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Preliminary assessment of river floodplain condition in Europe

Authors:
Lidija Globevnik, Kathrin Januschke, Jochem Kail, Luka Snoj, Alessandro Manfrin, Muhammet Azlak, Trine Christiansen, Sebastian Birk

ETC/ICM Consortium Partners:
Helmholtz Centre for Environmental Research (UFZ), Fundación AZTI, Czech Environmental Information Agency (CENIA), Ioannis Zacharof& Associates Llp Hydromon Consulting Engineers (CoHI(Hydromon)), Stichting Deltares, Ecologic Institute, International Council for the Exploration of the Sea (ICES), Italian National Institute for Environmental Protection and Research (ISPRA), Joint Nature Conservation Committee Support Co (JNCC), Middle East Technical University (METU), Norsk Institutt for Vannforskning (NIVA), Finnish Environment Institute (SYKE), Thematic Center for Water Research, Studies and Projects development (TC Vode), Federal Environment Agency (UBA), University Duisburg-Essen (UDE)

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Author affiliation
Lidija Globevnik – TC Vode, Slovenia
Kathrin Januschke – UDE, Germany
Jochem Kail – UDE, Germany
Luka Snoj – TC Vode, Slovenia
Alessandro Manfrin – UDE, Germany
Muhammet Azlak – EEA, Denmark
Trine Christiansen – EEA, Denmark
Sebastian Birk – UDE, Germany

EEA project manager
Trine Christiansen, Muhammet Azlak – European Environment Agency, Denmark

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c/o Helmholtz Centre for Environmental Research – UFZ
Brückstraße 3a
39104 Magdeburg

Web: https://icm.eionet.europa.eu/

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Authors and acknowledgements

EEA project manager:	Peter Kristensen, Trine Christiansen (EEA)
Authors:	Lidija Globevnik (TC Vode) Kathrin Januschke (UDE) Jochem Kail (UDE) Luka Snoj (TC Vode) Alessandro Manfrin (UDE) Muhammet Azlak (EEA) Trine Christiansen (EEA) Sebastian Birk (UDE)
Coordination:	Christiane Katterfeld (UFZ)
English check:	Shane Hume (CENIA)

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Executive summary

River floodplains hold a central role in supporting the status of water, nature and biodiversity conservation, climate change mitigation, and ecosystem services. They build an important link between rivers and their catchments, mainly through their water retention capacity and the lateral connectivity controlled by flood events and groundwater exchange, together with the presence of structural features such as side channels and wetlands. Today, floodplains are environmentally degraded due to many human activities such as settlement and agriculture existing for centuries. Studies suggest that only 10–30 % of Europe's floodplains remained in their natural conditions, often because lateral connectivity between the river and floodplain has been reduced. European policies such as the Water Framework, Floods, and Habitats Directives support the improvement and protection of floodplains. Recently the EU has adopted the European Green Deal, which aims to put Europe on a path of sustainable development through its EU Biodiversity 2030 Strategy, Farm to Fork Strategy, Chemical Strategy for Sustainability, Climate Law, Zero Pollution Action Plan, Climate Adaptation Strategy and Forest Strategy. Among the many steps of achieving the Green Deal objectives, the EU Biodiversity 2030 Strategy has set a target to create free-flowing rivers along at least 25 000 km of rivers in Europe, through removal of barriers and restoration of floodplains and wetlands. It is important to address floodplains through European policies as future pressures are likely to increase. Across Europe, new developments threaten even the presently least disturbed floodplains.

The main objective of this report is to present a methodology for assessing floodplain condition in terms of extent, structure and processes on a European scale, together with the first results. The methodological approach builds on similar elements to those used to assess water body ecological status under the Water Framework Directive (WFD) and is performed using datasets available with Europe wide coverage, analysed at the sub-catchment level. The datasets available include a Copernicus riparian zone dataset, modelled hydrological parameters, and results from the 'Free-Flowing Rivers' database. This study did not have access to datasets on flood protection structures or other hydromorphological pressures, hampering an explicit assessment of lateral connectivity. Such data would greatly improve results.

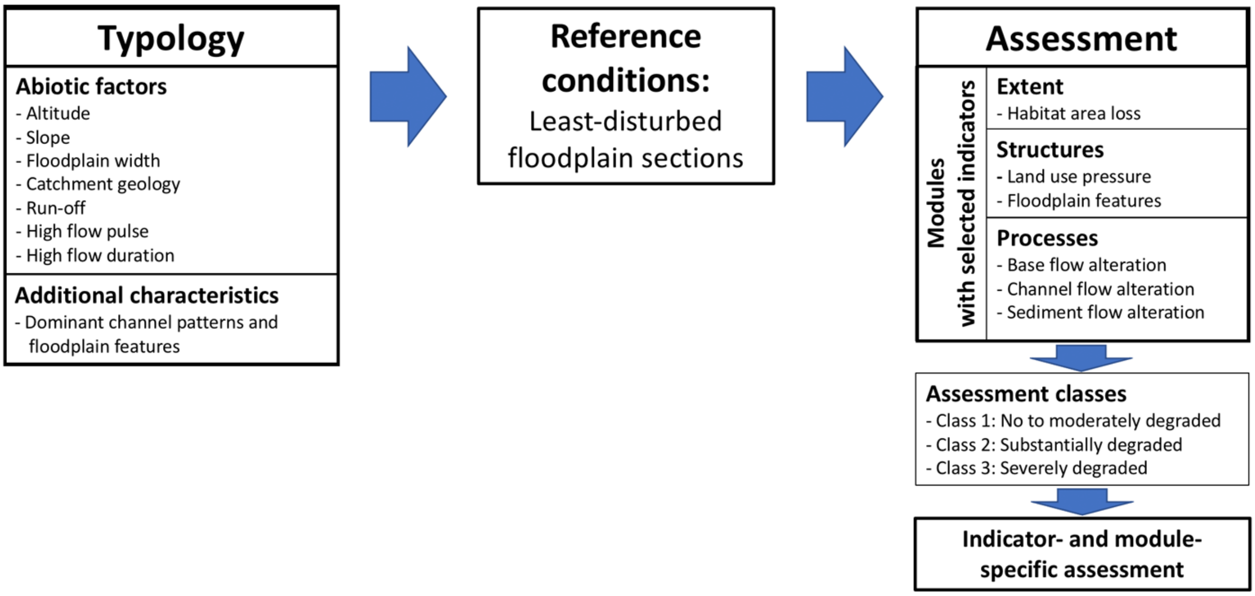
First, an ecological floodplain typology was developed by classifying floodplains according to natural abiotic factors (e.g. altitude and valley slope), which are known to govern floodplain habitat conditions but are not affected by human alterations. These factors allowed to distinguish between seven ecological floodplain types characterised by distinct habitat features. The reference conditions for assessment naturally differs between these floodplain types, and values for relevant type-specific reference conditions were identified from a set of least-disturbed floodplain sections across Europe. Each floodplain type is described in a fact sheet including information on related ecosystem services (e.g. recreation), their supporting value for nature conservation as well as threats by human impacts and actions to restore and preserve these unique ecosystems.

Second, within each floodplain type, a set of indicators describing floodplain extent, structures and processes has been assessed by comparing the present observed habitat conditions to type-specific reference conditions at the spatial scale of river sub-catchments. The three modules 'extent', 'structures' and 'processes' assess:

1. the **extent** of floodplains indicated by the loss of type-specific floodplain habitats;
2. the degree of disturbance to near-natural floodplain **structures** indicated by land use pressure and the presence and abundance of distinct, type-specific natural floodplain features like oxbow lakes, bars and dunes, and wetlands;
3. the degree of disturbance on near-natural floodplain **processes** indicated by base flow alterations, river flow regulation, and sediment flow alterations.

Indicators were assessed against a standard of least disturbed conditions for each of the three modules and categorized into three classes according to the degree of degradation (no to moderately degraded; substantially degraded; severely degraded). The full approach is shown in Figure 1.

Figure 1: Flow-chart describing the approach used for the definition of ecological floodplain typology and the assessment of floodplain habitat conditions in river sub-catchments



The availability of data on a European scale enabled developing typology and assessment of the floodplain condition for 70 % of the river sub-catchments, which can be considered covering a representative share of Europe's floodplains. The preliminary assessment results are shown in Map 1.

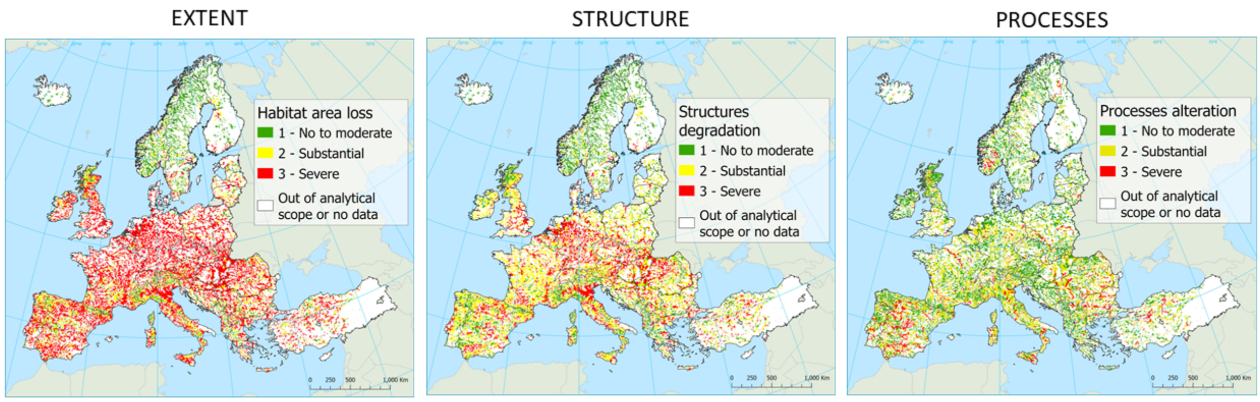
The preliminary assessment results reveal clear signals of degraded floodplain condition. Almost 75 % of Europe's floodplain area shows a severe reduction of floodplain extent, whereas 14 % is substantially degraded, leaving only 12 % of the area with moderate or no loss. Similarly, 41 % and 38 % of the floodplain area show severely or substantially degraded structure. Severely degraded structure occurs where land use is almost entirely characterized by urban areas and agriculture, both of which contribute strongly to degrading floodplain structures as a consequence of modified river channel, drainage and dikes. As a supplement to the structure indicator, naturally occurring floodplain features such as bars, dunes, oxbow lakes and wetlands have been assessed. This showed that such type-specific features were only present at 6 % of the floodplains.

The floodplain processes module shows the combined integrity of physical processes expressed as base flow, degree of flow regulation and sediment transport, all of which are important for maintaining floodplain habitats and support the lateral connection between river and floodplain. It was however not possible to include the actual flooding into this module as flooding is regulated by flood protection structures (data not available). None-the-less for those processes captured, the assessment shows severe or substantial alterations in 60 % of Europe's floodplains.

Both the module on extent and the module on structure relate to the reduced lateral connectivity between river and floodplain. The type-specific floodplain sections selected for developing the least disturbed reference conditions are all sections where this connectivity largely remains. Hence the deviations calculated, correspond to reduced connectivity in response to increased pressures from human activities. Furthermore, the process assessment suggests that improving natural flow processes in rivers is also needed for improving floodplain condition.

The condition assessment developed in this report can contribute to define a methodological framework for assessing the current floodplain condition in relation to a least disturbed reference. It also serves as a basis for discussing knowledge gaps and restoration needs on a European scale. Future restoration objectives for floodplains should target re-establishing lateral connectivity with rivers, as this is a fundamental property for improving its condition. It also needs a broad approach to establish space for rivers by considering improvements to floodplain extent and structures as well as the integrity of natural processes. Which is more important depends on local conditions? This analysis points to wide ranging restoration being necessary.

