WP3 Data Management Plan

Deliverable 3.1

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Indice

Executive summary

This report represents the data management plan (DMP) specifically applied to Work Package 3 (WP3), setting out to:

- Assemble well-documented indicators, which pertain to climate hazards, exposure, and vulnerability, from a variety of sources crucial for diverse applications,
- Transform a vast array of climate data into a set of custom indices for various emission scenarios, which serve as a basis for modelling climate hazards,
- Conduct a series of experiments to explore how hazard, exposure, and vulnerability indicators can be combined into custom risk assessments, specifically for the Po River Basin District, thereby accounting for its unique characteristics and challenges.

The WP3 specific DMP focuses on the data to be collected, analysed, and shared. It offers in-depth information about the types and sources of data, as well as the rules guiding data management, access, and reuse. The report structure aligns with the recommended template, covering key aspects like data types and sources, adherence to FAIR principles (Findable, Accessible, Interoperable, and Reusable), data ownership, security measures, and ethical principles. Although the report isn't intended for regular updates, revisions can be made as part of the project's reporting obligations. The comprehensive DMP for the entire project is discussed in a separate report, D1.4.

Riassunto in italiano

Questo rapporto rappresenta il piano di gestione dei dati (PGD) specificamente applicato al Work Package 3 (WP3). Il WP3 segue diversi obiettivi:

- Raccogliere indicatori, assieme alla loro documentazione, che riguardano i pericoli climatici, l'esposizione e la vulnerabilità, da una varietà di fonti e utili per diverse applicazioni,
- Trasformare un vasto array di dati climatici in un set di indici estremi, separatamente per vari scenari di emissione, che possono servire come base per la modellazione dei pericoli climatici,
- Esplorare le modalità di aggregazione degli indicatori di pericolo, esposizione e vulnerabilità per valutare i rischi climatici nell'ambito del distretto di bacino del fiume Po, tenendo debitamente in considerazione le sue peculiari caratteristiche.

Il DMP specifico per WP3 si concentra sui dati che vengono raccolti, analizzati e condivisi. Il documento offre informazioni dettagliate sui tipi e le fonti di dati, così come le regole che guidano la gestione, l'accesso e il riutilizzo dei dati. La struttura del rapporto PGD segue il modello raccomandato per questo scopo, elaborando gli aspetti chiave come i tipi e le fonti di dati, l'aderenza ai principi FAIR (Trovabili, Accessibili, Interoperabili e Riutilizzabili), la proprietà dei dati, le misure di sicurezza e i principi etici. Anche se il rapporto non è destinato ad aggiornamenti regolari, le revisioni possono essere fatte come parte degli obblighi di reporting del progetto. Il DMP completo per l'intero progetto è discusso in un rapporto separato, D1.4.

1 Introduction

Climax-Po is a LIFE integrated project with the primary objective of catalysing the implementation of the Italian climate adaptation strategy developed in 2014. Implemented over a period of nine years (2023-2032), the project aims at creating an innovative partnership for water governance at the river basin district scale, enhance the knowledge base on current and future climate risks, and demonstrate systemic and smart adaptation in line with the EU Adaptation Strategy form 2021. aims to enhance our understanding of climate-related hazards, vulnerabilities, and risks. The anticipated outcomes include a harmonized collection of data from diverse sources, a set of standardised climate risk indices, and a platform for sharing risk data and knowledge specific to river basin district.

Open data foster transparency, accountability, and innovation. Making data freely accessible to researchers, policymakers, and citizens promotes transparency, accountability, innovation, evidence-based decision-making, and stimulates economic growth and development. The European strategy for data aims to establish a unified European data space[1], working as a comprehensive data market. This space ensures the security of personal and non-personal data while enabling citizens and businesses to access extensive high-quality data, promoting value creation and minimizing the environmental footprint. Climate risk assessment (CRA) is a data-intensive exercise that entails the analysis and integration of diverse factors, encompassing hazards, exposures, and vulnerabilities. This process involves the comprehensive collection, processing, and analysis of extensive data.

