Makaurau, Aotearoa, New Zealand. The site was severely flooded during the Anniversary Day floods in 2023. A new urban masterplan, a new urbanist grid with high-density housing and highly impermeable surfaces, has been proposed. The paper discusses the likely hydrological consequences of such a plan, including the exacerbation of the present flooding due to the increase of the site's impermeable surface.

The paper then discusses an alternative design proposal for the site that aims to privilege the underlying landscape. This proposal acknowledges the complex landscape of gullies and wetlands that were erased in the construction of the racecourse. Building on this indigenous landscape, the design approach uses NBS to turn the flood zone into a new green space to absorb runoff and detain flooding. At the same time, the study explores ways to avoid increasing runoff from the new housing by reducing the footprint of the new housing. The design study uses GIS modelling and the rational method to measure the impact of rainfall in the 2023 Anniversary Day flood and assess different design scenarios. Using NBS, the alternative master plan proposes a green landscape that enhances soakage and creates new public spaces for the community.

The Avondale racecourse development case study demonstrates the development of an intertwined design strategy. Understanding the underlying Indigenous landscape and then using NBS to ameliorate future flooding,

This strategy is then scaled up to encompass the rich and complex hydrological landscape of the Tāmaki Makaurau isthmus. A vision of a regional-scaled green infrastructure based on the discovery and liberation of Tāmaki Makaurau's awa and ripo becomes clear. The newly liberated awa ensures the city's safety by providing for the ready conveyance of future flooding, while the restored ripo detains the worst of the flooding. This new hydrological landscape has social, cultural, and ecological benefits. The rediscovered stream system becomes a new park system for the citizens of Tāmaki Makaurau while rebuilding indigenous biodiversity.

**Keywords:** Nature-based solutions , Climate Change , Pluvial Flooding, Green Infrastructure

### References

Altes, E.K., Rutte, R., 2023, *The Making of the Netherlands - Landscape, Cities and Architecture*, Thoth. Bradbury, M., 2020, *Water City: practical strategies for climate change*. Routledge. De Bruijn, H., de Bruijne, M., ten Heuvelhof, E., 2015, *The Politics of Resilience in the Dutch 'Room for the River' project*, *Procedia Computer Science* 44: 659-668. European Environment Agency, 2021, *Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction*. In EEA Report. Retrieved from <https://www.eea.europa.eu/publications/nature-based-solutions-in-europe> Green, D., O'Donnell, E., Johnson, M., Slater, L., Thorne, C., Zheng, S., et al., 2021, *Green infrastructure\_ The future of urban flood risk management\_ -Green - 2021 - WIREs Water -Wiley Online Library*. Hamers, E. M., Maier, H. R., Zecchin, A.C., & van Delden, H., 2023, *Effectiveness of Nature-Based Solutions for Mitigating the Impact of Pluvial Flooding in Urban Areas at the Regional Scale*. *Water*, 15(4), 642. <https://doi.org/10.3390/w15040642> Nillesen, A.L., 2019, *Spatial Quality as a decisive criterion in flood risk strategies: An integrated approach for flood risk management strategy development, with spatial quality as an ex-ante criterion*, TU Delft. Reid, J., Challies, E., Tau, T.M., Awatere, S., 2024. *Adapting to climate change through nature-based solutions and indigenous knowledge: the case for landscape-scale ecosystem regeneration in the Rokohouia Delta, Kōtuitui New Zealand* *Journal of Social Science*

**Acknowledgments:** Faculty and students of the Unitec Institute of Technology. Phil Wihongi of Ngāti Whātua Ōrākei

## Suds For Water and Climate Challenges in Murcia: a Cardimed Case Study

Elena de Vicente Aguilar<sup>1,\*</sup>, Eva Mena Gil<sup>1</sup>, Simón Nevado Santos<sup>1</sup>, Manuel Valls Sevilla<sup>2</sup>,  
Laurent Joseph Emile Pouget<sup>3</sup> and Maria Del Mar Castro Garcia<sup>4</sup>

<sup>1</sup>*Empresa Municipal de Aguas y Saneamiento de Murcia, S.A.*

<sup>2</sup>*Ayuntamiento de Murcia*

<sup>3</sup>*Cetaqua, Centro Tecnológico del Agua*

<sup>4</sup>*Aquatec*

### Abstract

The Region of Murcia, located in south-eastern Spain, is one of the most arid areas in Europe, experiencing persistent water scarcity due to low annual rainfall, high evapotranspiration, and increasing demand from urban, agricultural, and industrial sectors. At the same time, climate change is intensifying extreme weather events in the region, particularly sudden and intense rainfall episodes which lead to frequent localised flooding. These dual pressures—scarcity and flooding—pose significant challenges for water management and urban resilience, especially in highly urbanised neighbourhoods where impermeable surfaces and outdated drainage infrastructure prevent the absorption and redistribution of stormwater. One such area is Zaraiche Garden, in the city of Murcia, where stormwater from the Espinardo stream regularly overwhelms the existing system, causing flash floods that affect not only the park but also nearby residential and commercial zones, including a major retail complex. In this context, as part of the CARDIMED Horizon Europe project (GA 101112731), Murcia is conducting a feasibility study to explore the replicability of a Sustainable Urban Drainage System (SUDS) designed to mitigate flood risk, enhance water reuse, and improve the urban environment through a Nature-based Solution (NbS) tailored to the Mediterranean context. The proposed intervention seeks to transform Zaraiche Garden into a multifunctional space that not only absorbs and channels excess stormwater, but also stores it for future use. The expected benefits include a measurable reduction in flood frequency and severity, the reuse of captured water for the irrigation of green spaces—replacing up to 1 hm<sup>3</sup> per year of potable water use—and the redistribution of this water into Murcia’s traditional network of irrigation ditches (acequias), which are both ecologically and culturally valuable. Additionally, by increasing vegetation and tree cover in the area, the solution aims to mitigate the urban heat island effect and improve local microclimates. This pilot aligns with regional and municipal priorities for sustainable water management and supports Murcia’s broader strategy to adapt to climate change through integrated, cross-sectoral approaches. The project is informed by and contributes to the recently developed “Guía Básica de Diseño de Sistemas Urbanos de Drenaje Sostenible (SUDS)” published by Aguas de Murcia, which offers technical and

practical guidance for the design and implementation of SUDS across the city. This guide recognises the multifunctional role of SUDS in improving water quality, controlling runoff, enhancing biodiversity, and creating more liveable urban spaces, and serves as a reference for municipalities aiming to integrate blue-green infrastructure into local planning. By combining the insights from this guide with the objectives and resources of the CARDIMED project, the Zaraiche pilot represents a unique opportunity to evaluate the real-world applicability of NbS in a Mediterranean city facing complex climate challenges. The outcomes of this feasibility study—both technical and social—will inform future steps in scaling up the solution, not only in Murcia but across other Mediterranean regions included in the CARDIMED replication framework. Ultimately, this case study serves as a microcosm of the broader transition towards nature-based urban resilience, where innovative water management, ecosystem restoration, and climate adaptation converge to support more sustainable and inclusive cities.

