
ENVIRONMENTAL
INTELLIGENCE
for Global Change
EI
LAB

Environmental Intelligence Lab 2024

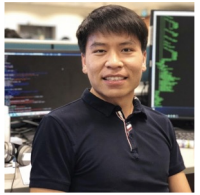
Faculty




Research





Phd Students










Ongoing projects

CLINT
CLIMATE INTELLIGENCE

BECLICK
behavioural modelling

SAHARA

GoNEXUS
Tools and solutions for governing the nexus

PRINT FLOODS

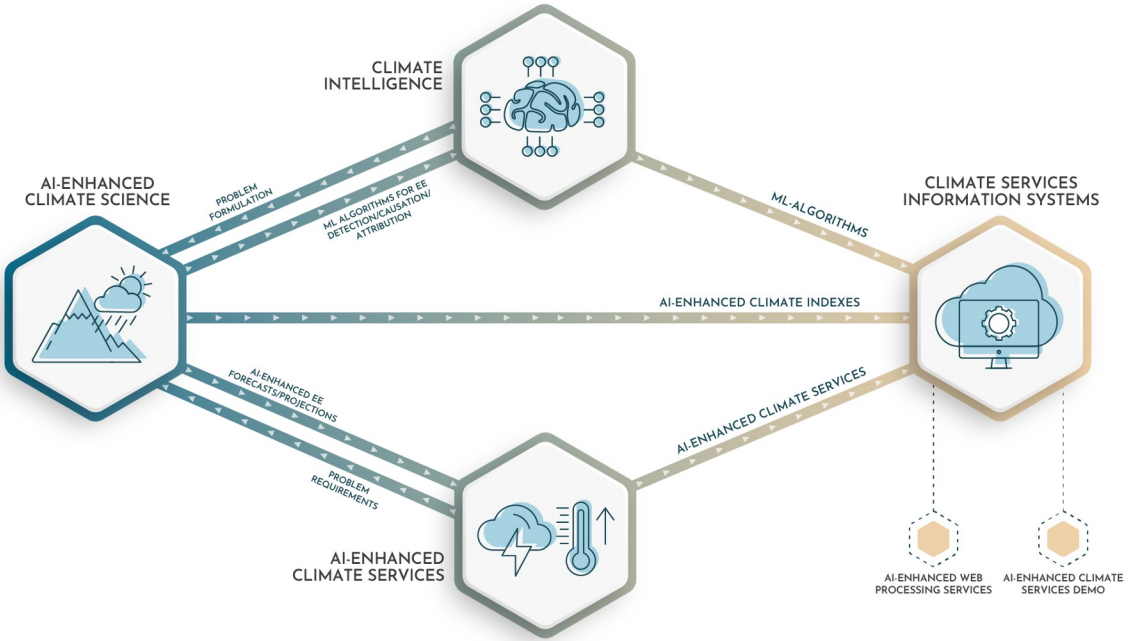
MELTED

SOS Water
GROUNDWATER
SURFACE WATER
BIODIVERSITY
WATER DEMAND
EXTREMES
WATER SCARCITY
WATER POLLUTION

NEWAVE

CLImate INTelligence: Extreme events detection, attribution and adaptation design using machine learning

CLINT
CLIMATE INTELLIGENCE

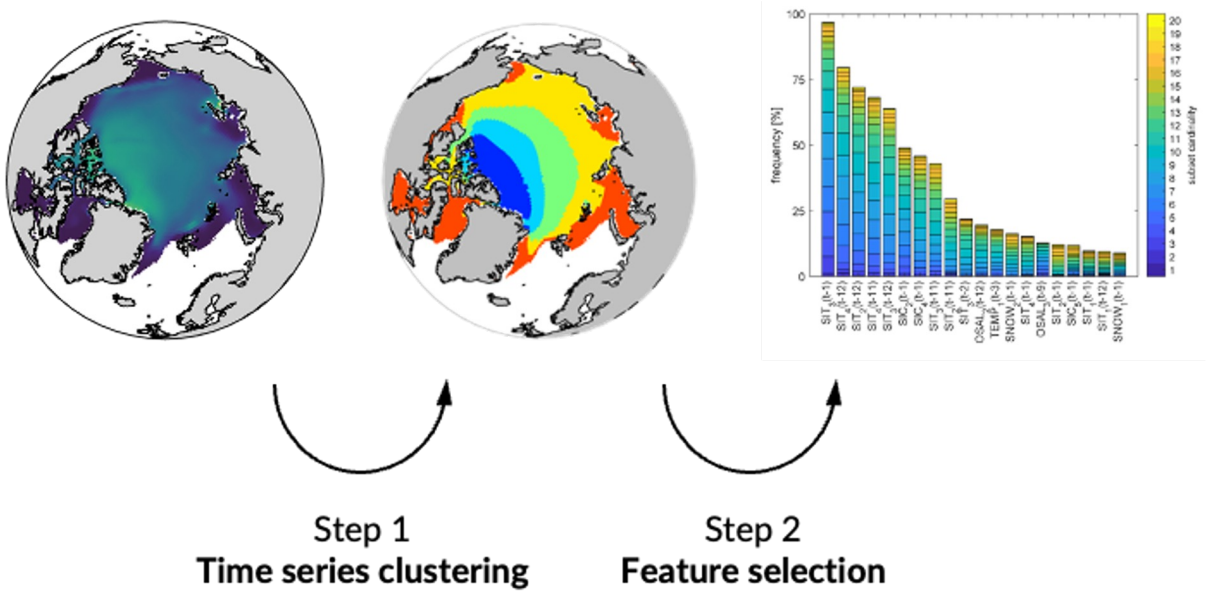


- Tropical cyclones
- Heatwaves and tropical nights
- Extreme droughts
- Compound events and concurrent extremes

- Discovering data augmentation best practices for tropical cyclone intensity estimation with deep learning
- A pan-European analysis of drought events and impacts

MachinE Learning for arcTic ice prEDiction:
a 2-step framework to model Arctic sea ice dynamics