Map 1: Maps showing the preliminary assessment of European floodplains by the three modules extent, structure, and processes



1 Introduction

River floodplains are unique ecosystems and are an important part of Europe's natural capital (EEA, 2019a), covering 7 % of the continents area and up to 30 % of its terrestrial Natura 2000 site areas. Floodplains are flat valley landscapes adjacent to watercourses, formed by river channel dynamics at large spatial and temporal scales and constantly re-worked. Floodplain formation, like lateral channel migration and meander cut-offs, acts at timescales in the order of 100–1 000 years (Knighton, 1998), and floodplain turnover-rates in the same order of magnitude were reported in the literature (Richards et al., 2002; Beechie et al. 2006). Rivers and their adjacent floodplains are very dynamic ecosystems closely linked through flooding, lateral groundwater exchange and organism fluxes.

The river channel and its floodplain form a structural and functional unity, referred to as the river-floodplain system (Junk et al., 1989; Tockner et al., 2000). The high hydro- and morpho-dynamics result in a high spatial habitat heterogeneity, making floodplains biodiversity hotspots (Hamilton, 2009; Cantonati et al., 2020). These hydro- and morpho-dynamics and related habitat conditions differ along the river continuum and across geographical regions, leading to the formation of distinctly different floodplains (Puckridge et al., 1998; Tockner et al., 2000).

Nowadays, floodplains worldwide are highly modified due to flood protection, river navigation, water abstraction and storage, hydropower use, river sediment mining, agricultural land use and forestry. This resulted in river straightening and deepening, disconnecting side-arms, drainage, and surface transformations (Heritage et al., 2016). These extensive modifications prevent natural flooding, morpho-dynamics and habitat formation across Europe. In Europe, up to 90 % of floodplains are cultivated and therefore functionally extinct (Tockner et al., 2010; Hein et al., 2016; Schindler et al., 2016). The resulting floodplain loss of 70–100 % over the past centuries, which was estimated for larger European rivers, and the high impact of hydromorphological pressures in nearly all European countries are well-known. The majority of large rivers are not free-flowing (EEA, 2016; EEA, 2019a). The overall bad status of floodplains is also known from assessment results of the Habitats Directive: only 17 % of floodplain habitats and species have good conservation status (EEA, 2019a).

Floodplains hold a central role in supporting the status of rivers, nature conservation, climate change mitigation and adaptation, and ecosystem services (EEA, 2019a). This makes floodplains relevant in a EU environmental policy context (e.g. WFD, Habitats Directive, Floods Directive, Biodiversity Strategy, European Climate Law proposal). The achievement of various policy objectives seems directly related to the floodplain condition (e.g. Grizzetti et al., 2019; EEA, 2019a) and supports the improvement and protection of floodplains. However, a holistic view on the riverine ecosystem for effective restoration management and a systematic assessment is missing (Friberg et al., 2016). For instance, floodplains are part of the WFD, but the assessment has an exclusive focus on the river channel. In line with the Common Implementation Strategy (CIS) for the WFD (2000/60/EC), the CIS guidance on wetlands (EC, 2003) was developed pointing out the important role of floodplains as an integral part of river systems. Furthermore, it contains recommendations on how to clarify the role of wetlands in the river management process by showing case studies, and how to apply the most environmental and cost-effective management approaches. However, in the present river basin management plans, floodplains are largely neglected.

The Floods Directive covers floodplains, but legislation aims at improving flood risk management rather than achieving environmental objectives. Yet the Biodiversity Strategy 2030, sketching Europe's ambitious, long-term plan for protecting nature and reversing the degradation of ecosystems (EC, 2020), has the objective to remove barriers and to restore at least 25 000 km of rivers in Europe into free-flowing rivers by 2030, through the removal of barriers and the restoration of floodplains and wetlands.

Regional assessments of the environmental floodplain condition have been conducted across Europe (e.g. Brunotte et al., 2009; Schindler et al., 2016; Funk et al., 2019), and a first European overview about the floodplain loss, hydromorphological pressures and the distribution of free-flowing rivers has been given (EEA, 2019a). However, a consistent assessment method for floodplains which considers the distinct, type-specific characteristics of floodplains across European regions and their extent, structure and processes is still missing. This is needed for strategic planning of restoration and to build synergy effects across existing policies which relate to floodplains.

This report provides a method to assess floodplain habitat conditions on a European scale, presenting the underlying assessment approach and data bases, as well as a classification of floodplain habitat conditions at the spatial resolution of river sub-catchments. The basic principle of the assessment approach is in line with the WFD (Nõges et al., 2009). Hence, it rests upon the notion of natural floodplain habitats represented by hydromorphological elements in the floodplain. In their natural state, these elements differ between river-floodplain systems across Europe. Therefore, natural floodplain types were identified, which enable a type-specific assessment of European floodplains.

We first developed a European ecological floodplain typology. Floodplains were classified and grouped using a cluster analysis based on abiotic factors known to govern floodplain habitat and biota but not affected by human alterations. These abiotic factors include altitude, slope, floodplain width (topography), catchment geology and three hydrological factors (modelled natural river discharge, high flow pulse and high flow duration). Since the abiotic factors are similar within a floodplain type, the resulting floodplain habitats will also be similar under natural conditions. However, in contrast to the underlying abiotic factors, the resulting floodplain habitats or features like oxbow lakes are often affected by human alterations. Therefore, the floodplain features of each floodplain type were identified and described based on a set of remaining least-disturbed floodplain sections across Europe. Fact sheets summarize important characteristics of the floodplain types and show examples of remaining least disturbed floodplains across Europe. They illustrate the high value of floodplains and their ecosystem services, e.g. for recreation, their supporting value for nature conservation as well as threats of human impacts, and actions to restore and preserve these unique ecosystems.

Second, we developed an assessment approach which focusses on the floodplain habitat condition. In general, the habitat condition is affected by human pressures acting on several aspects of floodplains and relates to the so-called ‘ecosystem multi-functionality’, which is the ability of the floodplains to provide multiple ecosystem services (Funk et al., 2019; Erös and Bányai, 2020). Therefore, the assessment approach is based on an analytical framework of three modules covering the floodplain extent, structures and processes; ecosystem services are not included yet. In total, six indicators were developed to describe different aspects of floodplain disturbance:

- the **extent of floodplains** in terms of the habitat area loss indicating the loss of type-specific floodplain habitats;
- the degree of disturbance to **near-natural floodplain structural elements** with land use pressure indicating anthropogenic changes of floodplain topography and habitat integrity, and floodplain features indicating the presence and abundance of large distinct natural floodplain features like oxbow lakes, bars and dunes and wetlands;
- the degree of disturbance on **near-natural floodplain processes** with base flow alterations indicating altered hydrodynamics, high river flow alteration indicating altered morpho-dynamics, and sediment flow alteration indicating impaired floodplain sediment dynamics.

For each, the present observed habitat conditions were compared to type-specific reference conditions at the spatial scale of river sub-catchment. The type-specific reference conditions were defined on the basis of the set of least-disturbed floodplain sections for floodplain extent and structures and based on modelled data for floodplain processes. Indicators were assessed in three classes ranging from natural to moderately degraded (Class 1), substantially degraded (Class 2), to severely degraded (Class 3).

Our contribution pursues the necessary awareness-raising for the 'floodplain-file’ in the policy discussion (Heritage et al., 2016; EEA, 2019a), providing the groundwork for addressing relevant mitigation options. Therefore, the report describes the data-driven development of floodplain types and the evaluation of the current environmental condition of European floodplains, offering an evidence base for substantial policy analysis. This evaluation is considered as an assessment of the human impact on floodplains, which encompasses the loss of biodiversity and major services provided by these ecosystems (Schindler et al., 2014; Tomscha et al., 2017).

2 Assessment framework and data basis

2.1 Conceptual framework

2.1.1 Definition of floodplain area

Our technical definition of the riverine floodplain is the area adjacent to the low-flow river channel, which is more or less frequently covered with water in times of high river flow. The spatial extent of the floodplain is defined by the 'flood-prone area' (Box 2.1, Figure 2.1) which is the area flooded during a 100-years flood (1 % flooding probability = 1 % chance of happening in any given year) if no flow regulation and flood protection works (related to navigation, hydropower, water diversion, urbanisation) are in place. Nowadays, such flow intervention works are commonplace, dividing the flood-prone area into an 'active floodplain', still flooded during high river flow, and the 'former floodplain' behind the flood protection works, which is no longer inundated. Since there is no consistent European-wide dataset on flow regulation works and the active floodplain, we were not able to distinguish between the active and former floodplain and, hence, considered the whole flood-prone area in our analysis (i.e. active and former floodplain). This allowed to include the present land use of the 'former floodplain' into the assessment, pointing at current ecosystem service provision and restoration potential of these areas.

It is very important to note that our definition of the flood-prone area does not only include the usually flat area (floodplain) inundated when rivers burst their banks and the water overflows. It also includes parts of the river channel only wetted at river discharges between low-flow and bank-full. This transitional and dynamic zone provides important habitats (such as open gravel bars) and is part of the 'riparian ecotone' *sensu* Verry et al. (2004), i.e., the area between the purely aquatic low-flow channel and the pure terrestrial ecosystems not influenced by river floods (Figure 2.1).

Box 2.1 Terminology

Flood-prone area: Lateral extent of the river channel and its floodplain. Width that would be flooded during a 100-year flood if no channel regulation or other hydrotechnical works (e.g. dikes, dams, canals) are in place.

Low-flow channel: River channel wetted during low flows.

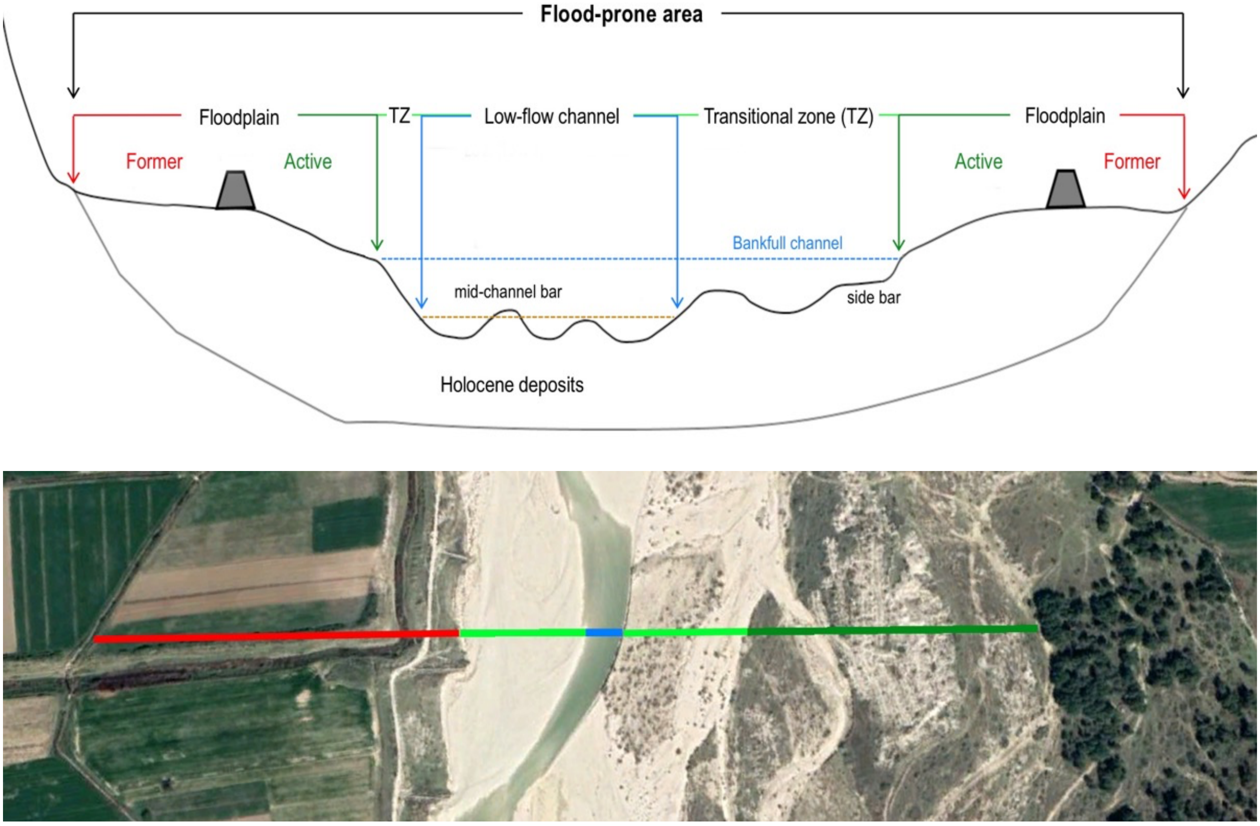
Bank-full channel: River channel wetted during bankfull flows (usually once or twice a year under natural hydrological conditions).