**Keywords:** Sustainable Urban Drainage System (SUDS), Nature-based solutions (NbS), Climate resilience, Urban flooding, Water reuse, CARDIMED, Murcia, Mediterranean cities

### **References**

Aguas de Murcia & Ayuntamiento de Murcia (2022). *Guía Básica de Diseño de Sistemas Urbanos de Drenaje Sostenible (SUDS)*. Murcia, Spain.

**Acknowledgments:** This work is carried out as part of the CARDIMED project (Climate Adaptation and Resilience Demonstrated in the Mediterranean Area), funded by the European Union under the Horizon Europe programme (Grant Agreement No. 101112731). We would like to thank all local and regional stakeholders involved in the development of this replication study, as well as the leaders and contributors of Work Package 7 for their valuable coordination and support in advancing the project's replication strategy.

## Assessing the Short and Long-Term Impact of Green Roofs on Urban Air Quality: Eindhoven Case-Study

Miguel Rosa<sup>1,\*</sup>, Bruno Augusto<sup>1</sup>, Vera Rodrigues<sup>1</sup>, Rita Mendonça<sup>2</sup>, Carlos Borrego<sup>1</sup> and Ana Ascenso<sup>1</sup>

<sup>1</sup>*CESAM and Department of Environment and Planning, University of Aveiro*

<sup>2</sup>*BUILT CoLAB*

### Abstract

The environmental consequences of an ever-growing urban population are one of the major challenges of our time. Urban areas need to achieve a balance between sustainable development and population growth. Air pollution and urban heat are two of the significant health problems that urban areas are currently facing. One of the suggested measures presented as a sustainable way to address the current and future challenges in urban environments are nature-based solutions (NBS). This study quantifies the effect of green roofs as a solution to these problems in an urban area (Eindhoven, The Netherlands).

This study explores a new methodological approach to evaluate the effect of green roofs on air quality using a Gaussian model (URBAIR). Additionally, using the results from a hedonic pricing simulation model (SULD), the long-term effects of green roofs were evaluated by incorporating changes in population dynamics and urban density into the modeling system, which affects air pollutant emissions and, thus, the city's air quality.

Three modelling scenarios were assessed: 1. baseline scenario (without green roofs), 2. Short-term scenario (with green roofs), and 3. Long-term scenario (with green roofs and including changes in population dynamics). The results indicate that green roofs can positively influence air quality at the urban level; however, in the long-term, changes in urban density can lead to small effects on air pollutant concentrations (positive and negative) throughout the study domain influenced by the location of the NBS.

**Keywords:** Air quality modelling, City, Nature-based solutions.

**Acknowledgments:** The authors acknowledge the financial support from the Fundação para a Ciência e a Tecnologia (FCT) through national funds within the project SAGE: Assessing socio-economic and land use effects of green roofs on urban air quality through integrated modelling (2023.14746.PEX)

## **From Water Scarcity to Resilience: Indicators For Nature-Based Solutions in Semi-Arid Urban Environments**

Valeria Volpi-León, Juan C. Seck Tuoh-Mora, Carlos A. Bigurra-Alzati, Alma D. Juárez-Sedano and Liliana Lizárraga-Mendiola

*Área Académica de Ingeniería y Arquitectura, Universidad Autónoma del Estado de Hidalgo, Mineral de la Reforma, 42184, Mexico*

### **Abstract**

En las regiones semiáridas, la combinación de baja pluviosidad y alta variabilidad, infraestructura hídrica obsoleta y rápida urbanización genera un doble desafío: escasez de agua e inundaciones recurrentes. Estos problemas exigen soluciones basadas en la naturaleza (SbN) que restablezcan el ciclo hidrológico urbano y optimicen el uso del agua. Este estudio propone indicadores cuantitativos basados en parámetros urbanos, demográficos e hidrológicos que evalúan la efectividad de las SbN en una zona residencial densamente urbanizada del centro de México para a) maximizar la captación de agua de lluvia (CPR) para autoconsumo, b) aumentar la infiltración y la recarga de acuíferos, c) reducir la escorrentía no utilizada, y d) determinar la suficiencia hídrica. Los cálculos utilizaron datos de precipitación (23.5 mm/24 h, con una probabilidad de ocurrencia del 75%), coeficientes de escorrentía ajustados a diferentes usos del suelo, caracterización del uso del suelo (viviendas y otros edificios, superficies de techos, áreas verdes, vialidades y estacionamientos) y datos demográficos (número promedio de usuarios, consumo de agua requerido y volumen recibido). Aprovechar las precipitaciones para mitigar la escasez hídrica en viviendas y edificios comerciales durante al menos 6 meses del año es factible. Asimismo, se determinó que solo el 23% de la escorrentía se infiltra, aunque este porcentaje podría incrementarse si se implementan jardines de lluvia y zanjas de infiltración en áreas verdes y medianas. El agua captada en azoteas (CWH) es suficiente para cubrir el 53% de la escasez hídrica actual. Finalmente, el 51% de la escorrentía se pierde en el drenaje, lo que demuestra la urgencia de implementar estrategias de retención. Los resultados indican que a) la CWH es factible en climas semiáridos, b) las SbN no son intercambiables: su diseño debe priorizarse según los indicadores, y c) la metodología es escalable y replicable en contextos con escasez de precipitaciones. En conclusión, los indicadores propuestos diagnostican fallas en la gestión hídrica urbana y orientan las inversiones en SbN con el máximo impacto, equilibrando la seguridad hídrica y los objetivos de adaptación climática.

