DELIVERABLE 2.2

Report on data requirements for biophysical and socio-economic assessment of NbS efficiency

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Land4Climate

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Abbreviations

EU	European Union
FRR	Front Running Region
LAND4CLIMATE	Utilization of private land for mainstreaming nature-based solution in the systemic transformation towards a climate-resilient Europe
NbS	Nature-Based Solution
OGD	Open Government Data
OPERANDUM	OPEn-air laboRAtories for Nature baseD solUtions to Manage environmental risks
WP	Work Package

Executive Summary

Deliverable 2.2 (D2.2) outlines the data requirements for sustaining an efficient methodology for the assessment of the Nature-Based Solution (NbS) efficiency and effectiveness in mitigating hydro-meteorological hazards and adapting the territory to enhance the climate resilience. The deliverable describes the key data and information required to capture the bio-geophysical processes, engineering characteristics, economic costs and social acceptance to be monitored in order to optimize the NbS implementation. As such, it integrates the monitoring and modelling methodology of D2.1 “Report on the modelling and monitoring methodology and NbS performance indicators” by identifying the necessary data to assess the local and non-local aspects of the NbS implementation and the target area of the intervention and deliver a transferrable recommendation to be declined across different environments. Ultimately, the report provides a collection of available datasets specifically for the target area of the intervention in each Front Running Region (FRR).

Keywords

Data requirements, Nature-based Solutions, risk assessment

1. Introduction

1.1 Scope of the Report

The pursuit of climate resilience that the project LAND4CLIMATE strives for is marked by the promotion and implementation of multifunctional Nature-Based Solutions (NbS) on private land. The adopted approach is that of a Living Lab, where the local knowledge and needs provided by local stakeholders integrate with a ground-based evaluation of NbS efficiency and effectiveness to promote a co-designed and co-developed NbS implementation and to provide land policy instrument and business models to mainstream further upscaling and replication. The focus is given to the six Front-Running Regions (FRR), the project's Living Labs where testing and demonstrating NbS potential for climate resilience against a multitude of different hydro-meteorological hazards that affect the central and peripheral parts of the continental biogeographical areas.

The primary purpose of this report is to develop a comprehensive guideline that outlines effective data needs for NbS efficacy evaluation and monitoring throughout the lifetime of the intervention. The starting point is the identification of no-regret NbS to be implemented in each FRR, a procedure that has been tackled in D1.9 "List of stakeholders preferred no-regret NBS measures – Front-Running Regions" where each FRR delivered a list of preferred NbS based on the climate-risk maps developed within WP1, consultation with local stakeholders, and aligned with the implementation strategy deployed within each FRR. From there and with additional consultation with the FRR partners (through bilateral meetings, see section 3), a selection of the preferred NbS is finalised so that each FRR would obtain an efficiency and effectiveness assessment for at least one NbS as an outcome of WP2. Since the selection of the preferred NbS is functional to the definition of the modelling strategy, a more exhaustive description of the NbS is given in D2.1 "Report on the modelling and monitoring methodology and NbS performance indicators", while in this deliverable the focus is more towards the characterisation of the target area for the implementation. Therefore, this report complements deliverable D2.1 "Report on the modelling and monitoring methodology and NbS performance indicators" in identifying necessary data, whether available or desired, to guide a performance assessment of NbS efficiency and effectiveness. Since NbS can endure for many years or even decades, it is crucial to incorporate decadal timescales into the design performance evaluation strategy. This approach ensures a long-term monitoring and evaluation of NbS owed to the availability of existing resources within the FRRs, effectively addressing stakeholder requirements and facilitating ongoing research opportunities. Moreover, it provides a first intake of the necessary data to support the NbS efficiency and effectiveness evaluation foreseen by the D2.3 "Report on multi-scales numerical simulations of the performance of the NbS" and a basis for the NbS implementation under work package WP4.

The deliverable is aimed at supporting NbS implementation within the FRRs, by highlighting the data necessity for a thorough performance evaluation. It will also provide a baseline of available data for integrating the performance evaluation through numerical simulations and address the missing data that could be useful in future planning of similar interventions. Data will compose of bio-geophysical quantities responsible for affecting the risk, engineering information on the structure and maintenance of the selected NbS, and socio-economic constraints for the NbS implementation and acceptance.

The scheme for data requirement will be designed to be general and replicable in other contexts outside the project and for other NbS. The contextualization to the specific FRRs and specific areas of intervention necessitates to be tailored upon the local needs, stakeholder knowledge, laws and regulations that determines the data availability. The existence of monitoring system on each territory subject to the intervention is dictated by the choices of governmental and local authorities. Stress the necessity for sustained ground-based information is among the scope of this report that provides public, private and non-governmental organisations with the knowledge and tools that enable human progress, economic development and nature conservation to take place together.

1.2 How data fit into the methodology for the NbS performance evaluation

Related to the LAND4CLIMATE methodology for assessing the NbS performance in reducing the local effects of hydro-meteorological risks, data collected in the target areas for the NbS implementation serves two purposes:

1. Establish the baseline: a baseline is the current status of the target area to explore changes and improvement upon, e.g., by dedicated programs, policies and suitable interventions. In this context, the baseline can either be the target territory before the NbS implementation, or simultaneously on areas with similar conditions but without implementing an NbS. Collecting a complete dataset addressing the local characteristics of the target area and that of the local hazards contribute to create the baseline. This exercise helps the understanding of the phenomena associated with the risk and the intervention, and the processes regulating the local dynamics.
2. Support the numerical investigation: Numerical models are the core tools to evaluate the NbS implementation scenarios. Data collected in the target area is essential to setup the simulation according to the specific characteristics of the territory and the climate hazards. This comprises input data to setup the simulation and data to validate the results. Comparing the baseline with the NbS-implemented scenarios allows observing the performance of such an intervention - i.e. whether and to what extent the expected outcomes have been achieved (Cutter et al. 2010).

Following OPERANDUM[1] methodological workflow (OPERANDUM D4.3, 2021), available data from monitoring activities or existing databases are a complementing component to the numerical model-ling. Although LAND4CLIMATE methodology (see D2.1 “Report on the modelling and monitoring methodology and NbS performance indicators”) is centred around a numerical assessment of the intervention, the available data from the FRRs can support the evaluation. However it is crucial to highlight that data requirements overcome the mere use as model input or for validating the simulation. Data, whether collected through ad-hoc monitoring, from existing databases or as local knowledge, are a key component for the NbS performance evaluation as they provide ground-based evidence ex-ante (why an NbS is needed) and ex-post (how is the NbS performing) intervention. For the sake of completeness and to strengthen the link with the modelling methodology, a brief mention to the monitoring workflow is given.

[1] OPERANDUM (OPEn-air Laboratories for Nature baseD solUtions to Manage hydro-meteo risks) was a 4.5 years (2018-2022) H2020 project aimed at delivering the tools and methods for the validation of Nature-Based Solutions to enhance resilience in European rural and natural territories by reducing hydro-meteorological risks (https://www.operandum-project.eu/).

Parallel and integrated with the modelling workflow, data from monitoring experiments or available dataset follow a similar investigation concept in seven steps (**Fehler! Verweisquelle konnte nicht gefunden werden.**):

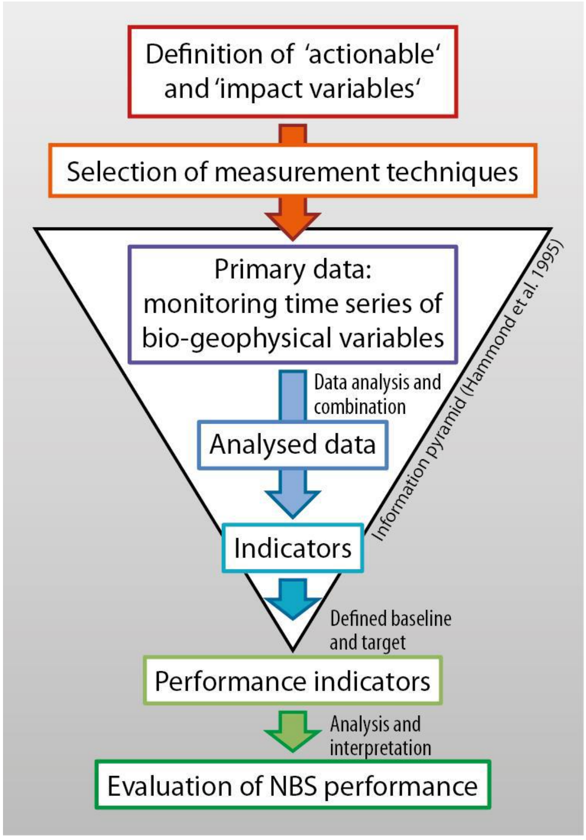

Figure 1: Workflow for evaluating the performance of NbS based on time series acquired from monitoring experiments (modified from Figure 4, OPERANDUM D4.3, 2021)

(i) Definition of actionable (environmental characteristics which are directly changed by the implemented NbS) and impact (characteristics which change due to the effects of an NbS) variables based on the characteristics of the risk the NbS is meant to. (ii) Selection of the appropriate measurement technique or the meaningful existing data to tackle the problem in question. (iii) Collection of data through monitoring activities or retrieval of available data. (iv) Analysis of primary data, (v) development of indicators in line with the guidance from D2.1 “Report on the modelling and monitoring methodology and NbS performance indicators”. (vi) Construction of performance indicators after defining the baseline, which is based on the data analysis of the target area before the NbS implementation. The last step in the workflow is (vii) the analysis and interpretation of the results of the performance indicators derived from the integrated measurements and numerical simulations to evaluate the performance of the NbS. A systematic collection and analysis of these data would integrate the modelling assessment of NbS to design a holistic approach for the evaluation of NbS efficiency and effectiveness, as advocated in D2.1 “Report on the modelling and monitoring methodology and NbS performance indicators”.

2. Data Requirements for NbS Performance Evaluation

This section focuses on defining the essential data requirements for the FRRs, effectively aligning LAND4CLIMATE's perspective on NbS performance evaluation with the feasible implementation of specific NbS interventions. It is crucial to recognize that the interpretation of these requirements is context-dependent, necessitating a tailored approach for each FRR.

In addressing hydro-meteorological risks, LAND4CLIMATE emphasizes the importance of examining both current conditions and the evolving challenges posed by climate change. A thorough understanding of relevant processes is vital for strategic data collection. Given that NbS aims to meet societal needs, developing a "holistic view" of the socio-ecological system – comprising inter-connected biophysical and socioeconomic elements – the location where an NbS is implemented becomes imperative. Grasping the interactions between NbS and the socio-ecological system enables effective data collection for assessing impacts, highlighting the importance of stakeholder consultation in crafting this comprehensive view (Nesshöver et al., 2017).

Effective monitoring is a cornerstone of successfully assessing the impact of NbS. It offers vital quantitative and qualitative evidence regarding the benefits generated through NbS interventions. Engaging in NbS monitoring means systematically collecting data to evaluate the environmental status and to detect changes that highlight either degradation or restoration. To ensure that monitoring is effective, it is critical to clearly establish objectives and select appropriate data analysis methods beforehand. This approach guarantees accurate assessments and a comprehensive understanding of the physical, chemical, and biological dynamics at play in the environment under investigation.

