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**Wetlands-based solutions for  
climate change adaptation, risk  
prevention and mitigation**



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# **WETLAND4CHANGE**

**Wetlands-based solutions for climate change adaptation, risk  
prevention and mitigation  
Euro-MED0200309**

## **Preliminary study and technical guidance report for the mapping and assessment of the flood regulation wetland service**

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## List of Abbreviations

- AEMET** : National Meteorological Agency (Spain)  
**AVAMET** : Valencian Association of Meteorology (Spain)  
**BD Forêt** : French forest database (France)  
**CLC** : CORINE Land Cover  
**CN** : Curve Number  
**DSM** : Digital Surface Model  
**DEM** : Digital Elevation Model  
**DTM** : Digital Terrain Model  
**EcValue** Economic Value  
**EO-based** : Earth Observation Based Layer  
**EU** European Union  
**EVassets** : Exposure and Vulnerability of assets related to population  
**EVpopulation** : Exposure and Vulnerability of the population  
**FAO-UNESCO** : Food and Agriculture Organization of the United Nations – United Nations Educational, Scientific and Cultural Organization  
**GDP** : Gross Domestic Product  
**GHSL** : Global Human Settlement Layer  
**GHS-POP** : Global Human Settlement – Population dataset  
**GIS** : Geographic Information System  
**GIS Sol** : Scientific Interest Group on Soils (France)  
**GPW** : Gridded Population of the World  
**HCB** : Hydrological Characteristics of the Basin  
**HEC-HMS** : Hydrologic Engineering Center's-Hydrologic Modelling System  
**HSG** : Hydrologic Soil Groups  
**IBA**: Important Bird Areas  
**IDF** : Intensity-Duration-Frequency curves  
**IGME** : Geological and Mining Institute of Spain  
**IGN** : National Institute of Geography (France & Spain)  
**ISTAT** : Italian National Institute of Statistics  
**JRC** : Joint Research Centre  
**LAU** : Local Administrative Units  
**LULC** : Land Use / Land Cover  
**MAES** : Mapping and Assessment of Ecosystems and their Services



**MDT** : Digital Terrain Model  
**MMU** : Minimum Mapping Unit

**MWO**: Mediterranean Wetland Observatory  
**NBS** : Nature Based Solution  
**NDVI** : Normalized Difference Vegetation Index  
**CNIG** : National Center for Geographic Information  
**PESPKA** : Regional Plan for Adaptation to Climate Change  
**PGRA** : Flood Risk Management Plan (Italy)  
**PPRI** : Flood Risk Prevention Plan (France)  
**PAPI** : Programme d'Actions de Prévention des Inondations (France)  
**RAS** : Autonomous Region of Sardinia (Italy)  
**RGP** : Runoff Generation Potential  
**RMC** : Risk Mitigation Capacity  
**RUSLE** : Revised Universal Soil Loss Equation  
**SCS-CN** : Soil Conservation Service Curve Number  
**SCHAPI** : Central Service for Hydrometeorology and Flood Forecasting Support (France)  
**SIE** : Water Information System (France)  
**SIOSE** : Land Cover and Use Information System (Spain)  
**SWOS** : Satellite-based Wetland Observation Service  
**USDA** : United States Agriculture Department  
**Vlgicruces** : French river monitoring service  
**WFD** : EU Water Framework Directive  
**WRC** : Water Regulation Capacity

### **Partners name abbreviated**

**UF** : University of Forestry | Bulgaria  
**EKBY** : Goulandris Natural History Museum/ Greek Biotope - Wetland Centre | Greece  
**UVEG** : University of Valencia | Spain  
**MEDSEA** : Mediterranean Sea and Coast Foundation | Italy  
**TdV** : Tour du Valat | France  
**ETC-UMA** : European Topic Center - University of Malaga | Spain



## 1. Introduction

Flood protection is one of the most important regulating ecosystem services that affect water-related disasters. Policies are shifting towards calling for and investing in **Nature-based Solutions (NbS)** in their attempts to reduce flood risks on the population, namely in settlements close to water bodies and in previous heavily modified flood plains. Forests, floodplains, riverbanks, alluvial wetlands, riparian vegetation and other densely vegetated areas normally provide natural flood mitigation and water regulation services as they reduce the water flow and influence water retention capacities. These ecosystems affect the water balance mainly through **interception** and **infiltration**. Interception depends on the structure of the ecosystem above ground (land cover and vegetation density) while the infiltration is strongly determined by the soil properties. The surface runoff, being the main factor influencing flood formation, also depends on abiotic factors like soil, lithology and topography.

Knowing that in this report, the focus will be on river basin floods only (i.e. marine submersions are not considered here), the regulating role of floodplain wetlands is usually emphasized but attention should be given to the function, capacities, and limitations of other ecosystems throughout river basins that also play a role in controlling the processes of water balance increasing or reducing the impact of floods. For that reason, it is necessary to separate service production (supply) areas from service benefit (demand) areas.

The importance of the regulating services to human wellbeing relies on their preventive or mitigating functions. Flood hazards prevention is an important function of some ecosystems such as wetlands or forests, known as the capacity to redirect or absorb part of the incoming water from precipitation, reducing the surface runoff and consequently the amount of water or river discharge. This ecosystem service is essential before flood occurrence and in some cases it could even prevent it. The other important role of floodplain ecosystems and alluvial wetlands is flood mitigation, being the role they play when the flood is already formed ensuring a retention mechanism of the water surplus preventing its spill or superficial flow, thus reducing flood's destructive power.

A flood regulation indicator should therefore consider the damage mitigation role of eco systems by measuring their water storage capacity as well as their flood prevention role which does not only depend also on several other factors and functional processes such as interception and infiltration, surface parameters like



roughness and slope as well as external factors like rainfall quantity and intensity, seasonal state of the vegetation and initial soil saturation.

## 2. Foundations

To assess the flood regulation capacity of wetland ecosystems, three main hydrologic parameters should be considered: the **infiltration rate**, the **surface runoff** and the **peak flow**. The first one is important to estimate the regulation function of the soils. As the flash floods are formed predominantly by the surface runoff, the soils with highest infiltration capability have the highest water regulating capacity as they “absorb” more water, thus reducing the amount of the surface runoff and the flood hazard. The other two parameters represent the function of the ecosystem to redirect part of the incoming water and to delay the movement of the surface runoff. The relationship in this case is the opposite, in the sense that areas with lower surface runoff and peak flow will have a higher water regulation capacity. The topography also has a significant influence on flood regulation functions. Areas in the higher parts of the catchment usually show higher amounts of precipitation, where there are increases in the number of extreme precipitation cases recorded. The steeper slopes in these areas also facilitate a faster downward movement of the water reducing their retention capacity.

The demand for the flood regulation service is related to the benefits from the society. In this case, the benefit is life security and protection of goods and properties. A flood regulation indicator considering supply and demand as defined previously and applied spatially would identify areas where efficient natural flood protection and mitigation are to be achieved, i.e. where the supply of flood regulating ecosystem services by nature on the one hand and the societal demand on the other hand match spatially. Unlike other ecosystem services, the flood regulation service must be provided in the same area where the demand is located as flood regulating services cannot be imported from other regions (Fisher et al., 2009; Nedkov and Burkhard, 2012). Water retention in regulating ecosystem service supply areas prevents excessive water flows during flood events, providing direct benefits to people living in affected regions.

Based on that, an indicator on flood regulation service should consider three key variables:

- i. **The ecosystem or land use capacity to provide the service:** Each ecosystem has several characteristics that enable it to control floods with different degrees of effectiveness (e.g. the presence of vegetation, mulch on the ground, etc.).



- ii. **The service demand:** In the case of flood control, mainly areas where human activities are concentrated (i.e. agroecosystems, urban areas, roads, etc). Sensitive natural or semi-natural areas with high ecological or cultural value may also be considered.
- iii. **The environmental conditions influencing the generation and distribution of floods and their regulation:** Precipitation, topography, land management, lithology, soil texture, vegetation density, etc. In practice, the variables affecting the infiltration capacity and surface roughness, anything that could contribute to flood generation and determine the way an ecosystem contributes to service supply.

Previous work along this line was developed by some Wetland4Change partners in the last stages of SWOS Horizon 2020 project (2015-2018), which proposed a methodology to assess flood regulation service of wetland ecosystems combining GIS, remote sensing data and hydrological modeling. However, there are processes affected by interpretation according to expert knowledge, so the method is open to improvements to offer more harmonized results between study areas, allowing more precise comparisons between basins. Wetland4Change proposes to use this methodology as a basis and make the relevant improvements to address the existing limitations, proposing data sources and defined criteria applicable to all river basins in the Mediterranean region, as well as at pan-European and global scales.

### 3. Proposed methodology

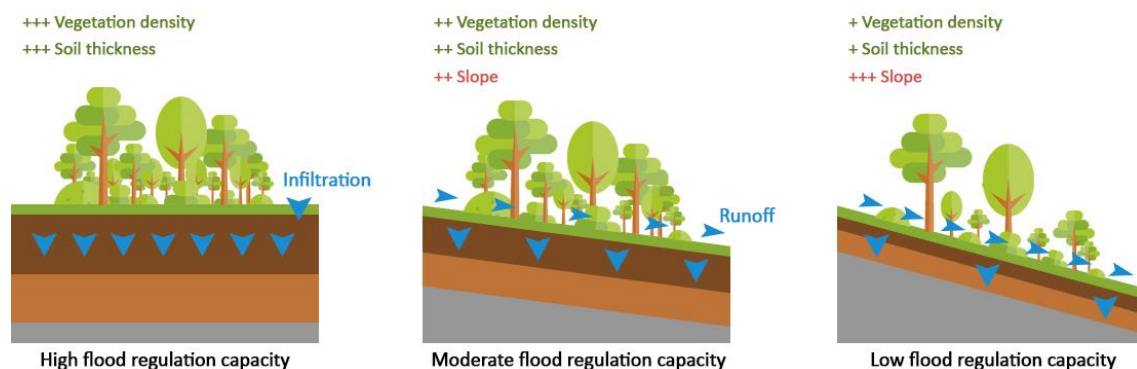
Among the three variables previously presented, environmental conditions are the most critical and complex to assess since the generation of floods depends on many factors. Although in general the principal cause is rainwater runoff, there are other causes such as snowmelt, tides or groundwater flows but these could be even more complex to understand and require the availability of much data of the study area, usually not available for most studied river basins. In addition, these kinds of floods are more linked to specific areas of the territory (e.g. high mountain, karst, or coastal areas) and they are processes that can hardly be assessed with GIS and remote sensing tools. Therefore, to simplify the workflow and produce a suitable indicator for most scenarios, the proposed method will focus on rainy-fluvial river basin floods only. Other types of floods observed in some of the selected Wetland4Change pilot sites, such as marine submersions, will not be addressed here.

The ecosystem capacity to provide the service relies also on the environmental conditions. The existence of a certain type of ecosystem depends on the conditions necessary for their development. At the same time, environmental conditions also determine its level of development and, therefore, its capacity to regulate floods. Hence, when the optimal development conditions are met, an ecosystem can offer the service to its maximum potential.



### 3.1. Land Use / Land Cover capacity

A very simple way to map ecosystem services based on Land Use / Land Cover (LULC) would be assigning scores to each type of LULC class depending on their capacity to provide a given service, based on the supply and the demand (Burkhard, 2012). In the case of flood regulation, a forest would have a high score while a sparsely vegetated area would have a low score. However, one cannot assume that these scores have a uniform distribution within the basin's limits as the properties of the same ecosystem type, which regulate floods, can change, for instance, from the upstream to the downstream. For example, a dense forest in a flat area, with a deep porous soil will have a high regulation capacity. A similar forest located on a steeper area with a shallower soil will offer less service due to topography and soil thickness. A more extreme case would be one in which a high slope and shallow soil hinder the full development of the forest and affect the vegetation density. A similar case would be a change in lithology and soil that promotes other types of vegetation, or the impact of pests and diseases. Therefore, introducing data on environmental and ecosystems conditions can help considering all these parameters influencing the flood regulation capacity of the river basins (Figure 1).



**Figure 1.** Changes in flood regulation capacity within the same type of ecosystem (forest) due to environmental conditions.

These conditions not only determine the supply of the service, but they also have some influences on the service demand. Within the same type of LULC, there may be more sensitive areas than others, in this case especially by the location or distance to flood risk areas. Thus, an urban area near the riverbed will have a greater demand for the service in comparison with a remote built-up area. Even at the same distance from the river channel, an urban settlement on a hill will have less demand than one located at a lower elevation. Another example would be a crop field in an area of high slope or clay soils against another in a flat or very porous soil area. The first one will have a greater demand for the regulation service because of its vulnerability.



### 3.2. Environmental variables needed

The first step to assess the supply and demand of the flood regulation service is to know the behavior of flooding with the assessed catchment including: the origin of floods, which areas are most affected, existing mitigation measures in place, whether it is a recurring problem or has been caused by an inadequate land management decisions, etc.

The methodology proposes a hydrogeological modeling with HEC-HMS tool (Hydrologic Engineering Center's Hydrologic Modelling System), developed by the US Department of Defense, and Soil Conservation Service Curve Number (SCS-CN) Method to estimate catchment and river hydrological parameters and use this information together with data on the spatial extent of flood risk areas of the studied catchment to assess the supply capacity of the ecosystems and the potential demand by human population of the flood regulation service. The tool and model proposed offer adequate results for the work scale (hydrological basin) with a good relation between the detail of information required as inputs and the results obtained, which minimizes limitations due to lack of *in-situ* or high-resolution local data, allowing use of available large-scale spatial information such as products from the Copernicus Land Monitoring Service. Input data are discussed in Section 4 of this document "Data requirements".

