2nd Workshop on Sustainable Finance
Spoke 4 - GRINS

Università Ca'Foscari Venezia

GRINS FOUNDATION

Unravelling the Interplay Between Land Use Change and Surface Water Quality in Italian Watersheds

Authors: Hung Vuong PHAM, Samuele CASAGRANDE, Olinda RUFO, and Andrea CRITTO

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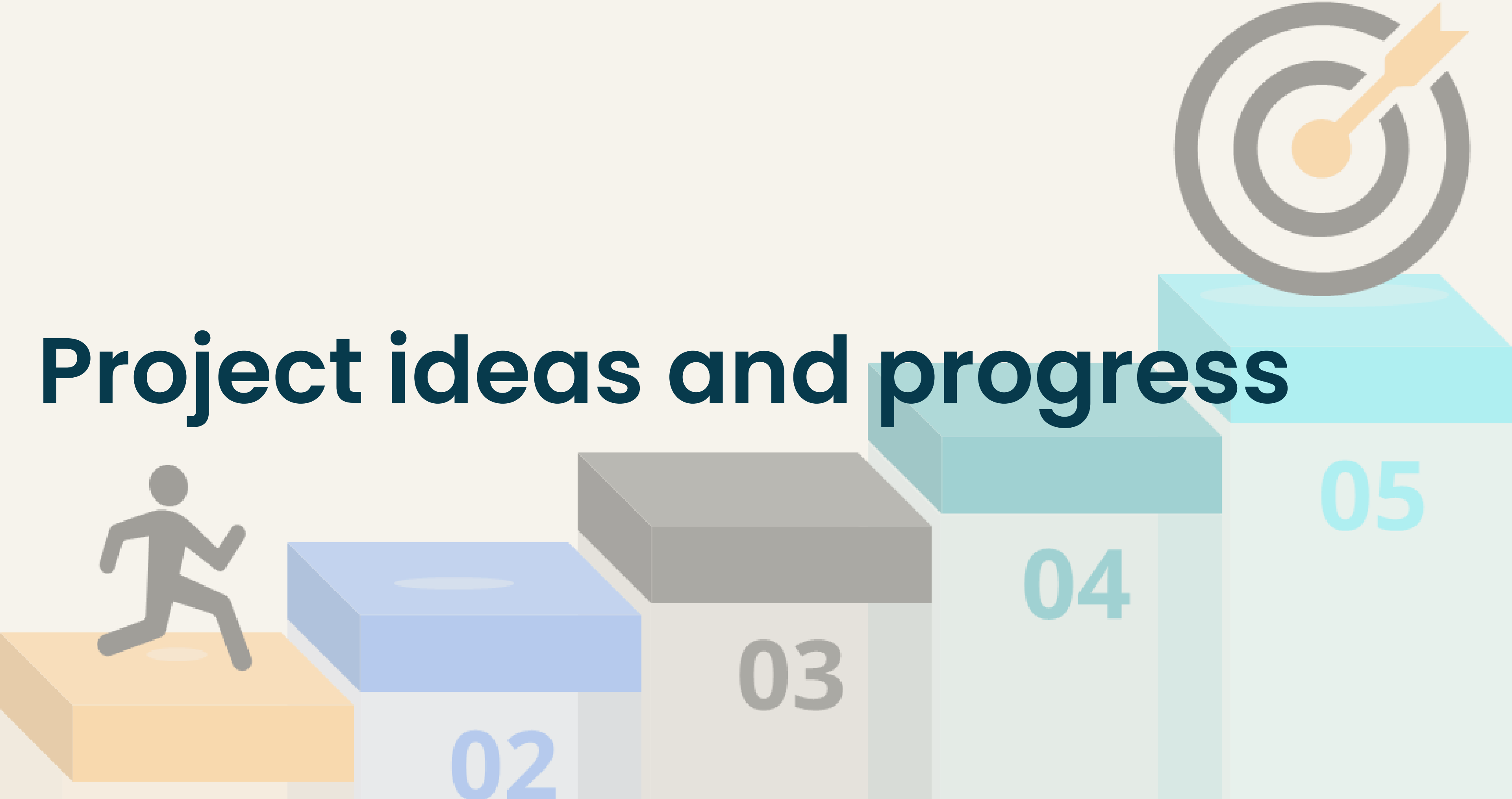
Project ideas and progress



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Objectives

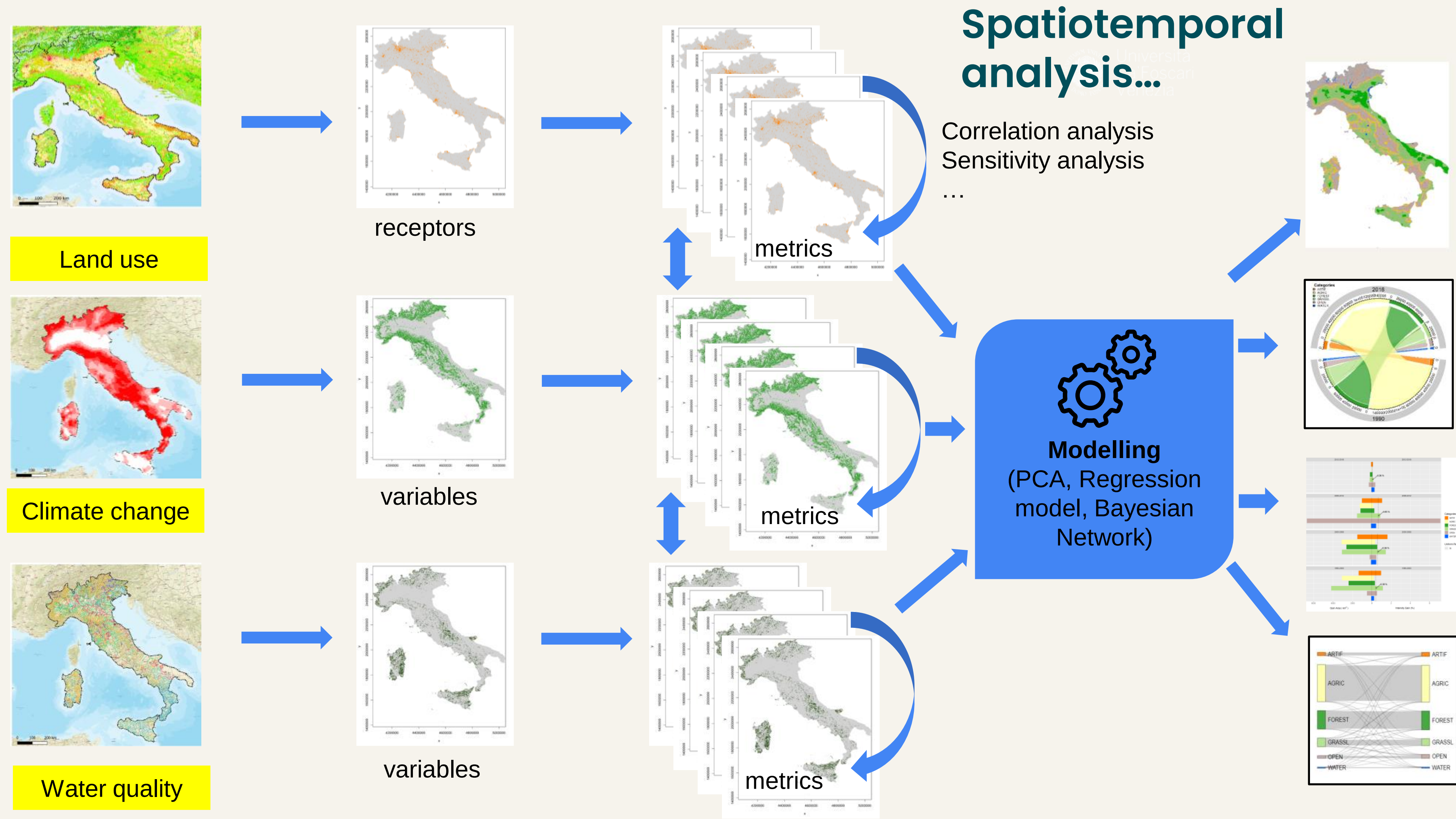
- Evaluation of land use/land cover change **(LULCC)** impacts on water quality in accordance to WFD (e.g., indicators and their spatio-temporal trend)
- Evaluation of climate change **(CC)** impacts on water quality in accordance to WFD (e.g., indicators and their spatio-temporal trend)
- Analysis of spatio-temporal dynamic impacts and interaction of LULCC&CC on water quality (e.g., addictive, synergistic, compound, etc.)
- Risk assessment and scenario analysis to assist policy-makers in designing mitigation and management strategies (e.g., storyline for different desired future)

