Planning and Evaluating NATure-based solutions within local authoritiEs – the PENATE project

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Context

Since 2019, IPBES and IPCC have emphasized the need to jointly address biodiversity loss and climate change. This is especially important in urban areas, which are already affected by climate disruptions and offer limited space for biodiversity. In France, several regulations (e.g. RE2020, PLUi, PCAET) address these challenges, but their implementation requires tailored tools for local authorities.

Nature-Based Solutions (NbS) baim to protect and restore ecosystems to strengthen territorial resilience. However, their regulatory integration faces key limitations. These include the lack of assessment tools that account for ecosystem services (ES), the sectoral handling of public policies, limited knowledge about vegetation and thermo-hydraulic interactions, and poor understanding of how NbS function across spatial scales.

Objectives

The objective of the French ANR PENATE project is to establish a link between biophysical processes, ecosystem functions/services, and public policies within an urban territory. To achieve this, our interdisciplinary consortium aims to address the following scientific questions:

. What are the drivers, constraints, and challenges for implementing the NbS in an urban area from ecological, legal, political, and social perspectives?

. How can we objectively quantify and optimize the multifunctional performance and efficiency of NbS through a systemic and multi-scale approach?

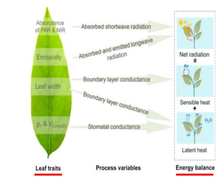
The answers will enable to objectively assess the **multifunctional** and the **evolving** characteristics of NbS, particularly concerning the following **targeted issues**: mitigating heat islands, managing stormwater and flooding, maintaining ecological continuity, and achieving a net gain in biodiversity. The intended **systemic**, **interdisciplinary**, and **multi-scale** approach will seek optimization, from the site of implementation to the territorial scales where various regulations and development strategies are applied.

The PENATE project will rely on 4 Territorial Communities (TCs) where NbS projects are currently implemented and monitored for the mentioned issues.

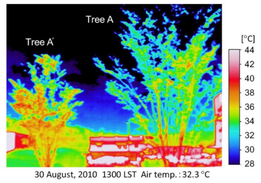
Task 1: Vegetation development and NbS multifunctionality

Objective: to improve modeling of the biophysical representation of vegetation in NbS, focusing on its thermo-hydraulic behaviour. By accounting for vegetation development and plant functional traits (Violle et al., 2007) as dynamic predictors of water and energy transfers in the soil-plant-atmosphere continuum, the influence of present and future climate scenarios will be better assessed.

Method: some **monitoring campaigns** will be carried out to assess changes in the expression of plant functional traits in studied NbS (i.e. LAI, stomatal conductance, surface cover, ...). Trait evaluation will be performed through ground-based measurements (e.g. leaf porometry, evapotranspiration chamber, thermal camera, image analysis) collected during these campaigns. Besides, the development of a biophysical model reflecting the complexity of planting design will be achieved to better illustrate and predict the thermo-hydraulic functioning of NbS.



Relationships between functional traits and thermal flux

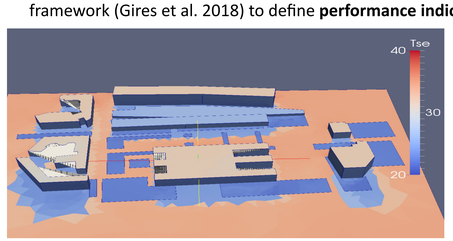


Surface temperature from thermal camera

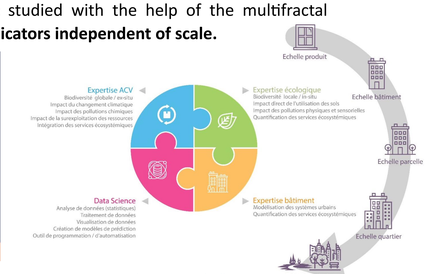
Task 3: Integrated Method for the Multifunctional assessment of the NbS

Objective: to develop an integrated method for assessing the multifunctionality of NbS across spatial scales and by considering the present high kinetics of climate change (inputs from Task 1), as well as the public policies and legal framework (inputs from Task 2). It will lead to the computation of multi-scale assessment indicators relevant for decision making.