Transitional zone: Mid-channel and side-bars, and river banks not wetted during low flows, but wetted during bank-full flows.

Active floodplain: Part of the flood-prone area flooded at 100-year flood under present condition and maybe limited by channel regulation or other hydrotechnical works.

Former floodplain: Part of the flood-prone area prevented from flooding during a 100-year flood due to channel regulation or other hydrotechnical works.

Figure 2.1: Schematic cross-section (top) and example (bottom) of the flood-prone area including parts of the low-flow channel (blue), bank-full channel only wetted at river discharges above low-flow (transitional zone; light green) and the active (dark green) and former (red) floodplain



Source: Bottom image: Google Maps (2020)

2.1.2 Assessment framework

This report aims at assessing the current habitat condition of European floodplains using the natural state undisturbed by human activities as a benchmark, i.e. the natural state is considered the desired target or reference condition. The assessment is done by quantifying the deviation of the present conditions from the natural reference state, using a set of indicators, that each describe an important aspect of floodplain condition.

However, the natural habitat condition of floodplains differs across Europe as factors governing floodplain structures and processes naturally differ across Europe, depending on the position in the river continuum and the geographical region. For example, large open gravel bars develop in braiding rivers and are formed by the continuous transport and deposition of large amounts of gravel sediment, which is governed by bedrock geology, sediment load, river discharge and valley slope. Therefore, large open gravel bars are a characteristic of large alpine rivers with large amounts of sediment delivered by the tributaries. In contrast, large oxbow lakes naturally occur in wide lowland floodplains where they are formed by the process of meandering and meander cut-offs, which is governed by factors like floodplain sediment cohesiveness, valley slope and channel geometry. They are naturally absent in narrow floodplains of steep mountain rivers in confined valleys where meandering rivers cannot develop.

Therefore, different natural reference conditions have to be defined for different floodplains. These reference conditions are comparable if the governing factors and the resulting natural processes and forms are similar. Hence, similar floodplains can be grouped into types and the type-specific conditions used as a reference for the assessment of all floodplains of the same type. The development of a European ecological floodplain typology was therefore considered a prerequisite for the assessment of floodplain extent, near-natural forms and processes.

In this section we describe the general assessment framework and approach and give an overview on (1) the European floodplain typology and (2) the selection of assessment modules and indicators.

European floodplain typology

The development of a European floodplain typology follows an ecological approach based on environmental factors like altitude and slope, which are known to govern floodplain habitats and biota but not affected by human alterations. Several environmental factors were selected *a priori* according to their relevance and data availability at European scales. A cluster analysis was used to identify the most important environmental factors (= typology factors) to distinguish between seven ecological floodplain types. These types provide the necessary distinction between natural floodplain states, paving the way for a type-specific assessment. In principle, the channel pattern of the river (e.g. meandering or braiding) is an important typology factor to be considered in an ecological floodplain typology. This is because floodplains are closely connected to the river, and floodplain forms and habitats depend on river hydro- and morpho-dynamics. Depending on the natural channel pattern, different floodplain features and habitats develop (like oxbow lakes in floodplains of meandering rivers and large gravel deposits in floodplains of braiding rivers). However, the data necessary to assess which channel pattern naturally occurs (e.g. river substrate size, natural river bank-full width to calculate specific stream power) were not available on a European scale. Moreover, the existing hydromorphological floodplain typology (Rinaldi et al., 2016) which includes information about resulting channel patterns has not been yet assigned to European rivers and translated to a Europe-wide map of hydromorphological river and floodplain types. Hence, a practical application of this typology is not possible. As a consequence, different channel patterns can occur in the ecological floodplain types developed in this report.

Due to the fact that environmental factor values are similar within a floodplain type, the resulting floodplain habitats will also be similar under natural conditions. However, while the factors used for setting up the typology can be considered undisturbed and in near-natural conditions, the related processes and resulting floodplain habitats or forms may be altered by human activities. For example, a low valley slope would naturally result in a meandering channel pattern and floodplain features like oxbow lakes in a wide valley, but these floodplain features might be missing due to the straightening of the river channel and drainage systems which were built by humans for agricultural land use. Therefore, reference conditions for floodplain forms had to be derived based on the concept of ‘minimally disturbed’ or ‘least-disturbed’ reference sites (*sensu* Stoddard et al., 2006). This concept is in line with the Water Framework Directive, which defines reference conditions as showing “no, or only very minor, evidence of distortion” (WFD Annex V; European Commission, 2000). Therefore, the natural channel patterns (classified according to Rinaldi et al., 2016) and related floodplain features of each floodplain type were identified and described based on a set of remaining least-disturbed floodplain sections across Europe.

As a result, each floodplain type was divided into sub-types (see Section 3), depending on the channel pattern (like meandering) and related floodplain features located in the floodplain and in the transitional zone like oxbow lakes, bars and wetlands. As the characterization of sub-types is based on the set of selected least-disturbed sections, it does not cover the whole variety of floodplain types and channel patterns present in Europe but gives a representative overview.

For each of the seven ecological floodplain types, the type-specific natural reference conditions according to environmental factors, dominant channel patterns and floodplain features were described. The reference conditions for the governing factors (like altitude and valley slope) correspond to the typical range of values in least-disturbed floodplains of each type. The reference conditions for the dominant channel patterns and resulting floodplain features were derived from the set of least-disturbed floodplain sections.

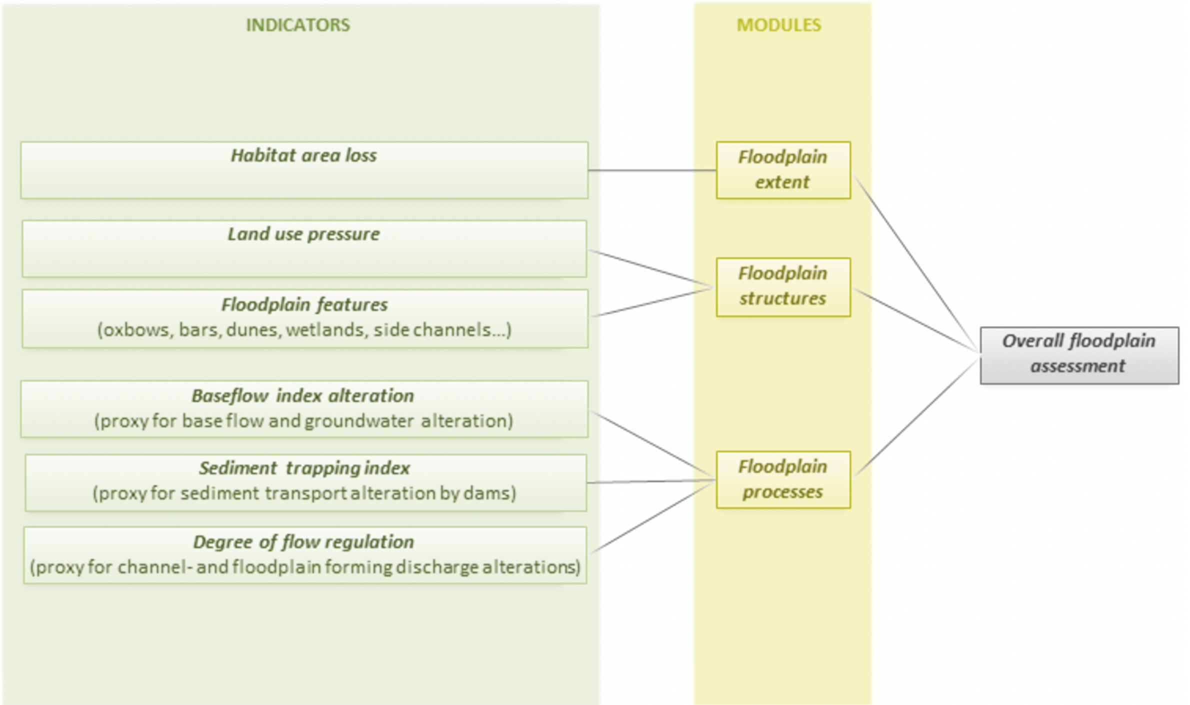
Assessment modules and indicators

In contrast to rivers, floodplains have not only been impaired in respect to their quality but also their extent has been substantially reduced due to flood protection measures coupled with river channelization and land use intensification. Therefore, the naturalness of floodplain habitat has to be assessed in qualitative and quantitative terms. Floodplain extent can be assessed by quantifying the loss of type-specific habitats. Floodplain quality has to be assessed separately in respect to the presence and abundance of floodplain structures as well as the naturalness and functioning of relevant hydrological processes. This is for the following reason: Floodplains develop at large spatial and temporal scales. For example, processes in meandering rivers related to floodplain formation like lateral channel migration and meander cut-offs act at timescales in the order of 100-1 000 years (Knighton, 1998), and floodplain turnover-rates in the same order of magnitude were reported in literature (Richards et al., 2002; Beechie et al., 2006). Therefore, natural floodplain structures do not necessarily imply natural hydrological processes. This means that some floodplain related features and habitats may be present but they are remnants from the past, while natural hydrological processes supporting their rejuvenation or formation are nowadays impaired. New features could also not be formed due to impaired channel natural morphological dynamics. In some exceptional cases, processes and channel morphology might have been restored recently, while floodplain forms did not develop yet.

Therefore, the assessment of floodplain habitat is done separately for the three modules 'extent', 'structures' and 'processes' (Figure 2.2). The indicator for the assessment of floodplain extent quantifies the loss of floodplain type-specific habitats. The assessment of floodplain structures includes two indicators: (1) the land use pressure based on land use data as a proxy for anthropogenic changes of floodplain forms and topography and (2) the presence and abundance of large distinct natural floodplain features such as oxbow lakes, bars and dunes and wetlands. They are compared to floodplain type-specific natural reference conditions. The assessment module of floodplain processes is evaluated using three indicators: (1) the 'base flow index alteration' approximates the human modification of base flow and groundwater conditions in the floodplain as an indicator of altered hydrodynamics, (2) the 'degree of flow regulation index' relates to a change in channel- and floodplain-forming river discharges as an indicator of altered morpho-dynamics, and (3) the 'sediment trapping index' relates to the amount of sediment retention by dams in the catchment upstream, thus quantifying the alteration of the floodplain sediment dynamics. All indicators are assessed into three classes and aggregated into a module-specific.