Land use change

Climate change

Case study
Italy

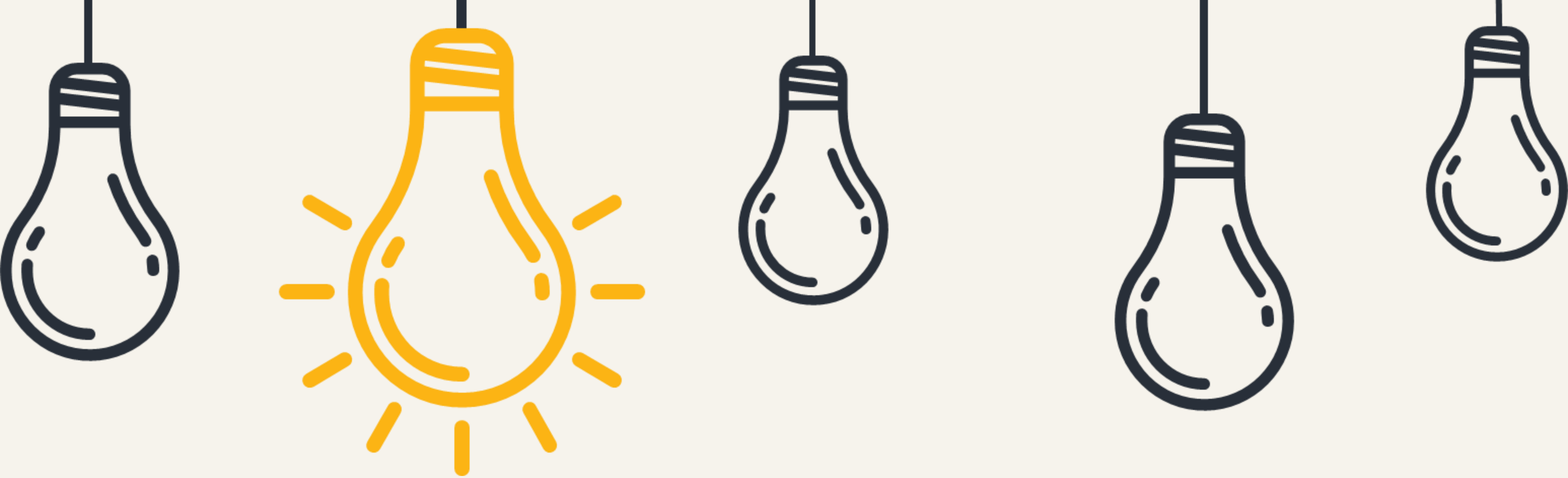
Water quality



Spatiotemporal analysis…
Correlation analysis
Sensitivity analysis
…
Land use
Climate change
Water quality
receptors
variables
variables
metrics
metrics
metrics
Modelling
(PCA, Regression model, Bayesian Network)
ARTIF
AGRIC
FOREST
GRASSL
OPEN
WATER

Overall progress

- Evaluation of land use/land cover change **(LULCC)** on Water Quality => Done. A Master's Thesis was successfully defended in October 2024.
- Evaluation of Climate Change **(CC)** on Water Quality => Complete the conceptual model, Positive evaluation of the 1st year PhD of Olinda Rufo
- Dessiminate the results in different conferences across Europe, China, and the USA.



Application on Land Use/ Land cover Change and Surface Water Quality

Objectives Of The Study

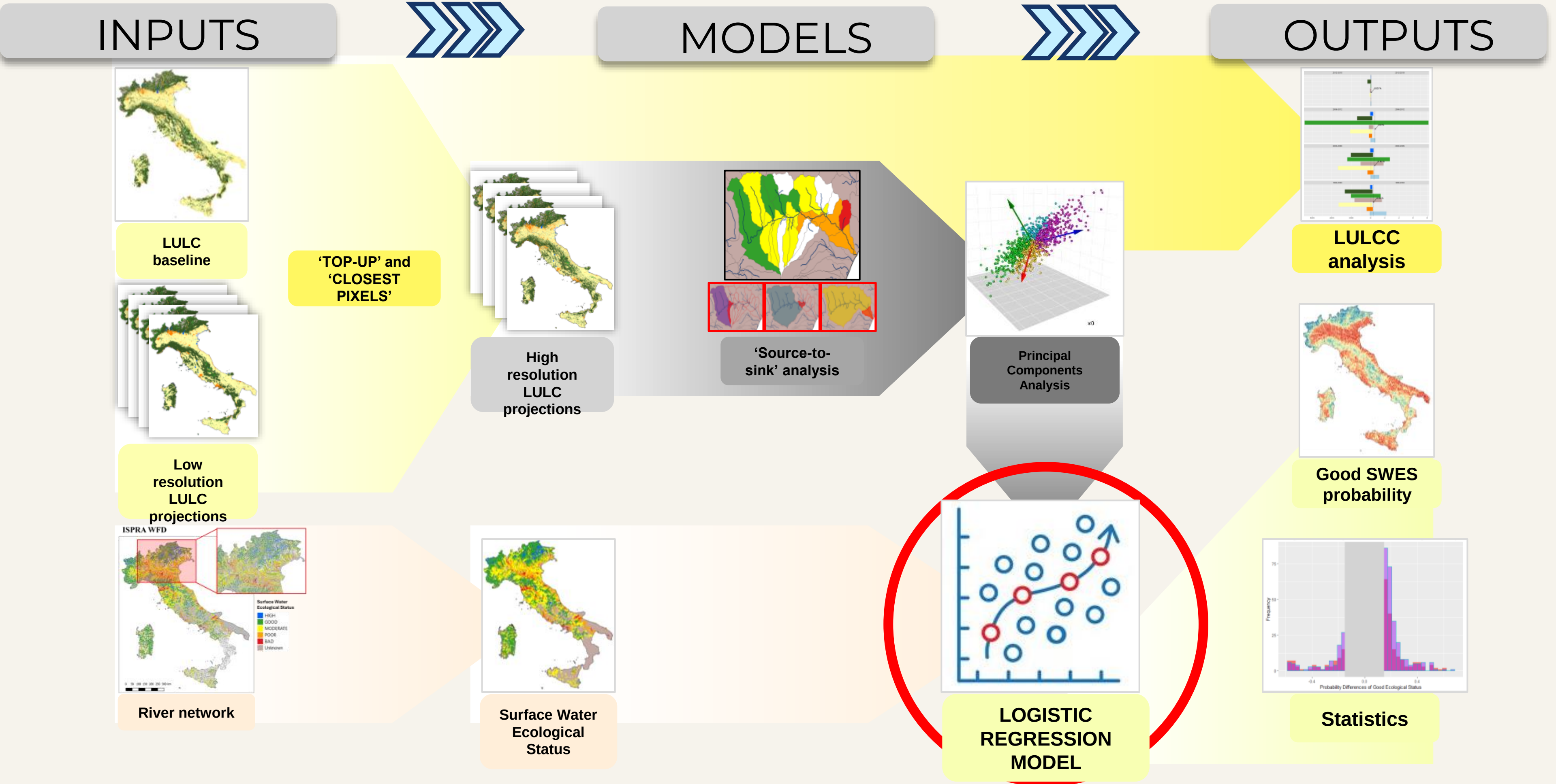
LU & LULCC Analysis

- LULCC between **1990** and **2018** in Italy.
- Baseline for **future LULC projections** and policy recommendations.
- **High-resolution LULC maps** for SSP-RCP scenarios