MELTED

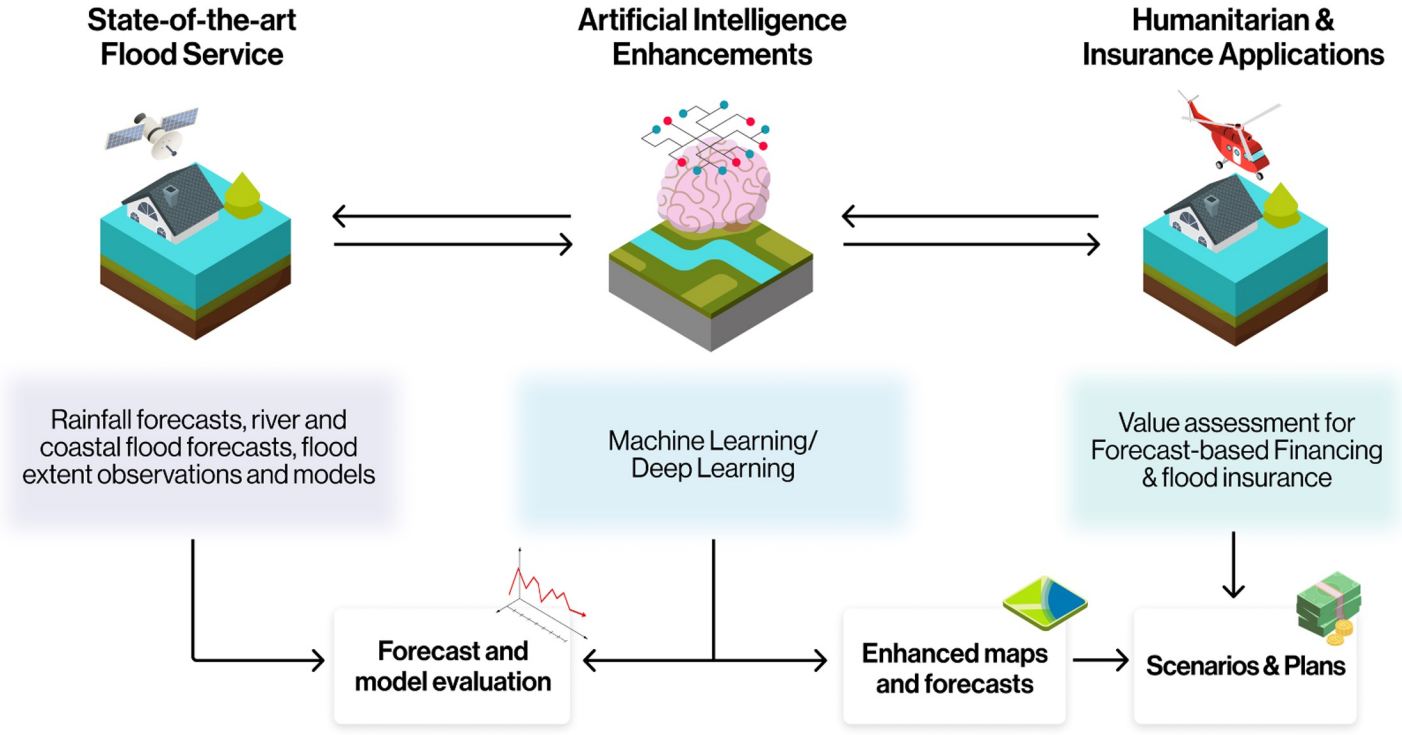


Aiming to balance:

- High **performance** and **accuracy** typical of Machine Learning
- Result **interpretability**

- Unveil unconventional interdependencies, paving the way for their formalization and inclusion in physical models.
- Improve the forecasting ability of sea ice.

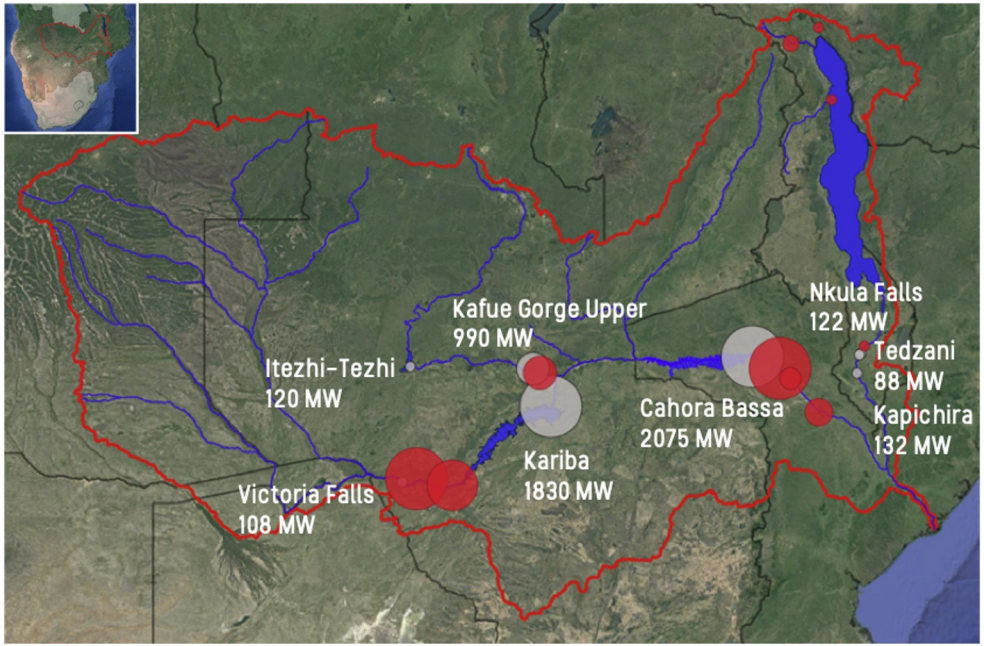
PRediction INTelligence for Floods (PRINTFLOODS)



Research Fund

Innovative tools and solutions for governing the water-energy-food-ecosystems NEXUS under global change

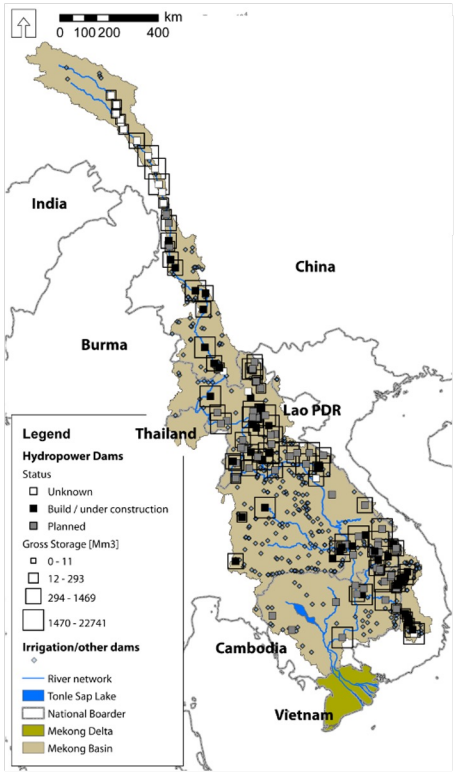
GoNEXUS
Tools and solutions for governing the nexus