**Keywords:** Urban runoff, Water security, Low Impact Development

## Agave Salmiana as a Functional Component of Bioretention Devices in Semiarid Climates

Andrés Pérez-Aguilar, Marcelino Antonio Zúñiga-Estrada, Liliana Lizárraga-Mendiola and Gabriela Alejandra Vázquez Rodríguez

*Universidad Autónoma del Estado de Hidalgo*

### Abstract

Bioretention cells are effective nature-based solutions for controlling urban runoff. These systems use layers of filtering materials, including coarse-grained soil and a vegetative cover, to enhance infiltration and improve water quality. The soil component plays a crucial role in removing pollutants such as heavy metals, which tend to adsorb onto soil minerals. Plants also aid in pollutant removal by bioaccumulating metals in their tissues or translocating them from roots to shoots. While bioretention cells are commonly applied in temperate climates, their use and performance in arid and semiarid regions remain underexplored. In this study, the xerophytic plant *Agave salmiana* was integrated as the vegetative component of bioretention cells, and its capacity to remove lead (Pb)—a prevalent heavy metal in urban runoff—was evaluated.

Three columns were filled with locally sourced filter media and sandy loam soil, each planted with one *A. salmiana* specimen. Synthetic urban runoff (SUR) containing 1 mg Pb/L was applied at 99 mL/h for 8 hours per cycle, over 12 cycles. Lead concentrations were measured at the inlet and outlet of each column. After the experiment, soil samples underwent sequential BCR extraction to determine Pb partitioning among soluble/exchangeable, reducible, oxidizable, and residual fractions (Quevauviller et al., 1994). Plant tissues were separated, digested, and analyzed. Lead content in SUR, soil fractions, and plant tissues was measured using atomic absorption spectroscopy. Mass balance calculations and bioaccumulation and translocation factors were used to assess phytoremediation potential.

The bioretention columns achieved an average Pb removal efficiency of 96%. Lead was primarily retained in the oxidizable soil fraction, indicating a strong association with organic matter. Pb was also detected in both root and shoot tissues of *A. salmiana*, with bioaccumulation and translocation factors suggesting a moderate capacity for phytoextraction. These results highlight *A. salmiana* as a promising candidate for enhancing bioretention systems in semiarid climates and improving the quality of urban runoff.

**Keywords:** xerophyte, heavy metals, urban runoff, lead, phytoremediation

### References

Quevauviller, P., Rauret, G., Muntau, H., Ure, A.M., Rubio, R., López-Sánchez, J.F., Griepink, B. (1994). Evaluation of a sequential extraction procedure for the determination of extractable trace

metal contents in sediments. Fresenius' Journal of Analytical Chemistry, 349, 808-814.

## **Nature-Driven Greening Metropolis; the Case of Monterrey, Mexico**

Rob Roggema

*Professor Regenerative Culture, TEC de Monterrey*

### **Abstract**

In this paper we will present the potential transformation of the city of Monterrey into a nature-driven green metropolis. The city suffers from droughts, heat, a problematic air quality, occasional severe floods and torments and impermeable surfaces. It has a low percentage of green spaces compared to other large cities. The conurbation suffers landscape pain, in the form of excavated quarries, intrusion of illegal constructions in nature reserves, (ultra) large scale low density industrial buildings, barriers such as disconnective high- and railways. Moreover, the natural creek system is invisible, hidden and disconnected in more than 17,000 places, creating a dangerous and risky situation. To heal and love the city again, the green metropolis strategy focuses on uncovering the natural creek system and providing this with a robust green and ecological corridor system, before embedding urban land uses within that system. This way a future green scenario emerges in which the metropolis is transformed in a healing city and green and nature reconquers urban and industrial space. This is manifested through implementing small scale eco-acupuncture interventions, such as Miyawaki reforestation and urban milpa food growth, which substantiates the long-term nature-driven strategy. The presentation will highlight the methodology of Landscape First urbanism, show the way the landscape pain is mapped, and how strategies are deployed to regenerate the metropolitan area of Monterrey. Moreover several examples will be presented how small scale reforestation, renaturalization and hyperlocal urban agriculture is designed, developed and implemented.

**Keywords:** Landscape First, Green metropolis, Nature-driven, Monterrey, Landscape pain

### **References**

Roggema, R.; Rubio Cisneros, I.I.; Junco López, R.; Ramirez Leal, P.; Ramirez Suarez, M.; Ortiz Díaz, M. Loving and Healing a Hurt City: Planning a Green Monterrey Metropolitan Area. *Land* 2025, 14, 164. <https://doi.org/10.3390/land14010164>

## Outdoor Urban Milpa System Next to the Tec Greenhouse in Monterrey, Nuevo León

Igor Ishi Rubio-Cisneros<sup>1,\*</sup>, Robert Edwin Roggema<sup>1</sup>, Enrique Puga-de los Reyes<sup>2</sup>, Alicia Ramirez-Medrano<sup>3</sup>, Esther Pérez-Carrillo<sup>3</sup> and Ana Sofía Haro Montoya<sup>1</sup>

<sup>1</sup>*Tecnológico de Monterrey, Escuela de Arquitectura, Arte y Diseño, N.L., Monterrey, N.L., 64849, México*

<sup>2</sup>*Invernadero Académico y de Transferencia, Tecnológico de Monterrey, N.L., 64840, México*

<sup>3</sup>*Tecnológico de Monterrey, Escuela de Ingeniería y Ciencias, Monterrey, N.L., 64849, México*

### Abstract

The city of Monterrey, located in northeastern Mexico, is accelerating its climate actions to enhance the well-being of its citizens and recover degraded ecosystem services. Organic urban agriculture utilizing a milpa system is an experimental approach that fulfills the urge for healthy produce and environmental benefits. The 'Reinventing Traditions' project at Tecnológico de Monterrey experiments with the foodscapes of Nuevo León, conducting research in urban settings, while preserving the cultural identity of local food production and the heritage of traditional recipes.

The project meets the following objectives: 1- Cultural preservation of cultivation practice with heritage dishes; 2- Culinary innovation by preparing keystone dishes mixing healthy ingredients; 3- Impact on public health from agricultural practices and organic consumption; 4- Sustainable growth, design, construction, and local produce; 5- Community engagement by seed exchange, replicating the land management with local communities; 6- Knowledge dissemination promoting these practices beyond Nuevo León in publications, through educational experiences, artistic exhibitions, and tasting events; 7- Public recommendations supporting cultural heritage preservation, sustainable agriculture, and public health.