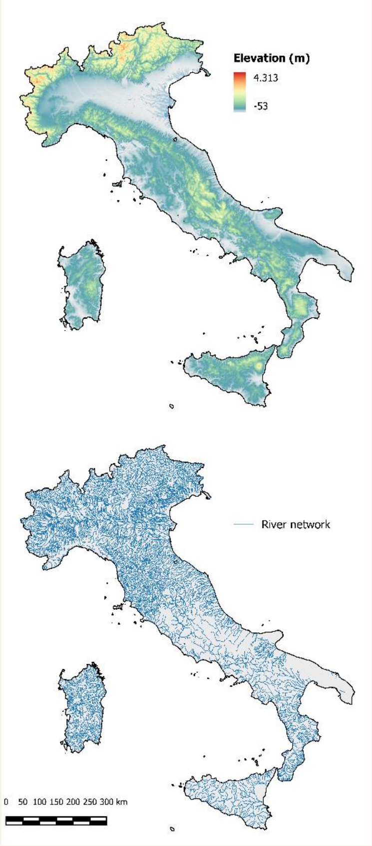
LULC Influence On SWES

- Influence of **upstream LULC** on downstream water quality.
- Likelihood of achieving a **good SWES** under different future **SSP-RCP scenarios**.

Overall methodology



Case Study Area



Location

47°50'29" N to 35°47'00" N Lat.

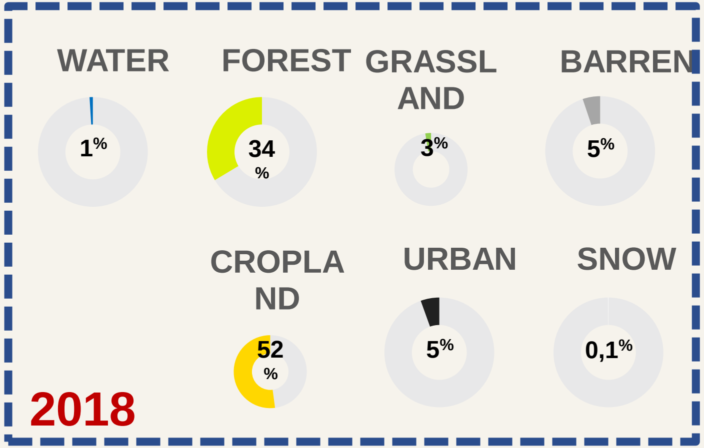
6°32'05" E to 18°31'01" E Lon.

Coastline

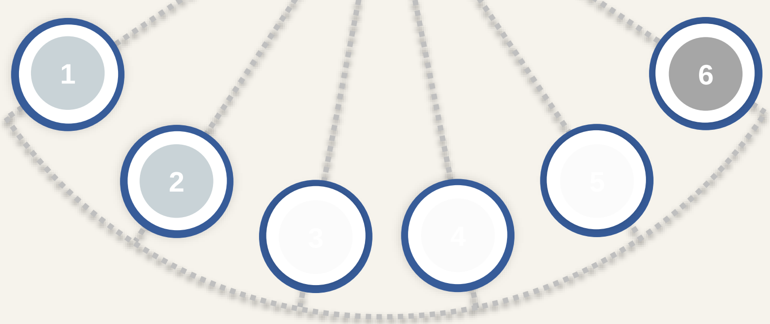
7,375.3 km

Total area

302,073 km^2



Case Study Data



1

Land Cover (CORINE)

Spat. Domain: Europe
Spat. Res.: 100 m * 100 m
Time Frame: 1990 – 2018
Format: Vector/Raster

2

LULC projections (Chen, 2022)

Spat. Domain: Global
Spat. Res.: 1 km * 1 km
Time Frame: 2015 –2100
Format: Raster

3

River Network (GISCO)

Spat. Domain: Europe
Spat. Res.: 1 arc-second
Time Frame: – – –
Format: Shapefile

4

Watershed (GISCO)

Spat. Domain: Europe
Spat. Res.: 1 arc-second
Time Frame: – – –
Format: Shapefile

5

Watershed (HydroSHEED)

Spat. Domain: Global
Spat. Res.: 15 arc-second
Time Frame: – – –
Format: Shapefile

6

Water Quality WFD (ISPRA)

Spat. Domain: Italy
Spat. Res.: – – –
Time Frame: 2010 – 2016
Format: Vector/Raster

Surface Water Ecological Status

Water Frame Directive

1

High Status: Near-natural, undisturbed conditions. Physio-chemical elements within pristine ranges.
Full ecosystem functionality

2

Good Status: Some deviation from undisturbed conditions, physio-chemical elements still support ecosystem health. Nutrient levels higher than in pristine conditions.
Ecosystem remains functional

3

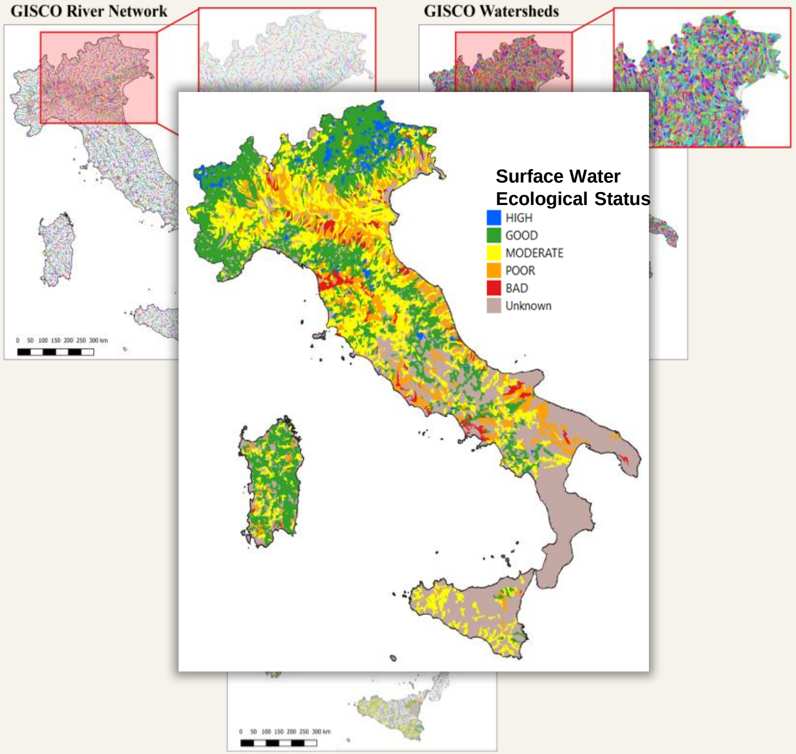
Moderate Status: Clear anthropogenic influence. While physio-chemical conditions support ecosystem functioning, they reflect more disturbance.
Suboptimal ecosystem health

4

Poor Status: Significant alterations from natural conditions. Physio-chemical elements are outside the ranges necessary for a healthy ecosystem.
Ecosystem degradation

5

Bad Status: Physio-chemical elements are at extreme, unnatural levels.
Ecosystem collapse and a near-total loss of biodiversity and ecological function



Land Use Land Cover

Layers Harmonization

1. CORINE Land Cover

Standardized framework for LULC analysis across Europe

Nomenclature:

- Level 1: 5 broad-level categories
- Level 2: 15 sub-level categories
- Level 3: 44 detailed thematic classes

2. ESA Climate Change Initiative (CCI)

Land use framework of the European Space Agency, used by Chen et al. (2022)