A Data Management Plan (DMP) ensures an effective and responsible management of data, promoting reproducibility, and data sharing. As such, DMP is made compulsory for the European research and innovation projects. The Plan is to meant outline how data will be collected, organized, stored, and shared throughout the research process and beyond. This report specifically focuses on the Data Management Plan (DMP) for WP3 of the project, while the comprehensive DMP for the entire project is detailed in a separate report, D1.4. It focusses focuses on the data collected, analysed, and shared as a result of WP3. It provides detailed information about the type of data and their sources, as well as the data management and sharing rules that govern access and reuse. Although this report is not intended for regular updates, to ensure the content and decisions remain current, an update can be generated as part of the project's reporting obligations.

The report structure follows the recommended template and comprises the following aspects:

- Section 2 provides a summary of the data type, its significance, and potential data sources.
- Section 3 details the decisions made to ensure the data in WP3 is FAIR (Findable, Accessible, Interoperable, and Reusable).
- Sections 4 to 6 elucidate the pertinent aspects of data ownership, security measures, and ethical principles governing the data handling procedures.

2 Data summary

Climate risk assessment is a process that aims to identify and evaluate potential risks and vulnerabilities posed by climate change. It involves analysing various factors, such as climate-related hazards, exposure of assets and communities, and the inherent vulnerabilities of different systems. By understanding these risks, policy- and decision-makers can develop informed strategies for building resilience, adapting to changing conditions, and safeguarding communities, economies, and the environment from the impacts of climate change. Climate risk assessment plays a crucial role in shaping policies and actions to ensure a sustainable and secure future in the face of climate challenges.

Climate and disaster risk assessment encompasses a multitude of risk factors (Table 1), typically identified as hazards - or climatic impact drivers - along with exposure and vulnerability elements. Climatic impact-drivers (CIDs)[2] are physical climate conditions that directly affect society and ecosystems, with both harmful and beneficial effects depending on system tolerance. Exposure encompasses a range of valued aspects that hold significant relevance for the structuring and functioning of societal organizations and that can be affected by climate hazards. Representation of exposure has greatly improved recently, thanks to new technologies. One major breakthrough is the use of Earth Observation (EO) data from satellites. The Copernicus EO services make it possible to continuously monitor the environment on a global scale, offering invaluable data on land, ocean, and atmospheric conditions. These services help track changes over time, such as shifts in land use, sea-level rise, and variations in air quality.

Vulnerability encapsulates how a specific hazard may affect an exposed element. As a concept, vulnerability is multifaceted, involving social, economic, institutional, and environmental dimensions. Our understanding of how vulnerability quantitatively impacts changes in risk and its temporal trends is currently limited. Moreover, vulnerability often varies according to the type of hazard and can differ among various groups of people. For instance, when assessing vulnerability to drought, researchers often consider sociocultural factors, such as demographic characteristics, adaptive measures like irrigation, and economic resources.

As a result of the task 3.1, WP3 will create an inventory of indicators describing climate hazards, exposure, and vulnerability. This inventory will serve as the basis for developing customized climate risk assessments, each uniquely designed to suit different purposes. The information for this inventory will be gathered from a diverse range of sources spanning multiple levels of governance. This includes international sources at both global and European levels, as well as national, regional, and municipal levels. In order to ensure a broad and inclusive perspective, various sources from local and regional governments will be used, in addition to data from research institutions and statistical offices.

Under Task 3.2, WP3 will develop a collection of climate variables and customized indices, covering a variety of emission scenarios. We will harness the breadth of available climate data, transforming it into a set of meaningful and context-specific indices that can aid in understanding and addressing the complex interplay between climate change, emissions, and socio-economic factors.