Comparing the assessment results of the different modules may help to identify the main reason for floodplain degradation and may give constructive signposts for future restoration approaches. For example, large parts of the floodplain habitat area in a selected sub-catchment might be lost (e.g. the floodplain extent module shows severe degradation), but the remaining features might be of high quality or large parts of the flood-prone area might still be covered with type-specific habitats (e.g. floodplain structural degradation is low). If hydrological processes are just moderately impaired in such cases, the restoration might be more efficient than in the case of highly impaired processes.

Figure 2.2: Full set of indicators (green boxes) to assess the three modules ‘extent’, ‘structures’, and ‘processes’



Note: Arrows indicate how indicators are combined into three modules

2.2 Data basis

Functional Elementary Catchments and main drains

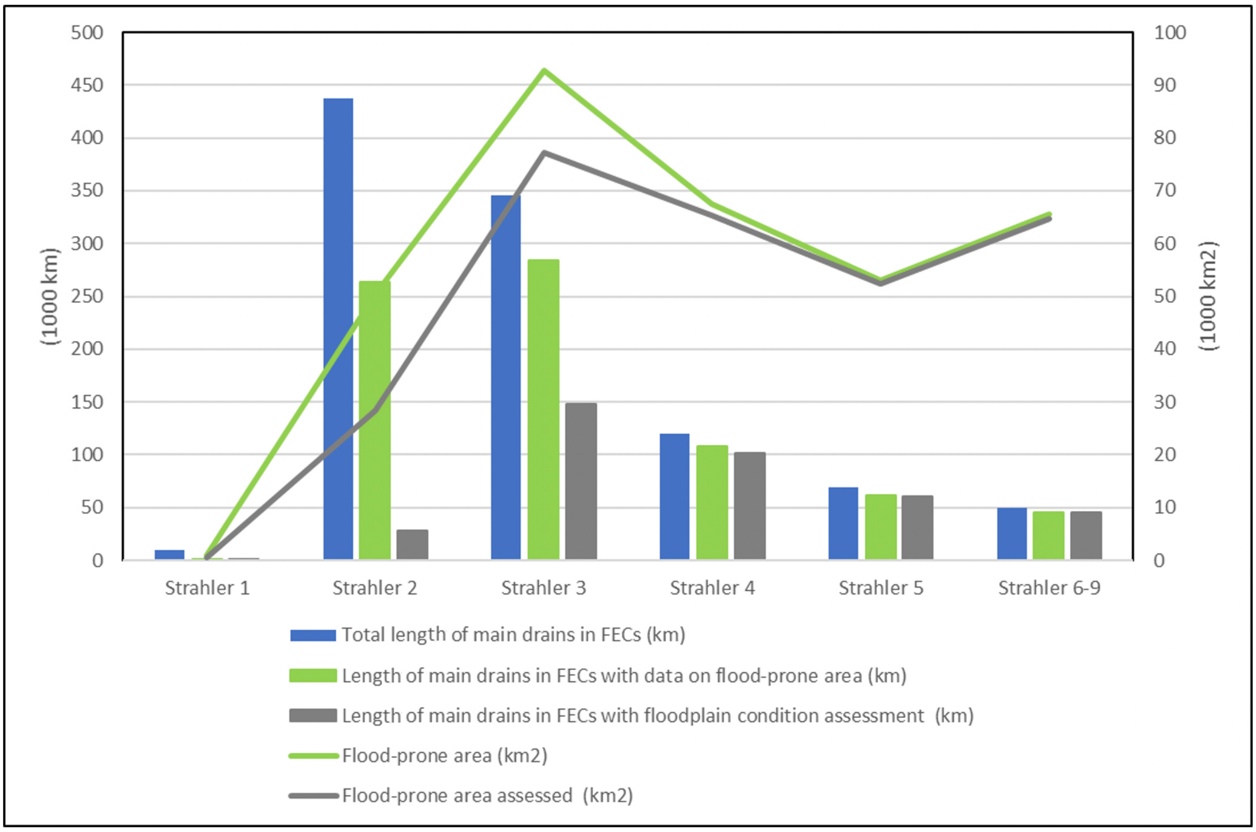
All data were compiled and modelled for sub-catchment units named Functional Elementary Catchments (FEC) that were derived from the Catchment Characterisation and Modelling (CCM) dataset and topologically integrated into the European Catchments and Rivers Network System (ECRINS) database (EEA, 2012). A FEC represents the hydrologic functionality of waterflow, specifically the drainage area between two consecutive larger tributaries of a river or its most upstream headwater catchment. It is a homogenous hydrological unit, also called ‘sub-catchment’. The river section in a FEC between both tributaries is named the ‘main drain’.

The spatial scale of the model is the territory of EEA-38 and UK countries: EU-27 and UK Member States, EFTA countries, Western Balkans countries and Turkey, all members or member candidate countries of the European Environment Agency (EEA). The territory covers a 5.80 million km^2 large area and is divided into 97 025 FECs with an average size of 60 km^2. The average length of the main drains in the model is 8.9 km, ranging from between 0.1 km and 136 km.

The FECs used as the basic analytical hydrological units cover a total of 764 000 km of rivers representing main drains. Data on floodplain extent was available for 74 % of this total river length, thus excluding 198 640 km of river length from the analysis. Data on floodplain extent were mainly missing for rivers of low Strahler order (Figure 2.3). Furthermore, 10 % of FECs featured lagoons, river deltas and large lakes. These were excluded from the analysis to avoid methodological uncertainties – FECs prone to flooding due to lake-level or sea-level rise are thus not considered in our work.

For the delineation of floodplain types, we had to confine the analysis to 65 510 FECs (covering 70 % of the EEA-38 and UK territory) corresponding to data availability of the typology factors. Furthermore, the type-specific dominant channel patterns were identified based on least-disturbed floodplain sections. This approach risks missing specific ecological floodplain types existing in Europe, including types of channel patterns not assigned to the floodplain types.

Figure 2.3: Pan-European data coverage on total river length, total floodplain area and assessed floodplain area by Strahler order



Note: River length refers to the main rivers of FECs (i.e. 'main drains'). Data coverage is poorer for rivers of a lower Strahler order. Strahler order 1: 98 % of river length or approximately 9 000 km missing; Strahler order 2: 40 % of river length or approximately 174 000 km missing; Strahler order 3: 18 % of river length or approximately 61 000 km missing.

Potential flood-prone area

The potential flood prone area (EEA, 2020a) was derived from two spatial layers, (1) the JRC flood hazard map for Europe 100-year return period, compiled with the flood model 'LISFLOOD' (Bates & De Roo, 2000; Alfieri et al., 2014) and (2) the Copernicus Potential Riparian Zone layer, compiled with data from the Copernicus Land Monitoring Service (Weissteiner et al., 2016; CLMS, 2019). This data represents the period 2010–2013.

The potential flood-prone area extends over 0.43 million km^2 (7.4 % of the EEA-38 and UK territory), covering parts of 78 145 FECs (81 % of all FECs in the EEA-38 and UK territory) with a total area of 4.77 million km^2 (Table 2.1). On the 1.03 million km^2 large territory of the EEA-38 and UK (17 % of the total), data on the potential flood-prone area is not available. These are headwater areas with streams of the lowest Strahler order. These streams have a smaller width of the flood-prone area (dimension perpendicular to water flow direction) as compared to the spatial resolution of the hydrological modelling (raster 100 m x 100 m), so the modelling did not give spatial results. In addition, for some of these streams the spatial data of the potential riparian zone is not available in the Copernicus Potential Riparian Zone layer due to the mapping size thresholds. Only features larger than 0.5 ha or longer than 10 m was mapped.

Data for the six indicators were available for 289 000 km^2 out of the known 330 000 km^2 of total flood-prone area (87 %). Again, the missing areas correspond to rivers of lower order. None the less, 98 % of flood-prone areas along rivers with a Strahler order equal to 3 were assessed, and 74 % of flood-prone areas along low order streams. Data coverage was least for rivers with a Strahler order of 2 with half of these rivers located in Nordic and Continental Europe (Figure 2.3).

Table 2.1 Basic statistics of the data coverage

	Description	Total area (mil. km^2)	Number of FECs	Sum of FEC's area or drainage area (mil. km^2)	Average length of river in a FEC (main drain) (km)
Geographical coverage of the analysis	Territory of EEA – 38 and UK countries: EU – 27 and UK countries, four EFTA countries, six Western Balkans countries and Turkey	5.8	97 025	5.8	9.0
Potential flood-prone area	Surface covered with water as modelled for a 100-flood event including surface of coastal lagoons, river deltas and lakes. Modelling assumption is that no flood protection measures are implemented to control flooding.	0.43	78 145	4.77	11.5

Copernicus Riparian Zone Land Cover/Land Use (Copernicus RZLC/LU)

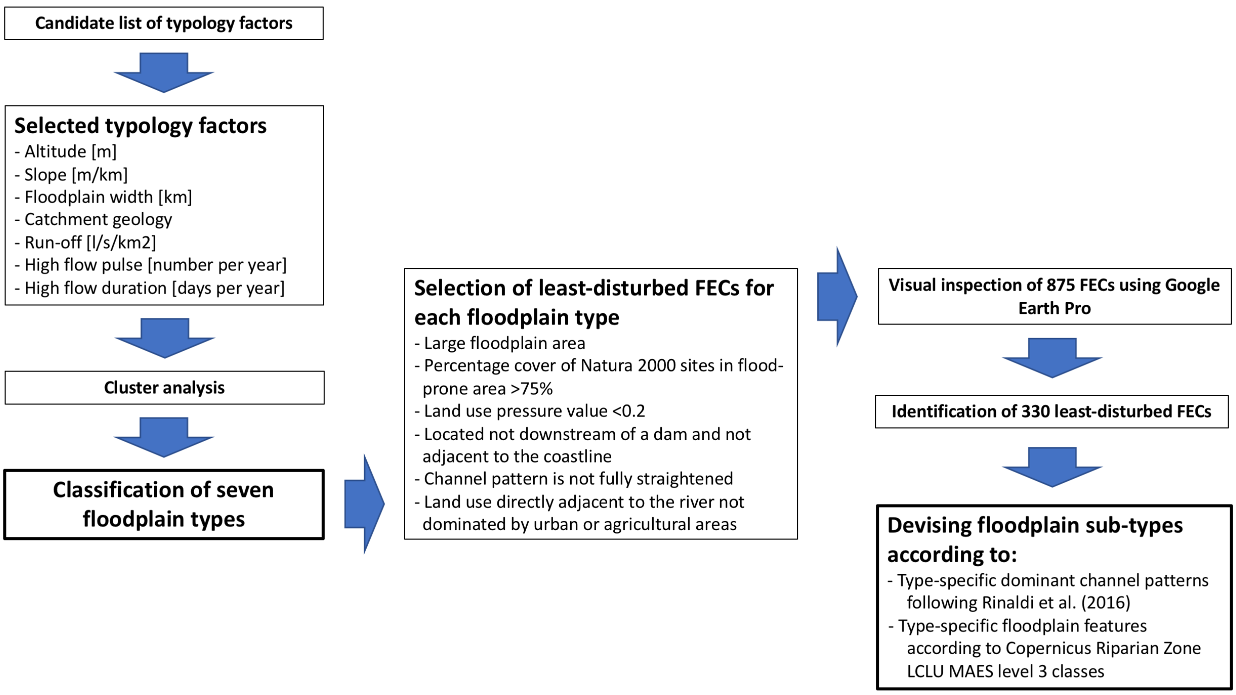
The high resolution land cover and land use dataset based on optical 2.5 m spatial resolution satellite imagery was available from the Copernicus Land Monitoring Service (CLMS, 2019) for areas along a buffer zone of rivers covering the EEA-38 and UK territory. The reference year is 2012 with a temporal coverage of satellite input data between 2010 and 2013. The mapping of land cover and land use in the Riparian Zone along a buffer zone of selected areas has a main objective to support the Mapping and Assessment of Ecosystems and their Services (MAES). MAES level 3 data were used (Tamame et al., 2018).