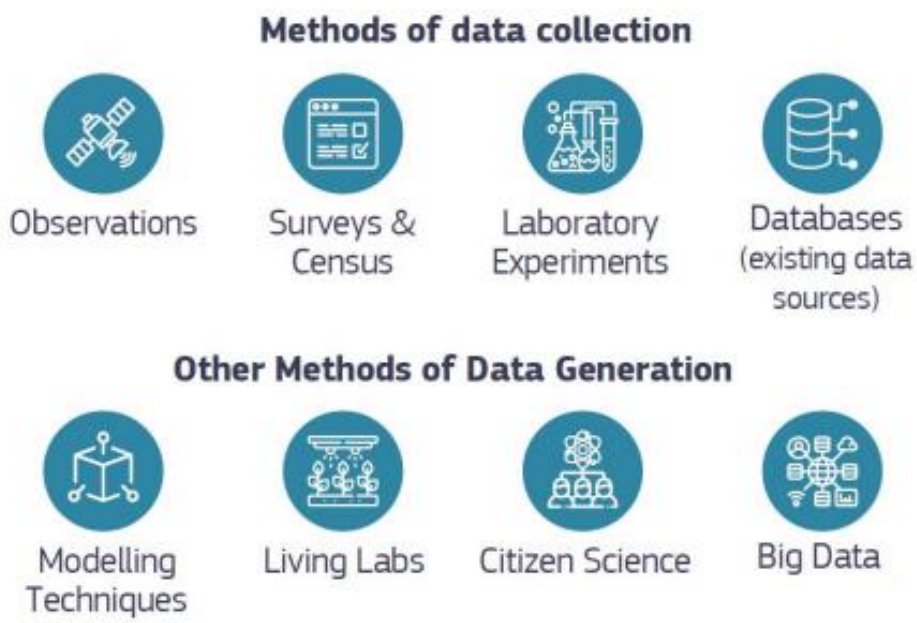

Figure 2: Data types and collection methods (modified from Figure 7-A of Dimitru and Wendling, 2021)

Figure 2 identifies the most common methods for data collection and generation when dealing with NbS performance evaluation, as reported by Dimitru and Wendling, 2021. As modelling techniques are debated for each specific FRR in D2.3 "Report on multi-scales numerical simulations of the performance of the NbS" and the remaining methods for data generation are covered as part of the Living Lab approach, this deliverable focuses on data collection methods, which is a first and essential step for the effective implementation and evaluation of NbS. This process should be underpinned by careful and strategic planning, advanced technical expertise, and an extensive understanding of the environmental context as well as its interactions with human activities. Such a comprehensive approach not only ensures the collection of relevant and precise data but also facilitates informed decision-making processes for monitoring and assessing the outcomes of NbS initiatives.

When it comes to collecting data for NbS monitoring and assessment, Dimitru and Wendling (2021) defined four categories of methods, namely: (i) Observations, (ii) Surveys and Censuses, (iii) Laboratory Experiments, and (iv) Databases. Each method serves a distinct purpose and is suited to different research questions, as delineated in Table 1.

Table 1: Methods for gathering data for NbS assessment

	Data Category for NbS assessment
 Observations	Observations play a critical role in tracking the efficacy of NbS interventions and their impacts on socio-ecological systems. Data gathering is performed using manual and automated approaches and can provide either qualitative or quantitative data. For quantitative data collection, techniques may involve direct measurements operated by automatic sensors. Qualitative data can be obtained through human perception and "sensing", a detailed (personal) process that includes careful watching, listening, and noting behaviours and interactions within the ecosystem (Kawulich, 2012). A key advantage of observations is the inherent objectivity. An observer, whether being a person or an instrument, does not interfere with the environments or subjects being studied, if not in a limited and often meaningless way. This property of observational studies helps to minimize biases that could distort the findings, thereby enhancing the credibility and reliability of the data obtained. Individuals' behaviours and attitudes toward NbS can also be a form of observational data. This type of observational study encompasses various methodologies for collecting data on how individuals behave, their attitudes, and, importantly, how they interact with one another as well as with their surroundings. Such observational methods have gained traction in recent years as effective tools for assessing the social benefits associated with NbS, but also the acceptance of the NbS within the community and perception the population has towards the intervention. Understanding these interactions means comprehending the influence community dynamics and individual well-being have on the specific risk the NbS is tackling. Once again, observations can be qualitative and quantitative. Quantitative observations involve measurable data, such as counting the number of visitors to a particular NbS site over a defined period. On the other hand, qualitative observations focus on more subjective aspects, such as the nature of interactions people have with the environment or how they engage with specific NbS features. This combination of quantitative and qualitative data allows for a richer understanding of the impacts of NbS on both individual behaviours and broader community practices.

Surveys & Census	Surveys and censuses are essential methods for the comprehensive collection of environmental, socio-demographic, and economic data, all of which are crucial for assessing the perception and expectations of NbS implementation. Additionally, these data sources can provide quantitative assessment of the realization of the NbS. A particularly significant source of this survey data emerges from administrative records. These records encompass series of information compiled and stored by various governmental bodies and organizations at international, national and local levels, including detailed reports on environmental conditions, statistics on natural resource use, ongoing projects in the field, permitting path[2], spatial planning, and other relevant datasets. Unlike more passive observation methods such as the automatic instrumentations, surveys employ an active approach in engaging individuals and communities and define a participatory strategy to get them involved (Ponto, 2015). These surveys involve participants selected randomly among local communities or strategically for the scope of the intervention, answering a series of quantitative and qualitative questions. The analysis of the responses from these participants is crucial to derive statistical insights on the population perspective that are representative of the broader community. This information can then be exported and generalised promoting a comparison across different demographic and geographic groups or within the different communities of the same territory. Census data serve as a complementary resource. While surveys are typically delivered to samples of the population, census targets everyone within a designated area, offering a complete landscape of socio-demographic characteristics. This comprehensive approach is particularly important within the context of NbS, where initial survey data can establish a baseline for understanding the conditions before the implementation, paving the way for the intervention to take place and monitoring of the NbS's well-being and efficiency in the long term. By capitalizing on these diverse data-gathering strategies, we can foster a more informed decision-making process aimed at sustainable management and enhanced ecological stewardship.
Laboratory Experiments	Laboratory experiments play a crucial role in natural science when the goal is to evaluate a specific process of interest, disentangling it from other processes that may alter the observation, thereby establishing clear cause-and-effect relationships. While observational studies rely on select samples of data from available databases, laboratory studies empower researchers to systematically manipulate specific settings to focus on the specific topic of the research. This approach allows to retrieve a very setting-specific dataset that enables a more comprehensive understanding of the measured variables and their cause-relationships. As a result, researchers are better equipped to identify and confirm the underlying mechanisms that drive the observed outcomes (Montgomery, 2008). In a more holistic view of the laboratory experiment, open-air laboratories can create real-world pilots to explore the intricacies of the process of interest in a semi-controlled environment. This approach also include the communities in each phase of the problem identification and study, integratigating the social sphere into the laboratory. In the context of NbS, laboratory experiments can serve two purposes. The first purpose enables the evaluation of individuals or community responses to the implementation of an NbS, providing insights into public perception and social acceptance. The results allow to establish a snapshot of behavioural responses to address whether the implementation of NbS is feasible in real-world settings. Second, laboratory studies can assess the environmental

[2] A set of regulations that define both general and specific requirements for engineering projects, including NbS, which must be fulfilled before the projects start and continue until the completion of such projects. The Permitting Path is the route through all these laws.

	performance of various NbS strategies, measuring their effectiveness in addressing ecological challenges such as climate change, urban flooding, or biodiversity loss under target geographical and environmental conditions. Furthermore, the data obtained from laboratory experiments can be especially valuable during the initial phases of NbS intervention planning to evaluate the potential for replication and upscaling of the tested interventions. This second purpose of laboratory experiments copes well with the concept of pilot studies, real-world laboratories were dedicated to testing hypotheses, refining methodologies, and gathering preliminary results to inform and promote larger-scale applications. This approach enhances the likelihood of successful NbS implementation by ensuring that the solutions are both scientifically sound and tailored to the specific needs of the environment and community being served.
Databases (existing data sources)	Databases are the ultimate complementary sources of information for the previous three categories. They provide a safe space where different types of already collected data are stored and are placed at the disposal of researchers and practitioners. Nowadays, databases are almost entirely accessible online through dedicated cloud resources or accessing keys, but a meaningful amount of historical data are stored in paper archives, especially when possessed by local governmental bodies. The online architecture and accessibility of these databases is typically not standard, although a reference dataset for specific topics may exist. Databases for scientific researchers are typically designed without a graphical interface and data can be downloaded or exported through application programming interfaces. User-friendly databases are often accessible through graphical interfaces such as online dashboards, providing easy access via dedicated tools to navigate the information stored in the database. In the context of NbS, database is essential in providing validated and quality-checked information about case studies of successfully implemented NbS, alongside with methodologies, intervention approaches, permitting path, and strategies to take inspiration from. An example is given by the GeoIKP platform developed within the H2020 – OPERANDUM project that offers insight into existing successful international NbS together with an overview on related policies and legislation, and a step-by-step plan for co-creating a novel NbS.

Moreover, it is essential to cultivate a deep understanding of the relevant factors, interactions, causal chains, and potential consequences associated with the climate hazards. This understanding can be achieved through various methods that outline the biophysical and socio-economic systems where the NbS operates. As a critical first step, identifying the necessary data types for evaluating NbS performance will set the groundwork for effective implementation and impactful results. In the following sections, data types are identified based on experience and lessons learnt from past projects that covered NbS implementation and divided in four main categories according to their nature: bio-geophysical, engineering, and socio-economic data. Note that for increasing the clarity in the data identification, social and economic data will be treated separately.

2.1 Bio-geophysical Data

Bio-geophysics is defined as the ensemble of physical processes and interactions within the biosystem that combines the fields of microbiology, bio-geoscience, and geophysics (Atekwana and Slater 2009). Within this context, bio-geophysics examines the links between dynamic biological processes and phenomenon enclosing geophysical processes and geologic materials. In the context of NbS, bio-geophysical data are a collection of information that evaluate the predisposition of a territory to host the NbS implementation and the change it might undertake after the construction. Owed to its broad definition, bio-geophysical dataset comprises a large variety of information tackling the different spheres of the earth system (biosphere, atmosphere, hydrosphere and lithosphere). These data are typically quantitative, as for the most part they come from an objective evaluation of a physical status, through observation or measurement. Qualitative investigation can also be important, especially for small areas of interventions where it is unlikely to have specific datasets describing the territory. For example, local knowledge can bring the memory of the land transformation and the history of hydro-meteorological events.

Many approaches that address a wide variety of the possible advantages and disadvantages of implementing nature-based solutions have been put into practice. Regarding data types, remote sensed data and in-situ observations and measurements are the two types of environmental observations that are crucial and frequently utilized to evaluate and track the bio-geophysical characteristics of an NbS site and to create a baseline. In certain instances, survey information obtained at the NbS location or from national databases is used to supplement these observations. These methods complement each other in covering the relevant spatial and temporal scales involved in the NbS evaluation. While the NbS itself is typically a small-scale implementation, especially when dealing with prototypes or when one of the scopes of the intervention is to study the NbS performance ex-post construction, the spatial scale of the hazards (and risks) is typically larger. Furthermore, the time evolution of a territory conformation is geological (except for landscape transformations because of extreme events) while the time scale of the NbS and its effects are limited to the lifetime of the NbS itself. The monitoring techniques cope with these scale requirements and align with the numerical model simulations that, in a similar way, might need to be obtained using different models to tackle the climate forcing (large scale climate condition/phenomenon driving the hydro-meteorological risk) and the local hazard (hydro-meteorological process that insists on the target area).

A list of bio-geophysical data required for the NbS performance assessment is provided in Table 2.