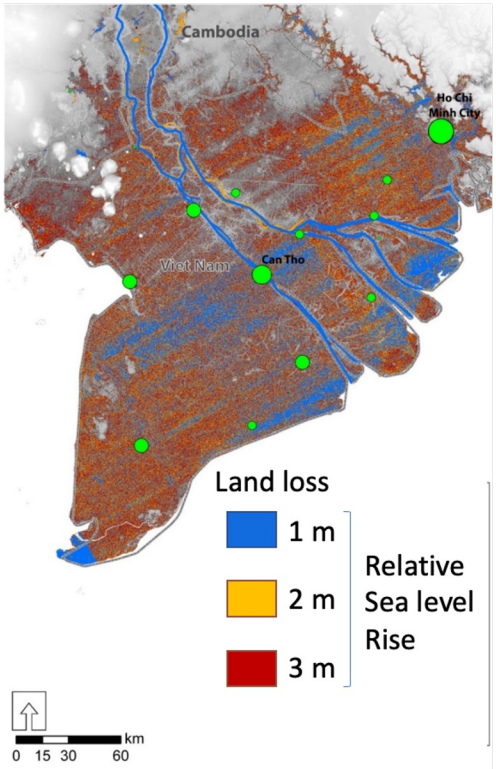


- Robust planning
- Dam sequencing
- Financial tools
- Agent-based models

- Power capacity expansion in the Southern African Power Pool: Synergies between hydropower and floating solar development
- Parametric insurance for hydropower: comparing alternative schemes and forecast conditioned policies

Water Resources System Safe Operating Space in a Changing Climate and Society





Downscaling planetary boundaries at the river basin scale

Integration of local models and global models

- Enhancing Mekong River Basin reservoir operations: Balancing Hydropower Production and Sediment Transport

Social learning and behavior modelling to face climate change

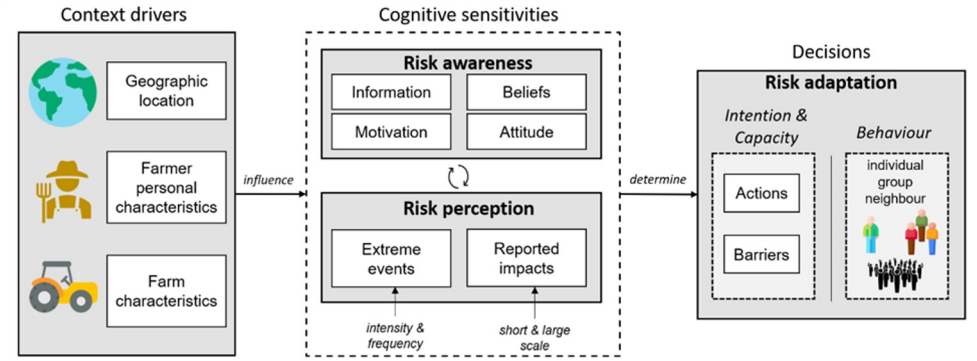
BECLICK
behavioural modelling

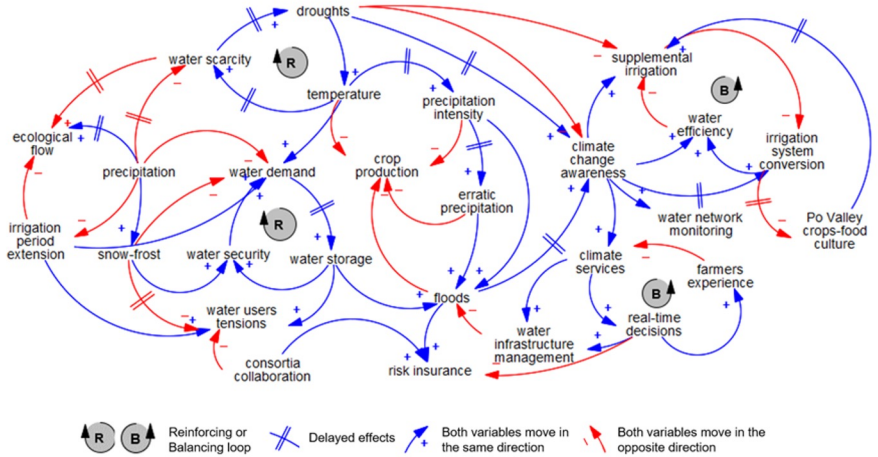
Topics

- Climate change awareness, perception and adaptive capacity
- Multi-objective water management
- Risk assessment and preferences
- Decision-making processes

Approaches

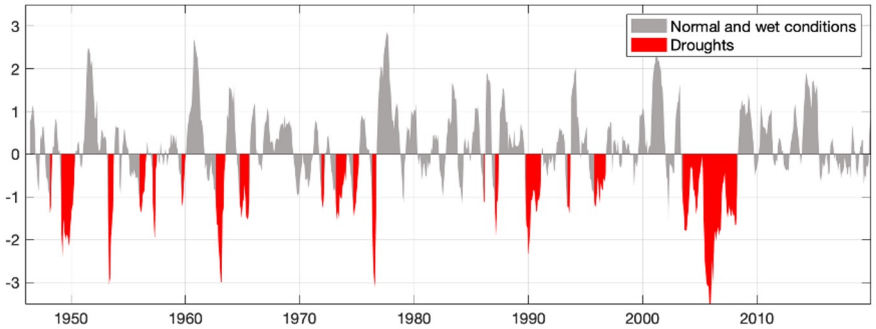
- Multi-Stakeholder behaviour analysis
- Causal/Network analysis
- Agent-Based Modeling

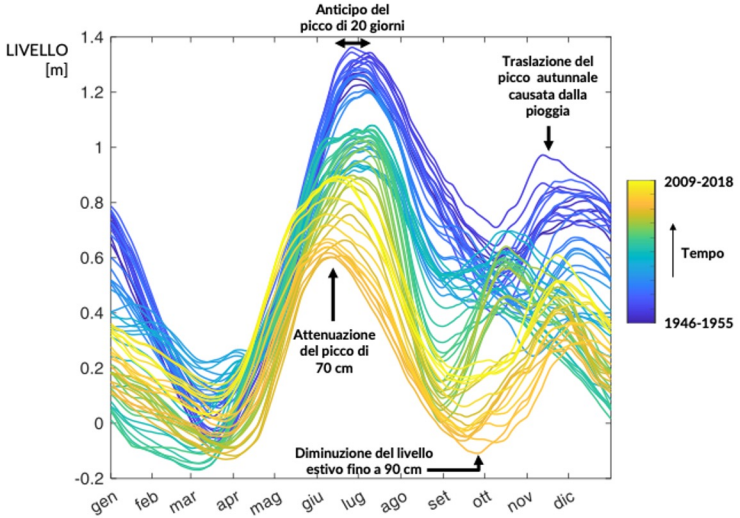




Storage enhanced drought management for resilient river basins

SAHARA





- Strategic planning of water storage expansion in Northern Italy
- Analysis of current and projected droughts
- Multisector adaptation design

- Enhancing droughts resilience via expansion of water storage infrastructures

NEWAVE: Next Water Governance

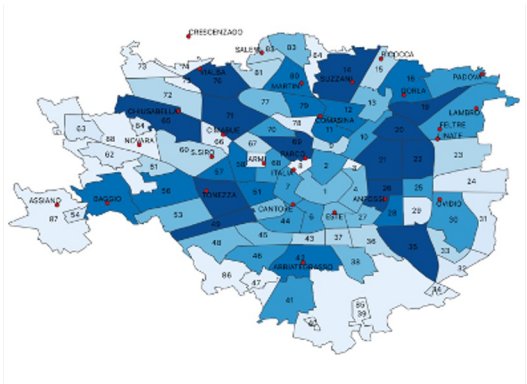
NEWAVE

1. Bring together an excellent **trans-national & transdisciplinary network** of water governance organisations;

1. Develop and implement a cutting-edge **actionable research agenda** on the key water governance **priorities** & **insights** for future directions;

1. **Train a new generation** of water governance **early stage researchers** (ESRs) and ensure that they have the **trans and interdisciplinary skills** to contribute to both the **academic** and **extra-academic** worlds.