3 Typology of European Floodplains

3.1 Introduction

The European floodplain typology describes the main types of floodplains present in Europe, including their environmental characteristics and their location mapped at the pan-European scale. It follows an ecological approach based on environmental factors (like altitude and slope) and floodplain forms (like bars) as habitats for biota. Given the wide spatial scope of this analysis, the resulting typology is meant to be relevant for pan-European evaluation, building the basis for a type-specific assessment of the current floodplain condition.

Figure 3.1: Detailed flow-chart of developing the ecological floodplain typology



The development of the floodplain typology was a stepwise procedure resulting in floodplain types and sub-types (Figure 3.1). Floodplain types were derived on the basis of environmental factors (i.e. 'typology factors'), which are known to govern floodplain habitat and biota but not affected by human alterations, available at the spatial resolution of the FECs. We compiled a list of candidate typology factors (Annex 1) for which we checked data availability, spatial distribution, and explanatory power. From these, we selected typology factors with high data availability and relevance as the basis for statistical processing of floodplain types. Detailed maps showing the spatial distribution and data availability of each typology factor are shown in Annex 2. The processing of floodplain types was done by cluster analysis based on the selected typology factors. Each floodplain type was then divided into sub-types, depending on the channel pattern such as meandering, and related floodplain features located in the floodplain and in the transitional zone such as oxbow lakes, bars and wetlands. This was done based on identifying and visually inspecting of least-disturbed FECs in Google Earth Pro (3D arial photography) for each floodplain type regarding dominant channel patterns (following Rinaldi et al., 2016). Visual inspection from aerial photos additionally allowed to identify details in high resolution.

Finally, we summarized all relevant information about the main characteristics of floodplain types in fact sheets. For each type, we give examples of floodplain sections including satellite images and additional descriptions to illustrate characteristics and to point out their uniqueness and value for nature conservation and importance for ecosystem services.

3.2 Selection and description of typology factors

Based on a list of 24 candidate typology factors (Annex 1) derived from spatial data mining, we selected seven factors for detailed analyses based on the following criteria:

- each factor is directly or indirectly relevant for the presence or formation of river floodplains in Europe;
- the factors can either be hardly altered by human activities (e.g. geomorphological parameters) or represent (modelled) near-natural conditions;
- data of factors are largely available on a European scale;
- the factors convey non-redundant information.

The latter criterion was statistically checked by multicollinearity analyses (Spearman $R < 0.7$, Variance Inflation Factor < 10; Dormann et al. 2013). Furthermore, we tested the clustering of various factor combinations, including several validation steps (not shown in this report). From these experiences, we concluded to perform the final analysis based on the seven typology factors as listed in Table 3.1. Detailed information about typology factors (descriptions and coverage across Europe) are given in Annex 1. Please also see Section 2.1.2 for the reasons and consequences of not including channel-pattern as a typology factor.

Table 3.1 Floodplain typology factors included in clustering

Category	Typology factor	Description	Unit	Data source
Morphology	Average altitude of FEC main drain	Average altitude of FEC main drain	m a.s.l.	EEA (2012)
	Slope of FEC main drain	Slope of main drain river within FEC	m/km	EEA (2012)
	Average floodplain width	Average floodplain width along the FEC main drain	km	EEA (2020b)
Geology	Dominant geo-chemistry in catchment	Dominant geo-chemical class in FECs catchment: siliceous, calcareous, mixed, organic	n/a	Lyche Solheim et al. (2019)
Hydrology	Specific run-off divided by catchment area	Mean annual run-off as modelled for FEC divided by FECs catchment area	$l/s/km^2$	Panagopoulos et al. (2019)
	High flow duration	Days per year with hydrological flow greater than 75^{th} percentile of daily flows	days/year	Globevnik et al. (2017a)
	High flow pulses	Number of events per year, when daily run-off (modelled river discharge) is greater than the 75^{th} percentile	events/year	Globevnik et al. (2017a)

3.3 Establishing floodplain types based on selected typology factors

On the basis of selected typology factors, we performed a cluster analysis for FECs with data on floodplain factors (for details see Annex 2), following the analytical approach of Borgwardt et al. (2019) which was established for the typology of very large European rivers. We used principal component analysis to identify the most important typology factors driving the variability in the dataset. Furthermore, we made a plausibility check of the resulting clusters by mapping their geographical distribution and comparing the statistical descriptors (e.g. median, quartiles, range, outliers) of each factor across the type clusters. Where necessary, we reallocated outlying FECs to more corresponding type clusters.

The cluster analysis of the seven typology factors resulted in eight clusters, amongst which two clusters featuring floodplains of the highlands showed very similar environmental characteristics. These two clusters were combined into a single type, yielding seven main types of European floodplains. Each type was labelled according to its characteristic environmental features. On the basis of box plots showing the distribution and value ranges of typology factors in each floodplain type and their main statistical descriptors (Figure 3.2), type-classes were defined which reflect the main environmental differences between the floodplain types (Table 3.2).

The principal component analysis revealed that the first two components explained 51.2 % of the data variability of the seven typology factors (Figure 3.2; for details see Annex 3). The first component correlated best with the factors 'Slope', 'Altitude' and 'Specific run-off, while the second component correlated best with the factors 'High flow pulse' and 'High flow duration'. Accordingly, most types separate well along the horizontal dimension, with broad lowland floodplains to the left and narrow highland floodplains to the right of the diagram. Nordic floodplains feature a prominent position due to their longer flood durations and the predominantly siliceous catchment geochemistry.

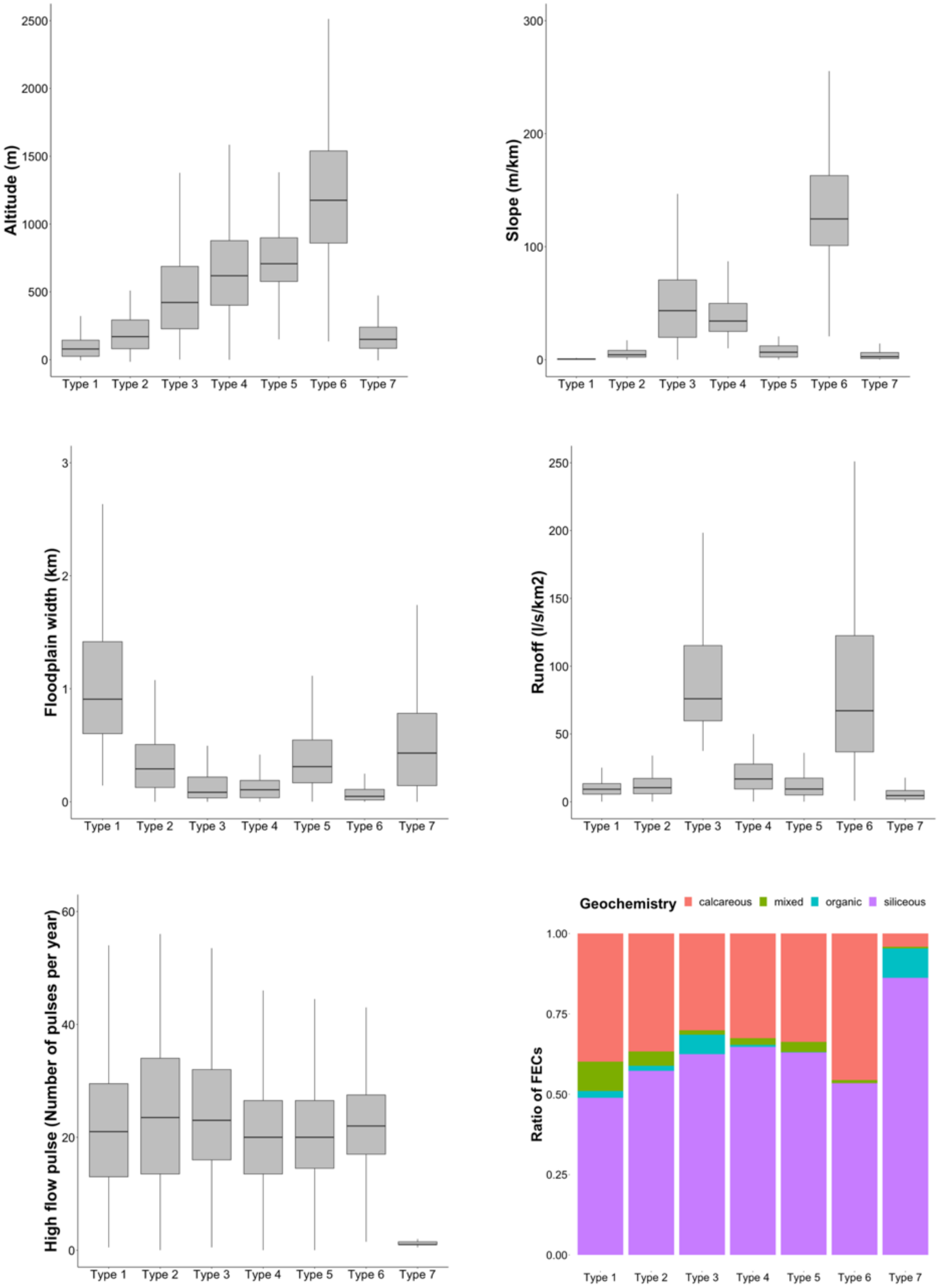
The seven floodplain types are distinctly distributed across the European continent (Map 3.1). Type 1 'Very flat lowland floodplains' and Type 2 'Flat lowland floodplains' cover most parts of the European lowlands, while Type 3 'Mid-altitude high run-off floodplains' and Type 4 'Mid-altitude low run-off floodplains' are located in the hilly regions – with Type 3 mostly located in hilly areas exposed to higher precipitations, and Type 4 located in the Mediterranean and eastern parts of the continent. The Type 5 'Mid-altitude plateau floodplains' are predominantly situated in the flat uplands of Spain and Turkey, but also in parts of the Scandinavian Mountains. Type 6 'Highland floodplains' is distributed across the Alps and Pyrenees, while Type 7 'Nordic lowland floodplains' is limited to Scandinavia and parts of the Baltic countries.

Out of a total 78 145 FECs, floodplain type could not be applied to 12 635 FECs due to missing background data. This means that floodplain typology was defined for 65 510 FECs, covering 70 % of the European territory. We excluded FECs with coastal lagoons, river deltas and large lakes (surface larger than 50 km^2), although they cover parts of the potential flood-prone area. The reason lies in the fact that selected typology factors are related to river and stream processes. In addition, typology has not been defined for a FEC that has a potential flood-prone area only at its confluence with a downstream river.