The runoff Curve Number (CN) is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excess. CN has a range from 0 to 100, but according to empirical tests the regular minimum value is 30. Low CN indicates low runoff potential while larger CN are for increasing runoff potential. The value depends on the hydrologic soil group, land use, land treatment, vegetation cover and hydrologic condition of the study area. Different references indicate the CN for specific land cover descriptions and hydrologic conditions.

To reflect different infiltration capacities, soils are divided into four hydrologic soil groups (HSG), so that the same LULC class can have 4 NC values depending on soil type. They are defined with the letters A, B, C and D, group A being the soils with the highest infiltration rate and group D those with the lowest. HEC-HMS and SCS-CN handbooks present specific details to assign the corresponding HSG based on the available soil data . A simple approach allows translating United States Agriculture Department (USDA) soil texture classes, the same used by FAO-UNESCO, into HSGs (Table 1).

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[1] <https://www.nrc.gov/docs/ML1421/ML14219A437.pdf>



\*Crop patterns and practices are also considered: contoured, straight row, terraced and residue cover.

**Table 1.** Correspondence between soil texture and HSGs (source: USDA).

<i>HSC</i>	<i>Soil textures</i>
A	Sand, loamy sand or sandy loam
B	Silt loam or loam
C	Sandy clay loam
D	Clay loam, silty clay loam, sandy clay, silty clay or clay

CN values also depend on the hydrologic conditions. Manuals defines different classes for this variable in croplands and natural vegetation areas:

- **Good:** vegetation covers more than 75%, litter and mulch adequately cover the soil.
- **Fair (only applicable to natural vegetation):** vegetation covers between 50-75%, not heavily grazed, some vegetation litter covers the soil.
- **Poor:** ground cover less than 50%, vegetation is destroyed by heavy grazing or regular burning, no litter and mulch coverage.

According to the three variables described above (LULC capacity, hydrologic soil group and hydrologic condition), proper CN values can be spatially assigned according to USDA (Table 2).

**Table 2.** Example of CN table from USDA TR55.

Cover description		CN for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pastures, grassland or range – continuous forage for grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass, protected from grazing and generally mowed for hay	–	30	58	71	78



	Poor	48	67	77	83
Brush – brush-weed-grass mixture with brush the major element	Fair	35	56	70	77
	Good	30	48	65	73

However, LULC classes included in USDA manuals are very simplistic and lack the level of detail of European standards and other widely used nomenclature systems, such as Ramsar for the definition of wetlands. Thus, part of the previous work conducted by some Wetland4Change partners (i.e. ETC-UMA and TdV) focused on producing a CN table compatible with CLC (CORINE Land Cover), MAES (Mapping and Assessment of Ecosystems and their Services) and Ramsar classification systems according to different crosswalks. This CN list ensures a better representation of wetlands and other coverages with high flood mitigation capacity present in Mediterranean countries, in addition to facilitating the inclusion of data at local and national scales, usually more detailed and diverse in terms of LULC classifications.

After defining the basin limits and the CN values, the last requirement for the hydrological modeling is to set the meteorological parameters to run HEC-HMS simulations. Any source of precipitation data is useful, always considering the use of the most detailed source in terms of spatial and temporal resolution, and the most reliable in terms of accuracy of the records. The input data can be precipitation grids or data extracted from gauging stations. The idea is to simulate an event of extreme rainfall in the study area. It is therefore necessary to make an analysis of the rainfall in quantity and temporal distribution to know the magnitude of precipitation in the region and which can potentially generate a flood event.

Once the model is run, the peak flow and drainage volume in the channels of the river and on the surface of the basin are obtained. The latter data indicates the percentage of rain transformed

into runoff and directly contributing to flooding for each sub-basin. It will be one of the variables to be considered to assess the supply of the flood regulation service.

Another relevant variable for the assessment of the flood regulation service (supply and demand) is the extent and frequency of flooding within the studied basin. If available, it is recommended to use validated information from reliable sources based on detailed studies of the river basin. Directive 2007/60/EC requires the existence of flood risk assessment studies to member countries, so at European level this type of ancillary data should be relatively easy to find. For those cases where it is not available, it is proposed to use mapping products that can provide information on the susceptibility and recurrence of floods, such as the Potential Wetland Areas



layer (Guelmami, 2023) provided by the Mediterranean Wetlands Observatory (available for all European and Mediterranean countries).

### 3.3. Assessment of service supply

The capacity of each LULC class to provide the flood regulation service is assessed by four components or sub-indicators (Table 3) using data derived from the water runoff modeling, the information on the extent of flooding as well as the analysis of the river network and the characteristics of all natural and semi-natural ecosystems to absorb the surplus of water:

- i. **Hydrological Characteristics of the Basin (HCB):** this sub-indicator shows the hydrologic behavior of ecosystems when facing an extreme event of precipitation and considers the supply capacity of the flood regulation service depending on the meteorological conditions of the study area. The overall supply of the ecosystem is defined as average values of the capacities based on the interception rates and the model results in the whole study basin. In this way, it is possible to know the role of a given LULC class in the generation of runoff according to its state of conservation and the environmental variables. The calculation of this sub-indicator is based on the results provided by HEC-HMS which are used to calculate the percentage of precipitation that is transformed into runoff.
- ii. **Runoff Generation Potential (RGP):** this sub-indicator represents the hydrologic conditions of the study area which are directly related with the theoretical generation of runoff. It shows the potential capacity of the flood regulation service supply of each area independently of the meteorological variables in the region. The calculation of this sub-indicator is based on the curve number values, so it considers the LULC classes, vegetation density, slope and soil properties. Therefore, this sub-indicator allows comparing the supply capacity between different study areas and types of land coverage identifying ecosystems that have similar hydrological conditions and that potentially can contribute more to the regulation of floods.
- iii. **Risk Mitigation Capacity (RMC):** this sub-indicator considers the capacity of the ecosystems to absorb the impact of floods and mitigate their destructive power when they can provide enough retention space for the water surplus to spill. This mitigation is defined by the extent of the areas at risk of flooding for different return periods, which are generally 10, 100 and 500 years; since they are the main regions of the basin hit by floods destructive power and which depend purely on the morphology and hydrological characteristics of the basin. However, this mitigation capacity is only found in natural ecosystems, while in agriculture and urban areas it has a cost in human lives and goods. Here based on the expert's knowledge, different scores could be used. Nevertheless, for Wetland4Change we propose to establish common values applicable to all pilots.



iv. **Water Regulation Capacity (WRC):** Here the role of the ecosystem is valued according to their properties affecting the generation of floods: the position in the watershed, the type of vegetation, water supply mechanism, etc. This component considers wetland and dry-land areas that act as water reservoirs or whose high regulation capacity is well known to adequately assess these ecosystems and not to underestimate their regulation capacity. Generally, in middle or downstream areas, the regulatory role of ecosystems is usually more important than upstream, as these areas receive all the runoff water that has been generated in the basin. But there are also cases in which upstream zones can also be very important working as reservoirs or reducing runoff and water speed. According to this, the same habitat classes may have different scores simply because of their position within the hydrological network. With the possibility of assigning scores, the role played by all these areas can be highlighted. Here experts are also free to apply their knowledge and criteria by giving different scores according to the assessment of all flood regulation properties and the water regimes of the region. Nevertheless, for Wetland4Change we propose to establish common values applicable to all pilots.

**Table 3.** Flood regulation service supply score table.

Hydrological characteristics of the basin (HCB)		Risk mitigation capacity (RMC)		Water regulation capacity (WRC)	
<b>Rain % into runoff</b>	<b>Score</b>	<b>Natural areas</b>		<b>Regulation</b>	<b>Score</b>
<20 %	5	<b>Return period</b>	<b>Score</b>	High capacity	2
20-35 %	4	10 years	3	Low Capacity	1
35-50 %	3	100 years	2	None/Very low	0
50-65 %	2	500 years	1		
65-80 %	1	<b>Agricultural/seminatural areas</b>		<b>Flood regulation service supply</b>  (Max. Score = 15 / Min. Score = 0)	
>80 %	0	<b>Return period</b>	<b>Score</b>		
<b>Runoff generation potential (RGP)</b>		10 years	2		
<b>Curve Number value</b>	<b>Score</b>	100 years	1		
<40	5	500 years	1		
40-50	4	<b>Artificial areas</b>			
50-60	3	<b>Return period</b>	<b>Score</b>		
60-70	2	10 years	0		
70-85	1	100 years	0		
>85	0	500 years	0		

Each of these components is represented by a georeferenced layer with different values according to the scoring. The result of the supply assessment is a layer generated from the sum of these four components, with values from 0 to 15, being 15 the maximum capacity of supply and 0 a null capacity to regulate floods.

$$\text{Service Supply Indicator} = \text{RGP} + \text{HCB} + \text{RMC} + \text{WRC}$$

The output result is a map representing the supply of the flood regulation service at the scale of the studied catchment area. It identifies zones of high capacity to supply the service which are areas that should not be occupied for human activities and must be properly protected and managed to maintain this ecosystem service intact and maximize its benefits. On the other hand, the map also helps to detect areas



with a low service provision where measures can be taken to improve it. With the help of the input data that have been used for calculating the supply indicator, such as the CN layer or the percentage of rain transformed into runoff, it is possible to locate those areas that contribute most to the floods and support the restoration of certain ecosystems as NbS to mitigate flood hazards.

### 3.4. Assessment of service demand

The demand for flood regulation ecosystem service is assessed by the analysis of the exposure and vulnerability of population and human assets within flood-prone areas, so data on the extent and frequency of flooding as well as the analysis of the vulnerability of different LULC classes and its importance in the study area are essential. Three components or sub-indicators are produced according to a scoring in Table 4:

- i. **Exposure and Vulnerability of assets related to population (EVassets):** this sub-indicator is divided into two related components:
  - a) **Land use potential vulnerability:** as the overall sensitivity to flooding of different types of LULC, with scores from 0 to 7, summarizing the potential losses (persons injured, property damage and disruption of economic activity) according to the LULC characteristics. Built on previous studies, scores were proposed for CLC classes in Table 4 for the land vulnerability assessment, but modifications can be made based on Wetland4Change experts' knowledge and other relevant LULC classification systems. Both natural and non-natural classes should be assessed, although it is expected that natural ones have value equal to 0.
  - b) **Susceptibility:** defined by the probability and extent to which floods will affect population and human assets. Scores from 1 to 3 are proposed according to the extent of flood risk areas for different return periods (10, 100 and 500 years). Areas around the river channels and floodplain will be the most affected by floods. Those remote areas beyond the reach of the risk do not see their demand increased due to this factor.

Wetland4Change will review the scores according to a common criterion to be applicable to all the selected pilot catchments.

- ii. **Exposure and Vulnerability of the population (EVpopulation):** this is an exposure (e.g. density) and vulnerability (e.g. age group, economic resources) to consider the different impact of floods on the population. The calculation of this sub-indicator should only cover the areas at risk of flooding. Based on previous studies, different criteria were proposed depending on the data available and the knowledge of the area. A simple and direct approach is to assess exposure and vulnerability based on LULC information, estimating the density and types of population that can be found in different areas (e.g. continuous vs discontinuous urban fabric). Socioeconomic information of the region can be of great help to support this assessment. For instance, hospitals,



schools, and residential areas are clear examples where to find vulnerable groups. When available, spatial data on population distribution, housing type or GDP could support the development of this sub-indicator and improve the quality of the results. Wetland4Change proposes an improvement of this sub-indicator based on population density and soil sealing data so that the method is harmonized regardless of the study region and expert criteria. Among the raw data sources that could potentially be used here to enhance this sub-indicator are the Gridded Population of the World (GPW), as well as the Global Human Settlement Layer (GHSL).

- iii. **Economic Value (EcValue):** the consequences of a flood event are more important if they affect urban settlements and highly profitable sectors which are significant for the local economy. This economic criterion can include factors such as monetary value, employment (commercial or industrial areas for example), or sentimental value (residential areas). Given a material lost it can be also considered who suffers the losses (economic level of the population) and the ease to replenish this loss (sentimental value). Therefore, this indicator is open to a broader interpretation, from a more general point of view, not only considered the physical resistance of the population (impact on health and life) and their economic activities (economic impact), but also the vulnerability of social assets of a non-productive nature, such as the cultural and ecological heritage. In previous studies, we proposed that residential areas are the most important followed by commercial and industrial areas, while agricultural areas are the least relevant. This criterion may change depending on the study area and its socioeconomic conditions, so Wetland4Change will also do a review of this sub-indicator for a common criterion for all pilot sites.