1. **• Trend detection/breakpoint detection**
2. • Driver identification/Input variable selection
3. • Demand clustering and characterization
4. **• Water demand modelling and prediction**



MARIE CURIE ACTIONS

Funded by the Horizon 2020 Framework Programme of the European Union

https://www.nextwatergovernance.net/

Types of theses

Methodological: aims at developing new approaches, methodologies, and algorithms to tackle key research problems - strongly research focused, aimed at advancing science

Requirements: strong math bases and programming skills

Application oriented: aims at integrating existing tools to solve real world problems - focus on policy relevant outcomes

Requirements: strong problem solving attitude and analytic skills; no strong expertise in one specific programming language but flexibility in handling and integrating different tools

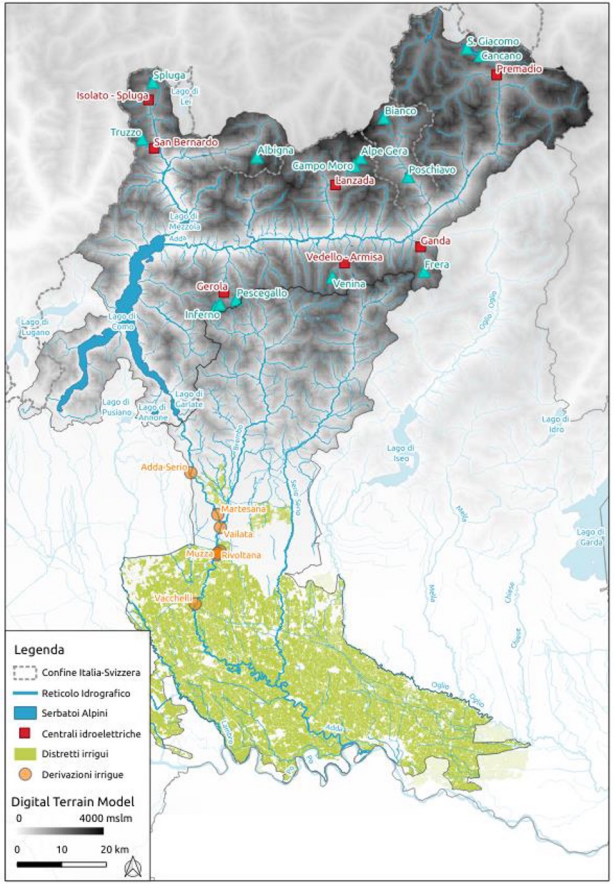
Timing

Full theses generally last 6 month + some warm up to align with previous work and train on the use of tools

List of thesis available:

1. Multi-sector multi-actor adaptation to climate change in the Adda river basin
2. Correction of ERA5 SWE using SNOW-IT
3. Water storage expansion for adapting to projected drought events
4. Exploring dam-induced impacts on river biodiversity across basin and continental scales
5. Exploring spatiotemporal dynamics of sediment transport in the Zambezi River Basin
6. Can Generative Artificial Intelligence be used to synthesize images of rare tropical cyclones?
7. Bias correction and spatial adjustment of global extreme rainfall events in reanalysis data using deep learning
8. Modelling the impacts of drought events on the European energy sector
9. Machine Learning for advancing the detection of drought events
10. Improving energy system modelling in the African continent under different climate policy scenarios
11. Advancing water systems control by leveraging multiple forecasts and policy classes via Deep Reinforcement Learning
12. Advancing water systems management: Bias correction and synthetic forecast generation
13. Integrating Local Perceptions through Climate Index Projections into Agent-Based Models for Climate-Resilient Agricultural Adaptation
14. Modelling farmer adaptation to changing flood risk

T1) Multi-sector multi-actor adaptation to climate change in the Adda river basin



MOTIVATION

The Lake Como water system is experiencing more frequent and intense extreme weather events that exacerbate the tradeoffs between different sectors and poses unprecedented challenges to water resource management. Efficient climate change adaptation strategies are thus necessary.

AIM

- Estimation the water inflow into Lake Como and three large hydropower reservoir
- Identification of optimal planning and management strategies using the EMODPS approach
- Assessment of the impact of new climatic regimes on different water sectors.

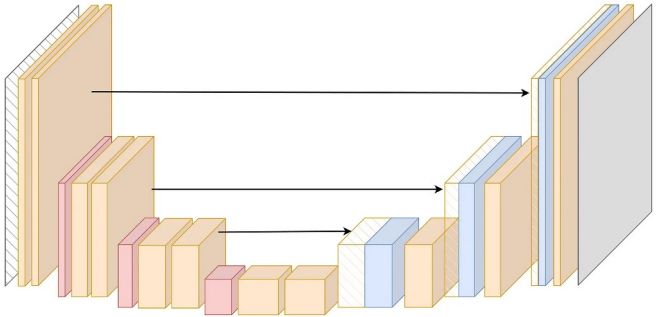
T2) Correction of ERA5 SWE using SNOW-IT

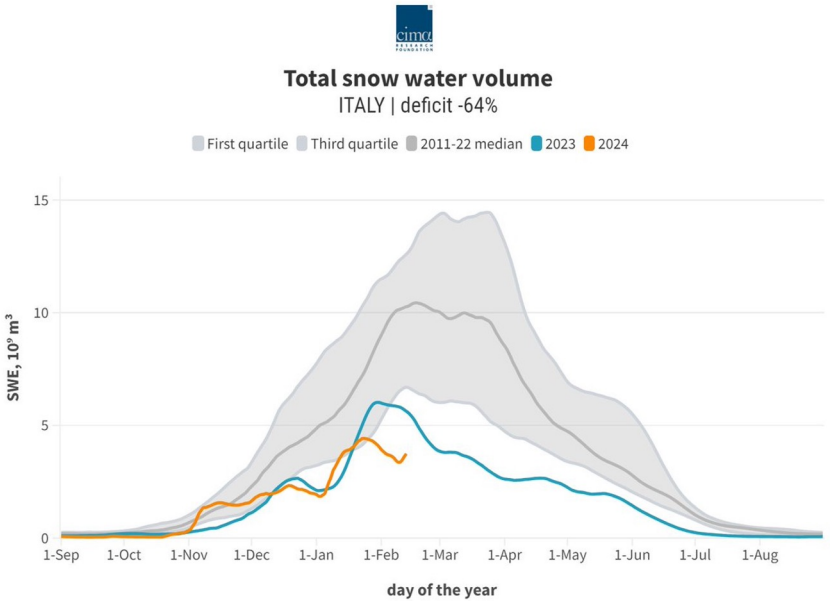
MOTIVATION

SWE data are essentials for water resource planning and climate change assessment in mountainous area, however measurements are rather scarce as well as difficult and expensive to obtain.