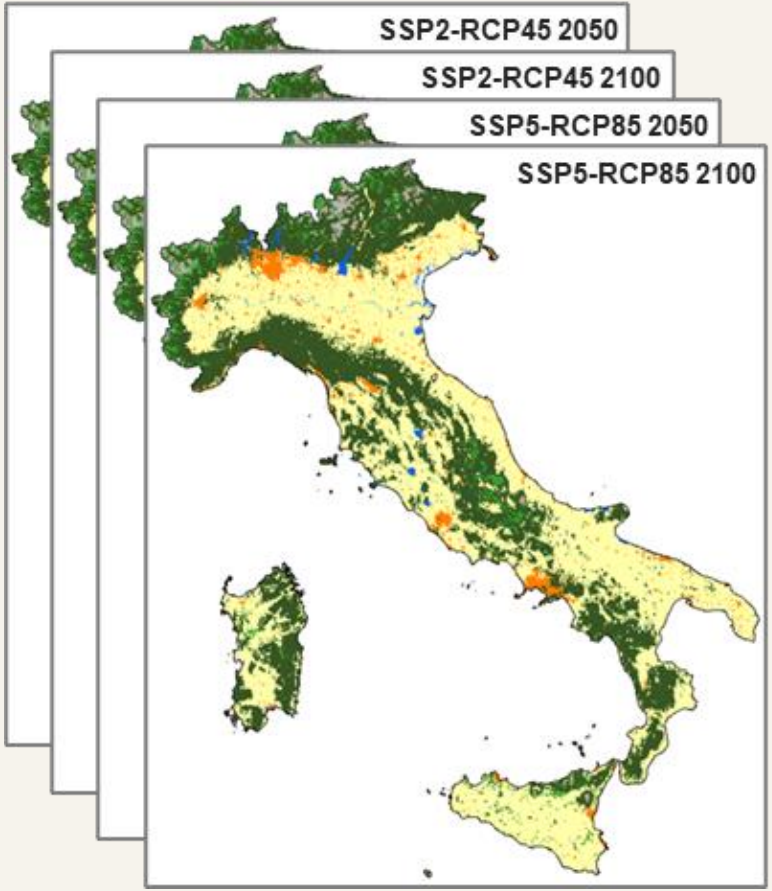
Nomenclature:

- 22 thematic classes

→ **Harmonization**: **7 macro-categories**

WATER | GRASSLAND | CROPLAND | SNOW

FOREST | BARREN | URBAN



Results - Land Use Land Cover Change Analysis

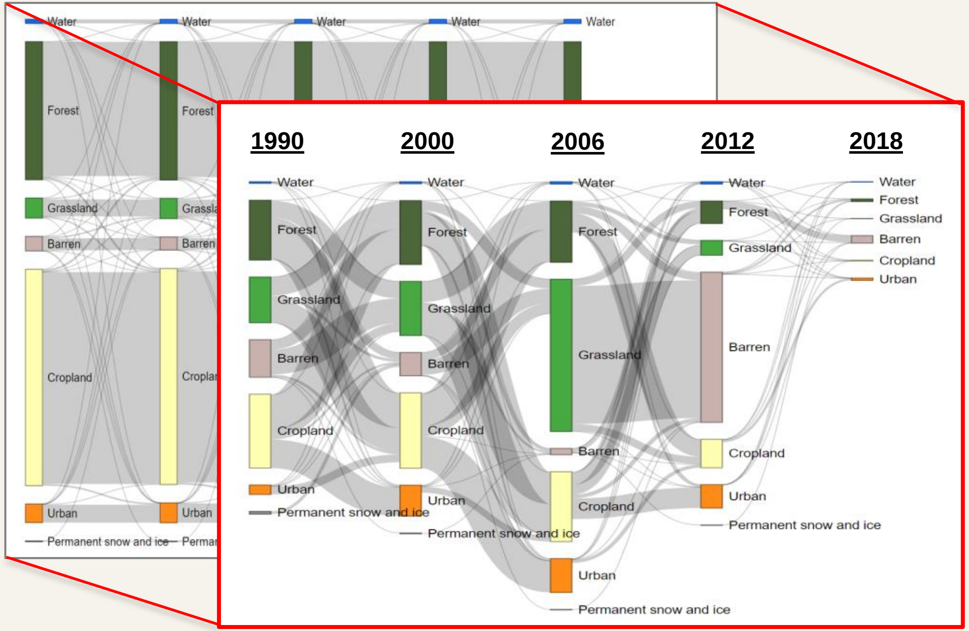
“Analysis of variations in how land is utilized or covered by different human or natural activities over time, aimed at understanding the ecological, socio-economic, and environmental dynamics affecting the landscape.”

Accumulated Changes Map
Frequency and intensity of land cover transitions at the pixel level
- → number of changes each pixel experienced **(a)**
- → number of pixel changes per watershed **(b)**

Net/Gross Changes
- → Gross Gains (GG): total area added to a category
- → Gross Losses (GL): total area subtracted from a category
- → Net Change (NC): difference between GG and GL

Intensity Analysis – Category level
How size and intensity of GG and GL in each category vary across categories for each time interval

Sankey Land
Net flow of LU area transitions between different LULC categories

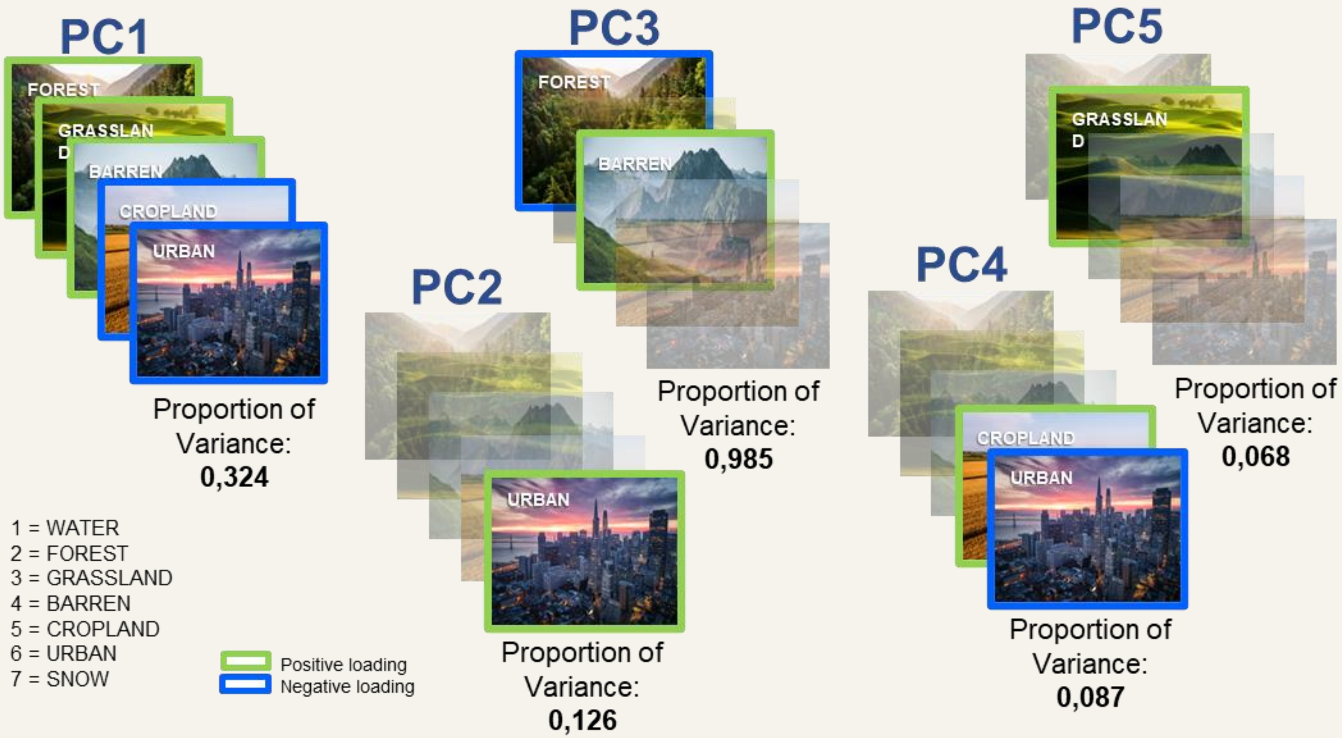


Results - Principal Component Analysis

Reduces dataset dimensionality while retaining the most significant variability.