**Table 4.** Flood regulation service demand score table.

Exposure and vulnerability of assets related to population (EVassets)			Exposure and vulnerability of assets related to population (EVassets)	
Vulnerability			Susceptibility	
CLC Code	CLC Class Name	Score	Return period	Score
111	Continuous urban fabrics	6	10 years	3
112	Discontinuous urban fabric	7	100 years	2
121	Industrial or commercial units	6	500 years	1
122	Road and rail networks and associated land	5		
123	Port areas	4		
124	Airports	4		
131	Mineral extraction sites	3		
132	Dump sites	2		
133	Construction sites	4		
141	Green urban areas	3		
142	Sport and leisure facilities	3		
211	Non-irrigated arable land	4		
212	Permanently irrigated land	4		
213	Rice fields	6		
221	Vineyards	1		
222	Fruit trees and berry plantations	1		
223	Olive groves	1		
231	Pastures	3		
241	Annual crops associated with permanent crops	3		
242	Complex cultivation	3		
-	Other classes	0		

Exposure and vulnerability of the population (EVpopulation)	
Population exposure	Score
Vulnerable population	2
High density	1

Economic value (EcValue)	
Economic value	Score
Residential	3
Industrial/commercial	2
Crops	1

<p><b>Flood regulation service demand</b> (Max. Score = 15 / Min. Score = 0)</p>
--------------------------------------------------------------------------------------



As for the supply, the result of this assessment is a layer generated from the sum of these sub-indicators, with values from 0 to 15, where 15 being the maximum demand of the service and 0 no demand of flood regulation.

$$\text{Service Demand Indicator} = EV_{\text{assets}} + EV_{\text{population}} + Ec_{\text{value}}$$

$$EV_{\text{assets}} = \text{Vulnerability} + \text{Susceptibility}$$

Service demand maps and their sub-indicators identify the areas most affected by floods and where mitigation and evacuation plans should focus. Sub-indicators related to population and economic importance can support territorial management by identifying high-risk areas where population or economic activities should be moved to other areas or where engineering solutions could be required to avoid significant damage.

## 4. Data requirements

The input data needed to apply the methodology described in this document are listed in Table 5. Some data sources are already defined to harmonize calculation methods and offer comparable results between pilot sites. For the others, alternative sources are proposed in case of not having specific information for the pilots. This is usually data available at a European or global level, therefore covering the whole Mediterranean region. In some cases, it can be produced from other sources (e.g. Earth Observation based layers, etc.).

Variables that are necessarily required to apply the methodology, given that they are its main pillars for flood modeling and service supply and demand assessment, are highlighted with **“M”** for **Mandatory**, in the list below. Data that are not totally necessary for the method, but useful to improve the results are marked as **“O”** for **Optional**.

**Table 5.** Data required for the initial steps to assess the flood regulation service at the scale of the selected catchments.

Variable name	Data type	Requirement (M/O)	Description
LULC	Layer	M	Detailed LULC map of the catchment area based on a nomenclature system that could be used to assess the flood regulation service, either in its original format or after a crosswalk. If no local data is available, pan-European (e.g. CLC or Copernicus High Resolution Layers) could be used. In the framework of Wetland4Change, it would also be



Variable name	Data type	Requirement (M/O)	Description
			possible to produce EO-based recent LULC maps with a high level of thematic accuracy if needed.
Wetlands extent	Layer	M	Map of wetlands extent within the studied catchments, highlighting the main wetland habitat types based on Ramsar definitions. In the framework of Wetland4Change, it would also be possible to produce EO-based recent wetland extent maps with a high level of thematic accuracy if needed.
Soil	Layer	M	Inventory of soil types with sufficient data on the soil properties to distinguish different hydrologic soil groups. It must include some information such as porosity, composition according to size of materials or type of soil according to international soils classification systems. If there are no local / regional soil data, JRC Soil Database and FAO / UNESCO soil data are suggested as alternative sources.
Vegetation	Layer	M	Vegetation cover and density data that can be extracted from EO-based products using vegetation indices. It is also possible to consider this variable only for specific classes in case there are difficulties obtaining this information for the entire basin (e.g. only considering classes of natural vegetation).
Digital Elevation Model (DEM)	Layer	M	Needed for the calculation of slopes, river network and other topographic indices and parameters of the hydrological modeling. Copernicus DEM, with a spatial resolution of 30m, is a good source for basin-scale work and is proposed as the main source.
River network	Layer	O	Spatial layer with the distribution and route of the rivers, at least the main ones, in the study area. If not available, it could be produced from the DEM, although a much lower spatial precision is expected, especially for small streams.
Hydrological basins	Layer	M	Spatial layer delimiting the river basin where the flood regulation service is assessed. This is usually produced as a modeling step using the DEM, but an official source would help validate the result.



Variable name	Data type	Requirement (M/O)	Description
Precipitation	Layer and/or metadata	M	Meteorological data on precipitation of the study area. It is suggested to check national or regional meteorological agencies. Alternative spatial explicit source of information is the global climate data for ecological modeling from WorldClim, which has raster layers of the monthly rainfall distribution with a resolution of up to 30 seconds. Given that the work is at the level of the Mediterranean region, it is to be expected, despite some differences, that the torrentiality of precipitation that causes flooding is quite similar. Therefore, a standard rainfall model could be established to apply to all study areas in case there are limitations to collecting this type of data. This would also make the results more comparable between regions.
Flood risk map	Layer	M	Delimitation of the areas at risk of flooding according to probability (usually in years of return period) as well as any relevant data on emergency and evacuation plans that inform the most exposed and vulnerable human assets. If not available, it could be estimated using mapping proxies such as the Potential Wetland Areas layer provided by the Mediterranean Wetlands Observatory (available for all European and Mediterranean countries).
Population distribution	Layer	O	Population distribution or density layer to assess the flood regulation service demand. Gridded Population of the World (GPW), as well as the Global Human Settlement Layer (GHSL) are proposed as a harmonized source for all pilot sites.
Socio-economic information	Metadata	O	Information to support the assessment of demand based on the economic activities within the assessed area, the income level of the population, age groups, etc. This can be based on reports, statistics and other documents if spatial information does not exist.



## 5. Comprehensive interpretation and integration of results

In addition, the flood regulation service supply and demand data can be merged to produce a map showing regional supply-demand balances as done by Nedkov and Burkhard, 2012. This combination is a simple subtraction of supply and demand which shows areas where the benefits in regulating the flood (supply) outweigh the damage that can be caused (demand) or vice versa. This can be especially useful in agricultural or other semi-natural areas to see if it is worth making changes in land planning to increase flood regulation capacity of the basin.

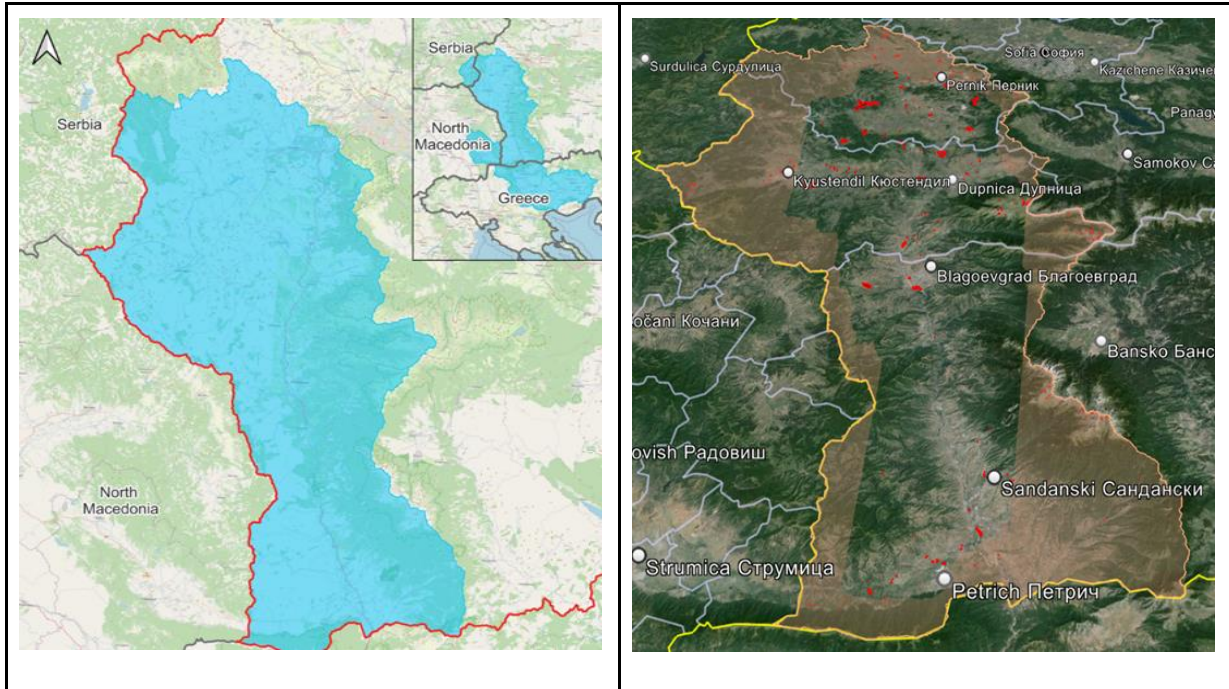
The main limitation of this approach is that supply and demand are not directly comparable because they are based on very different data and criteria. However, the balance is a source of additional information and a tool that complements the indicators and sub-indicators of supply and demand. All these data support identifying areas of interest within a mapped catchment where detailed research will be required to quantify demand and service capacity as well as to decide on the measures to be taken. They are therefore a first step in addressing the problem of improving flood regulation capacity within a hydrological basin, through conserving and/or restoring wetland ecosystems as NbS for instance.

## 6. Pilot sites

### 6.1. The catchment area of Struma (Bulgaria), Responsible LP UF

#### 6.1.1. Synoptic description of pilot site

The pilot site in Bulgaria – the catchment area of Struma (Figure 2), covers 197 small and medium sized wetlands of the Struma catchment. The Struma River rises from the southern slopes of Mount Vitosha, at 2246 m altitude, 250 m south of Cherni vrah peak. The river flows south and leaves the Bulgarian territory near the village of Kulata. The length of the river from the source to the Bulgarian-Greek border is 290 km, which makes it the sixth longest Bulgarian river after Danube, Iskar, Tundzha and Maritsa. The catchment area amounts to 17300 km<sup>2</sup>, which represents 9.73 % of the country's territory and covers parts of four Balkan countries - the Republic of Bulgaria, the Hellenic Republic, the Republic of North Macedonia and the Republic of Serbia.



**Figure 2.** Map of Struma catchment. Wetlands within Struma catchment



## 6.1.2. Data available for Bulgarian pilot

**Table 6.** Data required for the initial steps to assess the flood regulation service for the pilot case of PP01 Struma catchment Bulgaria (**M**: Mandatory, **O**: Optional).

Variable name	Data type	Description	Datasets gathered/produced by UF
LULC ( <b>M</b> )	Layer	Detailed LULC map of the catchment area based on a nomenclature system that could be used to assess the flood regulation service, either in its original format or after a crosswalk. If no local data is available, pan-European (e.g. CLC or Copernicus High Resolution Layers) could be used. In the framework of Wetland4Change, it would also be possible to produce EO-based recent LULC maps with a high level of thematic accuracy if needed.	<p><b>Available</b></p> <p><u>Name</u>: CORINE Land Cover Land Use 2018;</p> <p><u>Source</u>: European Environmental Agency</p> <p><u>Info</u>: Corine Land Cover within the catchment area of Struma</p>
Wetlands extent ( <b>M</b> )	Layer	Map of wetlands extent within the studied catchments, highlighting the main wetland habitat types based on Ramsar definitions. In the framework of Wetland4Change, it would also be possible to produce EO-based recent wetland extent	<p><b>Available.</b></p> <p><u>Name</u>: Wetlands in the catchment area of Struma</p> <p><u>Source</u>: UF, 2019.</p> <p><u>Info</u>: Detailed wetland mapping layer produced by University of Forestry during the WetMainAreas Interreg BalkanMed project.</p>



Variable name	Data type	Description	Datasets gathered/produced by UF
		maps with a high level of thematic accuracy if needed.	
Soil (M)	Layer	Inventory of soil types with sufficient data on the soil properties to distinguish different hydrologic soil groups. It must include some information such as porosity, composition according to size of materials or type of soil according to international soils classification systems. If there are no local / regional soil data, JRC Soil Database and FAO / UNESCO soil data are suggested as alternative sources.	<p><b>Available</b></p> <p><u>Name:</u> Soil map within the catchment area of Struma</p> <p><u>Source:</u> General Directorate of Geodesy and Cartography Sofia</p> <p><u>Info:</u> Spatial data on soil distribution in the catchment area of Struma. The map includes the type of soil according to international soil classification systems.</p> <p><u>Name:</u> Average soil moisture in the catchment area of Struma, from 1958 to 2019.</p> <p><u>Source:</u> WetMainAreas project</p> <p><u>Info:</u> Spatial data in average soil moisture from 1958 to 2019</p>



Variable name	Data type	Description	Datasets gathered/produced by UF
Vegetation (M)	Layer	Vegetation cover and density data that can be extracted from EO-based products using vegetation indices. It is also possible to consider this variable only for specific classes in case there are difficulties obtaining this information for the entire basin (e.g. only considering classes of natural vegetation).	<p><b>Not available</b></p> <p><u>We only have a Habitat</u> types mapping layer (Annex I habitats) in the catchment area of Struma.</p> <p><u>Source:</u> Bulgarian Ministry of Environment and Water</p> <p>For the use of EO-based vegetation indices, we need further guidance from the WP2 Leader in order for all pilots to apply the same thresholds and produce harmonized datasets.</p>
Digital Elevation Model (DEM) (M)	Layer	Needed for the calculation of slopes, river network and other topographic indices and parameters of the hydrological modeling. Copernicus DEM, with a spatial resolution of 30m, is a good source for basin-scale work and is proposed as the main source.	<p><b>Available</b></p> <p><u>Name:</u> Copernicus Global DSM</p> <p><u>Source:</u> Copernicus DEM (<a href="https://spacedata.copernicus.eu">https://spacedata.copernicus.eu</a>)</p> <p><u>Info:</u> Copernicus Digital Elevation Model (30m) and Aspect and Slope, calculated based on the Copernicus DEM.</p>
River network (O)	Layer	Spatial layer with the distribution and route of the rivers, at least the main ones, in the study area. If not available, it could be produced from the DEM, although a much lower spatial precision is expected, especially for small streams.	<p><b>Available</b></p> <p><u>Name:</u> Hydrographic network in the West-Aegean River Basin District</p> <p><u>Source:</u> Basin Directorate</p> <p><u>Info:</u> Spatial data on hydrographic network</p>