AIM

- Collection of SWE data from ERA5 and SNOW-IT reanalysis across the Italian Alps
- Training of a U-net-based framework to correct and downscale the input data from ERA5 (with SNOW-IT as target).

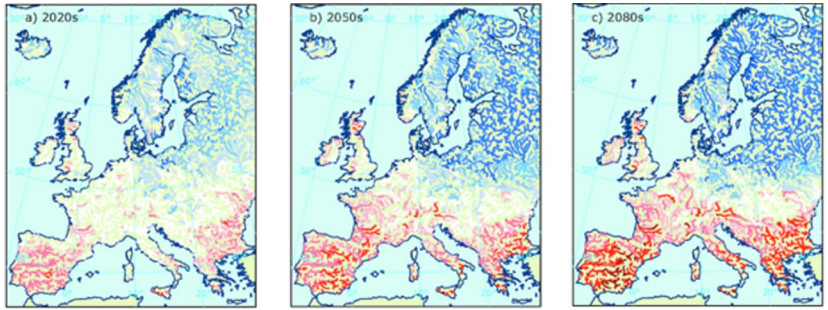




T3) Water storage expansion for adapting to projected drought events

MOTIVATION

Climate projections indicate up to a 40 percent reduction in minimum streamflow by the 2080s, with future droughts expected to be more severe and long-lasting.
Expanding storage can contribute in filtering the growing variability of hydroclimatic regimes and better align water availability and demands.



AIM

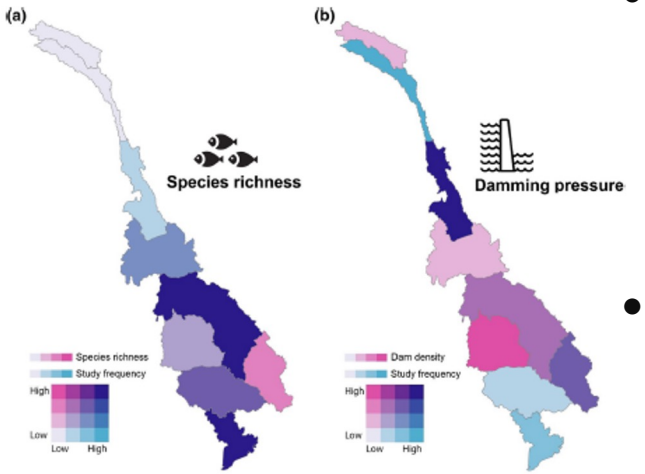
Strategic and robust planning of water storage expansion for improving drought resilience under climate change in Northern Italy

T4) Exploring dam-induced impacts on river biodiversity across basin and continental scales

MOTIVATION

Assessing the Dam-Induced impacts on riverine ecosystems, and integrating them into energy-water management models is an urgent need to highlight the trade-offs between clean hydropower energy production and the adverse effects that dams generate on local ecosystems.

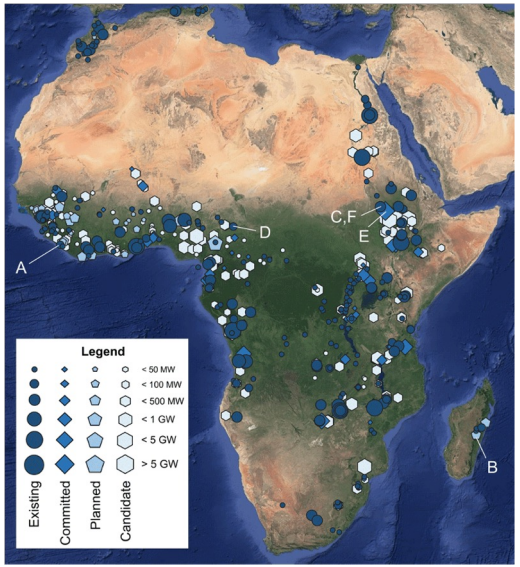
Basin Scale: Mekong River Basin



AIM

- Investigating how the planning of cost-optimal dams, considering various socio-economic and climatic scenarios, affects riverine ecosystems in the **African Continent** (1 student).
- Assessing the impact of optimal dam location and operation strategies on fish distribution within the **Mekong River Basin** (1 student).

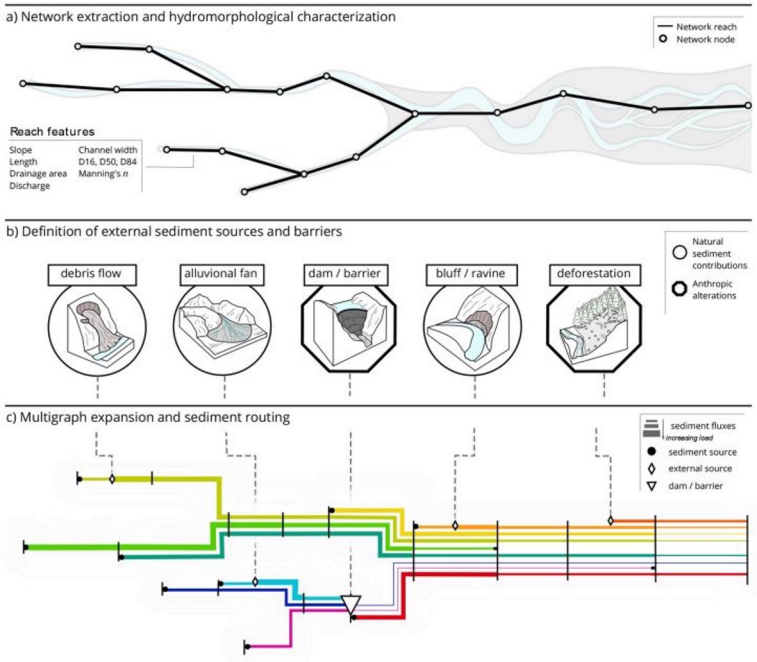
Continental Scale: Africa



T5) Exploring spatiotemporal dynamics of sediment transport in the Zambezi River Basin