Table 2: Bio-geophysical data requirement for an exhaustive NbS performance assessment

Data Type	Description	Examples	Sources
Geography (geo-referenced information)	Geographical characteristics summarise the general knowledge of the territory hosting the NbS. Those spans from the geographical context the territory fits into, to the detailed description of the land hosting the NbS. It comprises both qualitative (general description of the target area with respect to the region, also including local knowledge) and quantitative (specific intervention target, area characteristics) records. Information is geo-referenced. Additional information can come from population census and activities close or around the intervention.	Geographical context; characteristics of the target area for the NbS; population within the target area	Geo-referenced maps, municipality archives, local stakeholders

Topography	Topographic data are spatial representations of terrain elevation with respect to the mean sea level. They are typically presented as geo-referenced data gridded on a one-layer raster and visualized as maps. Typical data of this type are the digital elevation model (DEM) and digital terrain model (DTM), 3D graphics of the Earth surface (or a portion of it) without objects on top (bare surface representation). These data are typically retrieved from traditional topographic maps or derived from modern light detection and ranging (lidar) data and other sources gathered by airborne and space-based instruments through dedicated and world-wide used algorithms.	Digital elevation model, digital terrain model, topographic maps	Local archives (for local topographic maps), International or global databases (Eco-DataCube; Copernicus DEM; EEA DataHub; EarthData)
Land use and land cover	Land cover is defined as the observed physical land type that cover the earth's surface. This includes the physical material of the ground surface (bare soil, water surfaces, artificial covering) and the "obstacles" (natural or planted) above it (vegetation, human constructions). Land use is instead defined as the functional use of the land from a socio-economic point of view. In other words, it determines the type of human activities undertaken for a certain land cover. With topographic maps and soil records, land cover and use give an exhaustive baseline information on the terrain affected by the hydro-meteorological risk and the NbS implementation, together with the state-of-the-art of the existing human activities and biodiversity. The retrieval of land cover and land use (when possible) is performed through remote sensing using satellite images. Specifically, a combination of images with high temporal and low spatial resolution and those with high spatial and low temporal resolution are used.	GIS maps that show extent of different land uses (e.g. agricultural land, forests, settlements)	Satellite data (MODIS, Landsat), products of global monitoring initiatives (Corine Land Cover)
Environmental records (meteorological, oceanographic and soil records)	Environmental records account for the data and information concerning the earth climate system and its components. Within the context of this deliverable, atmospheric (meteorological), oceanic and soil data are the three main components of the environmental records while biodiversity and ecosystem data are treated separately. Environmental records can be collected and stored as direct (and derived) measurements, observations and records. They comprise a wide category of data useful to physically characterise the local hazard (and so the hydro-meteorological risks) and its impact within the target area. When NbS are accounted, they	Meteorological data: - air temperature and humidity - wind speed and direction - radiation - precipitation, snow cover Ocean data:	Environmental protection agencies datahub, municipality archives, international and global initiatives (ERA5 reanalysis, Copernicus datahub), existing database from past projects

	help building the baseline (ex-ante implementation) and the effect (ex-post implementation) of the intervention on the local hazard. Depending on the scale of the intervention and target region, environmental records span from satellite (with large spatial coverage but small space and time resolutions) to airborne (medium spatial coverage with good resolution, but typically a one-shot sampling) and to in-situ (time evolution of variables in one location) measurements. All of them come with advantages and disadvantages but their typically essential for a first estimation and for validating numerical models of bio-geophysical processes.	- water temperature, salinity, density - current speed and direction - wave height and velocity Soil data: - soil temperature and moisture - energy flux - properties of the materials Hydrological data: -water levels and discharge in rivers -groundwater levels	on the territory
Hazard/Risk history	Documents and records witnessing the occurrence and describing the impacts of target hydro-meteorological hazards. This includes knowledge of extreme events from the past and the damages to the territory; existing maps of vulnerability of the region; records of vulnerable groups and exposed settlements. Data from this category may come from official documents from local authorities and news from local/national newspaper	Past extreme events	municipality / regional / national archives, newspaper archives
Ecosystem and Biodiversity	This class comprises a wide variety of information concerning the ecological system of the target area and its variety of species. The continuous monitoring of the ecosystem variables can be used to understand and predict ecosystem response and resilience to multiple environmental and human stressors. Moreover, they can be used to monitor the status of the NbS and its territorial integration.	Plants and animal species	National, international and global initiatives (Natura2000), satellite data (MODIS, Landsat)

2.2 Engineering Data

Engineering data refers to all the physical and structural information of the NbS to translate the design into the practical implementation. This category also includes the information the constructor needs for the implementation, such as the characteristics of the location where the implementation is going to happen in line with the structural needs of the NbS. Engineering data are particularly useful not only before the implementation phase, by identifying the most suitable location based on the territory characteristics and permitting path, but also to monitor the structural stability of the NbS throughout its lifetime. The monitoring of the structural characteristics of the NbS is particularly relevant when the intervention is a prototype: it gives useful and continuous feedback to the constructor to promptly intervene with adjustments or maintenance, but also to improve the overall quality of the implementation for replication or future applications.

A list of engineering data required for the NbS performance assessment is provided in Table 3.

Table 3: Engineering data requirement for an exhaustive NbS performance assessment

Data Type	Description	Examples	Sources
NbS dimension (required space)	The geometric characteristics of the NbS at the time of the implementation, including an estimation of its expansion (for example due to the vegetation growth). If the NbS needs to be preserved from human activities, the geometric characteristics must include the dimension of the prohibited area.	Structural dimension of the NbS, growing rate	Construction project
Soil properties (from the point of view of the NbS construction)	Characteristics of the terrain in the target area of the NbS implementation that are relevant for the constructor. These data are typically retrieved from inspection of the target area by the constructor (qualitative data) and existing or ad-hoc measurements (quantitative data) the constructor considers essential for the implementation. This information ensures to find the best location for the implementation, which is as close as possible to the ideal configuration obtained in the design phase. Furthermore, it ensures the terrain “imperfections” play a minimal role in the longevity of the NbS. Integrating historical information on the impacts of hydro-meteorological hazards and extreme events in the region can inform the soil response to extreme stresses and strains, collecting information for an ex-ante assessment on the terrain response to the NbS implementation.	topographical conditions (or bathymetric conditions), hydraulic conditions, geotechnical parameters, natural conditions (presence and characteristics of vegetation and fauna), anthropic activities (e.g., presence of interfering structures, underground services)	Constructor inspection, Soil characteristics from environmental records
Obstacles / permitting path (for NbS construction)	Series of information that may determine the obstacles to the implementation of the NbS as designed by the constructor. This is particularly important when it comes to NbS because of the “living component” of the implementation that cannot negatively interfere with the existing ecosystem. From the analysis of the data from this category, the constructor must adapt the design of the NbS to satisfy the regulation of the target area, either being structural (dimension limits), positional (permission to build in a specific location), and ecosystemic (introduce living components that cope with the existing ecosystem).	National / regional / local regulations	Municipality archives, Environmental protection agencies, civil protection agencies
Technology	Any data or information that enable to monitor the stability and well-being of the NbS. Data can be collected through monitoring of structural parameters of the implementation or during timely visual inspections and on-the-spot monitoring by the manufacturers. This information favours the durability of the NbS implementation, its performance and the possibility	Structural parameters	Sensors within the implementation structure, visual inspection

	for a prompt intervention if maintenance is necessary.		

2.3 Economic Data

Economic data refers to the costs associated with the NbS. Three main groups can be depicted: costs associated with implementation, costs of maintenance, and prevented costs from damage reduction or carbon sequestration.

- NbS implementation costs comprise expenditures associated with all the different phases of the project realization, from the design of the solution to the laboratory tests, the site inspection, working personnel and actual construction. This is the most expensive group, also due to the lack of standards and regulation for the NbS design and construction that oblige to spend resources in preliminary tests and research.
- Maintenance costs are associated with the necessary interventions ex-post implementation to preserve the structural solidity and functional efficiency of the NbS. Especially in the case of composite NbS structures, being formed by a structural (natural or artificial) and a biological component, it is likely to have different maintenance schedules and agencies to perform it. Simple maintenance actions, such as surface cleaning or vegetation feeding, can be sustained by the local community, thus decreasing the costs.
- Damage reduction costs are the prevented expenditures due to the reduced damages to people and infrastructures owed to the presence of the NbS. This cost is always difficult to estimate as a direct attribution of damage prevention to the NbS, but rough estimations could be done at least through hypothetical considerations and approximate values. Co-benefits of the NbS can also provide cost savings because of positive effects of the NbS on external factors with respect to the main hydro-meteorological risk the NbS is implemented to address.

A list of economic data required for the NbS performance assessment is provided in Table 4.

Table 4: Economic data requirement for an exhaustive NbS performance assessment

Data Type	Description	Examples	Sources
Cost of the NbS construction	Information concerning the costs of the NbS, including all phases of the realization, from design to construction and personnel work. The total cost is a valuable piece of information to be compared with alternative grey/hybrid/natural solutions to the same problem and evaluate economic advantages and disadvantages for the implementation phase.	Quote for the implementation	Manufacturer
Maintenance cost (with respect to the	Information concerning the costs of the NbS maintenance for the duration of the expected lifetime of the implementation and beyond. This information includes the personnel work	Quote for the maintenance	Manufacturer, agency / private who

expected life-time)	and an estimate of possible structural interventions. The total cost of maintenance is a valuable piece of information to be compared with alternative grey/hybrid/natural solutions to the same problem and evaluate economic advantages and disadvantages in the long-term.		oversees maintenance
Natural resources (for maintenance)	Being the NbS a living implementation, its biological component needs to grow and be kept healthy throughout the expected lifetime of the NbS. This requires a supplementary maintenance with respect to the structural one previously listed and which is the sole maintenance intervention grey solutions necessitate. As for the structural maintenance, the maintenance costs for the natural component include the personnel work and an estimate of possible structural interventions. An estimate of benefits associate with ecosystem preservation and biodiversity enrichment can be added to this economical evaluation. The total cost of maintenance is a valuable piece of information to be compared with alternative grey/hybrid/natural solutions to the same problem and evaluate economic advantages and disadvantages in the long-term.	Quote for the maintenance	Manufacturer, agency / private who oversees maintenance
Damage reduction (in terms of cost reduction)	As NbS are designed to reduce the hydro-meteorological risk and the associated disaster risk, it is possible to assess the potential saving from damage prevention or reduction. An estimate of the cost prevented can be done as part or because of the NbS performance evaluation. A by-product of damage reduction is given by carbon sequestration operated by the NbS: it is possible to give a monetary value to the amount of carbon the NbS stores, transforming a climate risk reduction into a saved cost.	Costs associated with expected risk reduction compared to actual risk	Results from NbS performance evaluation, risk reduction

The economic data suggested here will inform and be aligned with the assessment of co-benefits and trade-offs as part of Deliverable 2.4.

2.4 Social Data

Social data encloses a wide variety of qualitative and quantitative information mainly concerning the participatory sphere of the local (but also non-local) communities towards the intervention, considering all its different phases. As discussed in D2.1 “Report on the modelling and monitoring methodology and NbS performance indicators”, in the context of NbS, social impacts can stem from two sources. Firstly, as a by-product of the implementation process adopted, and the type of stake-holder engagement undertaken which sees NbS as a social, environmental, and technical process, rather than to a specific NbS measure. Secondly, as a secondary impact of natural risk reduction and hazard mitigation, at times an indirect or unintended consequence of building an NbS infrastructure. Some of the main social aspects worth considering are public acceptance; perceptions of risk; knowledge and learning; social capital, empowerment and trust; aesthetic values; better access to nature and health; and policy governance. The ones deemed most relevant for the NbS in the FRRs are listed in Table 5 below. A wide range of data collection methods exists to gather information on these issues, including qualitative analysis (focus groups, interviews, workshops, observational methods), surveys, and co-participation methods, with the goal of measuring the interest, aware-ness, attitudes, claimed behaviour, commitment and acceptance level of the involved communities (See Table 13 in Annex for more details). There are two types of social data - qualitative and quantitative:

- Qualitative data are typically collected in form of interviews and are used to gather descriptive information, reflections and insights directly from individuals or groups. Perceptions, motivations and understanding of the intervention project or the context are common types of information that can be considered qualitative. These collection methods can be used as a vehicle for spreading knowledge or raising awareness outside the local community or to retrieve local knowledge providing an additional level of understanding of the local community and land. Although they are usually not numerical, qualitative social data can also be interpreted using modern analytical techniques through relationship attribution, association and evaluation (change from pre-intervention/ baseline to follow-up/ post-intervention) or semi-quantitative analysis with frequency runs and prioritisations depending on the sample size. When the qualitative data are gathered only from e local communities, and the sample size of the population under investigation is small this brings about restrictions and limitations with respect to the degree of representation, generalization and upscaling. Nonetheless, qualitative survey instruments are highly adaptable and participative in nature and can provide additional depth, nuances and explanations of the “why” behind some of the findings from more quantitative methods (Ritchie et al., 2014).
- Quantitative data are typically collected through questionnaires that gather data in (or convertible to) a numerical form, making statistical analysis much more manageable. To ensure a high quality of the collected data, questionnaires must be written in a simple, clear, un-biased manner avoiding leading questions and a misleading interpretation of results (MRS 2024).

A list of desirable social data for the NbS performance assessment is provided in Table 5. Some of the data presented provides descriptive insights and context, while other data provides analysis of impacts.