Variable name	Data type	Description	Datasets gathered/produced by UF
Hydrological basins (M)	Layer	Spatial layer delimiting the river basin where the flood regulation service is assessed. This is usually produced as a modeling step using the DEM, but an official source would help validate the result.	<p><b>Available</b></p> <p>Hydrographic network in the West-Aegean River Basin District</p> <p><u>Source:</u> WetMain Areas project</p> <p>Info:</p>
Precipitation (M)	Layer and/or metadata	Meteorological data on precipitation of the study area. It is suggested to check national or regional meteorological agencies. Alternative spatial explicit source of information is the global climate data for ecological modeling from WorldClim, which has raster layers of the monthly rainfall distribution with a resolution of up to 30 seconds. Given that the work is at the level of the Mediterranean region, it is to be expected, despite some differences, that the torrentiality of precipitation that causes flooding is quite similar. Therefore, a standard rainfall model could be established to apply to all study areas in case there are	<p><b>Available –</b></p> <p>Name: Average precipitation data for the period 1981 to 2020.</p> <p>Source: The data is publicly available at : <a href="https://app.climateengine.org/climateEngine">https://app.climateengine.org/climateEngine</a></p> <p>Info: Average precipitation data for the specific period.</p>



Variable name	Data type	Description	Datasets gathered/produced by UF
		<p>limitations to collecting this type of data. This would also make the results more comparable between regions.</p>	
<p>Flood risk map (<b>M</b>)</p>	<p>Layer</p>	<p>Delimitation of the areas at risk of flooding according to probability (usually in years of return period) as well as any relevant data on emergency and evacuation plans that inform the most exposed and vulnerable human assets. If not available, it could be estimated using mapping proxies such as the Potential Wetland Areas layer provided by the Mediterranean Wetlands Observatory</p>	<p><b>Available</b></p> <p>Name: Flood high risk management zones</p> <p>Historical floods occurred between 2011-2019</p> <p>Source: Basin Directorate</p> <p>Info: <a href="https://wabd.bg/content/wp-content/uploads/2024/01/BG4_Final_FRMP.pdf">https://wabd.bg/content/wp-content/uploads/2024/01/BG4_Final_FRMP.pdf</a></p> <p>-</p>



Variable name	Data type	Description	Datasets gathered/produced by UF
		(available for all European and Mediterranean countries).	
Population distribution (O)	Layer	Population distribution or density layer to assess the flood regulation service demand. Gridded Population of the World (GPW), as well as the Global Human Settlement Layer (GHSL) are proposed as a harmonized source for all pilot sites.	<p><b>Available Name:</b></p> <ul style="list-style-type: none"> <li>- Population data at LAU level for BG 2021 xls.</li> <li>- Historical population data from 1961 to 2011 at LAU level for BG Geospatial data;</li> </ul> <p><u>Source:</u> EUROSTAT</p> <p><u>Info:</u> Historical population data from 1961 to 2011 at LAU level for BG 2011</p>



Variable name	Data type	Description	Datasets gathered/produced by UF
Socio-economic information (O)	Metadata	Information to support the assessment of demand based on the economic activities within the assessed area, the income level of the population, age groups, etc. This can be based on reports, statistics and other documents if spatial information does not exist.	We aim to look for information on the economic activities of the area in the National Flood Risk Assessments and also in other relevant sources such as the River Basin Management Plans.

To assess the flood regulation ecosystem service, we will collaborate with national and regional regulatory bodies, including the Executive Environmental Agency and the Basin Directorate of West-Aegean Region, to obtain the necessary information for our study. We aim to investigate the synergies arising with the already existing National Flooding Risk Management Plans. By integrating detailed spatial data on wetland distribution and extent, we will adjust our flood regulation models to accurately assess the wetlands' contribution to flood mitigation.

On what concerns the flood regulation service supply we will run the hydrological model with the HEC-HMS tool (Hydrologic Engineering Center's Hydrologic Modelling System), using the average precipitation data for the period 1981 to 2020, in order to delineate the hydrological characteristics of the basin, as the percentage of precipitation that is transformed to runoff.

Next, we will estimate the runoff generation potential based on the Curve Number values. The CN will be estimated using the LULC class, soil type (A, B, C and D), vegetation cover (good, fair, poor) and slope (higher or lower than 3%). In order to account for the surface water dynamics, we will use three scenarios (permanently flooded area, temporarily flooded area without dense vegetation, not flooded or densely vegetated areas without open water) in LULC classes that this is applicable.

For the remaining two sub-indicators, risk mitigation capacity and water regulation capacity, we will use commonly agreed score values established within the Wetland4Change Project. To determine the hydrological characteristics of the basin,



we will reference data from the National Flooding Risk Management Plan, specifically the return periods of 20, 100, and 1000 years.

On what concerns the flood regulation service demand we will assess the exposure and vulnerability of assets (EVassets) related to population based on CLC 2018). We will assign higher scores for exposure and vulnerability in more anthropogenic landscapes, such as densely built urban areas. Scores were proposed for CLC classes in Table 4. The susceptibility component of the sub-indicator will be evaluated from 1 to 3 according to the different return periods. (20, 100 and 1000 yrs, as per table 4).

As for the exposure and vulnerability of the population (EVpopulation), we will be using LULC information estimating the density and types of population that can be found in different areas. If available spatial data on population distribution could be provided to support the development of this sub-indicator. Moreover, based on the availability of socioeconomic information more vulnerable groups (such as hospitals, schools and residential areas) can be identified.

For the economic value sub-indicator (EcValue), the indicator assessing the potential consequences in the area based on the economic criterion. Wetland4Change experts might need to adjust according to the region of the pilot test.

The flood regulation service supply and demand data will be merged to produce a map of regional supply-demand balances (Nedkov and Burkhard, 2012).

### 6.1.3. Potentials and weaknesses

By integrating detailed spatial data on wetland distribution and extent, we will adjust our flood regulation models to accurately assess the wetlands' contribution to flood mitigation. The analysis will assist in territorial management by identifying high-risk zones. In addition, measures against flood risk to be implemented by local administrative structures are foreseen in the Flooding Risk Management Plan of West-Aegean Basin Directorate. Having Gotse Delchev Municipality as an associate partner in the project, we are working closely with them to understand and sustainably implement those of the nature-based measures concerning wetlands.

## 6.2. Kerkini Lake and Strymon River catchment (Greece), Responsible EKBV

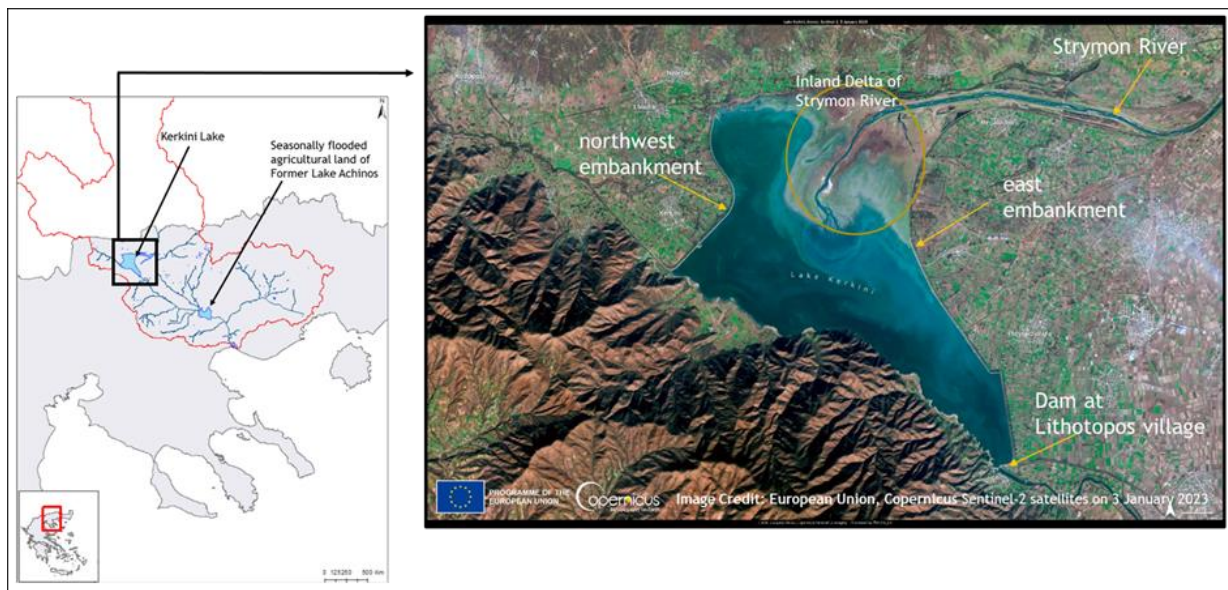
### 6.2.1. Synoptic description of pilot site

The pilot site in Greece is the Kerkini Artificial Lake and 87 small and medium sized wetlands of the Strymon River catchment (Figure 3).



Kerkini is a large, artificial freshwater lake located at the place of a former wetland complex of small lakes and marshes, since ancient times. It is fed by the Strymon River flowing in Greece from Bulgaria, which forms an inland delta, at the mouth of the lake. It was created in 1932, with the construction of a dam at Lithotopos village and of two embankments, on the east and on the northwest river banks to protect nearby villages. It was created for flood control and irrigation purposes. The construction of the dam on a previously wetland area, the bird migration corridor along the valley, and the shallow depth, made it one of the most important wetlands in Greece.

In 1977, Lake Kerkini was designated as a Wetland of International Importance (Ramsar). Later, it was included in the Natura 2000 Network and became the core of the Kerkini National Park. The catchment of Strymon River includes 13 Natura 2000 sites (7 SCI, 5 SPA, 1 SCI/SPA), 32 Wildlife Refuges, an Aesthetic Forest (Dasi Amygdaleona Kavalas), a Controlled hunting area of Serres and a Game breeding station (Chrysopigi Oreinon Serron).



**Figure 3.** Strymon catchment in the Greek pilot, with wetlands and hydrographic network within its boundaries. Satellite image of Artificial Lake Kerkiní.



**Figure 4.** Photos of the Lake Kerkin landscape. a) View of the lake from the north-west side, depicting the input of Strymon inside the Lake Kerkin. b) Cattle grazing in Kerkin Lake. c) Horses wandering and grazing around Lake Kerkin close to Lithotopos dam.

### 6.2.2. Data available for Greek pilot

Table 7 provides the list of available datasets that have been collected for the Greek pilot site, following the guidelines of the WP Leader. For data that are not yet available, there is a description of their planned acquisition or creation through spatial processing or modelling approaches.

**Table 7.** Data required for the initial steps to assess the flood regulation service for the pilot case of PP02 Kerkin Lake and the wider catchment of Strymon River (**M**: Mandatory, **O**: Optional).

Variable name	Data type	Description	Datasets gathered/produced by EKBY
LULC ( <b>M</b> )	Layer	Detailed LULC map of the catchment area based on a nomenclature system that could be used to assess the flood regulation service, either in its original format or after a crosswalk. If no local data is available, pan-European (e.g. CLC or Copernicus High Resolution Layers) could be used. In the framework of Wetland4Change, it would also be possible to produce EO-based recent LULC maps with a high	<p><b>Available</b></p> <p><u>Name:</u> CORINE Land Cover Land Use 2018</p> <p><u>Source:</u> Copernicus Land Monitoring Service (<a href="https://land.copernicus.eu/en/products/corine-land-cover/clc2018">https://land.copernicus.eu/en/products/corine-land-cover/clc2018</a>)</p> <p><u>Info:</u> Detailed LULC map of the catchment area covering 32 CLC classes (Level 3) for the 2018 reference year. The dataset has a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a Minimum Mapping Width (MMW) of 100 m for linear phenomena and is available as vector dataset.</p>



Variable name	Data type	Description	Datasets gathered/produced by EKBY
		level of thematic accuracy if needed.	<p><u>Name:</u> SWOS ecosystem mapping  <u>Source:</u> SWOS-EKBY  <u>Info:</u> Land Use Land Cover type SWOS mapping product for the Artificial Lake Kerkini and catchment area. There are 2 available datasets, both with high level of thematic accuracy (&gt;85%)</p> <p>One depicting the ecosystems in 2017, according to the MAES nomenclature, as this modified and enhanced by the SWOS team specifically for wetland ecosystems.</p> <p>The other, depicting the wetland types and the upland land cover/use in 2017, according to the hybrid classification system of CORINE Land Cover and Ramsar typology, as developed in GlobWetland-II project.</p>
Wetlands extent (M)	Layer	Map of wetlands extent within the studied catchments, highlighting the main wetland habitat types based on Ramsar definitions. In the framework of Wetland4Change, it would also be possible to produce EO-based recent wetland extent maps with a high level of thematic accuracy if needed.	<p><b>Available.</b></p> <p><u>Name:</u> Wetlands of Greece "Continental part" in the Catchment area of Strymon  <u>Source:</u> EKBY, 2019.</p> <p><u>Info:</u> Detailed wetland mapping layer produced by EKBY during the WetMainAreas Interreg BalkanMed project.</p>