MOTIVATION

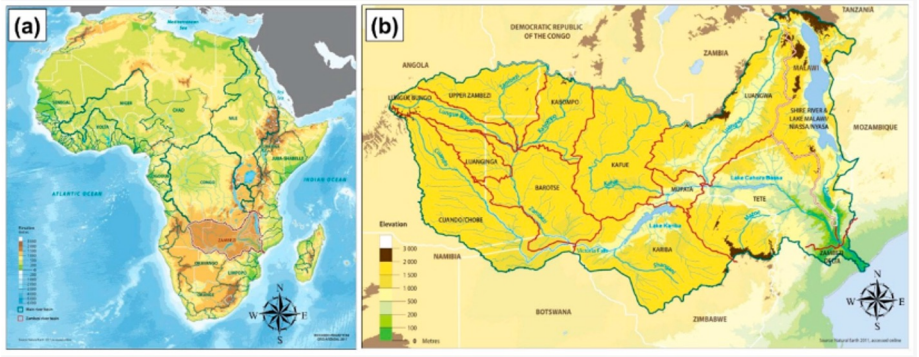
River sediment transport processes are directly linked to ecosystem services, and they are highly affected by river anthropic alterations. Characterizing basin-scale sediment connectivity is a crucial task to enhance our ability to quantify potential future alterations resulting from anthropogenic disturbances.



AIM

Configuring D-CASCADE for the Zambezi River Basin to investigate its spatiotemporal evolution of sediment supply and delivery.

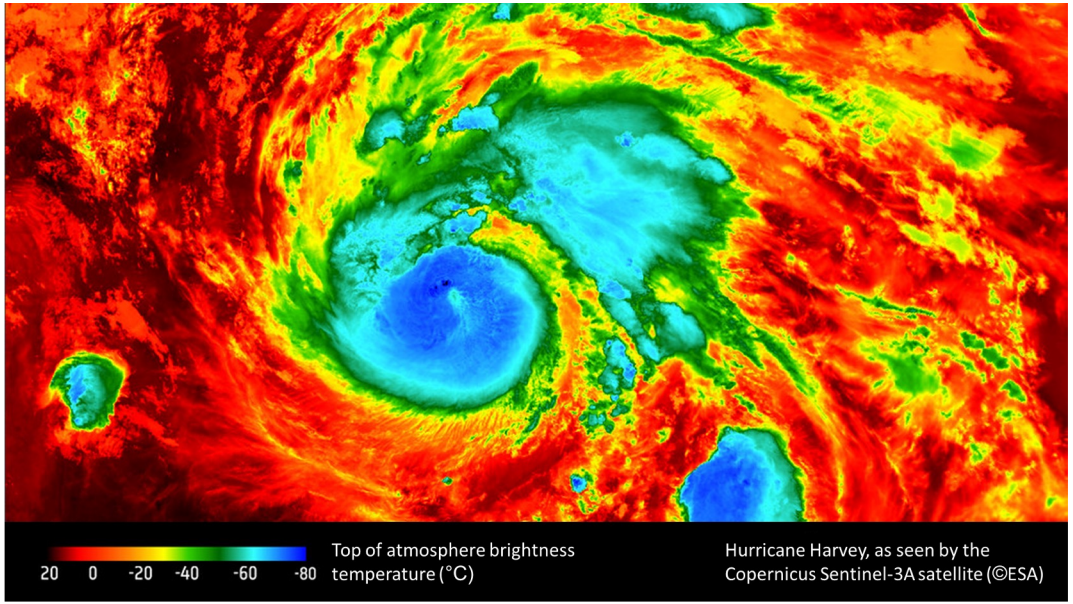
Evaluating the effects of multiple heterogeneous drivers of change in river sediment dynamics, including dam construction and operation.



T6) Can Generative Artificial Intelligence be used to synthesize images of rare tropical cyclones?

MOTIVATION

Tropical cyclones killed 700,000 people in the last 50 years. Estimating and predicting their intensity is crucial to reduce their destructive impacts. Unfortunately, because they are rare events, there is too little data on them to train deep learning models.



AIM

To use cutting-edge generative artificial intelligence algorithms (e.g. stable diffusion) to generate new images of extremely intense tropical cyclones, to create a new dataset with which to train intensity estimation deep learning algorithms.

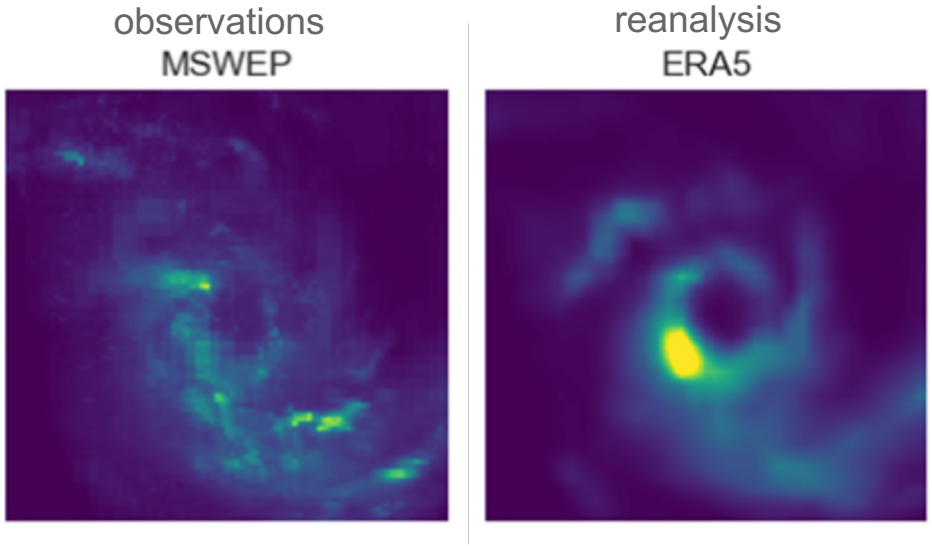
T7) Bias correction and spatial adjustment of global extreme rainfall events in reanalysis data using deep learning

MOTIVATION

Precipitation data from the ERA5 reanalysis dataset is often used in hydrology. However, it has severe biases, especially for extreme precipitation events. In our lab, we develop a deep learning algorithm to reduce these biases for precipitation of tropical cyclones (TCs).

AIM

To adapt the algorithm to work for global extreme precipitation for generic events (not only TCs).