The milpa is located outside an academic greenhouse near the TEC campus of Monterrey, on the north bank of Arroyo Seco Creek (Latitude 25.645547°, Longitude -100.283493°). The agriculture by design comprises a general workflow for two sowing seasons per year, such as: (i) site selection and sector analysis; (ii) distributing plantations by sectors under a shade mesh and uncapped below the tree canopy; (iii) land preparation, raised bed construction, and soil improvement with organic compost; (iv) native seed selection, exploring the incorporation of challenging plants of the region, and choosing plant associations per strata for germination; (v) planting corn (*Zea mays*), beans (*Fabaceae*), squash (*Cucurbita maxima*), garlic (*Allium sativum*), amaranth (*Amaranthus cruentus*), oregano (*Origanum vulgare*), creole tomato (*Solanum lycopersicum*); (vi) watering, monitoring growth, and organic pest control; (viii) harvesting for culinary delights and grain collection for compositional analysis in the lab; (ix) post-harvesting treatments to plants, seeds, and soil.

The urban conditions at Monterrey in these milpas allow land to yield maize and associated plants. Although challenging, the project's success in preserving the life and growth of plants has been achieved through a collaborative process involving various stakeholders, including local communities, researchers, schools, artist residences, and chefs.

**Keywords:** milpa, organic agriculture, urban foodscapes, culinary heritage, northeastern Mexico

## **Making a Post-Earthquake Urban-Rural Landscape Resilient: Landscape Planning Approach in Kahramanmaraş Province**

Nilgul KARADENİZ<sup>1,\*</sup>, Sule KISAKUREK<sup>2</sup> and Sebahat ACIKSOZ<sup>1</sup>

<sup>1</sup>*Prof. Dr.*

<sup>2</sup>*Assoc. Prof. Dr.*

### **Abstract**

The city of Kahramanmaraş is located on a large plain surrounded by steep hills and is under the influence of the Mediterranean climate. Topographic, hydrological and climatic diversity has also made the vegetation and wildlife extraordinarily diverse.

On February 6, 2023, two earthquakes of 7.8 Mw and 7.5 Mw, called "great earthquakes", occurred in the Pazarcık and Elbistan districts of Kahramanmaraş. The surface rupture created by the M7.5 earthquake is approximately 135 km long and the largest lateral displacement observed as a result is approximately 8.5 m.

The severe consequences of these severe earthquakes are still intensely affecting the city of Kahramanmaraş. Today, one of the most critical issues in the earthquake region is the lack of spatial plans that can prepare urban/rural areas for such disaster processes.

However, the issue of supplying the urgent housing need after the earthquake has taken precedence over all other critical issues and the process of intensive construction has begun in the city center and inner/outer rural areas. The fertile agricultural lands and even wetlands in the plain have begun to be irreversibly damaged by the construction activities.

In this case, it is of vital importance to urgently determine the current status of all natural landscape components and processes that support the city in all aspects and to conduct spatial planning procedure focusing on them.

Geodesign is a 6-stage landscape planning approach that enables the production of decisions compatible with nature by utilizing the natural/cultural components and processes of the landscape and the collaboration of many professional disciplines.

In this study, the first findings of a three-year research project aimed at making the rural and urban structure in Kahramanmaraş, which became even more fragile after the earthquake, resilient against catastrophic processes will be shared. In this context, Geodesign is considered as an effective planning mechanism that can ensure the healthy functioning of ecological processes and thus contribute to the creation of a resilient city, and first of all, the steps of the Geodesign process are defined. Accordingly, the first three stages were tested and firstly the changes in the natural landscape layers after the earthquake were determined and possible sensitive areas/areas that need "healing" were determined. On the other hand, it is also aimed to discuss the steps of the Geodesign process followed in the project with TERRAenVISION participants and to receive the comments/suggestions of them.

**Keywords:** Resillience of post-earthquake cities, Geodesign, Landscape components and processes

### References

- Fonzino, F., & Lanfranchi, E. (2018). Geodesign Project on Post-Earthquake Rehabilitation: Co-Designing a Strategy for Norcia. In A. Leone & C. Gargiulo (Eds.), *Environmental and territorial modelling for planning and design* (pp. 633-642). FedOAPress.  
<https://doi.org/doi:10.6093/978-88-6887-048-5>
- Li, W., & Milburn, L.-A. (2016). The Evolution of Geodesign as a Design and Planning Tool. *Landscape and Urban Planning*, 156, 5-8.
- Karadeniz, N., Afşar, F. A., Akkaya, İ., Aksoy, O., Ceylan, K. S., Çirak, B. N., Çirkin M., Gürcan, C., & Şenöz Orsan, E. (2020a). Urban Valley as Ecological Corridors in Cities, Imrahor Valley, Turkey. In the *International Geodesign Colloboration Changing Geography by Design*. Esri Press.
- Karadeniz, N., Orsan, E. Ş., Taskin, R. A., & Cetinkaya, Z. (2020b). Re-Interpreting the Imrahor Valley (Ankara-Turkey) in terms of Green Infrastructure Directing Urban and Rural Development. *Acta Horticulturae et Regiotecturae*, 23(2), 87-95.
- Kavanoz, S. E. (2020). "Kentsel Direnç" Kavramı Üzerine. *Kent ve Çevre Araştırmaları Dergisi*, 2(1), 5-24.  
<https://dergipark.org.tr/en/pub/yykentcevre/issue/55330/733459>
- Kaya, M. Y., & Osman, U. (2019). Ekosistem Hizmetleri ve Mekânsal Planlama İlişkisinin Peyzaj Planlama Çerçevesinde Değerlendirilmesi. *Düzce Üniversitesi Bilim ve Teknoloji Dergisi*, 7(3), 2166-2193.
- Renaud, F. G., & Murti, R. (2013). *Ecosystems and Disaster Risk Reduction in the Context of the Great East Japan Earthquake and Tsunami: A Scoping Study Report to the Keidanren Nature Conservation Fund*. Roger Sayre, Deniz Karagulle, Charlie Frye, Timothy Boucher, Nicholas H. Wolff, Sean Breyer, Dawn Wright, Madeline Martin, Kevin Butler, Keith Van Graafeiland, Jerry Touval, Leonardo Sotomayor, Jennifer McGowan, Edward T. Game, Hugh Possingham, 2020. An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems, *Global Ecology and Conservation*, Volume 21, <https://doi.org/10.1016/j.gecco.2019.e00860>
- Steinitz, C., 2012. *A Framework for Geodesign: Changing Geography By Design*. ESRI Press.
- Tuğaç, Ç. (2019). Kentsel dirençlilik perspektifinden yerel yönetimlerin görevleri ve sorumlulukları. *İdealkent*, 10(28), 984-1019.

## **From Fallow to Flourishing: Nbs Ideas and Implementation Strategies For Belfast**

Seán Cullen

*Queen's University Belfast*

### **Abstract**

Implementing nature-based solutions (NBS) in Belfast offers distinct challenges and opportunities shaped by the city's unique post-industrial landscape and complex socio-political history. The city's fractured urban form - marked by aging infrastructure, derelict land, and the remnants of industries such as shipbuilding, glassworks and linen production - create a patchwork of both obstacles and potential.