Table 3.2 European floodplain types, selected typology factors and type-classes

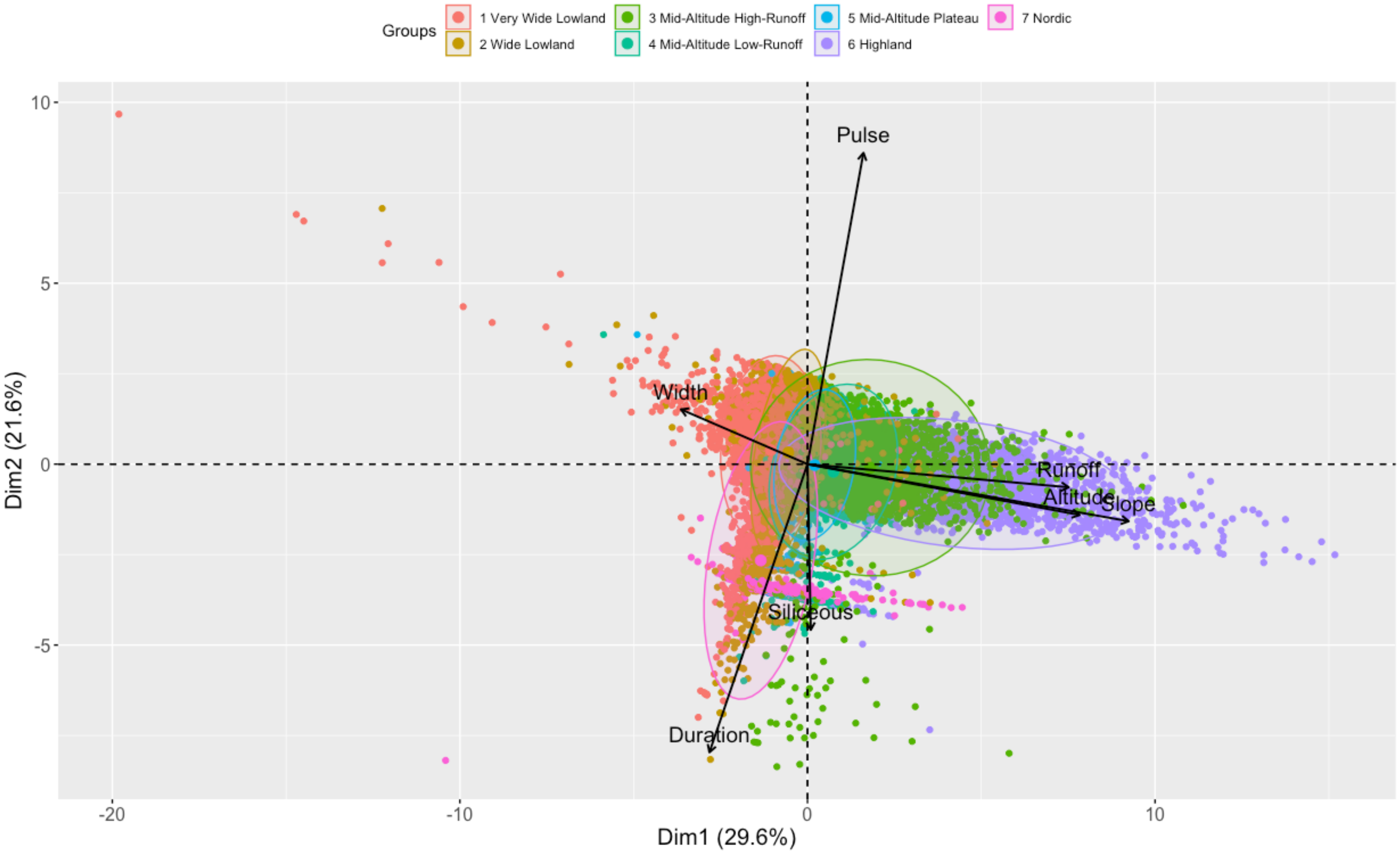
Floodplain type	Altitude [m]	Slope [m/km]	Floodplain width [km]	Run-off [l/s/km²]	High flow pulse [number per year]	High flow duration [days per year]
1 Very flat lowland floodplains	Lowland (< –200)	Very flat (< 1)	Very wide (> 0.6)	Low (< 20)	High number, highly varying range (1–-30)	Short (< 5)
2 Flat lowland floodplains	Lowland (< 300)	Flat (1–10)	Wide (0.1–1.0)	Low (< 40)	High number, highly variable range (14–34)	Short (< 5)
3 Mid-altitude high run-off floodplains	Mid-altitude (200–800)	Steep (10–100)	Narrow (0.04–0.25)	High (> 50)	High number, highly variable range (16–32)	Short (< 5)
4 Mid-altitude low run-off floodplains	Mid-altitude (200–1000)	Steep (10–100)	Narrow (0.04–0.25)	Low (< 40)	High number, moderately variable range (14–27)	Short (< 5)
5 Mid-altitude plateau floodplains	Mid-altitude (500–800)	Flat (1–10)	Wide (0.1–1.0)	Low (< 30)	High number, moderately variable range (15–27)	Short (< 5)
6 Highland floodplains	Highland (> 800)	Very steep (> 100)	Very narrow (< 0.1)	High (> 40)	High number, moderately variable range (17–28)	Short (< 5)
7 Nordic lowland floodplains	Lowland (< 300)	Flat (1–10)	Wide (0.1–1.0)	Low (< 20)	Low number, unvarying range (1–2)	Long (> 50)

Figure 3.2: Plots of selected typology factors across the seven European floodplain types



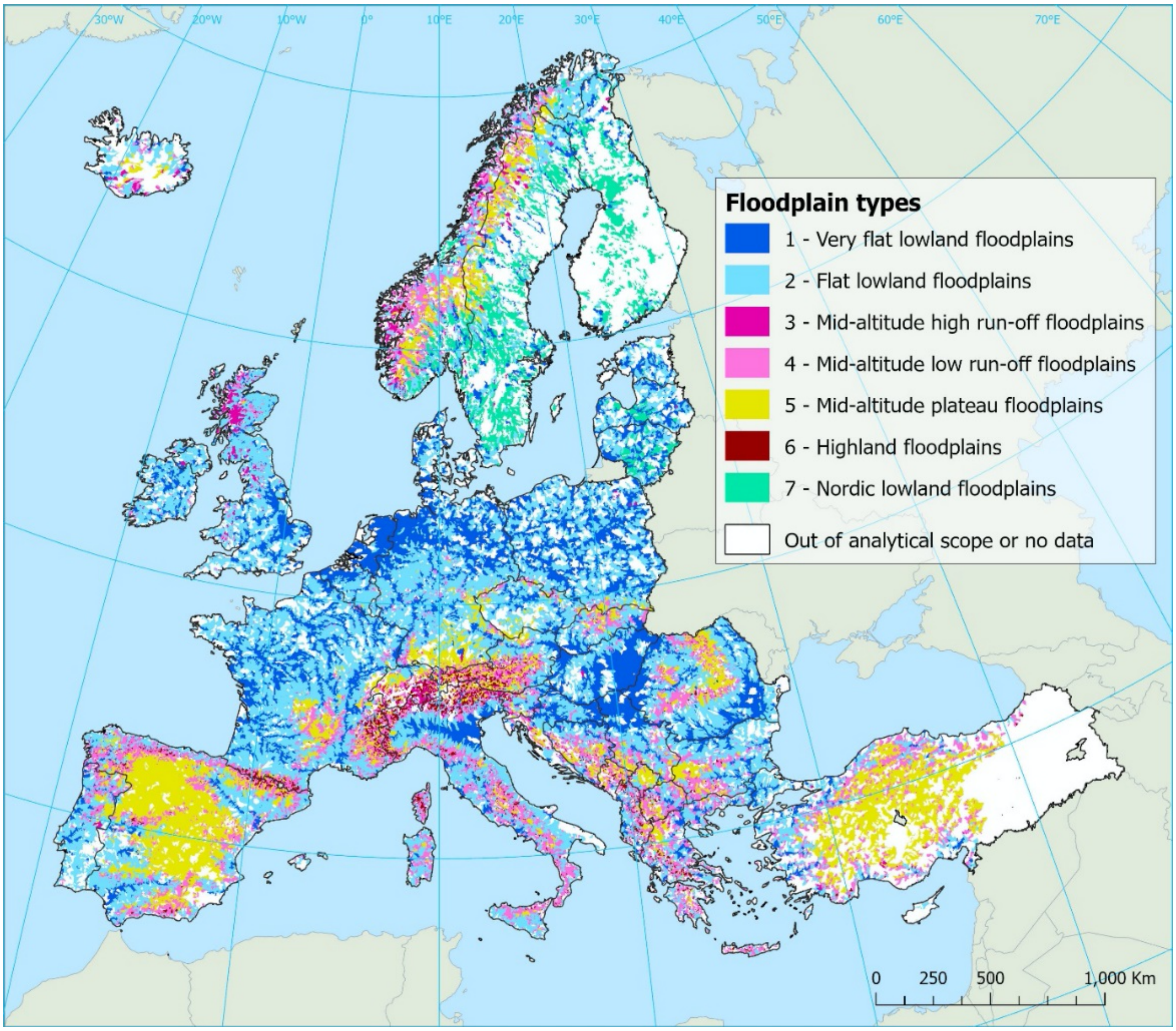
Note: Outliers are not depicted in any of the plots.

Figure 3.3 Bi-plot of the Principal Component Analysis



Note: Bi-plot of the Principal Component Analysis, depicting all FECs with their type allocations and the typology factors in relation to the first two principal components. The length of the arrows corresponds to the magnitude of correlation.

Map 3.1: Map of the European floodplain types



3.4 Additional factors characterizing the floodplain types

3.4.1 Seasonality of river discharges

For each FEC, the month with highest discharge was identified based on monthly discharge data which was modelled for undisturbed hydrological conditions (Panagopoulos et al., 2019) and allocated to each of the seven floodplain types. This allowed to portray the seasonality patterns of high discharges across the floodplain types (Figure 3.4).

Seasonality differences are most obvious between the two lowland floodplain types (Types 1 and 2) on the one hand, with high discharges in early spring (March to April), and the mid-altitude plateau, highland and Nordic floodplains (Types 5, 6 and 7) on the other hand, with high discharges in late spring to early summer (April to June) (Table 3.3). For Types 3 and 4, the season of high discharges lies in-between: for the 'Mid-altitude high run-off floodplains' (Type 3) in late spring (April to May) and for the 'Mid-altitude low run-off floodplains' (Type 4) from March to May.

Figure 3.4: Monthly distribution of highest discharge for the seven floodplain types