Table 1 Definitions and examples of risk drivers (based on IPCC Sixth Assessment Report[3])

#	Data type	Definition	Examples
1	(1) Climate hazards, (2) Climatic impact-drivers	(1) potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources. (2) physical climate system conditions (e.g., means, events, extremes) that affect an element of society or ecosystems.	(1) heatwaves, droughts, floods, storms and hurricanes, wildfires, sea-level rise, hailstorms, landslides, extreme cold or snowstorms, tornadoes. (2) rising sea levels, increasing temperatures, more frequent and severe extreme weather events, rainfall and snowfall, ocean acidification, shifts in ecosystem dynamics, melting glaciers, changes in soil moisture, alterations in disease patterns, disruptions in ocean currents
2	Exposure	presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.	population density, critical facilities such as hospitals and emergency services, natural ecosystems, cultural heritage sites, land use patterns, supply chains, public services
3	Vulnerability	propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt	socioeconomic status, age, health, educational level, institutional capacity, access to resources, social networks, preparedness, ability of communities and systems, to anticipate, cope with, resist and recover from the impact of climate hazards
4	Resilience	capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure	robust infrastructure, economic stability, access to resources, social cohesion, strong governance and institutional frameworks, effective disaster response mechanisms, community awareness and education, adaptive capacity

In its final phase, under Task 3.3, Work Package 3 (WP3) will conduct a series of experiments to explore how hazard, exposure, and vulnerability indicators can be combined into custom risk assessments specifically for the Po River Basin District. These tasks highlight the diverse

nature of the data variables and sources that WP3 aims to gather and analyse. Essentially, the WP3 seeks to enable tailor-made risk assessment that accounts for the unique characteristics and challenges of the Po River Basin District.

3 FAIR data

3.1 Making data findable & metadata

Making data findable means adopting strategies that enable easy and efficient discovery of the data related to the WP3. To achieve this, we have adopted the following principles and choices:

Persistent Identifiers. Each dataset will be assigned a unique and persistent identifier, ideally the Digital Object Identifier (DOI). This is important to ensure that the data can be referred to, cited or referenced in publications. DOI is a unique alphanumeric string assigned to a digital object (such as a publication or dataset) and used to provide a permanent and stable link to the object. DOIs are managed by registration agencies and can be automatically assigned to datasets in open-access repositories. We will also produce a guidance on how to cite the datasets, promoting attribution and acknowledgment of data usage.

Metadata. We will provide comprehensive metadata for each dataset, including descriptive information, keywords, and relevant attributes. This metadata will be structured according to established standards, to enhance searchability and understanding. It will include information about the domain and potential uses, such as the dataset's nature, data source, scale (e.g., local, regional, national, global), target audience (e.g., water resource managers), associated scientific publications, possible restrictions, existence of similar datasets, integration possibilities with other project datasets, and potential for reuse. Additionally, the methodology and research design will be described, providing details about the study design, workflows, and other information for an accurate use of the data. Geospatial metadata will be included for new geospatial datasets. These will be accompanied by information about extent, quality, spatial and temporal reference, distribution, and version.

Data Cataloguing. The WP3 data will be indexed in searchable and user-friendly data catalogues and repository. We target the portals of the Project Coordinator – the Po River Basin District Authority (ADB Po), as well as national and European climate adaptation/knowledge portals and the open data portals of the institutional partners of the project.

- The Italian Platform on Climate Change Adaptation (climadat.isprambinete.it), maintained by the Institute for Environmental Protection and Research (ISPRA), is designed to foster knowledge sharing on climate change adaptation.
- The Climate-ADAPT portal is an initiative of the European Environment Agency (EEA) that serves as a comprehensive platform for accessing information on climate change adaptation in Europe. The portal provides a wide range of resources, data, and tools to support policymakers, practitioners, and the general public in their efforts to understand and respond to the impacts of climate change.

- Open data portals are online platforms that provide easy access to a wide range of datasets and information collected and maintained by various organizations and governments. These portals aim to promote transparency, accountability, and collaboration by making data available to the public in a format that can be easily accessed, downloaded, and analysed.

Standardized Naming Conventions. By adhering to standard conventions and guidelines, we will employ descriptive file naming for files, variables, and metadata, enabling rapid identification and retrieval of climate data. we will adopt the naming conventions endorsed by the Copernicus Climate Change Service for labelling climate variables, reference periods, and other relevant aspects.

Data Ontologies. We will use data ontologies and vocabularies to improve data discovery and enable semantic interoperability. Data ontologies define the relationships between different data elements and concepts, creating a common understanding of the data's meaning and context[4]. For example, climate and forecast (CF) metadata conventions is widely used standard for defining climate and forecast data. Climate Ontology is designed to represent climate-related concepts and relationships, facilitating interoperability and data integration in climate science.