This presentation explores a series of NBS initiatives in Belfast that collectively demonstrate the spectrum of implementation strategies, from top-down planning to bottom-up co-creation. It examines how these approaches generate different kinds of social, ecological, and spatial outcomes, and how they reflect varying theories of change within the urban context.

Top-down approaches often emphasise large-scale strategic interventions - such as citywide urban agriculture systems, integrated food-water-energy networks and urban intensification of underused areas. These projects leverage institutional power, long-term planning and qualitative evaluation methods to explore systemic shifts in lifestyle, infrastructure and economy.

In contrast, bottom-up initiatives emerge through collaboration with local communities, focusing on co-design, participatory visioning and small-scale site activation. Projects such as the UPSURGE urban park foreground community agency, place-based knowledge and experimental design processes that challenge conventional procurement and governance models.

Together, these diverse cases illuminate how NBS can become vehicles for cultural regeneration, environmental repair and civic innovation. The paper argues that the interplay between bottom-up and top-down modes of implementation - and the role of design within both - is crucial to unlocking the broader transformative potential of NBS in fragmented cities like Belfast.

**Keywords:** urban agriculture, implementation, co-design, Belfast

# **SB1/2/3: Inclusive and Collaborative Governance of Nature-Based Solutions: Advancing Awareness, Partnerships, and Socio-Environmental Justice**

## **Introducing the Landscape Digital Twin**

Henk Alkemade

*4DLandscapes*

### **Abstract**

The Landscape Digital Twin (LDT) is proposed as a tool to integrally assess, monitor, model and simulate landscape development from the -deep- past into the future.

A digital twin is a digital representation of a physical object, that can be used to simulate its behaviour in a digital environment. The concept has been used in engineering, architecture for decades and more recently in cultural heritage (“heritage twin”). In the case of the heritage twin it aims to combine all relevant available data related to the physical object in order to digitally document heritage in a more comprehensive way (Niccolucci et al, 2023).

While digital twins have proven their worth in numerous fields, systematically connecting spatial and temporal data for landscapes through a Landscape Digital Twin has yet to be fully realized. The LDT aims to merge spatial and temporal characteristics of landscapes, integrating data from various sources, both historical and contemporary. This holistic approach can greatly benefit scientific research, conservation, restoration, and sustainable land use practices.

The European Landscape Convention defines landscape as: “An area as perceived by people, whose character is the result of the action and interaction of natural and/or human factors” (Council of Europe, 2000). The landscape is the largest living archive of interactions between humans and nature, often spanning millennia. It provides an integrative framework for designing and monitoring Nature-Based Solutions (NBS). The perception of a landscape varies with the observer's viewpoint, and different features and relationships become apparent at different scales.

The LDT allows for connecting the location with a great diversity of sources. From topographical maps, satellite images, aerial photos, historical maps, archival material, historical images, research papers etc. It is interdisciplinary by nature, combining insights from earth sciences, ecology, archaeology, history, land use management and technologies such as remote sensing, data analytics and machine learning.

Like the physical landscape, the LDT is a living archive that can be continuously updated with new data. It is scalable, capable of representing elements ranging from the smallest features to continental-sized landscapes. It not only enables exploring the development in time of one particular landscape, but comparison with other relevant LDT's as well. The level of detail available may vary depending on the location and time period, but the LDT's flexibility ensures that it remains a valuable tool for diverse applications.

The Landscape Digital Twin represents a potentially transformative approach to landscape management. By providing a detailed, dynamic, and interactive model of landscapes, it enables stakeholders to monitor, predict, and optimize the outcomes of

Nature Based Solutions.

I would like to conclude with a call to action for discussing and investigating possible collaboration to create LDT's of landscapes of interest.

**Keywords:** Digital Twin, Landscape, NBS

**References**

1: arXiv:2302.07138, <https://doi.org/10.48550/arXiv.2302.07138>; 2.  
<https://www.aup-online.com/content/journals/10.5117/JEL2024.1.002.SHAK>

**Acknowledgments:** Prof. em. dr Anton Imeson for his continuing inspiration and encouragement

## **Measuring What Matters: Co-Creation Indicators For the Socio-Political Dimensions of Nature-Based Solutions**

Andreia Barbas<sup>1</sup>, Beatriz Caitana<sup>1</sup>, Joana Santos<sup>1</sup> and Gerd Lupp<sup>2,\*</sup>

<sup>1</sup>*CES - Centre for Social Studies, University of Coimbra, Coimbra, Portugal*

<sup>2</sup>*Chair for Strategic Landscape Planning and Management, TUM School of Life Sciences, Technical University of Munich, Munich, Germany*

### **Abstract**

TRANS-lighthouses, a Horizon Europe-funded project works on strengthening socio-politics as part of the political agenda for nature-based solutions towards transformative change to rethink and reframe the main elements that compose the complexity of creating inclusive, social and ecologically just solutions. For participatory monitoring and evaluation of co-creation processes around Nature-Based Solutions (NBS) involving all relevant stakeholders, impacts can be assessed using indicators at different stages of the co-creation processes. Indicators determine characteristics or signs to show a certain development or state that has occurred and is made visible.

To develop and build a set of indicators for the socio-political dimensions of NBS, as a first step, existing collections of indicators for evaluating the impacts of NBS were scrutinised. In the context of evaluating NBS, our work focuses on a critical and operational analysis of the European Commission's handbook of indicators (EC, 2021; a key publication collecting evidence from EU-funded NBS projects), in the project's dimensions: participatory governance (15 indicators), social (21), human-nature (14), and economic (7). Starting from this framework, we established a dedicated working group to question, refine, and expand the understanding of each indicator. This involved assessing their measurement units, timing within the project lifecycle, underlying research questions, data collection methods and tools, strengths and weaknesses, data type and scale, frequency, and required level of expertise.

The resulting insights were compiled into an Excel-based analytical matrix, which served as the foundation for 2 collaborative workshops with the entire project team composed of researchers and practitioners. These sessions led to the co-selection of 4-5 priority indicators per dimension, balancing relevance and feasibility in the project's specific context.