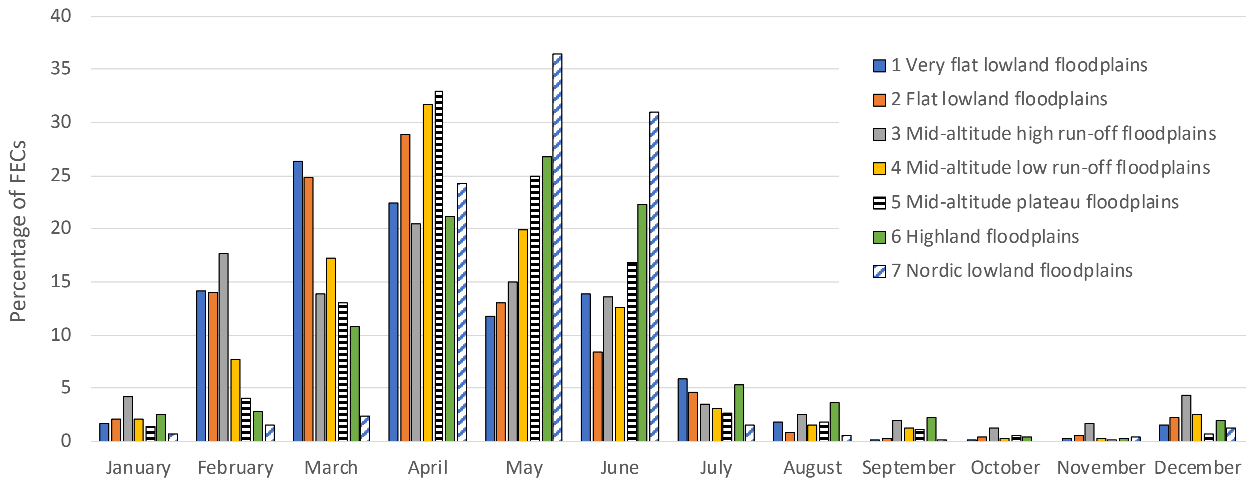


Table 3.3 Overview of seasonality of highest discharges for each floodplain type

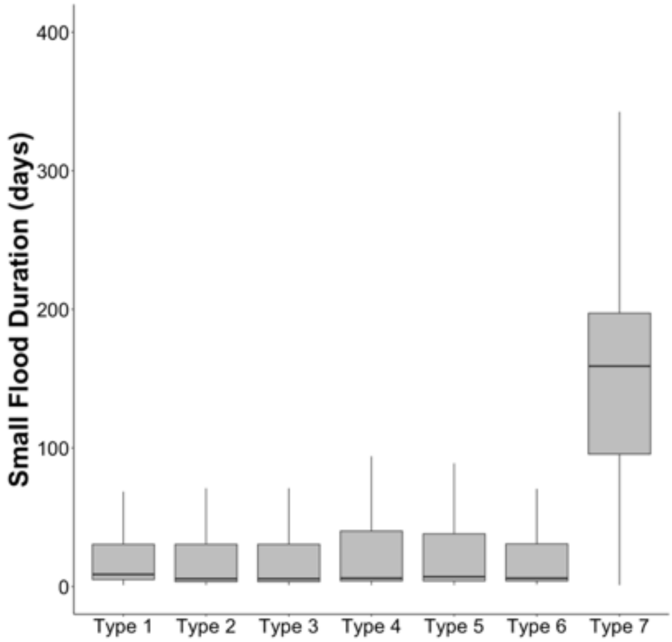
Floodplain type	Seasonality of high discharges
1 Very flat lowland floodplains	Early spring (March to April)
2 Flat lowland floodplains	Early spring (March to April)
3 Mid-altitude high run-off floodplains	Late spring (April to May)
4 Mid-altitude low run-off floodplains	Spring (March to May)
5 Mid-altitude plateau floodplains	Late spring to early summer (April to June)
6 Highland floodplains	Late spring to early summer (April to June)
7 Nordic lowland floodplains	Late spring to early summer (April to June)

3.4.2 Small flood duration

The duration of small floods describes the average (median) number of consecutive days with river rises that overflow the main channel. With modelled data representing undisturbed hydrological conditions being processed only after having established the floodplain typology outlined above, we allocated this factor to the established floodplain types by hindsight (Figure 3.5).

The pattern of the small flood duration across the types is similar to the high flow pulses shown in Figure 3.2: All types except for Type 7 feature on average, short durations of less than one month, while Type 7 features long to very long durations exceeding one month or more.

Figure 3.5: Distribution of the small flood duration values across the seven floodplain types



3.5 Devising sub-types based on near-natural channel patterns and related floodplain features

In principle, the channel pattern of the river (e.g. meandering or braiding) is an important typology factor to be considered in an ecological floodplain typology. Near-natural floodplains are closely connected to the river, and floodplain forms and habitats depend on river hydro- and morpho-dynamics. Depending on the natural channel pattern, different floodplain features and habitats develop (like oxbow lakes in floodplains of meandering rivers and large gravel deposits in floodplains of braiding rivers). Rinaldi et al. (2016) already developed a channel-pattern and hydromorphological floodplain typology with types mainly driven by specific stream power. However, the typology of Rinaldi et al. (2016) has not been yet assigned to European rivers and translated to a European wide map, which hinders the practical application of this typology. In principle, specific stream power, which governs the different types of channel patterns, can be calculated based on natural river channel slope and bank full channel width. Based on these factors a gross distinction can be made between meandering and braiding rivers by including information on river channel sediment size (Kleinhans & Berg, 2011). However, the data necessary to assess specific stream power or meandering vs. braiding channel patterns (i.e. natural river bank full width, river substrate size D_{50}) were not available on a European scale. As a consequence, different channel patterns and related floodplain features which can occur in floodplain types were delineated using a set of least-disturbed FECs across Europe.

3.5.1 Delineation of different channel patterns and floodplain features

Since information on channel patterns and floodplain features were not available on a pan-European scale, we selected least-disturbed FECs for each floodplain type and visually inspected channel patterns and floodplain features with a focus on FECs:

- with a large floodplain area in the respective floodplain type as they may better represent near-natural conditions; FECs with a small floodplain may be exceptional cases and/or altered by human activities;
- with a percentage cover of Natura 2000 sites in a flood-prone area > 75 %;
- with a land use pressure value of < 0.2;

- located not downstream of a dam;
- not adjacent to the coastline;
- for which channel pattern looks near-natural (e.g. not fully straightened);
- for which land use directly adjacent to the river is not dominated by urban or agricultural areas;
- which show no exceptional or untypical conditions (e.g. high share of bars and dunes at confluences or due to glacial outwash).

For the visual inspection of least-disturbed FECs, Google Earth Pro (3D aerial photography) was used as it offered the possibility to identify details in high resolution (or scale 1:500). For each floodplain type, selected least-disturbed sites were inspected regarding dominant channel patterns and floodplain features. In contrast to the assessment, also habitat features on a finer spatial scale were considered. Since the visual inspection was based on recent aerial pictures, least-disturbed FECs are currently in the best possible condition regarding all past changes and human influences on them; historical patterns were not considered.

Channel patterns were classified in five main patterns, adapting a modified version of the basic river typology of Rinaldi et al. (2016) (Figure 3.6): confined single-thread, sinuous, meandering, wandering and braided channel patterns.

The 'confined single-thread pattern' is missing a real alluvial floodplain since lateral channel migration is restricted by a narrow valley. The channel is confined by hillslopes and following the course of the valley and, hence, channel sinuosity is determined by valley sinuosity. Therefore, sinuosity might be high in confined meandering rivers where typical floodplain features of freely meandering rivers like oxbow lakes and scroll bars are missing. The narrow valley limits channel width, which is too low to allow for multiple-channel bars, resulting in a single-thread channel. Depending on channel slope, typical step-pool or pool-riffle channel features are present and some small bars can occur as a floodplain feature in the narrow transitional zone between the low-flow channel and the hillslopes. Therefore, floodplains of confined single-thread rivers are characterized by a low to moderate diversity of floodplain features in the transitional zone and real floodplain features are missing.

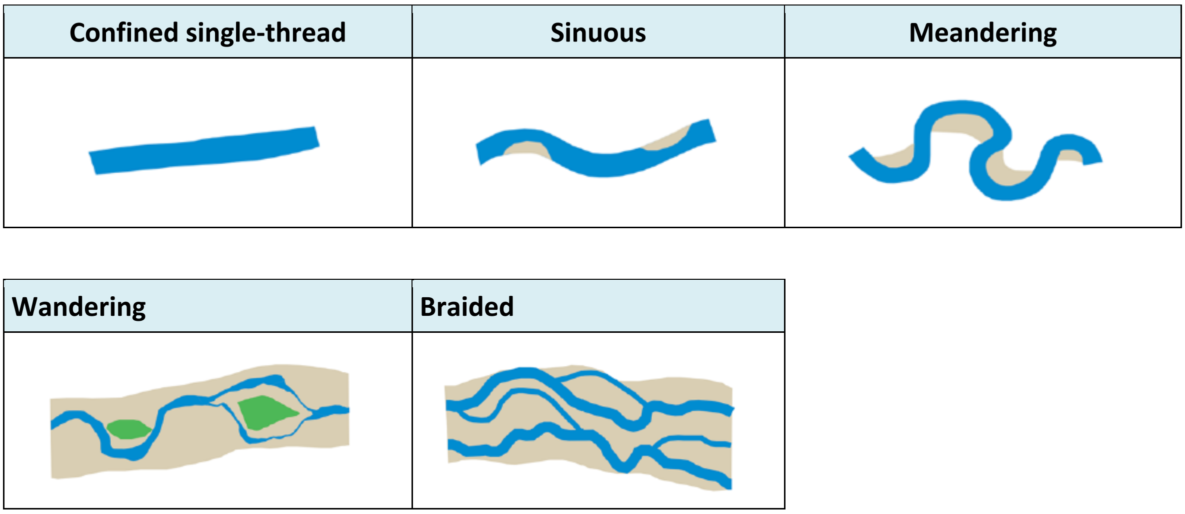
In the 'sinuous channel pattern', two different specifications can occur. In the first, lateral channel dynamics like bank erosion and deposition of side bars are still limited due to a somewhat wider but still narrow valley floor (partly confined) with high bank stability and low stream power. This results in a sinuous channel, typically with alternating side bars in the transitional zone between the low-flow channel and a narrow alluvial floodplain with few floodplain features, e.g. bars and floodplain forest. In the second, the river channel is located in a wide groundwater-determined wetland area with alluvial sediments where lateral channel dynamics like bank erosion and deposition of side bars is low due to very low slope, low flow velocity and long-lasting flooding periods. This results in a sinuous channel with huge wetland areas and forest patches.

In the 'meandering pattern', lateral channel dynamics are not confined by valley width and the river is freely meandering in a wide alluvial floodplain. A mixed sediment load consisting of bedload and suspended load leads to the deposition of cohesive floodplain sediments. The resulting relatively high bank stability, in combination with a moderate stream power, allows for the formation of highly curved meander bends with cut banks at the outer bends and the deposition of large points bars in the inner bends, at the transition between the low-flow channel and the floodplain. Continuous erosion and deposition lead to the lateral growth and downstream movement of the meander bends, re-working the floodplain sediments, the development of floodplain features like meander scroll bars, natural levees, dunes, back-swamps, and finally leading to meander cut-offs and the formation of oxbow-lakes. Therefore, floodplains with meandering channel patterns are characterized by a moderate diversity of floodplain features in the transitional zone and a very high diversity of floodplain features outside the bank full channel.

The ‘wandering channel pattern’ is a multi-thread channel resulting from local avulsions caused by sediment overload or the presence of large wood or the periodic formation of ice jams. This can force the flow to pass on the floodplain where high flow channels form that finally develop into secondary channels and a multi-thread pattern. This anabranching results in rather stable floodplain islands separating dynamic channels with alternating side bars or braided bars and islands. For this reason, floodplains of wandering rivers are characterized by a high diversity of floodplain features in the transitional zone between the low-flow channel and the floodplain and a moderate diversity of floodplain features like emerging high-flow channels, pioneer islands or locally mature islands. Small strips of the outer banks are vegetated with floodplain forest.

The ‘braided channel pattern’ is a multi-thread channel resulting from low bank stability (e.g. non-cohesive banks) in bedload dominated rivers and/or high stream power. Riverbanks in the transitional zone can easily be eroded, leading to wide and shallow channels and the formation of multiple braided bars per cross-section, separating several braided channels within the bankfull channel. These bars in the transitional zone between the low-flow channels and the floodplain are highly dynamic; vegetation can establish on less dynamic braid bars, further stabilizing them. Floodplains of braiding rivers are thus characterized by a very high diversity of floodplain features in the transitional zone – often considered being part of the floodplain in ecology – and a moderate to low diversity of floodplain features outside the bankfull channel.

Figure 3.6: Classification of channel patterns



Source: Reproduced from Rinaldi et al. (2016)
Note: See Annex 5 for aerial pictures as examples of channel patterns.

Floodplain features, located in the transitional zone (e.g. bars) and the active and former floodplain, were classified into seven main floodplain features according to the Copernicus Riparian Zone LCLU MAES level 3 classes (CLMS, 2019) (Table 3.4). For each floodplain type and dominant channel pattern, we calculated the share of different floodplain features in each least-disturbed FEC. Results were grouped according to floodplain type and displayed in box-plots to identify dominant features (Annex 4). Based on an additional visual inspection of floodplain features in least-disturbed FECs, a plausibility check was done. This was essential for the floodplain Types 6 and 7, for which the MAES level 3 data were not fully available for all selected least-disturbed FECs. The results of calculation and visual inspection were combined to identify characteristic near-natural floodplain features for each floodplain type and channel pattern. We differed between essential and dominant features which are always present in a near-natural floodplain of the respective type and channel pattern, and subdominant features which only occur in small-scale patches.