Table 5: Social data requirement for an exhaustive NbS performance assessment

Data Type	Description	Examples	Sources
Public awareness and perception	Unpacking the public’s level of understanding and perception of different elements like climate change, hazards, risk, resilience and NbS before and after the intervention to assess change.	Change in understanding or attitudes	Survey, discussion groups, climate walks, sentiment analysis

Public involvement	Involving the public in "their" land transformation is at the core of a constructive participatory approach that aims to embrace the NbS implementation and preserve its efficacy. The population can be involved in different phases of the project, fostering a co-design of the NbS, a co-development of the operational needs against the impacts of the hazard, a co-supervision supporting the constructor during the implementation and maintenance periods. An effective involvement is active: the population takes part in the different phases that lead to the NbS implementation by sharing local knowledge on the hydro-meteorological risk, creating consensus to support the intervention, spreading the study methods and results to mainstream the solution and increase acceptance in there and other territories. A first engaging effort from the project partners and stakeholders is required to create a community of interest, which can grow in time depending on several factors, such as individual interest in the topic, degree of the community involvement within the project activities, communication and dissemination actions. The public can be engaged to various degrees of effort from being informed, to being consulted, to being involved, to collaborating and, finally, to co-creating the implementation (Centre for Effective Services, 2019). Monitoring the level of involvement can be challenging, information can be extrapolated from the support received from the community, its growth rate, its willingness to participate to project-related events and the dedication to the welfare of the land	Number of participants to surveys, visits to the implementation site, participation to activities/events in the region	Survey, Interviews, social media, stakeholder mapping, sentiment analysis, climate assembly
Public acceptance	Upham et al. (2015) defines social acceptance as the attitude or behavioural response towards the implementation or adoption of a proposed technology held by the public in a specific country, region, or town. Public acceptance can therefore gain a passive implication, since being a response to an event it requires the event to be developed, proposed or finalised. Nonetheless, acceptance may also result in a propositional effort from the receiver that can volunteer to share their local knowledge, support the project, and manifest interest (also through social sharing). Public acceptance is also key to regular deployment of the design and physical implementation work and may provide	Participation to activities in the region, support the maintenance	Interviews, survey, climate assembly

	support during the maintenance phase of the NbS through public involvement.		
Landowners' acceptance and awareness	The specificity of LAND4CLIMATE towards private land requires the landowner's willingness to "donate" the land for implementation and an understanding of the potential benefits for the environment. According to LAND4CLIMATE objectives, the landowners can become the only social body the researchers and stakeholders of the FRRs must deal with. To gain and maintain the support of the landowner, establish a high level of acceptance and awareness towards the beneficial aspects of the NbS implementation is mandatory during the design and implementation phase to ensure a future commitment in dealing with maintenance.	Change in attitudes, behaviours, practices and participation	Interviews, discussion groups, ethnographic observations
Local Knowledge and learning	Knowledge developed by a local community over time, based on the life experience of living in a specific territory. Local knowledge includes historical facts and information that can contribute to identify the key risk a community is facing, the specificities of the territory to facilitate the location of the target area for implementation, indigenous initiatives and construction projects tackling the same issues that have existed, exist or are temporarily assembled and dismantled throughout the years.	Stories from local inhabitants, existing local records, changes in knowledge and learning, acquisitions of new skills	Storytelling, Interviews, local authority archives, ethnographic observations, surveys
Better access to nature and health	Through the creation of NbS measures like tiny forests, climate parks, unsealing of surfaces, wetlands, reforestation, restoration of flood plains and river courses, etc. local communities are provided with better access to nature which could positively impact on the local population's physical and mental health.	Accessibility (measured as distance or time) to green spaces for population (Caroppi et al., 2019), Perception of accessibility to nature	EUROSTAT or other local authority or regional statistics, surveys
Social capital, empowerment and trust	Though difficult to measure and to assess attribution, given the presence or lack of participatory process in NbS implementation this can lead to changes in community empowerment, social capital and trust also expressed through sense of belonging, connectedness to place and nature and social cohesion (European Commission 2021).	Changes in connections between stakeholders, claimed sense of belonging, N. of new social relations established, level of interaction among participants,	surveys (using standard questions like from the World Values Survey), interviews, network analysis, discussion groups

		self-assessment on project capability to influence trust among participants (Passani et al., 2020)	

Building on from the diagram in **Fehler! Verweisquelle konnte nicht gefunden werden.**, Table 13 in Annex 1 takes a closer look at the various different research approaches, methods and activities which could be used to assess change and, hence, measure the social impacts of the NbS measures.

It is worth briefly revisiting and highlighting some of the main drawbacks and limitations of using these suggested methods for assessing social impacts of NbS:

- One of the main limitations is linked to the difficulty of assessing attribution and correlation. It is difficult to isolate the specific social change and trace a direct link back to the process or implementation of a specific NbS. A lot of "background noise" and other confounding factors are at play (Dumitru and Wendling, 2021).
- The sample sizes for most of the research methods suggested tending to be quite small, are non-random and not statistically representative (but indicative), and there is a degree of sample selection bias (Anderson et al. 2021). Furthermore, it is widely accepted in the field that those most engaged or vested in the project tend to partake in research more, there is a research bias in the selection of research participants.
- Often data for social impacts are not based on actual or observed practices but are based on what respondents claim to think, to believe, to do, etc. (i.e. claimed behaviours). This further adds to the general data quality issues, as some indicators are not actual or observed but are based on claims, projections or expectations. (Nurmi et al., 2017; Dumitru and Wendling, 2021).

3. Data Demand in the Front-Running Regions

Data are an essential input for the setup of modelling and monitoring experiments. Bilateral meetings have been organized to discuss which data and relevant information are available in each FRR. The following questions were addressed during the bilateral meetings:

- Starting from the list of no-regret NbS reported in D1.9 "Report on multi-scale numerical simulations of the performance of the NBS", what are the target NbS that you would like to model in your Front-Running Region?
- In addition to the data already available resulting from WP1, what is the data availability in the Front-Running Region?
- Are there any essential information for NbS implementation that you expect the NbS assessment will provide?
- Can we use existing local knowledge?

- Have there been any previous relevant studies in the region?
- Is there a plan to assess the co-benefits and social impacts of the implementation?

The current section reports the answers to these questions to pave the way for the experiments planned in the next deliverables of WP2.

3.1 Austria – Lafnitz catchment

The Lafnitz catchment is located in eastern Austria. This Front-Running Region aims to implement NbS in the first place on agricultural land (hedges, vegetated buffer strips, and agroforestry) to prevent soil erosion and improve water management and thereby productivity. A second NbS priority lies on integrated heat and water management through establishing a sponge-city concept in the municipality of Rudersdorf (2,200 inhabitants). The identified project area in Rudersdorf represents a combination of public and private land, with the latter being currently more or less sealed. The intended NbS will consist of a combination of green and blue infrastructure (unsealing pavements, planting additional trees, green strips) to increase rainwater infiltration and underground retention to collect rainwater. The vegetation will contribute to lowering the air temperature with beneficial effects for heat stress. The sponge city has been chosen as the target NbS because an local politicians and landowners have expressed interest in improving the current situation through this NbS. The engagement approach with landowners will depend on the municipality. An exploratory meeting will be organized in spring 2025 and implementation can be expected ideally during 2026. The municipality and landowners may provide existing local knowledge. The implementation cost will depend on the scope of the actual project. **Fehler! Verweisquelle konnte nicht gefunden werden.** shows the project s ite which cover approximately 4000 m² (red area).

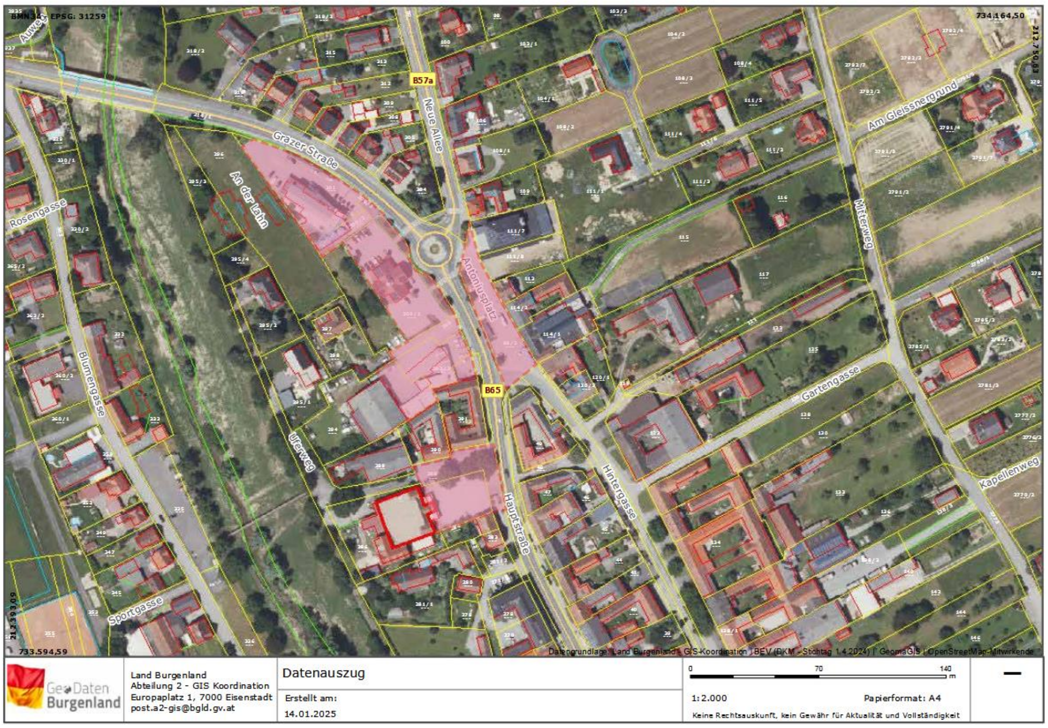

Figure 3: Project city for the sponge-city concept in Rudersdorf (Front-Running Region Austria)

The available bio-geophysical data includes topography, land use and cover, and meteorological records from weather stations. Other data may be provided such as building characteristics and vegetation species. Modelling experiments are expected to reveal the areas where the intervention is less impactful to optimize the design and the coverage of the intervention. Previous modelling studies are available from the HORA platform (https://www.hora.gv.at) concerning the surface water run-off depth and speed during urban- flood events (https://www.hora.gv.at/assets/pdf/Gefahrenhinweiskarte_Oberflächenabfluss_Bericht.pdf). Table 6 reports the available dataset within the region, but additional information that might support the NbS implementation and risk assessment can be found on the HORA platform.

Table 6: Available data in Front-Running Region Austria

<table>
<tr><th>Category</th><th>Data Type</th><th>Data Sub-Type</th><th>Resolution</th><th>Sources</th></tr>
<tr><td rowspan="10">Bio-geo-physical data</td><td>Geography</td><td>Georeferenced terrain characteristics on map visualization</td><td>At least 100 m</td><td>Federal Office of Metrology and Surveying (BEV)</td></tr>
<tr><td>Topography</td><td>Terrain raster</td><td>At least 100 m</td><td>data.gv.at (Open Government Data, OGD)</td></tr>
<tr><td rowspan="3">Land Use and Land Cover</td><td>Green spaces, water surfaces, roads, railway track</td><td>at least 100 m</td><td>data.gv.at (OGD)</td></tr>
<tr><td>Land Cover</td><td>at least 100 m</td><td>data.gv.at (OGD)</td></tr>
<tr><td>Areas protected under Natura2000 nature</td><td></td><td>data.gv.at (OGD)</td></tr>
<tr><td rowspan="2">Environmental Records</td><td>Meteorological maps</td><td></td><td>GeoSphere Austria</td></tr>
<tr><td>Hydro-meteorological records</td><td></td><td>eHYD platform (OGD)</td></tr>
<tr><td rowspan="2">Hazard-Risk History</td><td>Fluvial floods (risk)</td><td>at least 100 m</td><td>WISAplatform (OGD)</td></tr>
<tr><td>Landslide (risk)</td><td>at least 100 m</td><td>WISA plattform (OGD)</td></tr>
</table>

3.2 Czech Republic – National Park Bohemian Switzerland and Krásná Lípa

The main intervention in the Front-Running Region Czechia consists of the restoration of the small-scale site “Pod Cimrakem” by implementing typical elements of a sustainable urban drainage system (e.g., retention ponds, bioswales, and unsealing pavements) and closing drainage ditches in forest areas. These NbS are expected to enhance biodiversity, water retention, and groundwater recharge. Since the scale of the site considerably reduces the data availability, no modelling experiments have been selected.