This work provides significant contributions to the evaluation of NBS, especially by bridging the gap between theory and practice. Through a critical translation of the European Commission's indicator framework, this was particularly important in addressing complex and often intangible processes, such as participatory governance and social impact, which remain challenging to quantify. Creating an adaptable Excel-based analytical tool allowed for a structured examination of each indicator, and its collaborative refinement through a series of workshops ensured that the final selection

was both meaningful and feasible. To further support usability and dissemination, the selected indicators will be translated into practical indicator cards. This participatory and applied approach lays the groundwork for a more dynamic and systemic evaluation in future phases, where clusters of indicators may reveal deeper interconnections across the social, political, environmental, and economic dimensions of NBS.

**Keywords:** NBS Co-Creation, Socio-Politics, Justice, Inclusiveness, Indicators

### **References**

EC - European Commission: Directorate-General for Research and Innovation, Evaluating the impact of nature-based solutions - A summary for policymakers, Publications Office, 2021

**Acknowledgments:** TRANS-lighthouses has received funding from the European Union's Horizon Europe Framework Programme for Research and Innovation under Grant Agreement No. 101084628.

## **Assessment and Perception of Rural Socio-Ecological System Development in Suburban Conditions in Central Europe**

Marta Dobrovodská and Andrej Raniak

*Institute fo Landscape Ecology SAS, Bratislava, Slovakia*

### **Abstract**

The main objective of our study was to propose a methodology for identifying the course of the development of the rural socio-ecological system in suburban Slovakia at the municipality level. Our methodology is based on a comparison of data over two time horizons, both a quantitative evaluation over approximately 25 years (socio-economic indicators, social welfare indicators and land use) and a complementary sociological evaluation (a questionnaire survey on the perception of land use changes over the last 20 years, of expected change in the next 20 years, and of the ideal state of land use). We applied the method to the village of Báb as a pilot area. The resulting quantitative assessment showed that the development of the village has characteristics of developing residential use, complemented by conventional agriculture. The results of the survey on the perception of land use changes to date differ from the actual quantitative data. In terms of expected changes, residents expect primarily an increase in built-up areas and a decrease in agricultural, natural and semi-natural areas. Their vision of ideal land use is focused on slowing down the development of housing areas and turning attention to housing quality, spatial well-being and restoration of the agricultural character of the settlement. Our results confirmed that research on the linkages between the social and ecological subsystems can influence the well-being of local populations by taking into account their preferences or requirements for the landscape patterning, as well as for the development of economic activities, in the spatial planning process.

**Keywords:** internal migration, land use, indicators, social welfare, spatial planning

**Acknowledgments:** This contribution has been prepared with the support of the Agency for the Support to Research and Development, Project APVV-17-0377, "Assessment of recent changes and trends in agricultural landscape of Slovakia", and with the support of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences, Grant No. 2/0135/22, "Research of specific landscape elements of bio-cultural landscape in Slovakia".

## **Designing For Transformation: a Framework For Resilient and Sustainable Food Systems Within Safe and Just Operating Spaces**

Saskia Visser, Saskia D. Keesstra, Lena Grobusch, Stewart Gee, Laurene Lebelt, Denyse Julien and Aleksandra Goldys

*1Climate KIC, Plantage Middenlaan 45, 1018 DC, Amsterdam, Netherlands*

### **Abstract**

Food systems lie at the heart of some of the greatest challenges of our time—climate change, biodiversity loss, social inequity, and global health crises. Food systems are both drivers and victims of systemic fragilities, pushing planetary boundaries while failing to ensure basic social foundations. In response, there is growing recognition of the need for integrated, actionable frameworks that move beyond diagnosis to guide transformational change. This paper presents a novel framework for the design of resilient and sustainable food systems, drawing on and integrating four key conceptual pillars: the Planetary Boundaries framework (Rockström et al., 2009), the Doughnut Economy (Raworth; 2017), the 4 Returns approach from Commonland (Ferweda, 2024) , and the "safe and just operating space" paradigm (Oliver et al., 2022)

The framework begins by positioning food systems within the ecological ceilings and social foundations articulated by the Doughnut model, ensuring that environmental sustainability and social justice are addressed in tandem. It then adopts the Planetary Boundaries framework to define biophysical limits and identifies key thresholds relevant to food production, land use, water, nitrogen, and biodiversity. The 4 Returns model—return of inspiration, social capital, natural capital, and financial capital—is embedded as a core design principle for long-term, regenerative landscape development. To translate these conceptual foundations into practice, the framework emphasizes three sequential principles for transformation: Resilience, Sufficiency, and Efficiency. Resilience is prioritized to build systemic capacity to withstand shocks and stresses. Sufficiency guides the equitable distribution and use of resources, while efficiency ensures optimal use of energy, land, and labour without compromising system integrity. While existing models have contributed to a shared understanding of limits and needs, they often lack concrete pathways for integration and action. This framework aims to close that gap by offering a systems-based, transdisciplinary tool for the co-design of food systems that are ecologically safe, socially just, and economically viable. Transformation at the scale and speed required will demand such integrative approaches—ones that can align actors across scales and sectors toward a common vision of food system resilience.

**Keywords:** Food System Transformation, Planetary Boundaries, Doughnut Economy, Resilience, Sustainability Frameworks

## References

Rockström, J., Steffen, W., Noone, K. et al. A safe operating space for humanity. *Nature* 461, 472–475 (2009). <https://doi.org/10.1038/461472a>; Raworth, Kate. *Doughnut Economics : Seven Ways to Think Like a 21st-century Economist*. London: Random House, 2017. Ferwerda, W. (2024). *Commonland's 4 Returns: A Path to Sustainable Landscapes*, with Willem Ferwerda.

Digital or Visual Products

<https://www.designingnaturehalf.com/the-landscape-conservation-podcast/commonland-4-returns-framework-willem-ferwerda>; Oliver, Tom H et al. 2022 A safe and just operating space for human identity: a systems perspective *The Lancet Planetary Health*, Volume 6, Issue 11, e919 - e927

## **Advancing Climate Adaptation Through Forest-Based Nature-Based Solutions: a European Database Approach**

Saskia Keesstra

*Climate-Kic Foundation*

### **Abstract**

Nature-based solutions (NbS) in forests offer a range of strategies to mitigate and adapt to climate change and support ecosystem resilience and biodiversity. Key options include reforestation, afforestation, Sustainable Forest Management, Forest Conservation and Agroforestry. These NbS options [J(1) [S(2) in forests, if performed in a certain way, not only help mitigate climate change by sequestering carbon but also enhance the adaptability of both ecosystems and human communities to the impacts of a changing climate. An inventory of all NbS[C(3) [WV4] [S(5) for forests that are enhancing climate change adaptation (and important co-benefits for biodiversity and soil health) [M(6) [WV7] [S(8) [S(9) is being made in a database form. The database will include suitability mapping for: natural forest management and production forests in different climate zones in Europe, and under different socio-economic opportunities across Europe. The metadata collected such as geospatial, temporal, biophysical and socio-economic data, will be used to document and organize NbS in forestry systems, making it easier to analyze, share, and apply these solutions effectively. This metadata helps ensure that nature-based solutions are well-documented, transparent, and facilitating better decision-making, reporting, and replication of successful NbS initiatives.