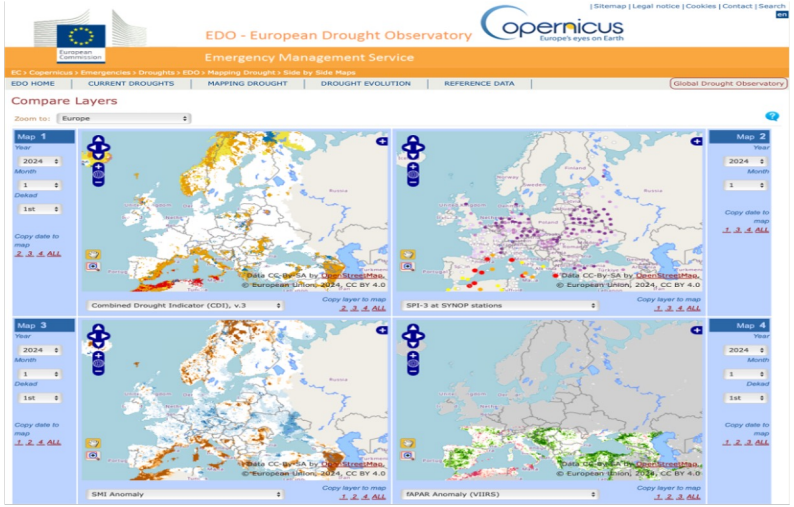
T8) Modeling the impacts of drought events on the European energy sector

MOTIVATION

Intensified by anthropogenic climate change, drought has become one of the most significant natural hazards in Europe. Although drought monitoring and management are extensively studied in the literature, traditional drought indices often fail at yielding precise information on detecting critical events and their associated impacts. This is due to the complexity of the phenomenon, for which there is no single definition, nor a comprehensive and sound methodology to assess its impacts across all sectors.

AIM

Creating new impact-based drought indices to better capture and represent drought-related impacts on the European energy sector (e.g. energy production outages due to drought events).



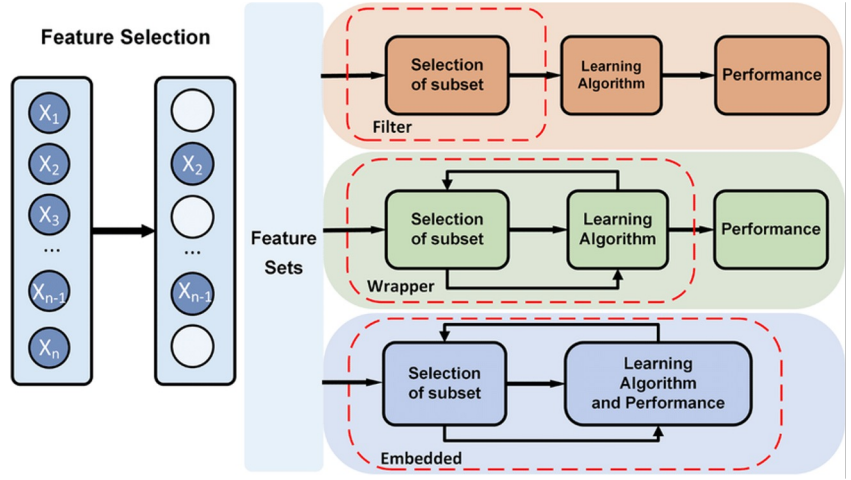
T9) Machine Learning for advancing the detection of drought events

MOTIVATION

Traditional drought indices often fail at yielding precise information on detecting critical events, capturing only a portion of the entire process. Machine Learning approaches are a valid alternative for the detection of drought events. Specifically, given a set of candidate features, the use of feature extraction algorithms allows the identification of the most relevant drivers of a drought event, which can be combined into a model able to detect the presence and/or the intensity of a drought event.

AIM

The aim of this thesis is benchmarking state-of-the-art feature extraction algorithms, possibly testing their performance on different case studies.



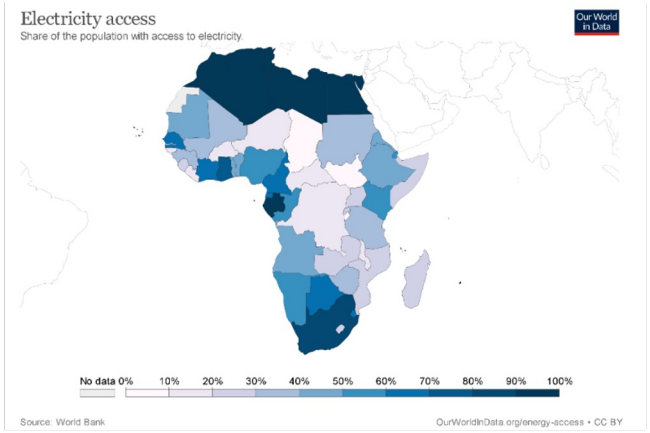
T10) Improving energy system modeling in the African continent under different climate policy scenarios

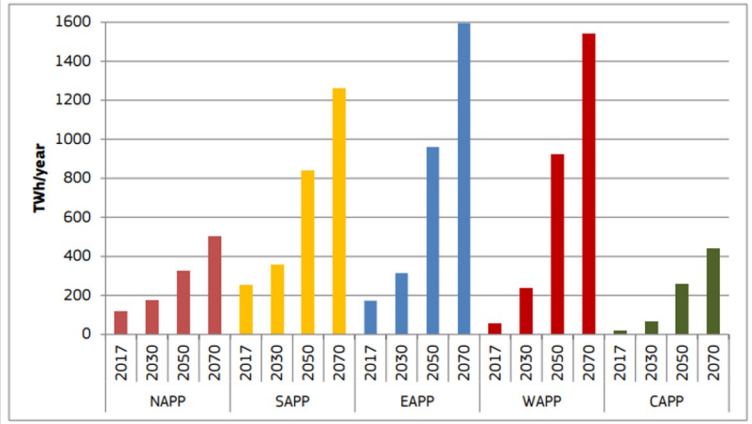
MOTIVATION

With climate change already impacting the African continent, it's essential to explore strategies for decarbonizing energy infrastructure and expanding capacity to meet current and future demand. While energy system models help to plan sustainable transitions, they often lack resolution to ensure power grid reliability, especially with high levels of variable renewable energy sources (VRES). Adapting power operation decisions with a high temporal resolution is essential to manage the intermittent power output of VRES over multiple scales.

AIM

The aim is to refine the characterization of availability patterns of VRES within energy system models while analyzing various climate policy scenarios across the African continent. This includes a specific emphasis on assessing hydropower availability, which serves as a key renewable resource in the region.



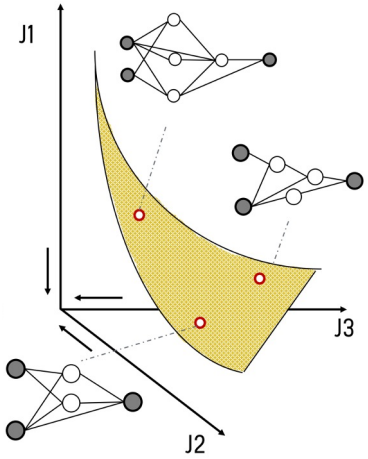


Electricity demand projections per power pool in the Sub-Saharan Africa in the reference scenario (Pappis et al., 2019)

T11) Advancing water systems control by leveraging multiple forecasts and policy classes via Deep Reinforcement Learning

MOTIVATION

Climate change has intensified flooding and droughts, prompting the need for improved water system control strategies. Flexible control policies are gaining traction due to their cost-effectiveness and utilization of advanced hydrological forecasting. Reinforcement learning techniques like Neuro-Evolutionary Multi-Objective DPS offer a dynamic approach to designing optimal control policies by incorporating multiple inputs, features and policy selection.