Table 7 reports the available data for this Front-Running Region that is mainly focused on bio-geophysical aspects. These data cover geography, topography, land use and cover, and only some aspects of hazard history and environmental records. The limited hydrological data (i.e., a LIDAR Digital Elevation Model (DEM), and river water level and discharge) has been evaluated as not sufficient to support a detailed hydraulic or hydrological modelling experiment. Available data in Front-Running Region Czechia are listed in

Table 7

Table 7: Available data in Front-Running Region Czechia

Category	Data Type	Data Sub-Type	Resolution	Sources
Bio-geo-physical data	Geography	Administrative boundaries of districts and Front-Running Region		on request from ZABAGED database of the Czech Cadastral and Land Survey Office
	Topography	Digital Elevation Model	preferably 1 m, at least 5 m	Platform ČÚZK
	Land Use and Land Cover	Buildings, green spaces, water surfaces, roads, railway track	at least 100 m	on request from ZABAGED database of the Czech Cadastral and Land Survey Office. Railway track are also available at Správa železnic portal
		Agricultural lands	at least 100 m	CORINE 3rd level. Specific data are available in public registers (**mze.gov.cz**) but the data cannot be downloaded
		Areas protected under European law (Natura2000 nature protection areas, National Parks, UNESCO biosphere reserves)		INSPIRE Czech map portal:
	Environmental Records	Soil map		Map portal of Research institute for soils and melioration:
		Water level data at gauges And River Discharge		Partially available at www.edpp.cz
	Hazard-Risk History	Urban and fluvial floods (depth and velocity)	at least 100 m	Hydroecological information system: heis.vuv.cz
		Heat Waves (number of summer and hot days)	at least 100 m	Maps for normal period are available as rasters from Czech Hydrometeorological Office.
Social data	Public involvement and awareness	Total population size and distribution		Statistics from the recent Census (2021) or from administrative registry (need to be selected one by one): vdb.czso.cz
		Age distribution of population		Partially available for some socio-demographic groups:

				vdb.czso.cz

3.3 Germany – County of Euskirchen

The German County of Euskirchen is a rural area in the southern region of the state of North Rhine-Westphalia. The county of Euskirchen has 198,967 inhabitants on a territory of 1,248.73 km², which is divided into two natural areas: Zülpicher Börde in the northeast, which is a part of the Lower Rhine Bay, and the forested Eifel in the southwest. In terms of topography and climate, the Zülpicher Börde includes Euskirchen, Zülpich, and Weilerswist, whereas the Eifel includes the other municipalities. For the agricultural spaces Miscanthus plantation, hedges and orchard meadows are currently proposed to farmers to address floods and drought events in rural areas. Conversely, urban NbS include a tiny forest of 370 m^2 (i.e., a densely planted mini-forests of native not-deciduous trees), a climate park, and other measures (e.g., unsealing pavements, bioswales, rain gardens, tree planting) on the private land of selected landowners spread in the entire county. Detailed investigations for the implementation of the tiny forest are in place for the location of Zülpicher Straße 5a-5d (Figure 4), a district with a total area of 1,383 m², where collaborations with housing associations are ongoing since the early stage of the project.

Figure 4: Tiny forest implementation area in Zülpicher Straße 5a-5d (Source: FRR Germany)

Table 8 reports the available dataset that are mainly bio-geophysical data (i.e., geography, topography, land use and cover, meteorological records) and social-acceptance surveys concerning climate-change perception. Other data will be added concerning plant species and implementation costs.

Table 8: Available data in Front-Running Region Germany

Category	Data Type	Data Sub-Type	Resolution	Sources

Bio-geo-physical data	Geography	Administrative boundaries of districts and front-running region	1:250000	Geologischer Dienst Nordrhein-Westfalen (geoportal.nrw)
	Topography	Digital Elevation Model	1 m	Geologischer Dienst Nordrhein-Westfalen (geoportal.nrw)
	Land Use and Land Cover	Buildings, residential areas, industrial areas, commercial areas, green spaces, water surfaces, agricultural lands, roads and train tracks	Parcel size	www.wcs.nrw.de Geologischer Dienst Nordrhein-Westfalen (geoportal.nrw) Geofabrik GmbH
	Environmental Records	Meteorological records (current situation and history from 3 weather stations in the county)		German Weather Service (DWD)
		Water level data at gauges And River Discharge		elwasweb.nrw.de
		Soil Map		Geologischer Dienst Nordrhein-Westfalen (geoportal.nrw)
Economic Data	Cost of the NbS construction	Implementation		Evaluated by TUDO supported by FRR Germany
		Planning		Evaluated by TUDO supported by FRR Germany
	Maintenance Cost	3-years maintenance		Evaluated by TUDO supported by FRR Germany
Social data	Public involvement and awareness	Citizen Perception of climate change and adaptation measures		Surveys
	Existing local knowledge			It can be provided by landowners

3.4 Italy – Emilia-Romagna Region

The implementation site in the Italian Front-Running Region is located Delta-Po Regional Park in the municipality of Ravenna. The identified plot is privately held by a single landowner. The agricultural areas that will see NbS implementation are low-level terrain close to several wetlands and the coast nearby to the delta of the Reno River. There are only a few residual natural dunes in the selected case study area while the habitat of the lagoon and human activities are threatened by storm surges and salt water intrusion through the river or during storm events. The implementation will consist of a multi-hazard system of NbS: a dune for storm surges and coastal erosion (i.e., avulsion), a salicornia plantation to absorb salt from seawater and reduce saltwater intrusion in streams and soil, and deep-rooted plants to strengthen the embankments of a stream and prevent floods in its delta. Since the design of dune and salicornia are more advanced, these measures have been chosen as target NbS that can both address hazards and provide co-benefits such as the enhancement of biodiversity and the preservation of agricultural practices and other income sources from the surrounding lands. The dune implementation will be tailored upon the experience gained and the prototype designed developed in OPERANDUM which characteristics and design will reproduce the original one (see Annex 2 for details). Furthermore, salicornia could be also a profitable business in the food market from crop fields that are currently unused and consume a lower amount of water for irrigation since these plants are tole-rant to saltwater. The permission procedures are ongoing. However, the implementers are confident to carry out the intervention in summer 2025. Modelling assessment can guide the implementation maximizing risk reduction and minimizing side effects (e.g., possible coastal erosion at the borders of the dune). Results can locally update the projection of the coastline in the Delta-Po Regional Park included in the Masterplan of the Park Coastline (2006).

Table 9 reports the current availability of the dataset. Bio-geophysical data support both an analysis of environmental co-benefits and the modelling of the interactions between NbS and hazard characteristics. This data category includes geography, topography, land use and land cover, meteorological and oceanographic records, and details concerning the habitat and species located in the surroundings of the site. A preliminary coastal topography survey is scheduled for the next months to assess constraints associated with the implementation. This survey is also essential for the final design of the dune structure with consequences on the implementation costs. Co-benefits may be assessed from an economic point of view as the provision of new natural resources, business activities, and biodiversity renewal. Despite the landowner can provide existing local knowledge by describing past hazardous events, the area is uncrowned by tourists limiting the assessment of social acceptance. However, several public and private institutions are interested in the outcomes of the NbS interventions (e.g., Civil Protection, Forestry Corp, Legambiente).

Table 9: Available data in Front-Running Region Italy

Category	Data Type	Data Sub-Type	Resolution	Sources
Bio-geo-physical data	Geography	Administrative boundaries of districts and front-running region		Available upon request from municipalities and region
	Topography	Digital Elevation Model (DEM)	5 m	Emilia-Romagna Region (Geo-portal)
	Land Use and Land Cover	Areas protected under European law (Natura2000 nature protection areas, National and Regional Parks)		Emilia-Romagna Region (mokaApp)
		Buildings, residential areas, industrial areas, commercial areas, green spaces, water surfaces, agricultural lands	100 m	Copernicus
		Roads and train tracks		Copernicus
	Environmental Records	Meteorological records		Regional Agency for Prevention, Environment and Energy of Emilia-Romagna (ARPAE) portal (Dext3r)
		Oceanographic records		Regional Agency for Prevention, Environment and Energy of Emilia-Romagna (ARPAE) portal (Dext3r)
		Habitat and species		Network Natura2000 vnr.unipg.it
Social data	Public involvement and awareness	Total population size and age distribution		ec.europa.eu/eurostat
	Existing local knowledge			It can be provided by the landowner (document concerning the experience of hazardous events and pictures)

3.5 Romania – Upper Timiș River Catchment

The Upper Timis River catchment is located in Western Romania in the region Banat. The catchment is affected by the dual challenge of hydrological drought and fluvial floods in tributaries. LAND4CLIMATE aims to reduce emerging risks through several NbS along the river Timis floodplains both in urban and rural environments: restoration of wetlands by re-introducing the gravel pits and riparian buffer zones, re-connection of floodplains, creation of retention areas, green roofs, afforestation, and reforestation. Since the Front-Running Region Romania is still in a negotiation phase with landowners, the exact location of each intervention is unknown. However, the most promising NbS in terms of implementation scale and effectiveness in hazard reduction is the restoration of wetlands through the implementation of gravel pits. This NbS is expected to mitigate floods and act as a water reservoir during drought periods as well as to recharge aquifers, improve water quality by filtering pollutants, stabilize the riverbed, foster biodiversity, and offer a recreational place for eco-tourism, education, and well-being.

Table 10 reports the available datasets that mainly cover the bio-geophysical category allowing a hydrological assessment of the NbS effectiveness in flood reduction. Available bio-geophysical datasets include geography, topography, land use and cover, and environmental records concerning hydrological and weather measurements. Results can be compared with previous hydrological maps obtained by project RO-FLOODS in 2021. The novel modelling experiments can provide new insights concerning the best NbS type and location to mitigate floods. To allow a more comprehensive assessment of NbS effectiveness, both engineering and economic data will be added at the end of the design phase. Activities with landowners will be organized to estimate changes in perceptions of risk and co-benefits.

Table 10: Available data in Front-Running Region Romania

Category	Data Type	Data Sub-Type	Resolution	Sources
Bio-geo-physical data	Geography	Administrative boundaries of districts and front-running region		Geoportal ANCPI
	Topography	Digital Terrain Model	1 m	Banat River Basin Administration
	Land Use and Land Cover	Residential areas, industrial areas, commercial areas, green spaces, water surfaces, agricultural lands		Corine Land Cover
	Environmental Records	Water level data at gauges, River Discharge and water quality from hydrological and water-quality stations		Banat River Basin Administration database
		Temperature, Precipitation from weather stations (current measuresand historical data)		Banat River Basin Administration database and National Meteorological Administration database
Social data	Public involvement and awareness	Total population size and distribution in municipalities		insse.ro and recensamantromania.ro
	Existing local knowledge			It can be provided by partners and local government.

3.6 Slovakia – Roňava River Catchment

Roňava River is a small stream located in South-Western Slovakia. The catchment was significantly anthropized resulting in drained agricultural land and a regulated river. Since the mountainous topography and ecosystem degradation, the area is affected by the occurrence of flash floods and drought which occurrence usually alternate between them. These main hazards can also trigger soil degradation and landslides. An open call for landowners has resulted in the selection of 7 sites of approximately 10-50 ha each. Figure 5 shows the location of these 7 sites that cover an area of about 10-km long. A technical report is in preparation to understand which sites are eligible for the NbS implementation and which NbS are more suitable for each site. Currently, the select no-regret NbS consists of a portfolio of measures that aims to slow down the water stream, reduce surface runoff and peak flow, recharge groundwaters, and store rainwater for dry periods. These NbS include water retention pits, contour trenches and rain gardens in crop fields, and check dams, surface drains and wetlands in both agricultural and forest lands. These NbS may also provide co-benefits such as the increase in agricultural productivity, the carbon sequestration in biomass, and the filtration of pollutants from runoff with beneficial effects for the water quality in the river basins and aquatic fauna.