Variable name	Data type	Description	Datasets gathered/produced by EKBY
Soil (M)	Layer	Inventory of soil types with sufficient data on the soil properties to distinguish different hydrologic soil groups. It must include some information such as porosity, composition according to size of materials or type of soil according to international soils classification systems. If there are no local / regional soil data, JRC Soil Database and FAO / UNESCO soil data are suggested as alternative sources.	<p><b>Available</b>, as:</p> <p>a) Soil map - Soil depth 1997 (Source: Ministry of Environment and Energy / General Directorate of Forests and Forest Environment <a href="http://mapsportal.ypen.gr/layers/geonode:edafmap_1997">http://mapsportal.ypen.gr/layers/geonode:edafmap_1997</a>)</p> <p>b) RUSLE parameters to estimate the soil erodibility index and further vulnerability for the best possible flood risk assessment. (C: cropping management factor, K: soil erodibility, LS: topographic factor, P: erosion control practice factor, R: erosivity) (Source: Ministry of Environment and Energy)</p> <p>c) FAO Digital Soil Map of the World (<a href="https://data.apps.fao.org/map/catalog/srv/en/g/catalog.search#/metadata/446ed430-8383-11db-b9b2-000d939bc5d8">https://data.apps.fao.org/map/catalog/srv/en/g/catalog.search#/metadata/446ed430-8383-11db-b9b2-000d939bc5d8</a>)</p>
Vegetation (M)	Layer	Vegetation cover and density data that can be extracted from EO-based products using vegetation indices. It is also possible to consider this variable only for specific classes in case there are difficulties obtaining this information for the entire basin (e.g. only considering classes of natural vegetation).	<p><b>Not available</b></p> <p>We only have available Habitat types mapping layer (Annex I habitats). For the use of EO-based vegetation indices, we need further guidance from the WP2 Leader in order for all pilots to apply the same thresholds and produce harmonized datasets.</p>



Variable name	Data type	Description	Datasets gathered/produced by EKBY
Digital Elevation Model (DEM) (M)	Layer	Needed for the calculation of slopes, river network and other topographic indices and parameters of the hydrological modelling. Copernicus DEM, with a spatial resolution of 30m, is a good source for basin-scale work and is proposed as the main source.	<p><b>Available</b></p> <p><u>Name:</u> Copernicus Global DSM</p> <p><u>Source:</u> Copernicus DEM (<a href="https://spacedata.copernicus.eu">https://spacedata.copernicus.eu</a>)</p> <p><u>Info:</u> Copernicus Digital Elevation Model (30m) and Aspect and Slope, calculated based on the Copernicus DEM.</p> <hr/> <p>Furthermore, we plan to develop a Digital Elevation Model (bathymetry, expected as ~1m resolution) of Kerkini artificial lake before May 2025.</p>
River network (O)	Layer	Spatial layer with the distribution and route of the rivers, at least the main ones, in the study area. If not available, it could be produced from the DEM, although a much lower spatial precision is expected, especially for small streams.	<p><b>Available</b></p> <p><u>Name:</u> Hydrographic network</p> <p><u>Source:</u> Hellenic Ministry of Environment and Energy</p>
Hydrological basins (M)	Layer	Spatial layer delimitating the river basin where the flood regulation service is assessed. This is usually produced as a modelling step using the DEM, but an official source would help validate the result.	<p><b>Available</b></p> <p><u>Name:</u> Management units of river basins of Greece</p> <p><u>Source:</u> Hellenic Ministry of Environment and Energy</p>



Variable name	Data type	Description	Datasets gathered/produced by EKBY
Precipitation (M)	Layer and/or meta data	<p>Meteorological data on precipitation of the study area. It is suggested to check national or regional meteorological agencies. Alternative spatial explicit source of information is the global climate data for ecological modelling from WorldClim, which has raster layers of the monthly rainfall distribution with a resolution of up to 30 seconds. Given that the work is at the level of the Mediterranean region, it is to be expected, despite some differences, that the torrentiality of precipitation that causes flooding is quite similar. Therefore, a standard rainfall model could be established to apply to all study areas in case there are limitations to collecting this type of data. This would also make the results more comparable between regions.</p>	<p><b>Not available</b></p> <p>Currently we are looking for the meteorological data used for the National Flood Risk Plan of the River basin of our pilot. In case it will not become possible to get access on this dataset, we will use the WorldClim data.</p> <p>However, there are available the IDF curves parameters (Ombrian_parameters_Kerkini.shp)</p>



Variable name	Data type	Description	Datasets gathered/produced by EKBY
Flood risk map (M)	Layer	Delimitation of the areas at risk of flooding according to probability (usually in years of return period) as well as any relevant data on emergency and evacuation plans that inform the most exposed and vulnerable human assets. If not available, it could be estimated using mapping proxies such as the Potential Wetland Areas layer provided by the Mediterranean Wetlands Observatory (available for all European and Mediterranean countries).	<p><b>Available</b></p> <p><u>Name:</u></p> <ul style="list-style-type: none"> <li>- Flood high risk management zones</li> <li>- Historical floods occurred between 2012-2019</li> <li>- Important historical floods</li> </ul> <p><u>Source:</u> Hellenic Ministry of Environment and Energy (<a href="https://gis.floods.ypeka.gr/?lon=23.722301573145234&amp;lat=40.31151997116558&amp;zoom=11">https://gis.floods.ypeka.gr/?lon=23.722301573145234&amp;lat=40.31151997116558&amp;zoom=11</a>)</p> <p><u>Info:</u> The datasets were produced in the context of flood risk management plans required under the Floods Directive. It integrates vulnerability.</p>
Population distribution (O)	Layer	Population distribution or density layer to assess the flood regulation service demand. Gridded Population of the World (GPW), as well as the Global Human Settlement Layer (GHSL) are proposed as a harmonized source for all pilot sites.	<p><b>Available</b></p> <p><u>Name:</u> Population data at LAU level for GR 2021</p> <p><u>Source:</u> EUROSTAT</p> <p><u>Info:</u> Includes xlsx and geospatial (vector) population data at Local Administrative Units (LAU) level for 2021</p>
			<p><u>Name:</u> Population density</p> <p><u>Source:</u> EUROSTAT</p> <p><u>Info:</u> Includes population density geospatial (vector) data at LAU level, produced by the "Population data at LAU level for GR 2021"</p>

Variable name	Data type	Description	Datasets gathered/produced by EKBY
			<p><u>Name</u>: Historical population data from 1961 to 2011 at LAU level for GR 2011</p> <p><u>Source</u>: EUROSTAT</p> <p><u>Info</u>: Includes xlsx and geospatial (vector) historical population data from 1961 to 2011 at LAU level</p> <hr/> <p>Furthermore:</p> <p>a) the Gridded Population of the World, Version 4 (GPWv4), that consists of estimates of human population (number of persons per pixel), consistent with national censuses and population registers, for the years 2000, 2005, 2010, 2015, and 2020. and</p> <p>b) the GHS-POP grid dataset of the Global Human Settlement Layer (GHSL), that depicts the distribution of residential population, expressed as the number of people per cell, between 1975 and 2020 and projections to 2025 and 2030,</p> <p>can be obtained, in order to produce more harmonized datasets.</p>
Socio-economic information (O)	Meta data	Information to support the assessment of demand based on the economic activities within the assessed area, the income level of the population, age groups, etc. This can be based on reports, statistics and other documents if spatial information does not exist.	We aim to look for information on the economic activities of the area in the National Flood Risk Assessments and also in other relevant sources such as the River Basin Management Plans, the Regional Plan for Adaptation to Climate Change (PESPKA) of the Region of Central Makedonia etc.

### 6.2.3. Potentials and weaknesses

For the assessment of flood regulation ecosystem service, EKBY aims to investigate the synergies arising with the already existing National Flood Risk Management



Plans. In particular, we aim to embed within the Wetland4Change assessment for the Greek pilot, the mapping results of the relevant flood risk plan, and for this, we are collaborating with the Regional Unit of Serres, which is one of our associated partners. Also, we plan to be in contact with the Ministry's subcontractor of the flood risk mapping, in order to investigate possibilities of provision of access to some of the datasets they used i.e. precipitation or thresholds applied in their modelling approach. In this case, we will be consistent with the standards set by the National Flood Risk Management Plans and adjust the models for flood regulation mapping integrating detailed spatial data on wetland distribution and extent which will allow us to assess their contribution in flood mitigation.

The river basin district of Strymon river and Kerkini Lake is quite a complicated one, with transboundary inputs from the Bulgarian part of Strymon river and this would represent a great challenge to model for our analysis in terms of data requirements. We seek for synergies with the National Flood Risk Management plan in order to align with our national and regional obligations and produce results that will be of use to our associated partner, the Serres prefecture. In the case that it will not be possible to have access to this raw data (i.e meteorological data) we will apply other available explicit spatial data (i.e WorldClim model). This may be a weakness in case our results will not be easily comparable with the results of the national flood risks maps. However, the great potential of the Wetland4Change flood assessment product is the fact that detailed spatial data on wetland distribution will be integrated for the first time in flood regulation assessments for the river basin district of Strymon. In addition, great potential comes from the fact that flooding assessment will be based on common score values that will be jointly established in the Wetland4Change via the testing in the 5 EU Mediterranean pilot wetlands.

### 6.3. Marceddì and San Giovanni Ponds (Italy), Responsible MEDSEA

#### 6.3.1. Synoptic description of pilot site

The coastal area of Oristano (Sardinia, Italy) is a complex and high-density system of rivers, lagoons, and salt marshes (Figure 5). Most of the wetlands are shallow eutrophic water bodies (approximately 0.5-2 m depth), around 7,700 hectares of which (over 60% of Sardinia's wetlands) are protected by the Ramsar convention and the Natura 2000 network. The Gulf of Oristano is characterised by the tight integration between the existing settlement structure and the environment characterised by the system of coastal wetlands. It is a low-density area, characterised by small concentrated urban zones, most of them located in the inland areas, and sprawl urbanisation related to fishing cooperatives, agricultural and livestock farms and small touristic villages located along the coast (Satta, 2014).



The southern wetlands of the Gulf are the Marceddì-San Giovanni lagoon compendium, which appears as a deep marine inlet artificially separated from the sea by a fishpond bridge and divided into two different wetlands: the Marceddì lagoon (900 ha), closer to the sea with brackish water, and the internal pond of San Giovanni (700 ha), characterised by freshwater inputs from the rivers Rio Mogoro, Rio Mannu, Rio Sitzzerri, and from some artificial canals.

The surrounding territory is dominated by the agricultural plain of Arborea on the north-east side, an expanse of regular fields bordered by the reclamation infrastructure (canals and roads), while to the west it is surrounded by the mountainous complex of Monte Arcuentu. The fishing activities in the Marceddì-San Giovanni lagoon are managed by the Consortium Coop. Riunite della pesca di Marceddì. Covering an area of 2610 ha, the fishing operations involve around 140 operators.



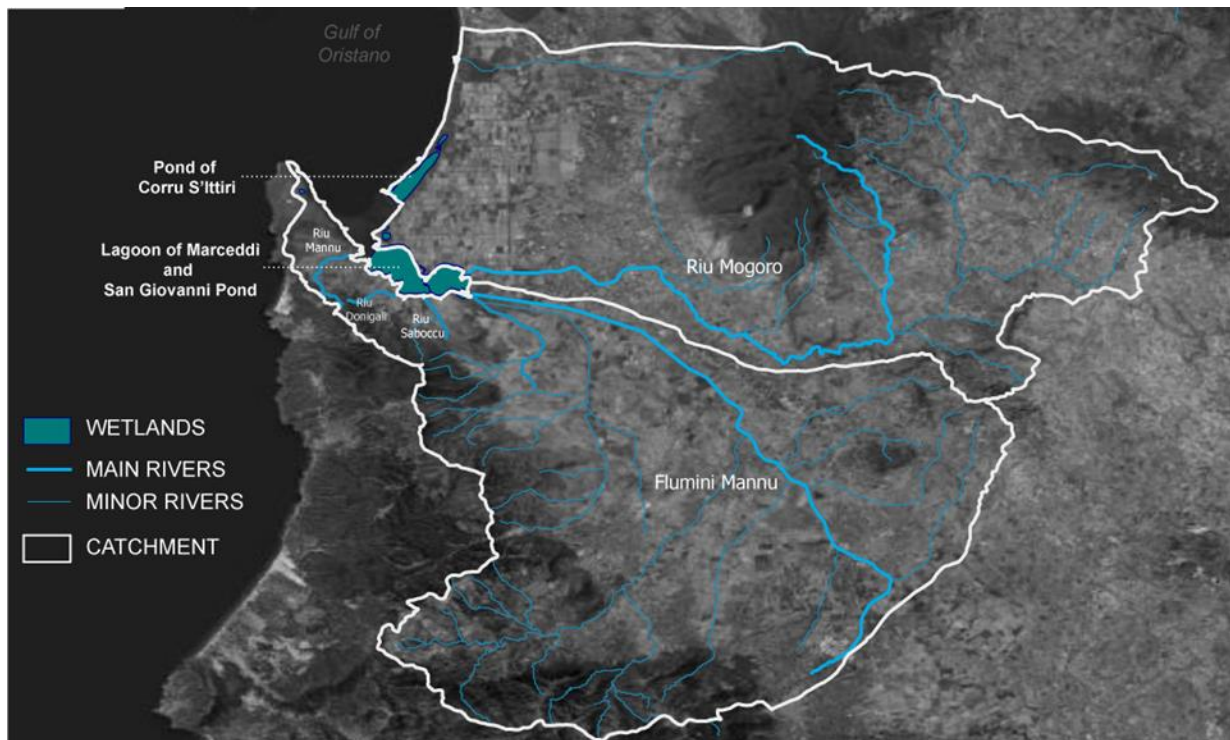
**Figure 5.** Map of the wetlands' system of Marceddì, San Giovanni and Corru S'ittiri in the Gulf of Oristano

Hydraulic interventions carried out in recent decades have significantly altered the original structure of the entire wetland system. These modifications have disrupted the natural water exchange conditions between marine and freshwater environments, leading to changes in the ecological conditions of the area due to sediment discharge into the water and impacting on the ongoing fishing activities.