→ **Principal Component (PC)**: linear combination of the original variables

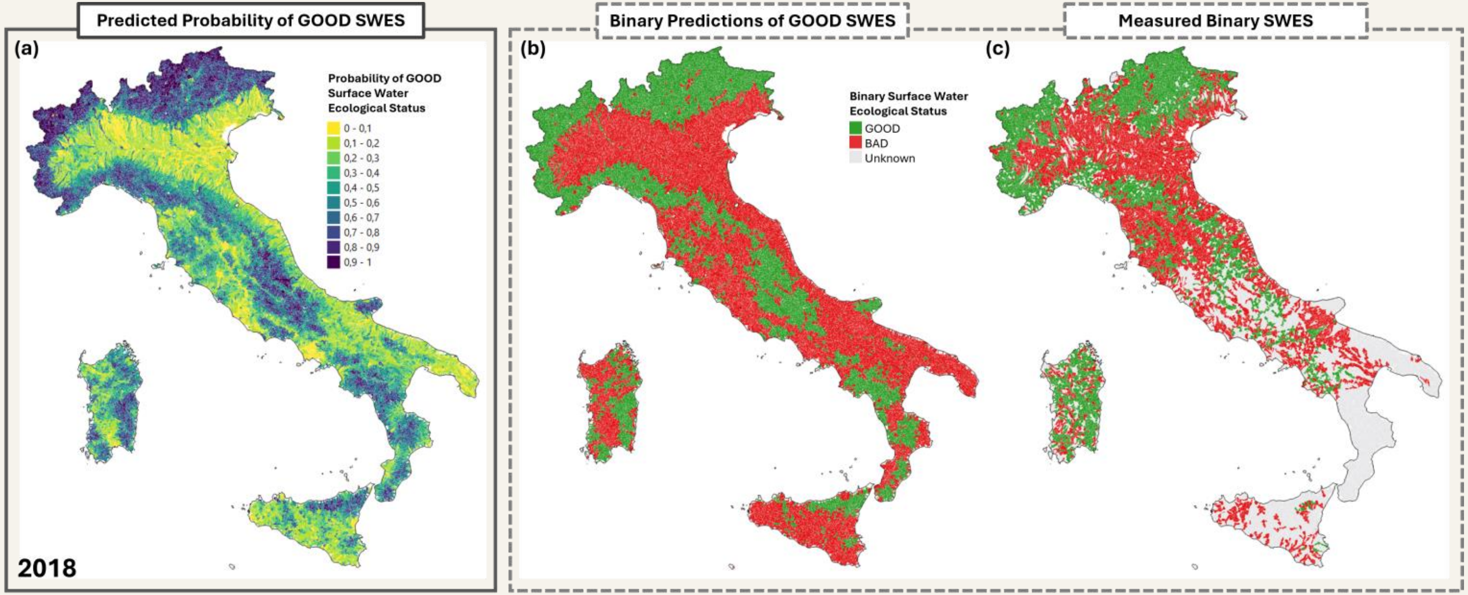
	PC1	PC2	PC3	PC4	PC5
ED_2	0,14	0,04	-0,25	0,01	-0,07
ED_3	0,20	0,07	0,07	0,14	0,45
ED_4	0,21	-0,03	0,30	-0,04	-0,08
ED_6	-0,17	0,29	0,10	-0,23	0,11
LPI_2	0,22	-0,01	-0,29	-0,19	-0,06
LPI_4	0,15	-0,11	0,43	-0,10	-0,13
LPI_5	-0,27	-0,07	0,06	0,26	0,02
LPI_6	-0,13	0,27	0,11	-0,34	0,14
PLAND_2	0,24	0,02	-0,33	-0,15	-0,09
PLAND_3	0,17	0,06	0,07	0,14	0,44
PLAND_4	0,18	-0,09	0,43	-0,08	-0,14
PLAND_5	-0,28	-0,03	0,03	0,25	0,01
PLAND_6	-0,15	0,31	0,13	-0,32	0,14
AREA_MN_2	0,17	0,08	-0,06	-0,06	-0,19
AREA_MN_4	0,13	-0,02	0,36	-0,02	-0,22
AREA_MN_5	-0,13	-0,03	0,09	0,30	-0,03
AREA_MN_6	-0,06	0,33	0,08	-0,13	-0,02
DIVISION_3	0,22	0,18	0,03	0,24	0,09
DIVISION_4	0,21	0,16	0,04	0,17	-0,11
DIVISION_5	0,20	0,23	-0,15	-0,12	-0,13
DIVISION_6	-0,09	0,35	-0,03	0,19	-0,20
IJI_2	0,21	0,21	0,05	0,00	0,09
IJI_5	-0,08	0,25	0,03	0,17	-0,09
PD_3	0,17	0,03	-0,02	0,08	0,44
PD_6	-0,18	0,15	0,08	-0,17	0,12
AI_2	0,20	0,10	-0,15	0,02	-0,16
AI_3	0,22	0,18	0,05	0,25	0,11
AI_4	0,23	0,13	0,15	0,14	-0,13
AI_5	-0,13	0,18	-0,06	0,26	-0,13
AI_6	-0,10	0,38	-0,01	0,15	-0,18



Results - Regression Model and SWES Predictions

Binary Logistic Regression (BLR)

Predicted Probability of GOOD SWES > 0,5 → 1 = GOOD
Predicted Probability of GOOD SWES ≤ 0,5 → 0 = NOT GOOD



Measured 2018 (c):
- 28.31% 'good' SWES
- 38.89% 'not-good' SWES
- 32.81% Unknown