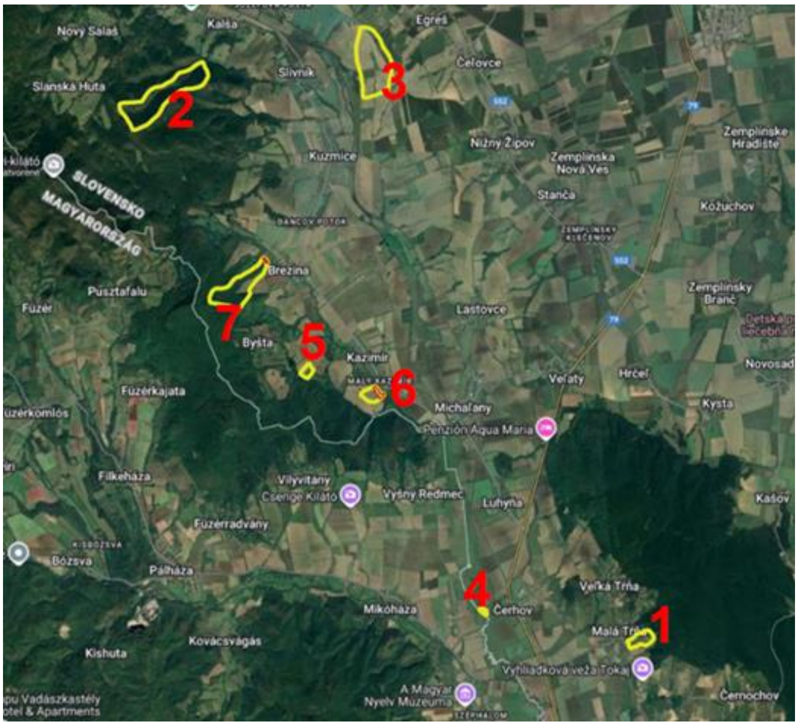

Figure 5: Location of the 7 sites that may be eligible for NbS implementation

Implementation sites and NbS – all of the identified implementation sites are located in the middle part of the territory which is prone to flash floods and droughts (

Table 11). All proposed solutions are aimed at increasing of potential of rainwater infiltration and runoff slowing down.

Table 11: Eligible sites and proposed NbS

Municipal-ity	Owner	Area	Type of land	NbS
Potential implementation sites and NbSs identified – higher probability of realization:				
Brezina	Veronika Vo-lochova	1,15 ha	Garden, built-up area	Rain garden, infiltration structures
Byšta	Ranč Dante	9,1 ha	Meadows, buildings	Infiltration strips, wetlands, small damming of a stream
Čerhov	Jaroslav Bajužík	22 ha	Meadows near the river	Water holding
Potential implementation sites and NbSs identified – lower probability of realization:				
Kazimír	Michal Sakal-Šega	3,82 ha	Meadows	Wetlands
Kalša	Lesy SR	155 ha	Forests	Stabilizing forest roads, measurements aimed to slow down water streams
Malá Tŕňa	Jaroslav Macik	25 ha	Vineyards	Various solutions aimed at water harvest-ing + against soil degradation
Slivník	Štefan Pavlík	140 ha	Arable land	More proposals

Table 12 reports the data that are currently available for the Front-Running Region Slovakia. Most of the data covers essential bio-geophysical aspects for flood and drought investigations such as geography, topography, land use and cover, soil maps, river water levels and dis-charge, tempe-rature, and precipitations. This information can be integrated with historical haz-ard data and previous modelling assessments from the CLIMADAM project. CLIMADAM clas-sified Slovak sub-basins based on the flood risk distributions considering soil and forest char-acteristics, the triggering of landslides, and water runoff. Some social data are already availa-ble, including population size and distribution, and questionnaires concerning people's aware-ness before NbS implementation. Conversely, engineering and economic data will be available after the conclusion of the technical documentation.

Table 12: Available data in Front-Running Region Slovakia

Category	Data Type	Data Sub-Type	Resolution	Sources
Bio-geo-physical data	Geography	Administrative boundaries of districts and g region		Territorial and administrative organiza-tion for the region (geoportal). Provided by relevant authority for the districts.
	Topography	Digital Elevation Model	preferably 1 m, at least 5 m	zbgis.skgeodesy.sk
	Land Use and Land Cover	Buildings, resi-dential areas, industrial areas,	at least 100 m	Territorial and administrative organiza-tion for the region (geoportal)

		commercial areas, green spaces, water surfaces, agricultural lands		
		Streets, railway tracks and stations		Openstreetmap
		Areas protected under European law (Natura2000 nature protection areas)		maps.sopsr.sk/
	Environmental Records	Soil map		Podny portal
		Water level data at gauges And River Discharge		SHMU (Surface) SHMU (Ground water) Historical data and River discharge available from the Hydro-meteorological Institute upon request
		Temperature	at least 100 m	Geoportal KSK
		Weather station (Precipitation)		SHMU (Precipitation)
	Hazard-Risk History	Fluvial floods (depth and velocity)	at least 100 m	mpt.svp.sk mpompr.svp.sk
		Heat Waves (number of summer and hot days)	currently at a larger resolution than 100 m	Ministry of the Environment (Database)
Social data	Public involvement and awareness	Total population size and distribution		disem.scitanie.sk
		Age distribution of population		DATAcube
		People awareness concerning NbS, hazards, and risks, before NbS Implementation		Questionnaires
	Existing local knowledge			It may be provided by landowners

4. Outlook

The current deliverable defines the data requirements to collect the major information to describe the target area for the NbS intervention, relatively to the hydro-meteorological risk to be tackled, and support the assessment of the NbS efficiency and effectiveness. The definition of data requirements is informed by D2.1 “Report on the modelling and monitoring methodology and NBS performance indicators” which this deliverable integrates by addressing the data availability in the FRRs as a first step to tailor the modelling and monitoring methodology to the specific interventions. The outcome of this deliverable serves different purposes:

1. Identify the data requirements for NbS efficiency and effectiveness evaluation: an exhaustive evaluation of NbS performance requires a combination of monitoring and modelling. To be effective, this approach leverage on a clear identification of data requirements to tailor a costructive investigation of the target area of intervention, ex-ante and ex-post implementation. This deliverable provides a structured categorization of data needs from past project experience and evidence from the literature to provide a general guidance for practitioners. It is worthy reminding that the data requirements is not meant only to support modelling practices but to evaluate climate risks and permitting paths for the intervention (ex-ante implementation) and monitor the impact and structural solidity of the NbS intervention (ex-post implementation). Although both scopes typically require ad-hoc monitoring beyond the actual implementation plan of the project, the identification of data requirements serves to integrate the holistic approach for the evaluation of NbS efficiency and effectiveness.
2. Determine the data availability in each FRR: the deliverable lists the available and openly accessible data for the target area of the intervention in each FRR (completed with data sources), highlighting the rich portfolio of information that can already been used for modelling and monitoring. By comparing the data availability in each FRR with the general data requirements, it is also possible to address which data categories are missing and where the FRRs can intervene the most. This comparison is not made in explicit within the deliverable to avoid redundancies, but some consideration can be made. Specifically, while data related to bio-geophysical processes are mostly covered by all FRRs, other aspects are less explored since they require an evaluation that will depend on the selection of the NbS to be implemented (engineering characteristics, economic costs) or initiatives to be conducted among the population (social data). Despite being lacking or not completed at this stage of the project, most data will become available with the NbS modelling assessment (D2.3 “Report on multi-scale numerical simulations of the performance of the NBS”) and closer to the implementation stage.
3. Bridge a connection within WP2 workflow: as already stated, this deliverable combines with D2.1 “Report on the modelling and monitoring methodology and NBS performance indicators” by supporting the monitoring and modelling methodology with the identification of data requirements for assessing the NbS efficiency and effectiveness. The initial identification of the modelling approach established in D2.1 “Report on the modelling and monitoring methodology and NBS performance indicators” will rely on the collected information from each FRR to obtain input data and/or validation data, as well as complementary information for the assessment of the risk reduction provided by the target NbS, as foreseen in D2.3 (“Report on multi-scale numerical simulations of the performance of the NBS”). The final match between the selected modelling approach and the

data required for the specific modelling in each FRR will be done in D2.3 ("Report on multi-scale numerical simulations of the performance of the NBS"). Data requirements and availability also align with and support the analysis foreseen in D2.4 ("Report on the assessment of potential co-benefits and trade-offs of the implemented NBS measures"), where the assessment of co-benefits and trade-offs of the NbS implementation will be covered through a multi-criteria analysis for each FRR to complement the NbS performance evaluation procedure. Overall, this deliverable will consist in a piece of the WP2 puzzle to deliver the performance of the target NbS, allowing D2.5 ("Configuration of local climate risk outcomes with climate-resilient NBS integration and permitting pathways") to synthesize the risk assessment within each FRR and deliver an evaluation of the feasibility of NbS implementation.

5. Conclusions

Data is fundamental to the success of NbS throughout its process of selection, implementation and maintenance, and to support a ground-based assessment of its reduction performance of the hydro-meteorological risks. It enables a comprehensive understanding of the current state of bio-geo-physical processes and characteristics of the territory, facilitates effective monitoring and evaluation ex-ante and ex-post implementation, quantifies the benefits both in terms of economic costs and social acceptance, supports informed decision-making, and underpins policy and funding efforts. Without robust data, the implementation and scaling of NbS would be significantly hindered, reducing their potential to address environmental and social challenges. Leveraging on this view, this deliverable has invested in identifying the key data requirements and availability in the target areas for the NbS implementation within each FRR to support the effective assessment and deployment of NbS. The outcome is a first necessary collection of available resources to be used in the reminder of the project to facilitate a more comprehensive and holistic assessment of NBS interventions.

References

Anderson, C.C., Renaud, F.G., Hanscomb, S., Munro, K.E., Gonzalez-Ollauri, A., Thomson, C.S., Pouta, E., Soini, K., Loupis, M., Panga, D. and Stefanopoulou, M. (2021). Public Acceptance of Nature-Based Solutions for Natural Hazard Risk Reduction: Survey Findings From Three Study Sites in Europe. Front. Environ. Sci. 9:678938. https://www.researchgate.net/publication/353357457_Public_Acceptance_of_Nature-Based_Solutions_for_Natural_Hazard_Risk_Reduction_Survey_Findings_From_Three_Study_Sites_in_Europe

Atekwana, E. A., & Slater, L. D. (2009). Biogeophysics: A new frontier in Earth science research. Reviews of Geophysics, 47(4).

Caroppi, G., De Paola, F., Giugni, M., Pugliese, F., Stanganelli, M., Urciuoli, G. (2019) Comprehensive Framework for NbS Assessment (Deliverable D4.1). Work Package 4—Technical Innovation to Design a Comprehensive Framework (UNINA WP Leader), H2020 Project PHUSICOS; Grant Agreement No. 776681; Norwegian Geotechnical Institute: Oslo, Norway, 2019. https://www.phusicos.eu/publication--results/

Centre for Effective Services (2019). Introductory Guide to Implementation. Stakeholder Engagement Process Handout Retrieved from: https://www.effectiveservices.org/resources/introductory-guideto-implementation

Cutter, S. L., Burton, C. G. & Emrich, C. T. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions, Journal of Homeland Security and Emergency Management 7(1).

Dumitru, A., & Wendling, L. (2021). Evaluating the impact of nature-based solutions: A handbook for practitioners.

European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/157060

European Commission: Directorate-General for Research and Innovation, Evaluating the impact of nature-based solutions – A handbook for practitioners, Publications Office of the European Union, 2021, https://data.europa.eu/doi/10.2777/244577

Kawulich, B. (2012). 'Collecting data through observation', Doing Social Research: A global context, McGraw-Hill, Berkshire.

Mahmoud, I. H., Morello, E., Vona, C., Benciolini, M., Sejdullahu, I., Trentin, M., & Pascual, K. H. (2021). Setting the Social Monitoring Framework for Nature-Based Solutions Impact: Methodological Approach and Pre-Greening Measurements in the Case Study from CLEVER Cities Milan. Sustainability, 13(17), 9672. https://doi.org/10.3390/su13179672

Montgomery, D.C. (2008). Design and analysis of experiments, John Wiley & Sons, New York.