Documentation. The datasets will be complemented by a detailed documentation that describes context, data collection methodologies, and data processing steps.

3.2 Making data openly accessible

All primary and rehabilitated secondary data, except for protected sensitive data, will be stored in the project open repositories. This will ensuring free, immediate, and permanent access.

Timely access. Early access to the datasets and other WP3 products will be made immediately after completing the quality assurance process designed of the project. The latter will involve both internal and external review, overseen by the Project Coordinator. Internal reviews will be conducted by the project team to ensure data quality, consistency, and adherence to data standards. This includes validating the accuracy and completeness of metadata, verifying data formats, and confirming proper data organization. External reviews will be sought from relevant experts and stakeholders outside the project team. These experts may include researchers from other institutions, domain specialists, or data repository curators. Their input will provide an unbiased assessment of data integrity, potential improvements, and suggestions for enhancing data accessibility.

Permanent access. The best way for ensuring a permanent access to the datasets is through storing them in the open access repositories. These are digital platforms that serve as centralized databases for hosting and sharing openly accessible data. These repositories play a crucial role in promoting data transparency, reproducibility, and collaboration across various disciplines. They offer a diverse range of datasets, encompassing fields such as climate science, environmental studies, social sciences, genomics, and more. Some repositories are discipline-specific, focusing on curated datasets relevant to a particular scientific area. Others are interdisciplinary, accommodating datasets from multiple domains, encouraging cross-disciplinary research and discoveries. Zenodo for example is an open-access digital repository

operated by CERN (European Organization for Nuclear Research) and a part of the European Open Science Cloud initiative.

As indicated elsewhere in this document, particularly section 5, the WP3 relies on a variety of data sources. Maintaining a strong connection with the data owners, who are responsible for the upkeep and maintenance of these datasets, is of utmost importance. This collaboration ensures that the information remains up-to-date and relevant. Additionally, there are several ongoing initiatives aimed at developing new portals and mechanisms for knowledge storage and retrieval, such as Risk Data Hub and Destination Earth. These platforms are dedicated to facilitating the access and exchange of crucial data related to risk management, climate adaptation, and environmental research.

- Risk Data Hub is a platform that serves as a central repository for storing and sharing data related to disaster risk management and climate resilience. Developed by the Joint research Centre (JRC), it aims to provide comprehensive and up-to-date information on various types of risks, including natural hazards, environmental threats, and socio-economic vulnerabilities. The platform is designed to facilitate easy access and retrieval of data for researchers, policymakers, and practitioners involved in risk assessment, preparedness, and mitigation efforts. Risk Data Hub is undergoing significant enhancements and expansions under the EU Mission Adaptation to Climate Change. As part of this initiative, the platform is being transformed into a comprehensive one-stop-shop for accessing data related to climate and disaster risk in Europe. The goal is to create a centralized and user-friendly repository that offers a wide range of information on climate hazards, vulnerabilities, and adaptation strategies.
- Destination Earth is a groundbreaking initiative launched by the EU with the aim of creating a digital twin of the Earth[5]. The program seeks to harness the power of advanced technologies, such as artificial intelligence, big data analytics, and high-performance computing, to develop a virtual replica of the planet Earth. This digital twin will provide real-time and highly detailed information about the Earth's natural processes, climate patterns, and human activities. The program envisions a wide range of applications, from climate and weather forecasting to urban planning, agriculture, and disaster preparedness.

Part of the work plan for WP3 is to develop a platform that facilitates the use and reuse of the produced projects. The form of the platform cannot yet be anticipated and will be developed over the next few years during the implementation of the project.

3.3 Making data interoperable

Making data interoperable is a key guiding principle of the Climax-Po project and the WP3. Interoperability refers to the ability of different datasets and systems to seamlessly communicate, exchange, and interpret data. It ensures that information can be effectively shared and utilized across various platforms, organizations, and domains.