Predictions 2018 (b):
- 37.87% 'good' SWES
- 62.13% 'not-god' SWES

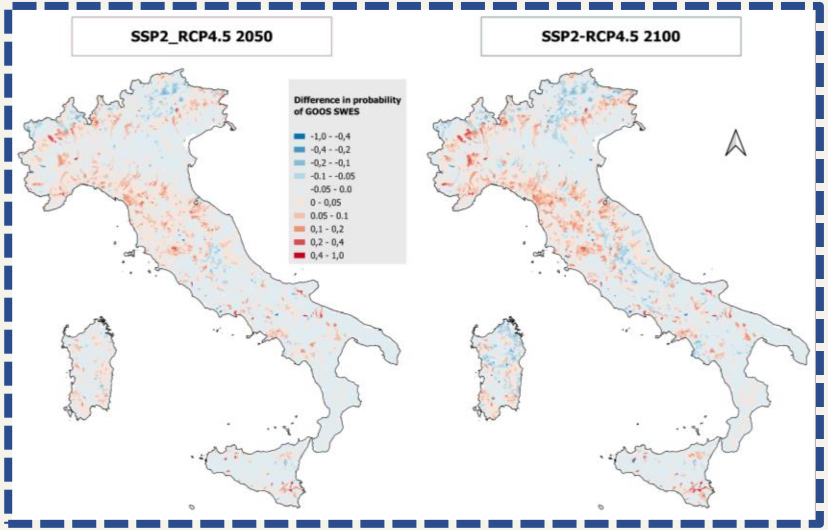
MC-CV: 89.54%
H&L: p-value 0.3949

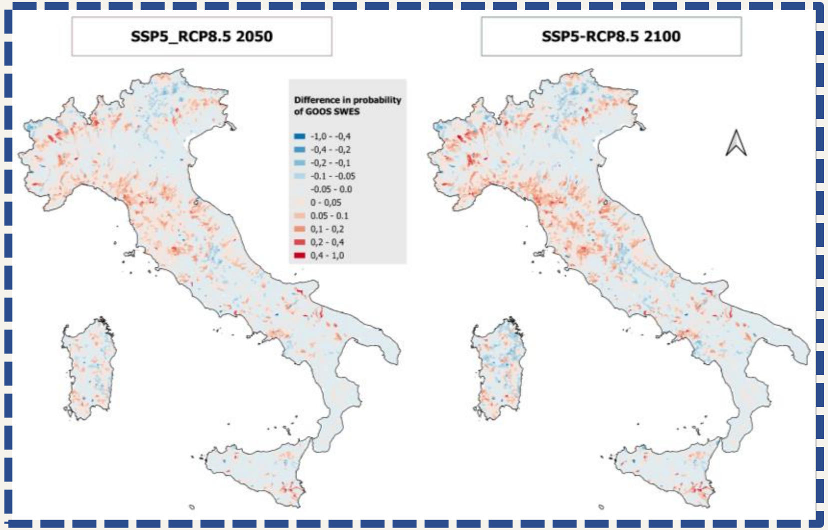
Results - Water Quality Predictions for Future Scenarios

Differences In Probability Of Good Ecological Status

→ $Probability\ Good\ SWES_{\ 2018} - Probability\ Good\ SWES_{\ SSP-RCP}$

- **Negative values** indicate that the probability of achieving good ecological status in 2018 was lower compared to that calculated for the respective SSP-RCP scenario → **INCREASE in water quality !!!**
- **Positive values** indicate that the probability of achieving good ecological status in 2018 was higher compared to that calculated for the respective SSP-RCP scenario → **DECREASE in water quality !!!**





Conclusions & Recommendations

- **Upstream-Downstream Dynamics**: Understanding upstream land use's influence on downstream water quality is critical for predicting surface water ecological status.

- **Conservation & Restoration**: Preserving and restoring natural areas is crucial for enhancing water quality across Italy.

- **SWES Projections**: In 2018, over 60% of Italian watersheds were predicted to fail in achieving good SWES. This percentage slightly increases under future SSP2-RCP4.5 and SSP5-RCP8.5 scenarios.

- **Hotspot Identification**: While significant changes are limited, the method identifies specific hotspots of improvement or decline in water quality, guiding targeted interventions in land use management and policy.

Project dissemination

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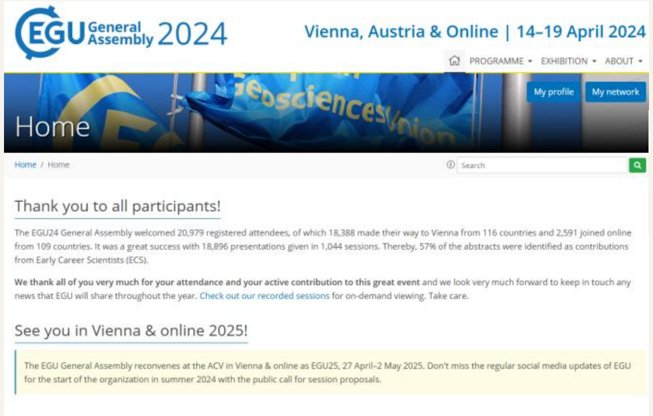
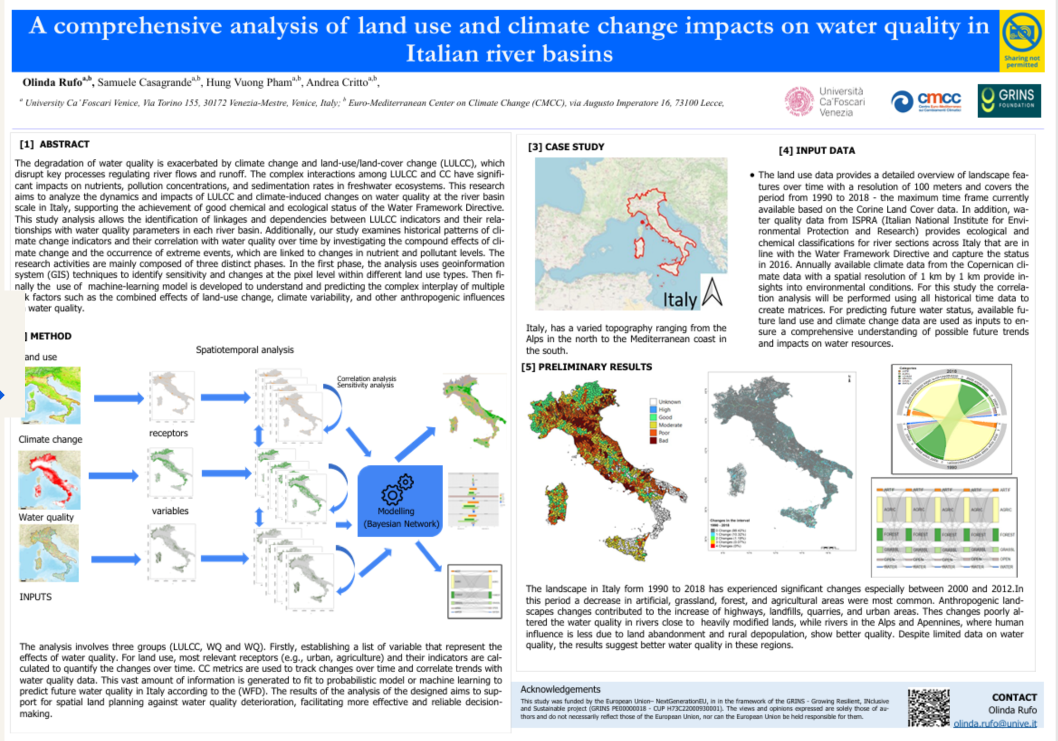


Poster



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Oral presentation

Multi-Risk Dynamics of Water Quality under Climate Change and Anthropogenic Pressures: An AI Approach Across Spatial Scales

Authors:

Jacopo Furlanetto[1,3,2], Diep Ngoc Nguyen[3,1], Olinda Rufo[3,1], Mathilda Vogt[3], Samuele Casagrande[3], Hung Vuong Pham[3,1], Anna Sperotto[3,1,4], Silvia Torresan[1,3,2], Andrea Critto[3,1]

[1] CMCC Foundation - Euro-Mediterranean Center on Climate Change, Italy
[2] National Biodiversity Future Center (NBFC), Palermo, Italy
[3] Department of Environmental Sciences, Informatics and Statistics, Ca' Foscari University of Venice, Venice, Italy
[4] BC3-Basque Centre for Climate Change, Scientific Campus of the University of the Basque Country, Leioa, Spain

Abstract

Water quality serves as a critical determinant of ecosystem health and directly impacts water-use sectors like agriculture and public health. However, the synergistic interactions between extreme climate events and anthropogenic activities can significantly alter water quality dynamics. Furthermore, these impacts are likely to be exacerbated within the context of ongoing climate change and socio-economic development. Our work aims at understanding the multi-risk dynamics for water quality at different spatial scales in Italy (Adige river basin, Veneto Region, and national level) respectively in three different projects (iNEST, Myriad-EU, and GRINS). This is achieved by leveraging heterogeneous data at different spatial and temporal scales, e.g. climate data, land-use data, and in-situ water quality measurements by using machine learning techniques and spatio-temporal Bayesian network models. Through the development of water quality multi-risk models, we explore the synergistic impacts of climate extreme events and anthropogenic pressures on physicochemical water quality parameters (i.e. nutrients, suspended solids, DO, temperature), and other key elements (i.e., biological, chemical, overall ecological status), considering also specific vulnerabilities and exposures of river networks and basins. Land-use and climate change impacts on water quality are analyzed in GRINS and MYRIAD-EU at the national and regional scales, respectively. MYRIAD-EU explores the interaction of multiple hazards (i.e., compound hot-dry and wet-dry events) using machine learning techniques, while GRINS focuses mainly on characterizing the effect of in land use/land cover changes with the Bayesian network model. Moreover, INEST focuses on the nexus between water quality indicators and the multiple water-dependent sectors (i.e. food and energy production). These approaches are being developed as potential tools to complement in-situ measurements with additional data sources (e.g. climate, land-use, etc.) for a better understanding of the multi-risk dynamics of water quality at various spatial scales and temporal horizons.