The Flumini Mannu catchment covers 631.5 km<sup>2</sup> (Figure 6). It drains the western Campidano Plain and surrounding hills, with its course significantly altered by human interventions. The river, once meandering, was straightened, and tributaries were diverted into the Sitzerri Torrent collector. The basin is mainly used for irrigated agriculture, with pastures and Mediterranean scrub in the higher areas.

The Rio Mogoro catchment, spanning 410 km<sup>2</sup>, consists of Eocene-Miocene sandstones, conglomerates, and volcanic formations. Its lower plains are shaped by alluvial and Pliocene-Pleistocene deposits. A key hydraulic intervention was the Santa Vittoria dam, built in the 1930s to regulate floods and support irrigation. The basin includes nine municipalities, with land use split between cereal cultivation in the plains and Mediterranean scrub in the hills. This basin also includes the Arborea reclamation drainage basin, a natural hydrographic network, relying on seawater and agricultural drainage. Historical irrigation changes, from surface to sprinkler systems, have reduced freshwater input, leading to increased effluents and environmental concerns. The plain, flanked by Quaternary dune systems, has a minimal gradient, making it sensitive to water management changes.



**Figure 6.** Map of the Flumini Mannu and Riu Mogoro catchments in the Italian pilot, with the hydrographic network within its boundaries.



### 6.3.2. Data available for Italian pilot

Table 8 provides the list of available datasets that have been collected for the Italian pilot site, following the guidelines of the WP Leader. For data that are not yet available, there is a description of their planned acquisition or creation through spatial processing or modelling approaches.

**Table 8.** Data required for the initial steps to assess the flood regulation service for the pilot case of PP04 (**M**: Mandatory, **O**: Optional).

Variable name	Data type	Description	Datasets gathered/produced by MEDSEA
LULC (M)	Layer	Detailed LULC map of the catchment area based on a nomenclature system that could be used to assess the flood regulation service, either in its original format or after a crosswalk. If no local data is available, pan-European (e.g. CLC or Copernicus High Resolution Layers) could be used. In the framework of Wetland4Change, it would also be possible to produce EO-based recent LULC maps with a high level of thematic accuracy if needed.	<p><b>Available</b></p> <p><u>Name</u>: CORINE Land Cover 2008, (uso_del_suolo_WGS84.shp)  <u>Source</u>: RAS <a href="#">Link</a>  <u>Info</u>: Minimum cartographic unit 0,5ha, Spatial coverage: Sardinia; Resolution / Spatial unit: 1:25.000</p> <p><u>Name</u>: CORINE Land Cover Land Use 2018  <u>Source</u>: Copernicus Land Monitoring Service <a href="#">Link</a>  <u>Info</u>: 44 thematic classes Year: 2018. Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a Minimum Mapping Width (MMW) of 100 m for linear phenomena. vector/raster 100 m</p> <p><u>Name</u>: Coastal Zones Land Cover/Land Use 2018 (vector), Europe, 6-yearly  <u>Source</u>: Copernicus Land Monitoring Service <a href="#">Link</a>  <u>Info</u>: Land cover/land use for 71 thematic classes for areas along the European coastline. Year: 2018 . Minimum Mapping Unit (MMU) of 0.5 ha and a Minimum Mapping Width (MMW) of 10 m. Vector data.</p>



<p>Wetlands extent (M)</p>	<p>Layer</p>	<p>Map of wetlands extent within the studied catchments, highlighting the main wetland habitat types based on Ramsar definitions. In the framework of Wetland4Change, it would also be possible to produce EO-based recent wetland extent maps with a high level of thematic accuracy if needed.</p>	<p><b>Available.</b></p> <p><u>Name:</u> Water surface (DBGT10K_22_v04 - 04 Specchio Acqua)  <u>Source:</u> RAS - <a href="#">Link</a>  <u>Info:</u> Spatial coverage: Sardinia; Resolution / Spatial unit: 1:25.000</p>
<p>Soil (M)</p>	<p>Layer</p>	<p>Inventory of soil types with sufficient data on the soil properties to distinguish different hydrologic soil groups. It must include some information such as porosity, composition according to size of materials or type of soil according to international soils classification systems. If there are no local / regional soil data, JRC Soil Database and FAO / UNESCO soil data are suggested as alternative sources.</p>	<p><b>Available:</b></p> <p><u>Name:</u> Geological map (geologica_2008.shp)  <u>Source:</u> RAS - <a href="#">Link</a>  <u>Info:</u> a homogeneous geological map covering the entire island; Resolution / Spatial unit: 1:25.000</p>



<p>Vegetation (M)</p>	<p>Layer</p>	<p>Vegetation cover and density data that can be extracted from EO-based products using vegetation indices. It is also possible to consider this variable only for specific classes in case there are difficulties obtaining this information for the entire basin (e.g. only considering classes of natural vegetation).</p>	<p><u>Name:</u> Normalised Difference Vegetation Index 2020-present <u>Source:</u> Copernicus <u>Info:</u> raster 300 m, global, 10-daily – version 2 from Copernicus</p> <p><u>Name:</u> Normalised Difference Vegetation Index 2016-present <u>Source:</u> Copernicus <u>Info:</u> (raster 10 m), from Copernicus</p>
<p>Digital Elevation Model (DEM) (M)</p>	<p>Layer</p>	<p>Needed for the calculation of slopes, river network and other topographic indices and parameters of the hydrological modelling. Copernicus DEM, with a spatial resolution of 30m, is a good source for basin-scale work and is proposed as the main source.</p>	<p><b>Available</b></p> <p><u>Name:</u> DTM <u>Source:</u> RAS <u>Info:</u> Raster with 1m px resolution</p>
<p>River network (O)</p>	<p>Layer</p>	<p>Spatial layer with the distribution and route of the rivers, at least the main ones, in the study area. If not available, it could be produced from the DEM, although a much lower spatial precision is expected, especially for small streams.</p>	<p><b>Available</b></p> <p><u>Name:</u> Hydrographic network (DBGTI0K_22_v04 - 04 Reticolo Idrografico Naturale.shp) <u>Source:</u> RAS <u>Info:</u> a shapefile of the water stream</p>



<p>Hydrological basins (M)</p>	<p>Layer</p>	<p>Spatial layer delimiting the river basin where the flood regulation service is assessed. This is usually produced as a modelling step using the DEM, but an official source would help validate the result.</p>	<p><b>Available</b></p> <p><u>Name:</u> Watersheds sardinia  <u>Source:</u> RAS  <u>Info:</u> a shapefile of two sub-basins extracted from the hydrological system of the main Basin</p>
<p>Precipitation (M)</p>	<p>Layer and/or metadata</p>	<p>Meteorological data on precipitation of the study area. It is suggested to check national or regional meteorological agencies. Alternative spatial explicit source of information is the global climate data for ecological modelling from WorldClim, which has raster layers of the monthly rainfall distribution with a resolution of up to 30 seconds. Given that the work is at the level of the Mediterranean region, it is to be expected, despite some differences, that the torrentiality of precipitation that causes flooding is quite similar. Therefore, a standard rainfall model could be established to apply to all study areas in case there are limitations to collecting this type of data. This would also make the results more comparable between regions.</p>	<p><b>NOT Available</b></p>



<p>Flood risk map (M)</p>	<p>Layer</p>	<p>Delimitation of the areas at risk of flooding according to probability (usually in years of return period) as well as any relevant data on emergency and evacuation plans that inform the most exposed and vulnerable human assets. If not available, it could be estimated using mapping proxies such as the Potential Wetland Areas layer provided by the Mediterranean Wetlands Observatory (available for all European and Mediterranean countries).</p>	<p><b>Available</b></p> <p><u>Name:</u> Coastal flooding hazard maps (PGRA_2017_Inviluppo_HiC)  <u>Source:</u> RAS  <u>Info:</u> The PGRA is the reference document for the management of flood risk, encompassing prevention and protection measures, as well as operational tools and governance mechanisms. Its purpose is to reduce the impacts on human life, the environment, cultural heritage, and economic and social activities</p>
<p>Population distribution (O)</p>	<p>Layer</p>	<p>Population distribution or density layer to assess the flood regulation service demand. Gridded Population of the World (GPW), as well as the Global Human Settlement Layer (GHSL) are proposed as a harmonized source for all pilot sites.</p>	<p><u>Name:</u> Population density  <u>Source:</u> EUROSTAT  <u>Info:</u> Includes population density geospatial (vector) data at LAU level, produced by the "Population data at LAU level. Year 2021"</p>
			<p><u>Name:</u> Population data  <u>Source:</u> ISTAT  <a href="https://www.citypopulation.de/en/italy/sardegna/oristano/095065__terralba/">https://www.citypopulation.de/en/italy/sardegna/oristano/095065__terralba/</a>  <u>Info:</u></p>
			<p>Gridded Population of the World, Version 4 (GPWv4), that consists of estimates of human population (number of persons per pixel), consistent with national censuses and population registers, for the years 2000, 2005, 2010, 2015, and 2020</p>



Socio-economic information (O)	Metadata	Information to support the assessment of demand based on the economic activities within the assessed area, the income level of the population, age groups, etc. This can be based on reports, statistics and other documents if spatial information does not exist.	<b>NOT Available</b>
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For the assessment of the flood regulation ecosystem service, MEDSEA aims to evaluate the potential benefits and challenges related to the regulation of floods in the wetlands of Marceddì and San Giovanni. Specifically, to assess the flood regulation service supply, according to the paragraph 3.3, the following sub-indicators will be calculated:

i. **Hydrological Characteristics of the Basin (HCB):** The hydrological model will be run using the HEC-HMS tool, utilizing monthly average precipitation data. The goal is to delineate the hydrological characteristics of the basin, specifically the percentage of precipitation transformed into runoff.

ii. **Runoff Generation Potential (RGP):** This will be estimated based on Curve Number (CN) values, considering LULC class, soil type (A, B, C, and D), vegetation cover (good, fair, poor), and slope (higher or lower than 3%). To account for surface water dynamics, three applicable scenarios will be analyzed for LULC classes: permanently flooded areas, temporarily flooded areas without dense vegetation, and non-flooded or densely vegetated areas without open water.

iii. **Risk Mitigation Capacity (RMC):** For this sub-indicator, as proposed in paragraph XX, commonly agreed score values established within the Wetland4Change project will be used, considering return periods of 10, 100, and 500 years.

iv. **Water Regulation Capacity (WRC):** Similarly for this sub-indicator commonly agreed score values established within the Wetland4Change project will be applied.

**Flood regulation service demand**, according to the paragraph 3.4, will be calculated based on the following sub-indicators:

i. **Exposure and Vulnerability of assets related to population (EVassets):** Vulnerability scores will be assigned according to LULC classes of artificial and agricultural areas, while susceptibility will be assessed based on the extent of flood



risk areas defined in the *Piano di rischio alluvioni della RAS* (Sardinia Flood Risk Plan).

ii. **Exposure and Vulnerability of the population (EVpopulation):** This layer will be calculated using LULC classes combined with available spatial data on population distribution at the local scale. In the absence of local data, international datasets will be considered.

iii. **Economic Value (EcValue):** Wetland4Change experts may adjust this indicator according to the specific characteristics of the pilot test region.

The integration of supply and demand data will culminate in creating maps that illustrate the regional supply-demand balance for flood regulation services. These maps will highlight areas where the wetlands' regulation benefits outweigh potential flood damages, or vice versa, ensuring alignment with parameters from national and regional models. Validation and methodological adaptation will involve partner collaboration to ensure the results are robust and contextually relevant for the pilot site of Terralba.

### 6.3.3. Potentials and weaknesses

Integrating detailed spatial data on wetland distribution and extent will allow for the adjustment of flood regulation models used in the *Piano di rischio alluvioni della Sardegna* (Sardinia Flood Risk Plan) to accurately assess the contribution of wetlands to flood mitigation. The analysis will support territorial management by identifying high-risk areas.

## 6.4. Albufera of Valencia (Spain), Responsible UVEG

### 6.4.1. Synoptic description of pilot site

The Albufera of Valencia is a representative Mediterranean coastal wetland located about 10 km from the city of Valencia (Figure 7). This geomorphological system consists of a sandbar and a lagoon with limited connection to the sea. Its formation dates back to the last Holocene interglacial period, approximately 10,000 years ago, with its current configuration established around 2,000 years ago. In addition to its ecological significance, the Albufera plays a crucial role in flood regulation, acting as a buffer zone that mitigates the impact of extreme weather events, particularly heavy rainfall and coastal surges. The surrounding rice fields further contribute to water management by retaining and gradually releasing floodwaters.



The Albufera of Valencia is part of the broader Júcar River basin, which significantly influences its hydrology and flood dynamics. The Júcar River, one of the major water sources in eastern Spain, supplies freshwater to the wetland through a network of irrigation canals, drainage systems, and direct inflows. However, extensive water management interventions, including dam constructions and agricultural diversions, have altered the natural water regime, affecting both the quantity and quality of inflows to the lagoon. Seasonal variations in river discharge, coupled with increasing water demands from agriculture and urban areas, create complex interactions that shape the Albufera's flood regulation capacity. Additionally, extreme weather events, such as heavy rainfall in the upper basin, can lead to rapid water level fluctuations, influencing the wetland's ability to function as a buffer against floods. Understanding the interplay between the Júcar River basin and the Albufera is essential for developing sustainable water management strategies that balance flood control, ecological integrity, and human water needs.