MRS (2024) MRS Guidelines for Questionnaire Design - Updated April 2024. Accessed online 24/01/2025: https://www.mrs.org.uk/standards/guidelines-for-questionnaire-design

Nesshöver, C., Assmuth, T., Irvine, K.N., Rusch, G.M., Waylen, K.A., Delbaere, B., Haase,D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk,J., Vandewalle, M., Vistad, O.I., Wilkinson, M.E., & Wittmer, H. (2017). The science, policy and practice of nature-based solutions: an interdisciplinary perspective. Sci.Total Environ. 579, 1215–1227.

Nurmi, V., Votsis, A., Prampolini, A., Passani, A., & Mägdefrau, N. (2017). D5.6 Report on iSCAPE socio-economic impact assessment methodology. OPERANDUM (2021) Deliverable 4.3: A report on protocols of experiments on NbS.

Passani, A., Janssen, A.L., Hoelscher, K. (2020), Impact assessment methodological framework v1 ACTION (Participatory science toolkit against pollution) EU Horizon Project.

Ponto, J. (2015). 'Understanding and Evaluating Survey Research', Journal of The Advanced Practitioner in Oncology, Vol. 6, No 2, pp. 168–171.

Ritchie, J., Lewis, J., Ormston, R., & McNaughton Nicholls, C. (2014). Qualitative Research Practice: A guide for social science students and researchers. Sage and NatCen.

Upham, P., Oltra, C., & Boso, À. (2015). Towards a cross-paradigmatic framework of the social acceptance of energy systems. Energy Research & Social Science, 8, 100-112.

Annex 1 – Research approaches and methods for social data

This Table 13 presents the different types of research approaches and methods that may be useful to collect social data for NbS. It is divided into three main sections: qualitative, quantitative, and overall approaches. For each section different methods and activites are introduced via a brief description, a list of references and, where applicable, websites to project examples that have used these methods.

Table 13: Research approaches and methods for social data collection

Qualitative
Stakeholder analysis & mapping
Description This involves mapping stakeholders by identifying all actors- indirect or direct involvement in the NbS process, measuring their level of importance and their degree of influence. This exercise becomes important for building the evidence base, political support, setting up governance structures and ensuring a legacy for the NbS as well as increasing its scalability. Stakeholder analysis could also involve more quantitative social network analysis or content analysis of text produced by stakeholders like sentiment analysis. Sentiment analysis is the process of analyzing digital text to determine if the emotional tone of the message and hence the feeling of the times is positive, negative, or neutral around a specific topic.
References • Annex 2: Methods and tools for inspiring an NbS co-creation assessment design in European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/157060 • Wehbe, M., Salmoral, G., LópezGunn, E., M. & Smithers, R.J. 2024. DIY Manual on engaging stakeholders and citizens in climate adaptation, including tools, good practices, and experiences. August 2024. EU Mission on Adaptation to Climate Change. European Union, Brussels. : https://climate-adapt.eea.europa.eu/en/mission/solutions/citizen-engagement-manual?activeAccordion=e87d5052-caba-474b-8933-72c5ab68603e • Home Office (2026). Social Network Analysis: 'How to guide'. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/491572/socnet_howto.pdf • Yanying Mao, Qun Liu, and Yu Zhang (2024). Sentiment analysis methods, applications, and challenges: A systematic literature review, Journal of King Saud University - Computer and Information Sciences, Volume 36, Issue 4. https://doi.org/10.1016/j.jksuci.2024.102048
Workshops

Description

Often more used as an opportunity to engage participants, but workshops can be used as a research tool to gather data and, potentially, to inform implementation. There are many different types of workshops including:

- Design Thinking Workshops that combine empathy towards the problem, creativity for generating ideas, insights and solutions as well as rationality. They are solution-orientated and can use gamification, serious games, etc.
- Citizen and climate assemblies enable a safe space for debate, political support, ownership of issues, and raising awareness about plans.
- Story telling or exchange workshop whereby climate impacts are communicated through narratives. This is effective for communicating adaptation, raising awareness and mutual learning. In such a setting techniques like Most Significant Change can be used. This involves the collection and systematic participatory interpretation of stories of significant change, it is a dialogical, story-based technique. Its primary purpose is to facilitate project improvement by honing in on explicitly valued aspects and away from less valued ones.

References

- Annex 2: Methods and tools for inspiring an NbS co-creation assessment design in European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/157060
- Wehbe, M., Salmoral, G., LópezGunn, E., M. & Smithers, R.J. 2024. DIY Manual on engaging stakeholders and citizens in climate adaptation, including tools, good practices, and experiences. August 2024. EU Mission on Adaptation to Climate Change. European
Union, Brussels. : https://climate-adapt.eea.europa.eu/en/mission/solutions/citizen-engagement-manual?activeAccordion=e87d5052-caba-474b-8933-72c5ab68603e
- Davies, Rick. (2005). The 'Most Significant Change' (MSC) Technique: A Guide to Its Use". 10.13140/RG.2.1.4305.3606. and Dart, J. and Davies, R.. (2003) Quick-Start Guide. A Self-Help Guide to Implementing the Most Significant Change Technique (MSC).

Project examples (where applicable)

- https://www.operandum-project.eu/

Discussion/ focus groups

Description

This is entails structured dialogue among a group of participants, usually led by prompting by a moderator/ facilitator who leads the discussion though different topics with the aide of some questions. The idea is to recreate a natural conversation flow around the topics of interest. It enables the exploration of how opinions, attitudes, orientations and behaviours or practices develop. They can be used to explore attitudes, perceptions, feelings, and ideas about different aspects of NbS like hazards, risks, resilience and infrastructure. A qualitative data collection method which can be integrated into any stage of the NbS process.

Within these discussion groups different tasks or activities can be organised like ranking or sorting of preferences, photovoice which encourages discussion of daily lives through the use of photos and creating links to the topic, photo elicitation which uses selected photos to elicit information, provoke reactions and encourage discussion and brainstorming or trouble shooting around specific themes.

References

- Ritchie, J. et al (eds) (2014). Qualitative Research Practice: A guide for social science

students and researchers. Sage and NatCen. • Table 1 in Manual on engaging stakeholders and citizens in climate adaptation, including tools, good practices, and experiences. August 2024. EU Mission on Adaptation to Climate Change. European Union, Brussels. • Annex 2: Methods and tools for inspiring an NbS co-creation assessment design in European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/157060
Project examples (where applicable) • https://www.operandum-project.eu/
Interviews
Description There are many different types of interviews. They can range from an informal conversation to collecting stories to a detailed structured in-depth interview. They can take place in-person on the NbS site (site-visit) or in another location, over the phone or online. They can be individual or with a small group of people. They can take place with co-walks or climate walks (in situ observations on the NbS site) which aim to collect impressions, feelings, knowledge and narratives about the area of interest from the individuals who use it. These interviews can also explore values, acceptance, perceptions of risk, change in learning, social capital, community empowerment and trust. The idea is to ensure that the interviewee feels at ease to share and can answer questions openly.
References • Ritchie, J. et al (eds) (2014). Qualitative Research Practice: A guide for social science students and researchers. Sage and NatCen. • Table 1 in Manual on engaging stakeholders and citizens in climate adaptation, including tools, good practices, and experiences. August 2024. EU Mission on Adaptation to Climate Change. European Union, Brussels. • Annex 2: Methods and tools for inspiring an NbS co-creation assessment design in European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/157060
Ethnographic or participant observations
Description This entails observing people in their natural surroundings to gain insights into their experiences, perspectives, perceptions, practices and behaviors. This method can provide an in-depth insight into a specific context, community, or culture. It can be conducted over an extended period or as a single occurrence (such as during an engagement event for landowners or a community planting event for local residents).
References • Ritchie, J. et al (eds) (2014). Qualitative Research Practice: A guide for social science students and researchers. Sage and NatCen. • Office for Health Improvement and Disparities (4 May 2020),*Ethnographic study: qualitative studies: How to use an ethnographic study to evaluate your digital health product.*, *https://www.gov.uk/guidance/ethnographic-study-qualitative-studies*

- Iphofen, Ron (AcSS) - European Commission (2021) DG Research and Innovation. Research Ethics in Ethnography/Anthropology.

Process feedback logs

Description

At times called learning logs or mistakes surveys they are intended for the project manager/ delivery partners to keep a running log of aspects that did not work well. At times this can be a visual compilation of how things looked different, they are used to grow, improve and learn as these insights, through feedback loops, inform the project delivery.

References

- Table 5 p. 62 in European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/157060

Project examples (where applicable)

- https://ediblecitiesnetwork.com/

Quantitative

Surveys

Description

A questionnaire that can be administered to the local population (residents, visitors, etc.) or project participants and stakeholders (including landowners) to assess acceptance, perceptions, attitudes, values, trust, behaviours, practices, etc. related to the NbS.

It can be administered pre- (baseline) and post- (follow-up) intervention or at the end-of-the project with retrospective framing to a specific time period to participants or those potentially impacted by the project. It can be done online, over the phone or in-person through door-knocking, on-site and at events. Similar questionnaires can be handed out as a feedback form post an event or gathering to gauge satisfaction levels. Usually these questionnaires are administered at a local or micro-level scale and often do not generate large sample sizes.

References

- MRS (2024) MRS Guidelines for Questionnaire Design - Updated April 2024. Accessed online 24/01/2025: https://www.mrs.org.uk/standards/guidelines-for-questionnaire-design
- Annex 2: Methods and tools for inspiring an NbS co-creation assessment design in European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/157060

Local statistical data

Description

Local descriptive statistics linked to social impacts (e.g. quality of life, place, community)

References

- Eurostat https://ec.europa.eu/eurostat/web/main/home
- OECD: https://localdataportal.oecd.org/

- Local authority or regional statistics

Overall approaches

Theory of change

Description

A comprehensive diagram with explanations of how and why a desired change is expected to happen in a particular context with mapping of the impacts and outcomes. The diagram illustrates why a particular intervention will lead to a certain change (a causal analysis) from objectives to input to activities/ intervention to outputs to outcomes to impact.

References

- Annex 2: Methods and tools for inspiring an NbS co-creation assessment design in European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/157060

Social monitoring impact

Description

An approach used in various EU Horizon projects linked to NbS and non-NbS projects which focuses the impact assessment or part of it on social aspects like, for example, in CLEVER Cities where the focus was on human health, wellbeing, social cohesion, environmental justice, citizen safety and security, etc. and in ACTION on community building and empowerment, social inclusion, researchers and research community growth and empowerment, knowledge, skills and competencies, changes in way of thinking, attitudes and values, and behavioural change.