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Oral presentation

An Artificial Intelligence Approach for Multi-Risk Dynamics of Water Quality Under Anthropogenic Pressures and Climate Change

Authors:

Andrea Critto[3,1], Diep Ngoc Nguyen[3,1], Olinda Rufo[3,1], Mathilda Vogt[3], Samuele Casagrande[3], Jacopo Furlanetto[1,3,2], Hung Vuong Pham[3,1], Anna Sperotto[3,1,4], Silvia Torresan[1,3,2]

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Abstract

Water quality serves as a critical determinant of ecosystem health and directly impacts water-use sectors like agriculture and public health. However, the synergistic interactions between extreme climate events and anthropogenic activities can significantly alter water quality dynamics. Furthermore, these impacts are likely to be exacerbated within the context of ongoing climate change and socio-economic development. The main aim of this work is to understand the multi-risk dynamics for water quality by leveraging heterogeneous data at different spatial and temporal scales, e.g. climate data, land-use data, and in-situ water quality measurements by using machine learning techniques and spatio-temporal Bayesian network models. Water quality multi-risk models are developed to explore the synergistic impacts of climate extreme events and anthropogenic pressures on physicochemical water quality parameters (i.e. nutrients, suspended solids, DO, temperature), and other key elements (i.e., biological, chemical, overall ecological status), considering also specific vulnerabilities and exposures of river networks and basins, including the nexus between water quality indicators and the multiple water-dependent sectors (i.e. food and energy production). Land-use and climate change impacts on water quality are analyzed at different spatial scales in Italy (Adige river basin, Veneto Region, and national level) respectively in three different projects (iNEST, Myriad-EU, and GRINS). These approaches are being developed as potential tools to complement in-situ measurements with additional data sources (e.g. climate, land-use, etc.) for a better understanding of the multi-risk dynamics of water quality at various spatial scales and temporal horizons.

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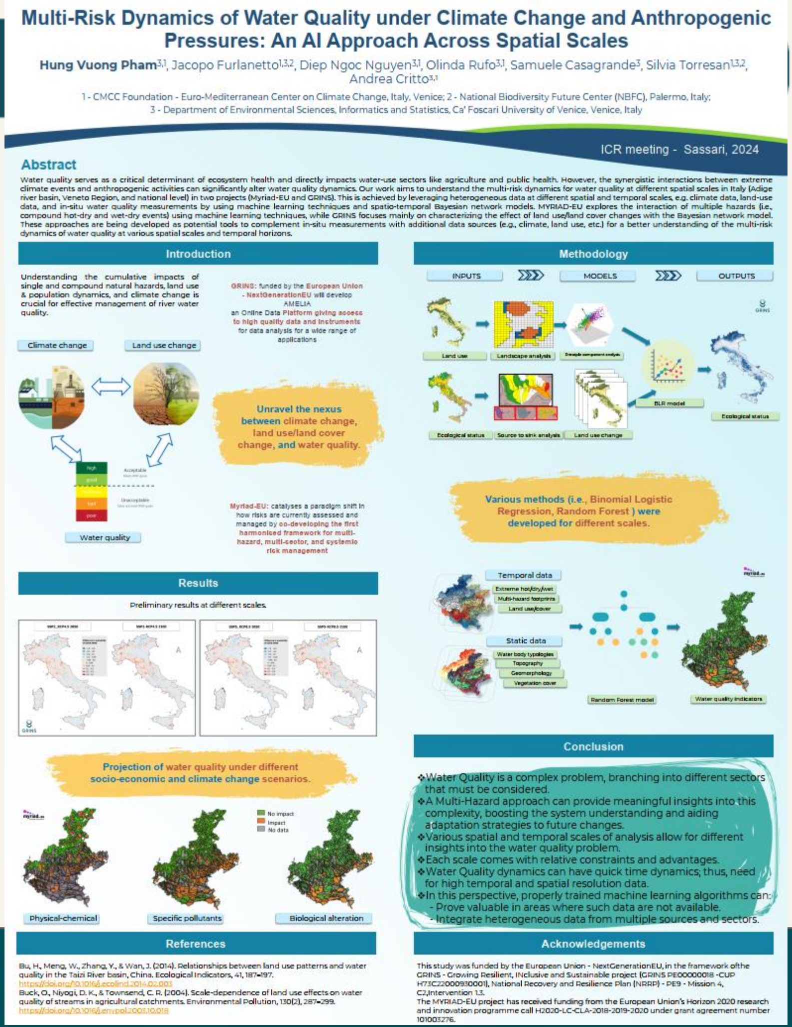
Poster



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Conference

Poster presentation

From land use to water quality: implications of historical changes and future scenarios in Italian watersheds

Olinda Rufo[a,b], Samuele Casagrande[a,b], Hung Vuong Pham[a,b], Andrea Critto[a,b],

The sustainability of freshwater availability and quality is seriously threatened by climate change (CC) and land-use/land-cover change (LULC). On the other hand, extreme weather and climate-related events depend strongly on LULC. Multiple evidence suggests that rapid global development is the main driving factor altering all the fundamental processes that control the hydrologic cycle and temporal and spatial variations of river basins. Moreover, the interaction between the upstream and downstream of a basin significantly impacts the overall status of the basin. Understanding the "source-to-sink" effect is crucial for managing water quality in river basins. This study aims to understand historical trends of land use changes from 1990 to 2018 in Italy and their impacts on water quality, providing a baseline model for predicting the probability of achieving good ecological status for each watershed under different Shared Socioeconomic Pathways (i.e., SSP2 and SSP5) and Representative Concentration Pathway (i.e., RCP4.5 and RCP8.5) for mid- and long-term timeframe. To achieve this bold objective, this study integrates Principal Component Analysis (PCA) and several regression models to explore the influence of various landscape metrics on the ecological status of each watershed, taking into account the effect of changes in land use from upstream watersheds to downstream ones. The outcomes reveal that conserving natural areas is essential for improving water quality across the territory. However, conservation efforts alone are insufficient without restoring places that were natural previously but are now used for agriculture and urban development. The use of agricultural practices that foster the coexistence and interconnection between natural areas and cultivated zones could be an effective method for mitigating the damage caused by unsustainable farming practices. Future work will focus on integrating climate change variables, including single and compound effects, and spatio-temporal occurrence of extreme events, such as flood and drought hotspots. Moreover, advanced probabilistic models (e.g., Bayesian Network) will be employed to assess the possible interactions between LULC and CC and their impacts on water quality. The outcomes of this analysis contribute to developing adaptive strategies that safeguard water resources and ensure the long-term sustainability of freshwater ecosystems.

What's next?