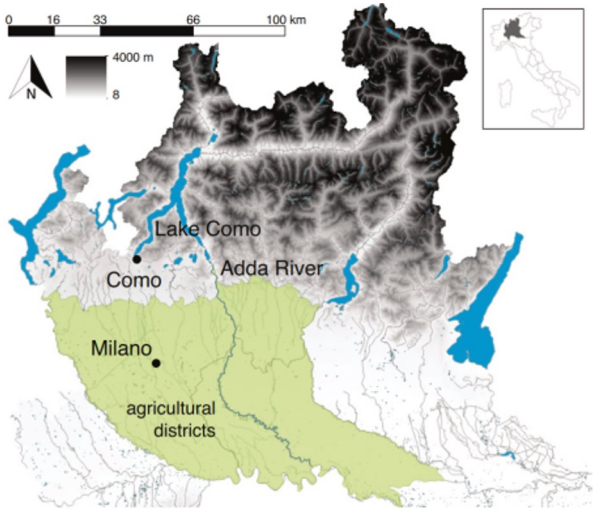
Adapted from Zaniolo et al. 2022

CASE STUDY

Lake Como

AIM

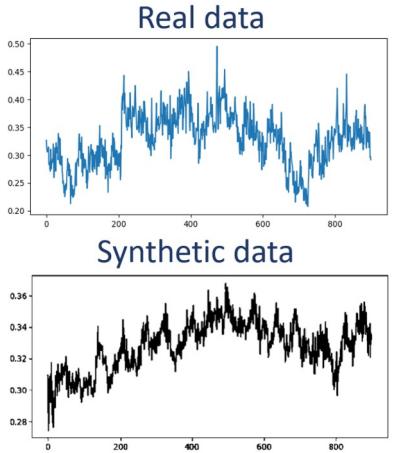
The aim of this thesis is to improve the NEMODPS deep Reinforcement Learning approach, building on it to better condition the operation of water reservoirs.



T12) Advancing water systems management: Bias correction and synthetic forecast generation

MOTIVATION

Precipitation forecasts in water systems management hold promise for enhancing medium- to long-term planning but are hindered by biases and limited data, notably in sub-seasonal lead times. To address these challenges, bias correction and synthetic forecast generation are emerging as effective methods, rectifying biases and utilizing historical data to improve forecast accuracy.



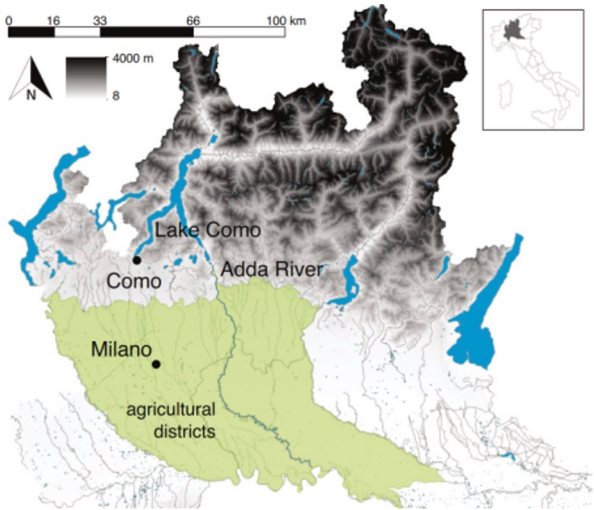
Adapted from Pinceti et al. 2022

CASE STUDY

Lake Como

AIM

The primary objective of this thesis is to develop bias-corrected synthetic forecasts for medium-term time ranges. The second objective is the implementation of a Stochastic Model Predictive Control method to test them.



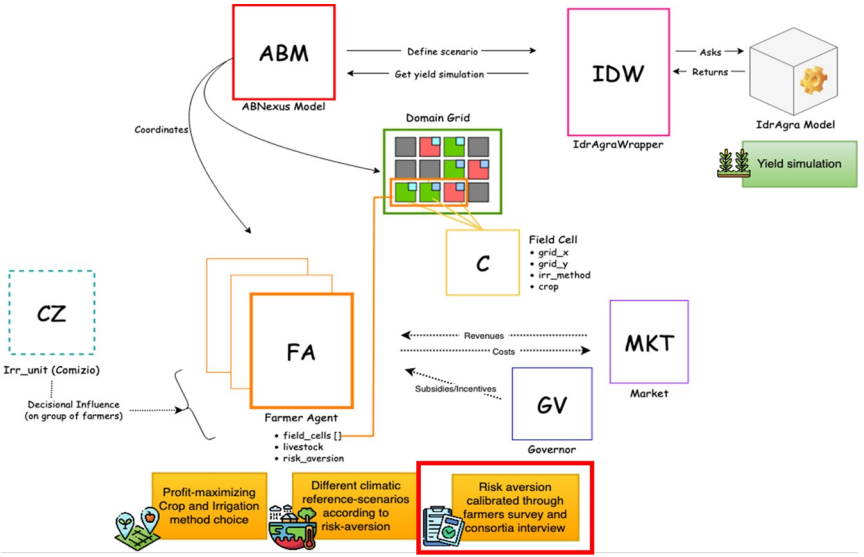
T13) Integrating local perceptions through climate index projections into Agent-Based Models for climate-resilient agricultural adaptation

MOTIVATION

Despite several advancements in embedding sophisticated behavioural theories, Agent-Based Models often overlook the crucial role of farmers' climate-driven beliefs, and their direct experiences with a changing climate, potentially leading to misleading policy insights. Indexes related to local climate extreme events, such as heatwaves, can serve as proxy variables for farmers' experience during decision-making process.

AIM

- Contribute to the projections of these indexes under various climate scenarios.
- Integrate this information into an existing Agent-Based Model, as influential variables in their adaptive strategies.
- Simulate and discuss consequences of the changes in farmers' behaviour



T14) Modelling farmer adaptation to changing flood risk

MOTIVATION

Climate change intensifies the frequency and severity of extreme weather events, such as floods and Tropical Cyclones, posing significant threats to agricultural communities, particularly in developing Countries. Farmers in these contexts often lack the financial and technological capacities to manage these risks effectively, leaving them highly vulnerable to crop losses.

AIM

- Model farmer adaptation by modifying an existing agent-based model (ABM) to:
  - Assess adaptation options, including risk transfer (insurance), risk reduction (changing crops), risk avoidance (migration)
  - Include a calibrated crop-damage function related to flood events
- Simulate historical and future scenarios to explore farmers' behavior and system-level resilience