References

- Mahmoud, I. H., Morello, E., Vona, C., Benciolini, M., Sejdullahu, I., Trentin, M., & Pascual, K. H. (2021). Setting the Social Monitoring Framework for Nature-Based Solutions Impact: Methodological Approach and Pre-Greening Measurements in the Case Study from CLEVER Cities Milan. *Sustainability*, *13*(17), 9672. https://doi.org/10.3390/su13179672
- Passani, A., Janssen, A.L., Hoelscher, K. (2020), Impact assessment methodological framework v1 for ACTION (Participatory science toolkit against pollution). https://zenodo.org/records/4432132#.YMn_e25CT0p

Project examples (where applicable)

- https://clevercities.eu/
- https://impetus4cs.eu/

Citizen science

Description

"Defined as the non-professional involvement of volunteers in the scientific process, commonly in data collection, but also in other phases of the scientific process, such as quality assurance, data analysis, and interpretation, problem definition, or dissemination of results." *Citizen Science Importance and Benefits.* Maritime Forum. https://maritime-forum.ec.europa.eu/contents/citizen-science-importance-and-benefits_en

Often incorporating participatory research methods can generate more efficiency in data collection, a greater sense of belonging, increased legitimacy and empowerment. Citizen Science or more participatory approaches in assessing social impacts of NbS does not need to be applied

across all data collection needs or research activities but can be selected for those tasks that are more fit for purpose. Similar approaches are empowerment evaluation, living labs and community-based participatory research.
References • Chapter 5, in particular Section 5.4 in European Commission: Directorate-General for Research and Innovation, Andersson, I., Ferreira, I., Arlati, A., Bradley, S. et al., Guidelines for co-creation and co-governance of nature-based solutions – Insights form EU-funded projects, Ferreira, I.(editor), Lupp, G.(editor) and Mahmoud, I.(editor), Publications Office of the European Union,2023, https://data.europa.eu/doi/10.2777/157060 • Passani, A., Janssen, A.L., Hoelscher, K. (2020), Impact assessment methodological framework v1 for ACTION (Participatory science toolkit against pollution). https://zenodo.org/records/4432132#.YMn_e25CT0p
Project examples (where applicable) • https://actionproject.eu/ • https://urbinat.eu/ • https://impetus4cs.eu/ • https://clevercities.eu/the-project/ • https://www.phusicos.eu/

Annex 2 – The artificial sand dune from OPERANDUM

The location for the dune was chosen by OPERANDUM partners insisting on the Italian region, in collaboration with local stakeholders, including the regional authority and local municipalities. The goal was to address the risks associated with coastal erosion and storm surges while preserving the natural area where the implementation took place. During the project proposal phase, the endorsement of local authorities, such as the Regional Authorities, along with key stakeholders like the Regional Agency for Civil Protection and Land Security, was secured. This support paved the way for designing and deploying the artificial sand dune. Following discussions with RINA Consulting, the project partner who designed the engineering components and guided the implementation of the dune, a strategy for designing the NbS was established. This was informed by extensive bathymetric surveys and site inspections, which provided a thorough characterization of the site and facilitated ongoing discussions with stakeholders from the beginning of the project, proving essential in the definition of the dune layout (Figure 6).

Figure 6. Layout of the artificial dune deployed in Lido di Volano, Italy

The beach where the dune was planned for implementation is part of a Nature Reserve, making it essential for the dune design to protect the site's biodiversity. It was evident from the start that the deployment area was ecologically sensitive and vulnerable to significant disturbances from storm surges and sea waves.

Artificial dune against coastal erosion

Artificial dunes are engineered structures designed to replicate the function of natural dunes, which are formed by wind-driven sand deposits along coastlines. These structures are intended to reduce coastal erosion and flooding in nearby low-lying areas. Acting as a barrier between the sea and land, they serve a similar purpose to seawalls. Dunes are dynamic systems that continuously adjust in response to changes in wind, wave action, climate, and sea level.

The artificial dune from OPERANDUM's project was constructed at Lido di Volano between April and May 2022, and it is currently being monitored for its morphological and deformation properties. To create the dune, sand deposits were mobilized and reshaped using bulldozers. These deposits were then reinforced with biodegradable materials, specifically wood and coir geotextile. The completed dune is 100 meters long, 3.5 meters high, and has an average slope gradient of 1:2 (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

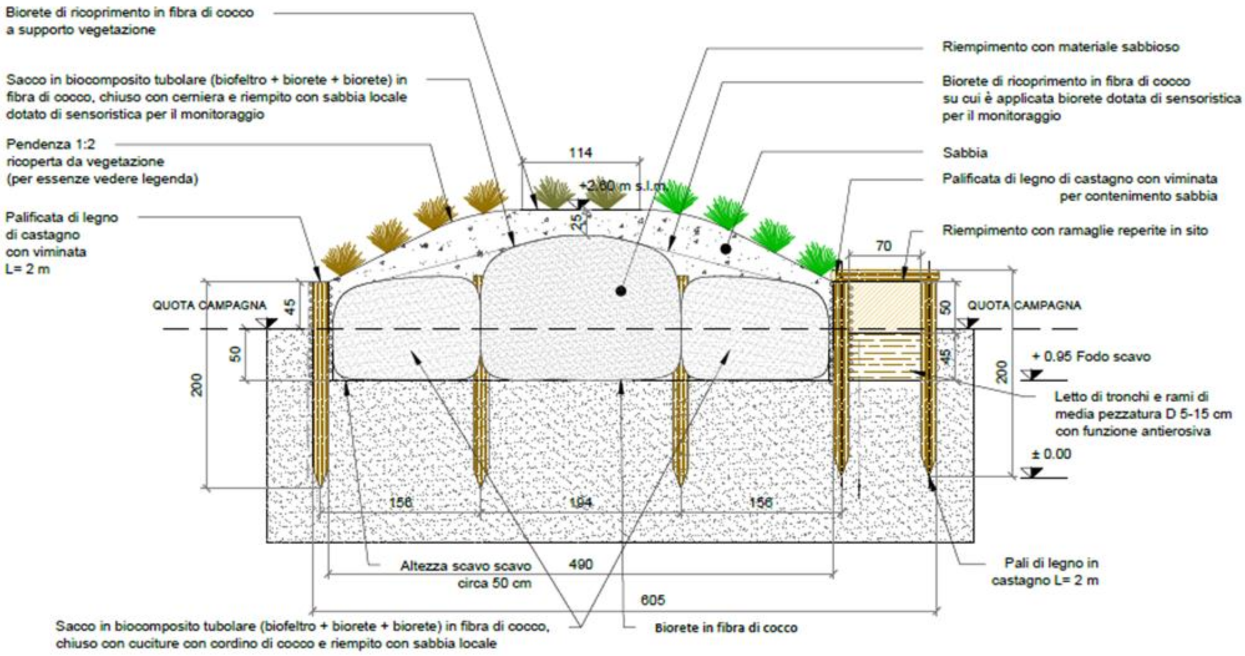

Figure 7: Sketch illustrating the cross-section of the dune typology 1, in which three tubular modules wrapped in coir fibre form the dune's inner structure (Source: OPERANDUM D3.3: Development and Implementation of NBS at the OALS)

The design of the dune comprises a structural section based on a tubular module solution, like the geo tubes traditionally used in the construction of coastal embankments. The cross-section of this structural solution was made of a central tubular module supported by lateral reinforcements in tubular form of smaller dimensions to maintain the 1:2 slope in each side of the dune. These modules were arranged longitudinally between four lines of wooden poles, conferring the dune the desired slope gradient and layout. The tubular modules were built with coir bags and hold between four lines of wooden poles to ensure the structural robustness and prevent the natural wind and water erosion of the sand (Figure 8**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 8: Initial phases of the artificial dune construction

Each module was filled with the sand excavated to create the bedroom for the dune structure and enclosed to prevent sand dispersion. The technology of coir bags for the central module and lateral reinforcers differed in the closing mechanism: while the reinforcements bags were closed by stitching, the central bag had an innovative hinge system to facilitate access to the inner dune structure in case management and maintenance operations are required (**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Figure 9: Coir bag technology within the artificial sand dune

The entire structure was then covered in a second layer of natural blankets and a thin layer (20-30 cm) of sand for camouflage with the coastal environment but allowing to plant a vegetation cover to root in the coir fibres. For the coverage of the artificial dune, the disposal of the blankets and the selection of plant species was based on the exposure of different sections of the dune: the seaward front, the top, and the landward rear. Two distinct plant cover solutions were implemented along the length of the dune, following the scheme in Figure 10 (top):

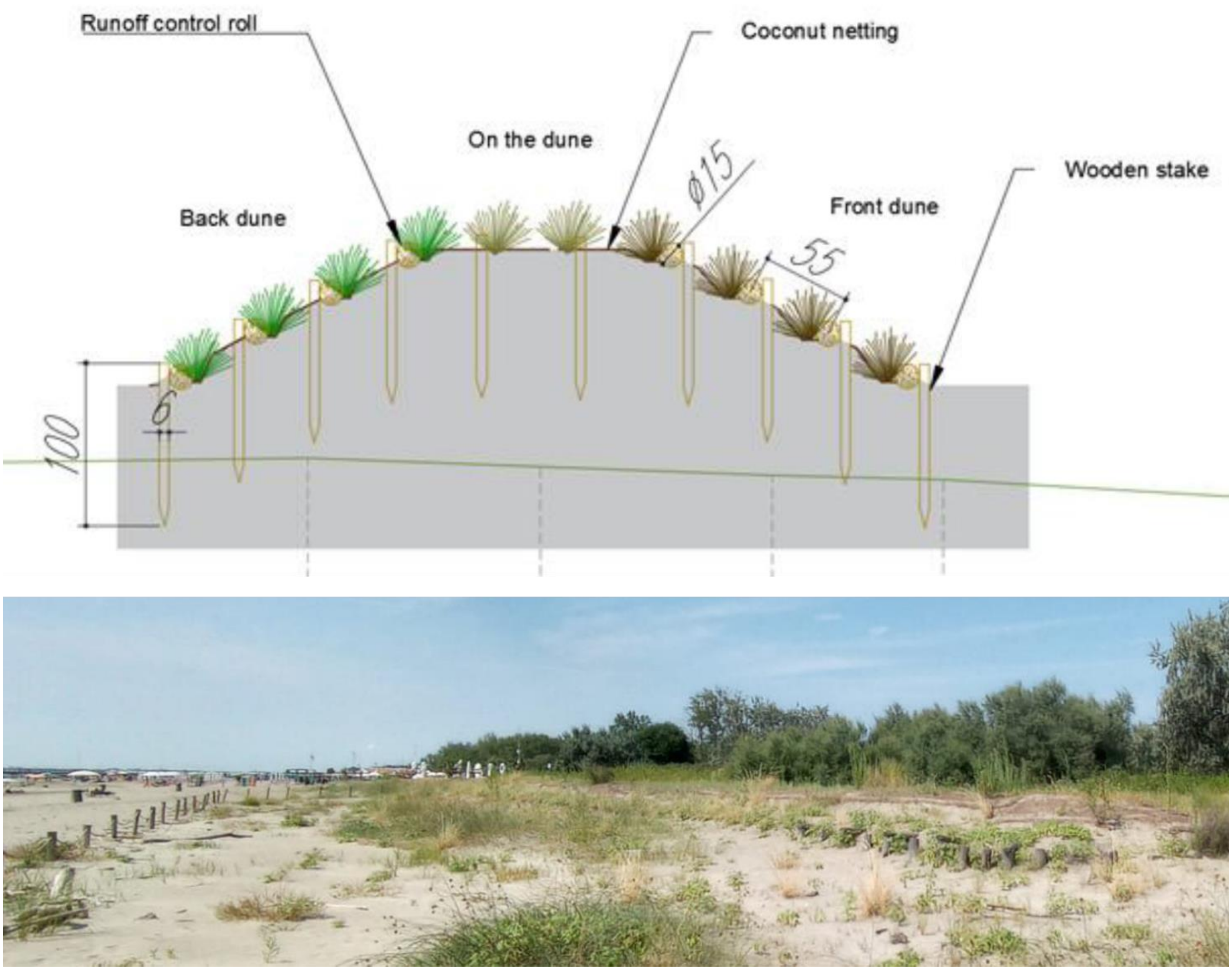

Figure 10: Design of the dune vegetation (top) and photo of the dune after two years from the implementation (bottom, photo by Francesco Barbano)

1. On the inland side (the back dune), the slope was covered with an erosion and runoff control blanket made of coir netting, supplemented with 2-meter-long coir logs that had a diameter of 15-20 cm. These logs were placed throughout the inward slope of the dune every 55 cm and positioned in front of each plantation line. The coir logs serve multiple functions: they help control runoff, dissipate energy, retain moisture, and promote vegetation growth and survival. The remaining areas of the dune were planted with psammophilous species by removing bulbs, cuttings, and young seedlings from local plants.
2. On the seaward side of the dune (the front dune), the surface was stabilized using wooden palisades made from local plant materials. Additionally, a plant cover using native species was established.

Over time, the coir blanket will gradually degrade, while the root systems of the vegetation will develop, ultimately becoming the sole element that ensures the dune's surface stability and allowing it to function naturally. On the seaward side of the dune, particularly at the terminal parts, an additional protective wooden structure was installed. This structure featured a double wooden palisade filled with wooden stacks and fascines sourced from available local plant materials. At the front of the dune, the fascines were laid horizontally, while they were placed vertically at the terminal section. These frontal structures act as a protective system for the toe of the dune and the landward area by absorbing energy and trapping sand carried by storm waves.

Two years after implementation (see Figure 10, bottom), the vegetation cover has expanded toward the frontal area of the beach, and the dune has successfully integrated into the coastal landscape.

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