**Keywords:** Biodiversity, Carbon Sequestration, Soil Health Metadata, Suitability Mapping, Socio-economic Factors, Ecosystem Resilience





# Index

## 1

137Cs technique 108

## A

abandonment 133  
adaptation 198  
adaptive management 112  
aggregate stability 189  
AgMAR 182  
agricultural landscapes 119  
agricultural management practices 77  
agriculture 74  
Agriculture 94  
agriculture 6.0 61  
agroecological landscape 37  
agroforestry 193  
agro-hydrological modeling 182  
airborne sensing 129  
Air quality modelling 224  
ALDO 164  
anaerobic digestion 85  
Antimicrobial resistance 51  
APP 67  
aquifer 150  
Argania spinosa 156  
Arid industrial zones 106

## B

Belfast 233  
Best management practice (BMP) 165  
bio-based materials 198  
biochar 84, 102, 166  
Biochar 87  
bioclimatic indices 104  
Biodegradation 89  
Biodiversity 44, 242  
Biodiversity-Driven Agribusiness 47  
Bio-inspired techniques 141  
Biological Ageing 60  
Biomass carbon storage 106  
Bioprocessing 200  
Bioremediation 150  
Bioretention cell (BRC) 165

birch 41  
Bosnia and Herzegovina. 73

## C

C3-derived carbon 116  
carbon farming 55  
Carbon Farming 171  
carbon sequestration 85, 121, 199  
Carbon sequestration 106, 164  
Carbon Sequestration 242  
CARDIMED 223  
cascina architecture 131  
Case Study 194  
Cereals 110  
chlorinated solvents 150  
circular agriculture 131, 166  
Circular Economy 63  
circular economy 219  
Citrus 91, 97  
City 224  
civic engagement 37  
Climat Change 44  
climate 177  
climate adaptation 131  
Climate Adaptation 146  
climate change 81, 85  
Climate change 113  
Climate Change 221  
Climate Change Adaptation 133  
Climate change mitigation 106  
climate data 104  
climate impact 104  
climate resilience 175, 207  
Climate resilience 216, 223  
climate-resilient agriculture 73  
Climate Resilient Land Management 87  
Climate Vulnerability 184  
CO2 emissions 102  
co-creation 147, 175  
co-design 233  
communication strategies 75  
community resilience 75  
CoMOLA 80  
comparative case study approach 202

compost 166  
Comprehensive Framework 214  
construction and demolition waste 219  
Control 97  
cooperation 61  
Co-production of Knowledge 146  
Coprophilous fungal spores 78  
Cover crops 100  
cover crops 189  
Crop phenology 127  
culinary heritage 230

## D

data cleaning 104  
Decentralized Flood Protection 186  
dechlorination 150  
Decision Support System (DSS) 65  
deep demonstrations 200  
Dehesa/Montado 83  
Dendrogeomorphology 204  
Diabase 118  
digitalization 67  
Digital Twin 236  
digitisation 61  
Doughnut Economy 240  
Drought 113  
droughts 53  
Dual-pol decomposition 127  
dual-pol radar 124

## E

ecological condition 112  
ecological interactions 36  
ecological restoration 37  
Ecosystem-Based Value Creation 47  
Ecosystem Resilience 242  
Ecosystem restoration 164  
ecosystem services 112  
Ecosystem services 216  
education 185  
Element mobility 118  
Emerging contaminants 51, 151  
energy landscapes 131  
environmental degradation. 177  
environmental education 37  
environmental indicators 157  
Erodibility 70  
Erosion 91, 94, 97, 100

ERT 134  
EU regions 202  
Europe. 119  
experiments 185  
exploratory data analysis 104  
extreme hydrometeorological phenomena  
204

## F

FAO Penman-Monteith 73  
fertile islands 156  
fertirrigation 193  
field campaign 180  
fire frequency 139  
flood risk communication 75  
floods 53  
Food System Transformation 240  
Forest 44  
forest inventory 157  
forest restoration 36  
Forestry 194  
former land use 116  
fruit production 73  
Fungal treatment 141  
fungal treatment 142  
Future Landscapes 162

## G

Generative AI 162  
Geodesign 232  
geomatics 177, 212  
Gerlach trough 57  
GIS 197  
GIS-based MCDA 182  
Google Earth Engine 153  
grain size distribution 57  
Granada 153  
grasslands 78  
grazing pressure 78  
green infrastructure 112, 197  
Green Infrastructure 221  
Green metropolis 35, 228

## H

Hargreaves-Samani 73  
heavy metals 151, 226  
heavy rainfall 41  
hedgerows 81

historical rural landscapes 81  
Hron river 113  
Hydraulic conductivity 180  
Hydrological characterisation 134  
hydrometeorological hazards 191  
hydrophobicity 189

## I

implementation 233  
Inclusive Governance 184  
Inclusiveness 238  
Indicators 238  
indicators 239  
Innovation. 60  
integrated evaluation 119  
interaction 139  
inter-institutional collaboration 37  
internal migration 239  
Iran 70  
irrigation optimization 73  
Italy 157

## J

Justice 238

## K

Keywords Carbon 44  
Keywords  
- Evapotranspiration 73  
Keywords—LUS = LAND USE SYSTEM 48  
Keywords  
- Traditional Andalusian Wines 60

## L

Land-Agri-Food Transition 87  
land cover 139, 157  
Landcover 164  
Land degradation 137  
Land Degradation 161  
land management 83  
Landscape 236  
Landscape components and processes 232  
Landscape First 35, 228  
landscape function analysis 168  
Landscape pain 35, 228  
Landscapes 162  
landslides.. 204  
landslides suscepibility 144

land surface temperature 197  
land use 239  
Land Use/Land Cover Classification 153  
LC = LAND COVER 48  
lead 226  
LFA 168  
light grey water 219  
Living Labs 171, 200  
Low Impact Development 225  
LUCAS 2018 153  
LUP4 LDN = LAND USE PLANNING FOR  
LAND DEGRADATION NEUTRALITY 48