Over time, the Albufera has undergone significant transformations that have influenced its hydrology and flood dynamics. These changes include a reduction in lagoon depth and perimeter due to sediment accumulation, affecting its water retention capacity; the replacement of seawater with freshwater from various sources, altering the lagoon's hydrological balance; and the expansion of the sandbar, leading to dune formation and an extensive beach, modifying water exchange with the sea. These changes have shaped the wetland's current state, impacting its flood regulation capacity and interactions with adjacent agricultural areas.

The wetland comprises several interconnected habitats that enhance its flood control functions. The lagoon, a shallow freshwater body covering about 2,400 hectares, serves as the central water reservoir, though eutrophication has affected its ecological balance. Marshland habitats and perimeter vegetation surrounding the lagoon help retain excess water, stabilize shorelines, and prevent erosion. The interdune depressions (Malladas) provide temporary water storage, helping to absorb and slow down floodwaters. Finally, the rice fields around the lagoon play a critical role in flood control, acting as seasonal floodplains with an extensive network of channels and floodgates that regulate water flow while supporting biodiversity.



**Figure 7.** Aerial and landscape pictures of Albufera Natural Park, showing the close relationship between its hydrology and the surrounding rice fields.

### 6.4.2. Data available for Spanish pilot

For the assessment of flood regulation in the Albufera of Valencia, various key data sources are available.



Several GIS layers and hydrological data covering the entire Júcar River basin provide information for flood regulation assessment. The Júcar River Authority (CHJ) maintains detailed hydrological models, including watershed boundaries, river networks, and flood hazard maps derived from historical flood events. Large-scale land use and land cover datasets, such as CORINE Land Cover and SIOSE, offer broader spatial insights into land use changes across the basin. The Spanish National Center for Geographic Information (CNIG) provides high-resolution Digital Elevation Models (DEMs) covering the full basin, which can be used for hydrological modeling and identifying flood-prone areas. Additionally, climatological datasets from AEMET and AVAMET, including long-term precipitation and temperature records are available. On the other hand, soil data can be provided from the University of Valencia partner, allowing for the identification of soil types based on lithological descriptions.

Land use and land cover (LULC) data are accessible through multiple digital map layers, including CLC1990\_GDB, SAR2017\_46\_Valencia\_GDB, and SIOSE\_Comunitat\_Valenciana\_2005\_GDB, covering the years 1990, 2005, and 2017. These datasets provide valuable information on land cover changes over time, which is crucial for flood regulation analysis.

For vegetation monitoring, vegetation indices are available, including Landsat imagery covering the Albufera area for the entire year (September 2023 - August 2024) and NDVI images derived from Sentinel-2 data for winter and summer 2023. These datasets offer insights into vegetation dynamics, which influence hydrological processes and flood mitigation.

A Digital Elevation Model (DEM) with 2-meter resolution is also provided by IGN, covering the period 2015-2017. This dataset is essential for understanding terrain morphology, modeling water flow, and identifying flood-prone areas.

This previous information at the basin level can be integrated with Albufera-specific information for the modelling. Regarding hydrology, a dataset on watersheds ("Watersheds\_albufera") includes a shapefile of two sub-basins extracted from the hydrological system of the Júcar main basin. Additionally, data on water streams ("main\_water\_streams") is available in shapefile format, representing the watercourses associated with these sub-basins.

Most of these datasets are publicly accessible and play a crucial role in assessing flood regulation processes, improving wetland management, and developing climate adaptation strategies for the Albufera of Valencia.



**Table 9.** Data required for the initial steps to assess the flood regulation service for the pilot case of PP04 (**M**: Mandatory, **O**: Optional).

Variable name	Data type	Description	Datasets gathered/produced
LULC ( <b>M</b> )	Layer	Detailed LULC map of the catchment area based on a nomenclature system that could be used to assess the flood regulation service, either in its original format or after a crosswalk. If no local data is available, pan-European (e.g. CLC or Copernicus High Resolution Layers) could be used. In the framework of Wetland4Change, it would also be possible to produce EO-based recent LULC maps with a high level of thematic accuracy if needed.	<p>File: CLC1990_GDB SAR2017_46_Valencia_GDB SIOSE_Comunitat_Valenciana_2005_GDB</p> <p>Format: Layer</p> <p>Description: digital map layers of the Land use and land cover of Valencia province</p> <p>Source: IGN</p> <p>Resolution / Spatial unit</p> <p>Temporal coverage: 1990 / 2005 / 2017</p> <p>Spatial coverage: Spain</p> <p>Link: <a href="https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#">https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#</a></p> <p>Data availability: Public</p>
Wetlands extent ( <b>M</b> )	Layer	Map of wetlands extent within the studied catchments, highlighting the main wetland habitat types based on Ramsar definitions. In the framework of Wetland4Change, it would also be possible to produce EO-based recent wetland extent maps with a high level of thematic accuracy if needed.	<p>File: Watersheds_albufera</p> <p>Description: a shapefile of two sub-basins extracted from the hydrological system of the Jucar main Basin</p> <p>Format: Layer</p> <p>Source: IGN</p> <p>Resolution / Spatial unit:</p> <p>Temporal coverage:</p> <p>Spatial coverage: Whole catchment</p> <p>Link: <a href="https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#">https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#</a></p> <p>Data availability: Public</p>



Variable name	Data type	Description	Datasets gathered/produced
Soil (M)	Layer	Inventory of soil types with sufficient data on the soil properties to distinguish different hydrologic soil groups. It must include some information such as porosity, composition according to size of materials or type of soil according to international soils classification systems. If there are no local / regional soil data, JRC Soil Database and FAO / UNESCO soil data are suggested as alternative sources.	<p>File: Cartografia_Geologica_IGME_GeologicaValenciana_400</p> <p>Specific information provided on soils taxonomy by the UVEG partner</p> <p>Description: Digital map layer of the geology/lithology of Valencia province (soil types can be determined from the lithology description).</p> <p>Mapas temáticos del ANE, España. Suelos. 2006</p> <p>Source: IGME, IGN</p> <p>Resolution / Spatial unit: Scale 1000000</p>
Vegetation (M)	Layer	Vegetation cover and density data that can be extracted from EO-based products using vegetation indices. It is also possible to consider this variable only for specific classes in case there are difficulties obtaining this information for the entire basin (e.g. only considering classes of natural vegetation).	<p>File: pnt_sentinel2_JUL-AGO_2023_mosaico_NDVI_Comunidad_Valenciana_hu30_COG pnt_sentinel2_ENE-FEB_2023_mosaico_NDVI_Comunidad_Valenciana_hu30_COG LC09_L1TP_199033_20231230_20231230_02_T1 LC09_L1TP_199033_20230925_20230925_02_T1 LC09_L1TP_199033_20231011_20231011_02_T1 LC08_L1TP_199033_20240802_20240802_02_RT LC08_L1TP_199033_20240530_20240611_02_T1 LC08_L1TP_199033_20240412_20240419_02_T1 LC08_L1TP_199033_20231120_20231122_02_T1</p> <p>Description: landsat imagery covering the albufera Area for the whole year ( september 2023 - August 2024) + two NDVI images calculated through sentinel2 imagery during the winter and the summer of 2023</p> <p>Source: IGN</p>

Variable name	Data type	Description	Datasets gathered/produced
			<p>Resolution / Spatial unit: 15m</p> <p>Temporal coverage: NDVI ( Jan-Feb 2023 / Jul-Aug2023)</p> <p>Spatial coverage: Albufera Park</p> <p>Link: <a href="https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#">https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#</a></p> <p>Data availability: Public</p>
Digital Elevation Model (DEM) (M)	Layer	<p>Needed for the calculation of slopes, river network and other topographic indices and parameters of the hydrological modelling. Copernicus DEM, with a spatial resolution of 30m, is a good source for basin-scale work and is proposed as the main source.</p>	<p>File: MDT02-WGS84-0770-1-COB2 MDT02-WGS84-0770-2-COB2 MDT02-WGS84-0747-4-COB2 MDT02-WGS84-0747-3-COB2 MDT02-WGS84-0722-3-COB2 MDT02-WGS84-0722-1-COB2 MDT02-WGS84-0721-4-COB2 MDT02-WGS84-0747-2-COB2 MDT02-WGS84-0746-4-COB2 MDT02-WGS84-0746-1-COB2 MDT02-WGS84-0747-1-COB2 MDT02-WGS84-0746-2-COB2 MDT02-WGS84-0722-4-COB2 MDT02-WGS84-0722-2-COB2 MDT02-WGS84-0721-3-COB2 MDT02-WGS84-0721-2-COB2 MDT02-WGS84-0721-1-COB2</p> <p>Description: (MDT) digital Terrain model (2m resolution)</p> <p>Source: IGN</p> <p>Resolution / Spatial unit: 2m</p> <p>Temporal coverage: 2015-2017</p> <p>Spatial coverage: Valencia</p> <p>Link: <a href="https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#">https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#</a></p> <p>Data availability: Public</p>



Variable name	Data type	Description	Datasets gathered/produced
River network (O)	Layer	Spatial layer with the distribution and route of the rivers, at least the main ones, in the study area. If not available, it could be produced from the DEM, although a much lower spatial precision is expected, especially for small streams.	File: main_water_streams Format: shapefiles in a zipped folder Description: a shapefile of the water streams related to the sub basins mentioned above Source: IGN Resolution / Spatial unit: Temporal coverage: Spatial coverage: Catchment Link: <a href="https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#">https://centrodedescargas.cnig.es/CentroDescargas/index.jsp#</a> Data availability: Public
Hydrological basins (M)	Layer	Spatial layer delimiting the river basin where the flood regulation service is assessed. This is usually produced as a modelling step using the DEM, but an official source would help validate the result.	File: Description: Source: Resolution / Spatial unit: Temporal coverage: Spatial coverage: Link: Data availability:



Variable name	Data type	Description	Datasets gathered/produced
Precipitation (M)	Layer and/or metadata	<p>Meteorological data on precipitation of the study area. It is suggested to check national or regional meteorological agencies. Alternative spatial explicit source of information is the global climate data for ecological modelling from WorldClim, which has raster layers of the monthly rainfall distribution with a resolution of up to 30 seconds. Given that the work is at the level of the Mediterranean region, it is to be expected, despite some differences, that the torrentiality of precipitation that causes flooding is quite similar. Therefore, a standard rainfall model could be established to apply to all study areas in case there are limitations to collecting this type of data. This would also make the results more comparable between regions.</p>	<p>File: Format: csv data Description: Source: AVAMET Resolution / Spatial unit: hour/day Temporal coverage: Spatial coverage: Link: <a href="https://www.avamet.org/mxo-mxo-prec.php">https://www.avamet.org/mxo-mxo-prec.php</a> Data availability:</p>



Variable name	Data type	Description	Datasets gathered/produced
Flood risk map (M)	Layer	Delimitation of the areas at risk of flooding according to probability (usually in years of return period) as well as any relevant data on emergency and evacuation plans that inform the most exposed and vulnerable human assets. If not available, it could be estimated using mapping proxies such as the Potential Wetland Areas layer provided by the Mediterranean Wetlands Observatory (available for all European and Mediterranean countries).	File: Description: Source: Resolution / Spatial unit: Temporal coverage: Spatial coverage: Link: Data availability:
Population distribution (O)	Layer	Population distribution or density layer to assess the flood regulation service demand. Gridded Population of the World (GPW), as well as the Global Human Settlement Layer (GHSL) are proposed as a harmonized source for all pilot sites.	File: Description: Source: Resolution / Spatial unit: Temporal coverage: Spatial coverage: Link: Data availability:
Socio-economic information (O)	Metadata	Information to support the assessment of demand based on the economic activities within the assessed area, the income level of the population, age groups, etc. This can be based on reports, statistics and other documents if	

Variable name	Data type	Description	Datasets gathered/produced
		spatial information does not exist.	

### 6.4.3. Potentials and weaknesses

The Albufera de Valencia plays a crucial role in flood regulation, acting as a natural buffer against extreme rainfall and coastal surges. The DANA flood event from October 2024 highlighted its capacity to retain excess water, reducing flood risks in surrounding urban and agricultural areas. The lagoon and rice fields provide temporary water storage, and its long-term hydrological monitoring supports flood modeling and adaptive management. Additionally, its alignment with EU policies (e.g., Floods Directive) and strong stakeholder engagement enhance its potential for nature-based solutions (NbS). However, hydrological alterations, such as sedimentation and regulated water discharges, have reduced its retention capacity, limiting its response to extreme events like the recent DANA. Competing land uses, particularly in agriculture and urban expansion, restrict flood mitigation flexibility. The site is also vulnerable to climate change, facing sea-level rise, storm surges, and saltwater intrusion risks. Data gaps in extreme event modeling and institutional coordination should be addressed to improve flood management.