Data interoperability enhance collaboration and efficiency, fosters reuse and reduced duplication. When data is interoperable, anyone can easily access and combine information from diverse sources. By establishing common standards and formats, data can be easily

repurposed for multiple applications, saving time, resources, and costs. Data interoperability is also important for the development of advanced technologies, such as artificial intelligence and machine learning. These technologies heavily rely on large and diverse datasets to train their algorithms effectively.

Table 2 includes the most common interoperable data formats that will be used in the WP3.

- Tabular data is organized in rows and columns, resembling a table format. CSV (Comma-Separated Values) and XLSX (Excel) are common formats used to store tabular data. CSV uses commas to separate values, while XLSX is a binary file format used by Microsoft Excel.
- Textual data consists of plain text and can be saved in various formats such as Rich Text Format (.rtf), which supports text formatting like bold, italics, and colours. Plain text files (.txt) contain unformatted text, and Hypertext Markup Language (.html) is used for creating web pages with hyperlinks and basic text formatting.
- Geospatial data contains information about geographic locations. NetCDF (Network Common Data Format) is a file format used to store multidimensional scientific data, often used in climate and weather research. TIFF (Tagged Image File Format) is commonly used for raster graphics and can also store geospatial information.
- Image data includes visual representations such as pictures and graphics. PNG (Portable Network Graphics) is a widely used format for lossless image compression, providing high-quality images with small file sizes. SVG (Scalable Vector Graphics) is a format that uses mathematical equations to define images, allowing them to be scaled without losing quality.
- Documentation files store written materials and information about a project or dataset. MS-Word (Microsoft Word) and PDF (Portable Document Format) are commonly used formats for creating and sharing detailed documentation. Reports and articles are often written in specific formats to meet publishing standards. LaTeX is a typesetting system used for creating high-quality scientific documents with complex formatting. MS-Word is used for general word processing and is commonly used for preparing reports and articles.

Table 2 Interoperable data formats envisaged in the WP3

Type of data	Recommended formats
Tabular data	CSV, XLSX
Textual data	Rich Text Format (.rtf). Plain text, ASCII (.txt). Hypertext Mark-up Language (.html).
Geospatial data	NetCDF; TIFF
Image data	PNG; SVG
Documentation	MS-Word; PDF
Reports & Articles	LaTeX; MS-Word

4 Data ownership and allocation of resources

WP3 will collaborate with external parties, including National and Regional Statistical Offices, regional administrations, and research centres, to access and utilize data, such as climate modelling results. While certain primary datasets might be protected by intellectual property rights (IPR), the majority of the data collected, transformed, and shared in this project belongs to the open-access domain.

Maintaining live links with the entities responsible for producing, updating, and disseminating the data used in WP3 is crucial for ensuring data accuracy and timely access. Incorporating new data sources, such as updated population census data and demographic distributions, is essential for accuracy. To ensure this, the input data collection will be organized as meta-catalogues of data to effectively track and reference the sources of information. In certain situations, the input data will be rehabilitated from original data sources, some of which may be publicly accessible, while others may not. Also in these cases maintaining a connection with the primary producers of the data will be crucial to ensure data accuracy and relevance in the rehabilitation process.

Data rehabilitation refers to the process of restoring, updating, or improving the quality and reliability of existing data that may have become outdated, incomplete, or otherwise compromised over time. It involves validating and enhancing the existing data through various methods such as data cleaning, data integration, and data normalization. The goal of data rehabilitation is to make the data usable and relevant for current analysis, research, or decision-making purposes.

Finally, the majority, if not all, of the data generated in WP3 will be free from intellectual property rights restrictions, allowing for both non-commercial and commercial use. New original or previously inexistent data can be created from data processing and analytical conducts (e.g. calculation of extreme indices form the observed or modelled data). Other data may encompass systematic observations, measurements, or interactions with study subjects or phenomena to address specific research questions or test hypotheses. This process involves designing appropriate methodologies, data collection instruments, and protocols to ensure the accuracy, reliability, and validity of the generated data. The newly created data contribute to expanding knowledge, understanding patterns or trends, and providing evidence to support scientific findings.