01

Finalization of the Manuscript on the analysis of LULCC & WQ to be submitted to a peer-reviewed journal

02

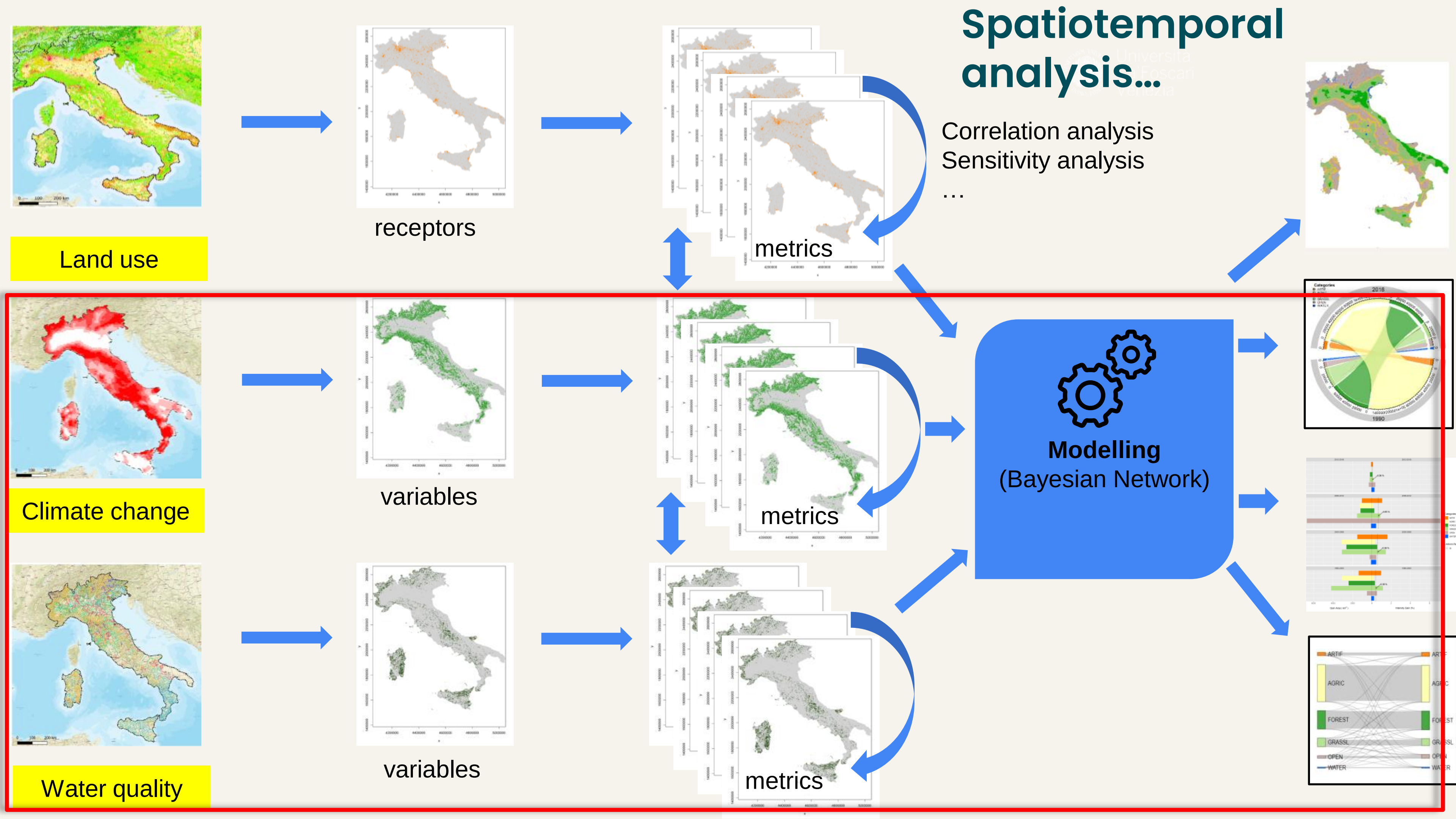
Proceed with the analysis of CC & WQ

03

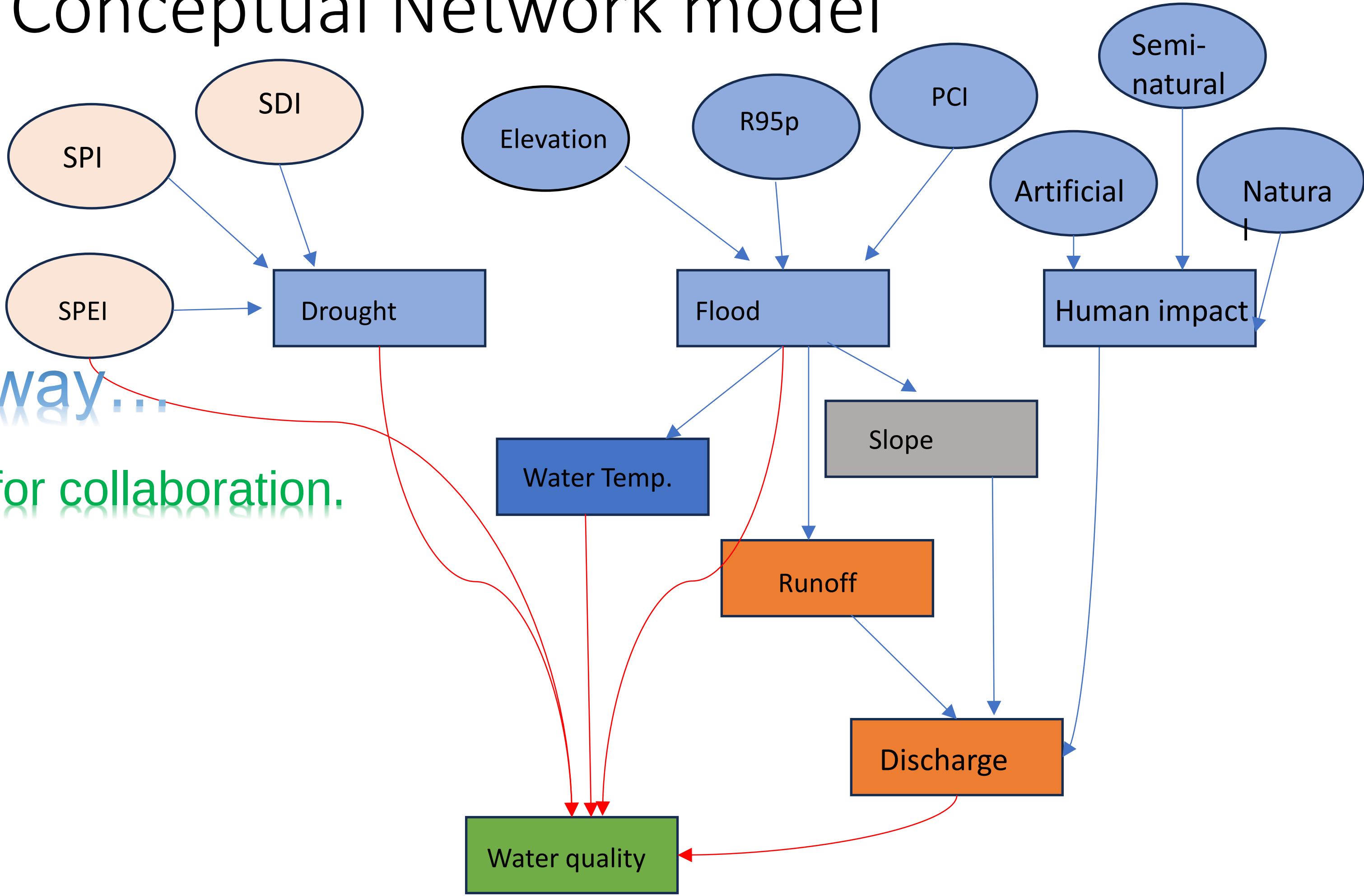
Contact ISPRA to get the data on water quality in 2022 for a complete analysis with a temporal dimension

04

Get in touch with Spoke 0 for the integration of data from the project's results and input data from different sources into the AMELIA platform.


Spatiotemporal analysis…
Correlation analysis
Sensitivity analysis
…
Land use
receptors
metrics
Climate change
variables
metrics
Water quality
variables
metrics
Modelling
(Bayesian Network)
ARTIF
AGRIC
FOREST
GRASSL
OPEN
WATER

Conceptual Network model



It is on the way...

We are looking for collaboration.

Water quality

Climate change

Morphology

Climate variables

Hydrology

Thank you for your attention!

Contact: Vuong Pham (Vuong.pham@unive.it)

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