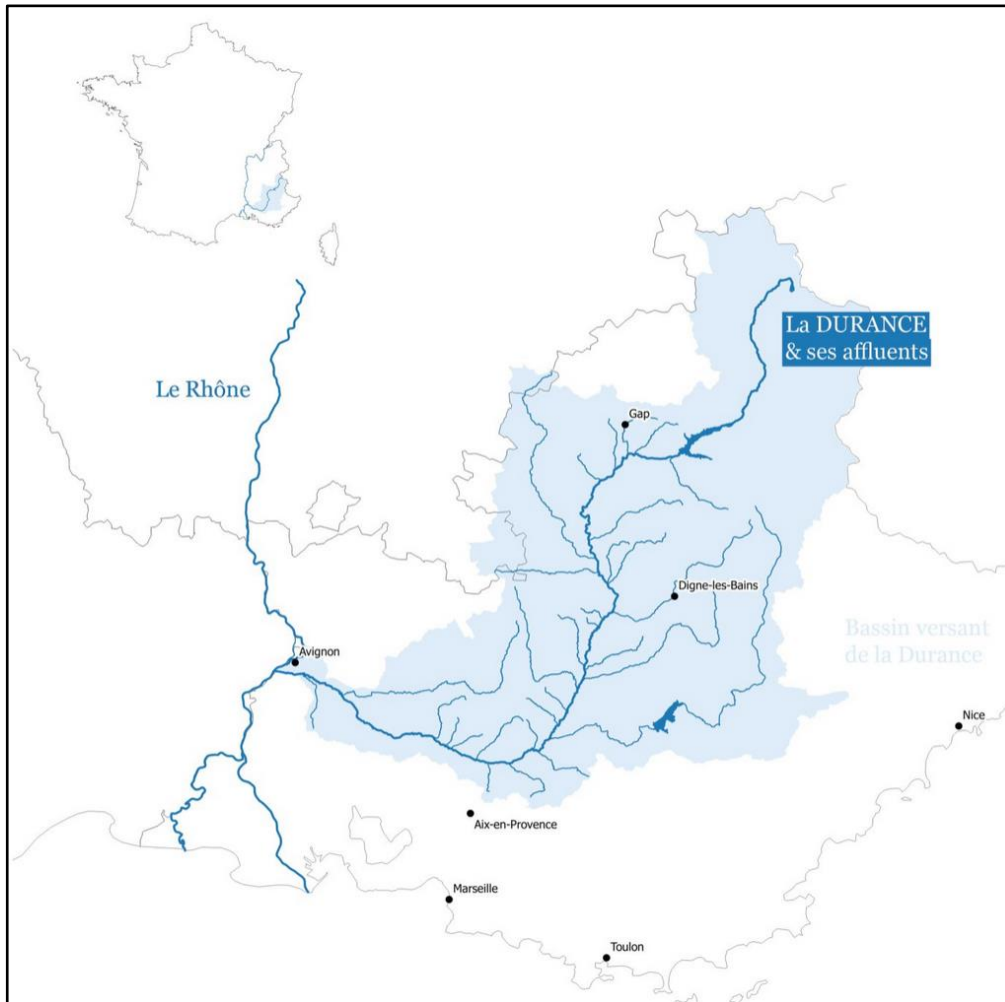
## 6.5. Durance river (France), Responsible TdV

### 6.5.1. Synoptic description of pilot site

The Durance is an alpine river influenced by the Mediterranean climate. It stretches for 323 km, originates in the Hautes-Alpes, and flows into the Rhône at Avignon (Vaucluse), draining a watershed of 14,225 km<sup>2</sup> (Figure 8). Characterized by sustained flows and significant gravel transport, it features a braided morphology. By supplying meltwater, it plays a crucial role in providing water to areas with water deficits during the spring and early summer. The most significant floods typically occur in the autumn. Although the Durance retains a natural appearance, numerous infrastructures, such as the Serre-Ponçon Dam (1961), have profoundly altered its hydraulic regime. These developments, which have artificially modified the river's functioning, are primarily aimed at storing water for summer irrigation and winter hydroelectric power generation. The average natural flow of the river at Mirabeau is around 180 m<sup>3</sup>/s, but a large portion of this flow is diverted to the industrial canal downstream of the dam. Despite these modifications, the Durance remains vulnerable to flooding due to its limited storage capacity and the contributing downstream tributaries. Approximately 158,000 people live in flood-prone areas, a



region that also hosts numerous economic activities, particularly agricultural, with farmland occupying a significant portion of the territory.



**Figure 8.** Map of the Durance river basin, the French Pilot Site for the assessment of the flood regulation ecosystem service.



**Figure 9.** Photo of the Durance valley.

### 6.5.2. Data available for French pilot

Variable name	Data type	Description	Datasets gathered/produced by UF
LULC (M)	Layer	Detailed LULC map of the catchment area based on a nomenclature system that could be used to assess the flood regulation service. If no local data is available, pan-European (e.g. CLC or Copernicus High Resolution Layers) could be used.	<p>Available</p> <p>Name: CORINE Land Cover 2018</p> <p>Source: Copernicus Land Monitoring Service</p> <p>(<a href="https://land.copernicus.eu/en/products/corine-land-cover/clc2018">https://land.copernicus.eu/en/products/corine-land-cover/clc2018</a>)</p> <p>Info: Detailed LULC map of the catchment area covering 32 CLC classes (Level 3) for the 2018 reference year. The dataset has a Minimum Mapping Unit (MMU) of 25 hectares (ha) for aerial phenomena and a Minimum Mapping Width (MMW) of 100 m for linear phenomena and is available as a vector dataset.</p>



<p>Wetlands extent <b>(M)</b></p>	<p>Layer</p>	<p>Map of wetlands extent within the studied catchments, highlighting the main wetland habitat types based on Ramsar definitions. In the framework of Wetland4Change, it would also be possible to produce EO-based recent wetland extent maps with a high level of thematic accuracy if needed.</p>	<p>Available ?</p> <p>Name: Wetlands in the catchment area of Durance river</p> <p>Source:</p> <p>Info: Detailed wetland mapping layer produced by.</p>
<p>Soil <b>(M)</b></p>	<p>Layer</p>	<p>Inventory of soil types with sufficient data on the soil properties to distinguish different hydrologic soil groups. It must include some information such as porosity, composition according to size of materials or type of soil according to international soils classification systems.</p>	<p><b>Available</b></p> <p>Name: Soils map</p> <p>Source: Groupement d'Intérêt Scientifique sur les Sols (GIS Sol) et Réseau Mixte Technologique Sols &amp; Territoires, Pédologie – Les sols dominants de France métropolitaine, 2019.</p> <p>Info:</p>



<p>Vegetation (M)</p>	<p>Layer</p>	<p>Vegetation cover and density data that can be extracted from EO-based products using vegetation indices. It is also possible to consider this variable only for specific classes in case there are difficulties obtaining this information for the entire basin (e.g. only considering classes of natural vegetation).</p>	<p>Available</p> <p>Name: BD Forêt</p> <p>Source: IGN - <a href="https://geoservices.ign.fr/bdforet">https://geoservices.ign.fr/bdforet</a></p> <p>Info : Vector database that allows the localization of forest areas according to the international definition of Forest by the FAO. It was produced through a semi-automated process using artificial intelligence (AI) based on BD ORTHO® datasets acquired between 2019 and 2022.</p> <p><u>Name</u>: Normalised Difference Vegetation Index 2020-present <u>Source</u>: Copernicus <u>Info</u>: raster 300 m, global, 10-daily – version 2 from Copernicus</p>
<p>Digital Elevation Model (DEM) (M)</p>	<p>Layer</p>	<p>Needed for the calculation of slopes, river network and other topographic indices and parameters of the hydrological modeling. Copernicus DEM, with a spatial resolution of 30m, is a good source for basin-scale work and is proposed as the main source.</p>	<p>Available</p> <p>Name: Copernicus Global DSM</p> <p>Source: Copernicus DEM (<a href="https://spacedata.copernicus.eu">https://spacedata.copernicus.eu</a>)</p> <p>Info: Copernicus Digital Elevation Model (30m) and Aspect and Slope, calculated based on the Copernicus DEM.</p> <p>Name: RGE ALTI</p> <p>Source: IGN <a href="https://geoservices.ign.fr/rgealti">https://geoservices.ign.fr/rgealti</a></p> <p>Info: The meshed digital terrain model that describes the relief of the French territory at a large scale..</p>



<p>River network (O)</p>	<p>Layer</p>	<p>Spatial layer with the distribution and route of the rivers, at least the main ones, in the study area. If not available, it could be produced from the DEM, although a much lower spatial precision is expected, especially for small streams.</p>	<p>Available</p> <p>Name: BD Topage / Carthage</p> <p>Source: Sandre - National Service for the Administration of Water Data and Reference Systems</p> <p><a href="https://www.sandre.eaufrance.fr/atlas/srv/fre/catalog.search#/metadata/7fa4c224-fe38-4e2c-846d-dcc2fa7ef73e">https://www.sandre.eaufrance.fr/atlas/srv/fre/catalog.search#/metadata/7fa4c224-fe38-4e2c-846d-dcc2fa7ef73e</a></p> <p>Info: The hydrographic reference system aims to describe the hydrographic features present in France, serving as a national framework for locating water-related data. The BD TOPAGE® database is designed to meet the shared needs of all stakeholders within the Water Information System (SIE), enabling them to exchange and collaborate across all scales on surface hydrographic elements nationwide.</p> <p>Additionally, it aligns with the requirement to comply with the INSPIRE directive.</p>
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<p>Hydrological basins (<b>M</b>)</p>	<p>Layer</p>	<p>Spatial layer delimiting the river basin where the flood regulation service is assessed. This is usually produced as a modeling step using the DEM, but an official source would help validate the result.</p>	<p>Available</p> <p>Name: BD Topage / Carthage</p> <p>Source: Sandre - National Service for the Administration of Water Data and Reference Systems</p> <p><a href="https://www.sandre.eaufrance.fr/atlas/srv/fre/catalog.search#/metadata/7fa4c224-fe38-4e2c-846d-dcc2fa7ef73e">https://www.sandre.eaufrance.fr/atlas/srv/fre/catalog.search#/metadata/7fa4c224-fe38-4e2c-846d-dcc2fa7ef73e</a></p> <p>Info: The hydrographic reference system aims to describe the hydrographic features present in France, serving as a national framework for locating water-related data. The BD TOPAGE® database is designed to meet the shared needs of all stakeholders within the Water Information System (SIE), enabling them to exchange and collaborate across all scales on surface hydrographic elements nationwide.</p> <p>Additionally, it aligns with the requirement to comply with the INSPIRE directive.</p>
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<p>Precipitation (M)</p>	<p>Layer and/or metadat a</p>	<p>Meteorological data on precipitation of the study area. It is suggested to check national or regional meteorological agencies. Alternative spatial explicit source of information is the global climate data for ecological modeling from WorldClim, which has raster layers of the monthly rainfall distribution with a resolution of up to 30 seconds. Given that the work is at the level of the Mediterranean region, it is to be expected, despite some differences, that the torrentiality of precipitation that causes flooding is quite similar. Therefore, a standard rainfall model could be established to apply to all study areas in case there are limitations to collecting this type of data. This would also make the results more comparable between regions.</p>	<p>Available –</p> <p>Name:</p> <p>Source: meteofrance</p> <p>Info: Average precipitation data for the specific period.</p>
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<p>Flood risk map (<b>M</b>)</p>	<p>Layer</p>	<p>Delimitation of the areas at risk of flooding according to probability (usually in years of return period) as well as any relevant data on emergency and evacuation plans that inform the most exposed and vulnerable human assets. If not available, it could be estimated using mapping proxies such as the Potential Wetland Areas layer provided by the Mediterranean Wetlands Observatory (available for all European and Mediterranean countries).</p>	<p>Available</p> <p>Name:</p> <p>Source: SCHAPI / VIgicrues / PPRI / PAPI</p> <p>Info:</p>
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<p>Population distribution (O)</p>	<p>Layer</p>	<p>Population distribution or density layer to assess the flood regulation service demand. Gridded Population of the World (GPW), as well as the Global Human Settlement Layer (GHSL) are proposed as a harmonized source for all pilot sites.</p>	<p>Available</p> <p>Name: Population data at LAU level for FR 2021 xls.</p> <p>-</p> <p>Source: EUROSTAT</p> <p>Info:</p> <p>Gridded Population of the World, Version 4 (GPWv4)</p> <p>Source : Center For International Earth Science Information Network-CIESIN-Columbia University.</p> <p>Info: consists of estimates of human population (number of persons per pixel), consistent with national censuses and population registers, for the years 2000, 2005, 2010, 2015, and 2020</p>
<p>Socio-economic information (O)</p>	<p>Metadata</p>	<p>Information to support the assessment of demand based on the economic activities within the assessed area, the income level of the population, age groups, etc. This can be based on reports, statistics and other documents if spatial information does not exist.</p>	

### 6.5.3. Potentials and weaknesses

The Durance River Basin plays a crucial role in flood regulation, acting as a natural buffer against extreme precipitation and snowmelt from the Alps. Different flood



events highlighted its capacity to absorb excess runoff, mitigating flood risks for downstream urban and agricultural areas. The basin's reservoirs, floodplains, and hydropower dams provide temporary water storage, while ongoing hydrological monitoring supports flood forecasting and adaptive management.

Additionally, its alignment with EU policies (e.g., the Floods Directive and Water Framework Directive) and strong coordination between the Rhone Rive water agency and local authorities enhance the potential for developing Nature-based Solutions (NbS) in the Durance Basin to regulate flood hazards. However, hydrological modifications—such as dam operations, sediment retention, and artificial flow regulation—have altered natural flood dynamics, reducing floodplain connectivity and limiting resilience to extreme events. Competing water demands from irrigation, hydropower, and urban growth further constrain flood management flexibility.

The basin is also vulnerable to climate change, with projected increases in extreme rainfall, glacier retreat, and shifting seasonal flow patterns. Rising temperatures and prolonged droughts exacerbate hydrological variability, intensifying both flood and low-flow risks. Addressing data gaps in extreme event modeling and improving institutional coordination will be essential for enhancing flood resilience across the Durance Basin.



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