The creation of new data through research refers to the process of generating original and previously unknown data as a result of conducting scientific investigations, experiments, surveys, or other research activities. Researchers collect data through systematic observations, measurements, or interactions with study subjects or phenomena to answer specific research questions or test hypotheses. This process involves designing appropriate methodologies, data collection instruments, and protocols to ensure the accuracy, reliability, and validity of the data generated. The newly created data contribute to expanding knowledge, understanding patterns or trends, and providing evidence to support scientific findings and advancements in various fields of study.

The resources of WP3 dedicated to collecting, rehabilitating, creating new data, as well as their documentation and sharing, are implicitly included in the labour of the participating partners. These are integral part of the workload. Other costs, such as the efforts related to

setting up and maintaining data platforms used for the whole project, are beyond the scope of this document.

5 Data security

WP3 is unlikely to work with datasets that may have restricted publication due to privacy and ethical considerations. Nevertheless, sensible data archiving and long-term preservation will be ensured through password-protected storage, using project's platform for cloud file storage and sharing. Data will be preserved indefinitely, allowing for potential longitudinal studies where agreed upon and unrestricted by embargoes or other restrictions. In addition to repository storage, the Project Coordinator will maintain a cloud drive with monthly security backups. Researchers responsible for data collection will process reusable data for easy accessibility and integration.

6 Ethical aspects

No significant ethical or legal issues are anticipated for collecting, sharing or storing the datasets of WP3, except for the potential restrictions on sensitive data acquired during experimental research and activities implying interviews or surveys. In such cases, the ethical and legal considerations will be meticulously evaluated, adhering to the EU's rules and regulations, and duly acknowledged in related reports or academic articles.

We acknowledge that data collection and risk assessment processes conducted in WP3 carries ethical implications, which include several important aspects. Firstly, the collection and handling of data must ensure the privacy and confidentiality of individuals and entities involved. Secondly, the potential impacts of climate risks on vulnerable populations or communities must be considered, ensuring that their rights and well-being are protected throughout the research process. Moreover, transparency and openness in data sharing and communication with stakeholders are essential to promote accountability and trust in the research findings. Additionally, the potential environmental and societal consequences of the risk assessment must be carefully evaluated to minimize any adverse effects and promote responsible research and innovation. Taking ethical considerations into account, we aim to conduct our study with integrity, positively contributing to individuals and the broader community.

Good research practices in the Climax-Po project are guided by fundamental principles of research integrity. All project partners adhere to these principles, which are outlined in the European Code of Conduct[6]. These principles include reliability, ensuring the quality of research from design to resource use; honesty, conducting and reporting research in a transparent and unbiased manner; respect for colleagues, participants, society, ecosystems, cultural heritage, and the environment; and accountability for the entire research process, from idea to publication and its broader impacts.

We will also follow the Horizon Europe regulation emphasizes responsible research and innovation (RRI) to ensure scientific research and technology development consider their societal and environmental impact. RRI prioritizes addressing societal problems, upholding ethical research practices, promoting gender equality, science education, and community

involvement in research. The MoRRI indicators, developed by the European Commission's Monitoring the Evolution and Benefits of Responsible Research and Innovation (MoRRI) project, assess the extent of responsible research and innovation practices. These indicators cover various aspects, including ethics, gender equality, public engagement, science education, open access, and governance. They assist research organizations in monitoring and evaluating the societal and environmental impact of research and innovation activities.

7 References

1. EC. *A European strategy for data. COM(2020) 66 final*. (2020).

2. Ruane, A. C. *et al.* The Climatic Impact-Driver Framework for Assessment of Risk-Relevant Climate Information. *Earths Future* **10**, e2022EF002803 (2022).

3. Intergovernmental Panel On Climate Change (Ipcc). *Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. (Cambridge University Press, 2023). doi:10.1017/9781009325844.

4. Schnegg, M. Ontologies of climate change: Reconciling indigenous and scientific explanations for the lack of rain in Namibia. *Am. Ethnol.* **48**, 260–273 (2021).

5. Bauer, P., Stevens, B. & Hazeleger, W. A digital twin of Earth for the green transition. *Nat. Clim. Change* **11**, 80–83 (2021).

6. ALLEA - All European Academies. *The European Code of Conduct for Research Integrity*. (ALLEA - All European Academies, 2023).