## M

machine learning 55, 208  
Machine learning 70  
magnetic susceptibility 108  
Mainstreaming 210  
Management 97  
MAOM 121  
mapping 112, 212  
MAR 180  
mass wasting processes 204  
measures 199  
Mediterranean 161  
Mediterranean agroecosystems 166  
Mediterranean cities 223  
Mediterranean wetlands 151  
microbial diversity 83  
Microbiology 60  
Microbiome 51  
microplastics 185  
milpa 230  
monitoring 124  
monitoring plans 193  
Monterrey 35, 228  
Montesa 91  
Multifunctional Forest Management 194  
multi-objective optimization 80  
multiple land degradation processes 119  
multiple linear regression 108  
multiple spatial scales 119  
multispectral data 129  
Murcia 223

## N

Natural Based Solutions 89  
natural ecosystem 198

Natural Rainfall 84  
Natural Source Zone Depletion 89  
Nature-based Solution 87  
Nature based Solutions 216  
nature-based solutions 53, 73, 182, 191  
Nature-based Solutions 137, 184, 202, 214  
Nature-based solutions 207, 210, 221  
Nature-based solutions. 198, 224  
Nature-Based Solutions (NBS) 37  
Nature-based solutions (NbS) 223  
Nature-driven 35, 228  
NBS 81, 175, 193, 236  
NBS Co-Creation 194, 238  
NDVI 129, 168  
non-structural measures 75  
northeastern Mexico 230  
northern India 182

## O

object detection 208  
olive mill wastewater 166  
olive pruning 166  
One health 51  
organic agriculture 230  
Organic Fertilizers 63  
Organic Matter 121

## P

Paludiculture 38  
ParetoPick-R 80  
Participatory Monitoring 184  
past herbivore 78  
Peatlands 38  
pedo-climatic condition 139  
Penicillium Chrysogenum 142  
pharmaceuticals 151  
phytoremediation 226  
Pig slurry 63  
pine 41  
Planetary Boundaries 240  
Plough Pan 186  
Pluvial flash floods 186  
Pluvial Flooding 221  
PNRR-NODES 208  
Policy Innovation 87  
pollen 78  
POM 121  
precision agriculture 67

precision restoration 36  
preparedness and engagement 75  
project database 173  
province of Granada 177  
public perception 191

## R

rainfall interception 41  
Raising Water Table 38  
Random Forest 153  
regenerative agriculture 53  
Regenerative Supply Chain 47  
regolith 180  
remote sensing 55, 157, 197  
Remote Sensing 133  
Remote sensing 164  
Resilience 240  
Resilience of post-earthquake cities 232  
Restoration actions 161  
Rice monitoring 127  
Risk Perception 146  
Rock alteration 118  
Rock powder 118  
runoff 41  
Runoff 91

## S

Sahel Resilience 184  
satellite 124  
Satellite Imagery 161  
satellite observation 208  
Scaling 210  
Scattering power components 127  
Seasonal Composites 153  
Sentinel-1 127  
Sentinel-2 153  
Shallow Landslides 134  
Shallow landslides 137  
SLM =SUSTAINABLE LAND MANAGEMENT  
48  
Slovakia 113  
Social innovation 65  
social welfare 239  
Socio-economic Factors 242  
Socio-Politics 238  
Soil 51, 70, 94, 97, 100  
soil classification 177  
Soil conservation 65

soil conservation 84  
 soil digital mapping 110  
 soil erosion 57, 77  
 Soil erosion 212  
 soil erosion mitigation. 131  
 soil fertility 166  
 soil health 173, 189  
 Soil Health Metadata 242  
 Soil improvement 141  
 soil improvement 142  
 soil indicators 193  
 Soil Living Labs (SLL) 173  
 soil managements 144  
 soil mapping 83  
 soil moisture content 77  
 Soil Moisture Monitoring 186  
 soil nutrients. 108  
 soil organic carbon 55  
 Soil organic carbon 106  
 soil properties 110  
 soil quality indicators 110  
 Soil rehabilitation 108  
 Soils 63  
 soils 151  
 Soil Water Assessment Tool 77  
 Soil Water Content monitoring 137  
 soil water repellency 189  
 Soil water repellency (SWR) 165  
 southern Piedmont 189  
 spaceborne sensing 129  
 Spain 91, 94, 100, 212  
 spatial planning 239  
 sponge 53  
 Stakeholder Engagement 146  
 Standards and Audits 47  
 steep slopes 57  
 stormwater 41  
 Strategies 210  
 succession 36  
 Suitability Mapping 242  
 surveys 67  
 sustainability 61  
 Sustainability 63, 94, 100  
 Sustainability Frameworks 240  
 sustainable agriculture 80, 147  
 sustainable land management 173  
 sustainable rural development 131  
 Sustainable Urban Drainage System  
 (SUDS) 223  
 sustainable water management 73  
 Sweden 74  
 SWMM 41  
 systematic review 173

## T

Theory of change 210  
 tomatoes 129  
 topography 139  
 Transformational climate change  
   adaptation 202  
 transformation labs 175  
 transition 116, 147, 199  
 tree canopy 41  
 Trichoderma asperellum 141

## U

UAV 156  
 urban agriculture 233  
 urban densification 197  
 Urban flooding 223  
 urban foodscapes 230  
 urban greening 41  
 Urban runoff 225  
 urban runoff 226  
 urban trees 41  
 USLE Plots 84

## V

Vegetation Effects on Drainage 186  
 Vernacular architecture 198  
 Vineyards 124, 134  
 vineyards 212  
 vineyards. 57  
 vineyard soils 185  
 Viticulture 65, 133, 137

## W

Wastewater Regulations 214  
 Wastewater treatment 214  
 water and nutrient retention 80  
 water ditches 81  
 water holding capacity 102  
 Water resilience 131  
 water reuse 219  
 Water reuse 223  
 Water security 216, 225

Watershed 70  
water storage 74  
Weathering indicators 118  
Wetter Farming 38

## **X**

xerophyte 226

## **Y**

Yield prediction 129  
YOLO 208  
YOLOv8 Object Detection 133

## **Z**

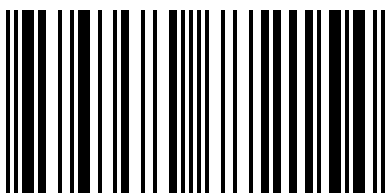
zero-effluent 200

## **Δ**

$\delta^{13}\text{C}$  116



ISBN 978-5-9807-7215-4



9 785980 772154 >