Method: The systemic nature of the method will be ensured through the use of **interdependent numerical models** capable of replicating exchanges in the soil-vegetation-atmosphere continuum: the coupled Multi-Hydro / Solene-Microclimat platform to assess NbS performances to mitigate heat island and urban flooding (Versini et al., 2023), and the hybrid HIBOU method (CSTB et al., 2022) to consider the NbS impacts in terms of Life Cycle Assessment (LCA) and ecological expertise. Model input and output time series and maps will then be studied with the help of the multifractal framework (Gires et al. 2018) to define **performance indicators independent of scale.**

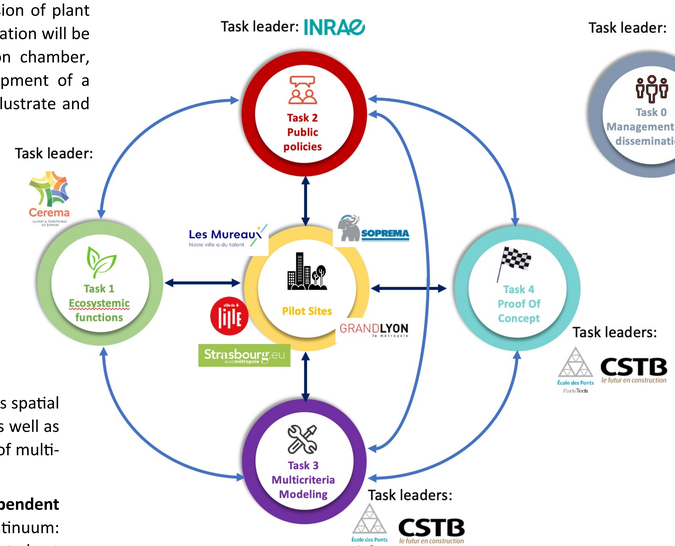


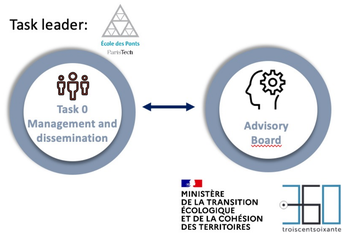
Surface temperature simulated with the coupled Multi-Hydro / Solene-Microclimat platform



The HIBOU methodology

Project organization





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Task 2: Public policies and legal framework

Objective: to analyze the ability of the territories to implement NbS on public or private land through the lens of **local development policy framework**, and to define a **common semantic** framework (e.g. objectives, indicators...). To Study the governance of NbS through the identification of legal and political obstacles and levers.

Method: interviews with stakeholders in each TC to identify the planning documents and legal instruments and highlight obstacles and levers to the NBS implementation, relationships between central government and local authorities. Finally, the tensions, limitations, or difficulties in implementing NbS will be identified in order to maximize their ecological functionality.

PLU Plan Local d'Urbanisme

PCAET Plan Climat Air Energie Territorial

Task 4: Development of a Proof of Concept (POC) tool

This final task will bridge the previous ones and offer the foundation for an operational tool, called **Proof of Concept** (POC). It will have five functions:

. Diagnose a territory (identify risks, issues, and continuity preservation) by leveraging existing data characterizing both land use and climate-related hazards (e.g. flooding, drought, etc.).

. Translate regulatory planning/management documents into quantified objectives.

. Propose initial state scenarios of NbS and plant species suitable for the targeted issues and quantified objectives.

. Model and assess the multifunctional performance of NbS with the multi-scale indicators (in combination or not with other solutions).

. Facilitate decision-making by considering TCs' difficulties and innovations through the representation of results and their interpretation using relevant indicators in accordance with regulations.

The TAP Project

The ANR PENATE project has been selected to participate to the TAP (Thematic Annual Programming) Action in the framework of the European project SD-WISHEES ("Supporting and Developing WIdening Strategies to tackle Hydroclimatic Extreme Events: impacts and Sustainable solutions for cultural heritage").

SD-WISHEES

SD-WISHEES aims to develop innovative tools and strategies to enable collaboration between diverse stakeholders in Europe and beyond to inclusively address the increasing threats posed to cultural heritage by hydroclimatic extreme events, such as droughts and floods.

The SD-WISHEES TAP Action plans to: (i) enhance the overall impact of cross-sector collaboration to address together the protection and sustainable management of cultural heritage in Europe, (ii) enable the exchange of knowledge, data, and research methodologies.

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