Table 3.4 Classification of floodplain features and assigned MAES level 3 codes

Floodplain feature	MAES level 3 code	MAES level 3 name
Sand and gravel bars, dunes, beaches	**621**	Beaches, dunes, sands (with 6213 being river banks at MAES level 4)
Oxbow lakes	**912**	Separated water bodies belonging to the river system
Wetlands	**711**	Inland freshwater marshes
Wetlands	**700**	Wetlands
Broadleaved floodplain forests	**31**	Broadleaved forests
Coniferous floodplain forests	**32**	Coniferous forests
Mixed floodplain forests	**33**	Mixed forests
Natural grasslands	**421**	Natural grassland prevailingly with trees and scrubs

3.5.2 Identifying near-natural channel patterns and floodplain features per floodplain type

In total, we visually inspected 857 FECs and selected 330 being 'least-disturbed'. Dominant channel patterns obviously differ between floodplain types (Table 3.5). 'Mid-altitude high run-off floodplains' (Type 3), 'Highland floodplains' (Type 6) and 'Nordic lowland floodplains' (Type 7) are each characterized by one dominant channel pattern, whereas in Type 1, 2 and 5 three different main patterns can be present. For 'Mid-altitude low run-off floodplains' (Type 4) the two channel patterns 'braided' and 'confined single-thread' were found. As the characterization of sub-types is based on the set of selected least-disturbed sections, it does not cover the whole variety of floodplain types present in Europe, but gives a representative overview.

Near-natural floodplain features per floodplain type and channel pattern (resulting from data analysis and visual inspection of least-disturbed FECs) are summarized in Table 3.6; detailed results of the data analysis are given in Annex 4. Although channel patterns are generally characterized by specific floodplain features (see descriptions in Section 3.5.1), their presence differs between floodplain types. For instance, for the braided pattern huge transitional zones with bars and floodplain features like broadleaved forest are typical. Dependent on the geographical region in which the floodplain type is located, coniferous forest (e.g. Type 3 'Mid-altitude high run-off floodplains') or natural grassland (e.g. Type 4 'Mid-altitude low run-off floodplains') can be important near-natural channel features.

Table 3.5 Number of visually inspected FECs and least-disturbed FECs per floodplain type and channel pattern

	Channel pattern								
Floodplain type	Braided	Confined single-thread	Meandering	Sinuous	Wandering	Total number of FECs	Total number of visually checked FECs	Total number of least-disturbed FECs	Number of least-disturbed FECs with MAES level 3 feature data
1 Very flat lowland floodplains	21		23		17	10 568	287	61	61
2 Flat lowland floodplains	27	38	15	14	11	25 217	192	105	98
3 Mid-altitude high run-off floodplains	21	8	1		1	3 200	87	31	31
4 Mid-altitude low run-off floodplains	12	15	1		2	10 837	83	30	30
5 Mid-altitude plateau floodplains	9	19	1	14	16	9 614	82	59	59
6 Highland floodplains	2	24		1	2	3 068	67	29	17
7 Nordic lowland floodplains			5	10		3 006	59	15	10

Note: Dominant channel patterns marked in green

Table 3.6 Near-natural floodplain features per floodplain type and channel pattern

		Floodplain feature						
Floodplain type	**Channel pattern**	**Bars and dunes**	**Oxbow lakes**	**Wetlands**	**Broadleaved forests**	**Coniferous forests**	**Mixed forests**	**Grasslands**
1 Very flat lowland floodplains	Meandering							
	Wandering							
	Braided							
2 Flat lowland floodplains	Confined single thread							
	Meandering							
	Braided							
3 Mid-altitude high run-off floodplains	Braided							
4 Mid-altitude low run-off floodplains	Confined single-thread							
	Braided							
5 Mid-altitude plateau floodplains	Confined single-thread							
	Sinuous							
	Wandering							
6 Highland floodplains	Confined single-thread							
7 Nordic lowland floodplains	Sinuous							

Note: Dominant feature is marked as dark green, subdominant feature is marked as light green.

3.6 Fact sheets describing the near-natural reference conditions of floodplain types

Fact sheets (see Annex 5) give an overview of specific characteristics of each floodplain type. This includes:

- short descriptions summarizing characteristics;
- map and figure with information about the spatial distribution across Europe and distribution (% coverage) of the respective floodplain type within the EEA-38 and UK countries;
- table with main characteristics (value classes: altitude, catchment size, slope, potential width, run-off rate, average flooding duration, seasonality of discharges);
- dominant channel patterns and habitat features;
- one example of a least-disturbed floodplain section per dominant channel pattern (least-disturbed floodplain sections identified in Section 3.5.1).

Examples for floodplain types and dominant channel patterns illustrate morphological characteristics of floodplain types under least-disturbed conditions. The examples highlight the natural value of remaining least-disturbed floodplain sections and contain additional information about nature conservation values and, if relevant, about social and cultural services and threats and actions to preserve these unique floodplain sections.

4 Assessment of European floodplains

4.1 Introduction

The assessment of European floodplains was conducted on the potential flood-prone area excluding the low-flow channel, i.e. for the usually flat area (floodplain) inundated when the river flow bursts its banks, but including parts of the river channel between low-flow and bankfull, as this transitional and most dynamic zone provides important habitats (such as open gravel bars). For the sake of simplicity, we refer to this as the “floodplain” in the following, bearing in mind that this also includes the transitional zone.

The assessment of floodplain habitats was done separately for the three modules ‘extent’, ‘forms/ habitats’ and ‘processes’ (Figure 2.1). Floodplain extent was assessed by quantifying habitat area loss. Floodplain forms/habitats were assessed using two indicators, one to describe land use pressure as a proxy for floodplain topography and the other to assess large-scale fluvial features (oxbow lakes, bars, wetlands). Floodplain processes were assessed by the indicator ‘base flow alteration index’ (Panagopoulos et al., 2019), a hydrodynamics-proxy for river base flow and floodplain groundwater alterations, and by two indicators for river connectivity developed by Grill et al (2019): the ‘sediment trapping index’ (sediment flow dynamics-proxy quantifying sediment retention by dams) and the ‘degree of regulation index’ (morphodynamics-proxy for altered channel- and floodplain-forming discharges). All indicators were assessed in three classes. This rather low number of assessment classes was chosen to ensure that floodplains falling into different classes are actually differing. The assessment results of the indicators were then combined to a module-specific assessment as shown in Figure 2.1.

The classes reflect the degree of alteration from type-specific reference conditions for each indicator. The type-specific reference conditions for the indicator ‘floodplain features’ were derived from the set of least-disturbed floodplain sections selected in Section 3.5.1 (see also Section 4.3.3 for more details). The reference condition for the indicators ‘habitat area loss’ and ‘land use pressure’ corresponds to no habitat area loss (0 %) and the lowest land use pressure (0 on a scale from 0 to 1). For process indicators, the respective indices were modelled for least-disturbed sections and used to define thresholds.

A normative description was phrased for each class in general and for each indicator in particular to ensure that the same class refers to a similar degree of degradation for all indicators (Table 4.1). Plausibility checks were conducted for each indicator, and the assessment method and/or the normative description were adapted accordingly to ensure that the assessment results generally correspond to the normative description of the assessment classes. For example, preliminary results for the module ‘extent’ and ‘structures’ were visually checked against land use data and satellite images for about 300 FECs.

For the assessment of the indicators for floodplain extent and floodplain forms, some FECs had to be excluded. Those FECs were excluded from the assessment modules ‘extent‘ and ‘structures’, where the flood-prone area did cover less than half of the length of the main river and, hence, results would not have been representative for these assessment modules (43 090 FECs left). In addition, the land use dataset used to calculate these indicators had some missing land use/land cover data (36 881 FECs left). Data to assess the module ‘processes’ were available for 64 363 FECs.

Table 4.1 General normative description of the three assessment classes for the indicators

Module	Indicator	Class 1 No to moderately degraded	Class 2 Substantially degraded	Class 3 Severely degraded
General	**General**	Reflects floodplain-type specific undisturbed conditions in some exceptional cases, but mainly shows some moderate levels of distortion resulting from human activity and moderate deviation from floodplain-type specific undisturbed conditions.	Deviates substantially from floodplain-type specific undisturbed conditions. Shows clear signs of distortion resulting from human activity.	Shows evidence of severe alterations and large portions of the relevant floodplains, forms and processes normally associated with the floodplain type under undisturbed conditions are absent.
Floodplain extent	**Habitat area loss**	The floodplain is mainly covered by type-specific floodplain habitats, but some moderate habitat loss may have occurred (habitat loss 0–33 %).	The floodplain is still covered by some type-specific floodplain habitats, but they are lost on larger parts of the floodplain (habitat loss 33–66 %).	The floodplain is mainly covered by non-type specific land uses and only small or even no parts are covered by type-specific floodplain habitats (habitat loss 66–100 %).
Floodplain structures	**Land use pressure**	Low to moderate land use pressure: Natural floodplain habitats or extensively used areas of high ecological value are dominant, with larger patches of non-natural forests or managed grassland, while agricultural and urban areas are scarce or absent (0–0.33).	Substantial land use pressure: Besides patches of type-specific floodplain habitats, there are also larger patches of non-natural forests, managed grassland and agricultural areas present, as well as small to medium sized urban areas (0.3–-0.66).	High to very high land use pressure: Few or no type-specific floodplain habitats, some non-natural forests and manged grassland present, but mainly covered by agricultural and urban areas (0.66–1.0).
	Floodplain features	Present: Area covered by floodplain features corresponds to the type-specific values of least-disturbed sites (median of least-disturbed sites for bars, oxbow lakes, and wetlands).	Not present: Floodplain features are missing, or the area covered is below the type-specific values of least-disturbed sites.	

Table 4.1 Cont.

Module	Indicator	Class 1 No to moderately degraded	Class 2 Substantially degraded	Class 3 Severely degraded
Floodplain processes	Base flow and groundwater alteration	Water uses in the catchment are only moderately altering the natural base flow of the river. Exchange of water between channel and groundwater is type-specific to seminatural condition; hydraulic connection between river water level at base flow with that of floodplain groundwater level supports type-specific floodplain habitats.	Water uses in the catchment are significantly altering the natural base flow that has type-specific characteristics. Hydraulic connections between river water levels at base flow and floodplain groundwater levels are weaker and surface-groundwater exchange is less dynamic.	Type-specific natural base flow is severely altered due to water uses in the catchment; exchange of stream water and groundwater is severely interrupted, including impaired groundwater dynamics in the floodplain
	Alteration of channel- and floodplain-forming discharges	No or moderate alteration of type-specific channel- and floodplain-forming discharges due to water storages by dams in the catchment (still supporting the presence of least-disturbed FECs for each floodplain type); high water discharge regime is not or is only moderately impaired.	Type-specific alteration of channel- and floodplain-forming discharges due to water storages in the catchment are substantial; longitudinal connectivity is substantially impacted.	Severe type-specific streamflow regulation, so timing, duration and magnitudes of channel- and floodplain-forming discharges are heavily altered due dams in the catchment; longitudinal flow connectivity is severely impacted.
	Sediment flow alteration	Natural to moderate sediment flow alteration due sediment trapping behind dams in the catchment. Existing sediment flow dynamics supports type-specific floodplain-related natural habitats.	Type-specific substantial alteration of sediment flow due sediment trapping behind dams.	Severe type-specific sediment flow alterations due sediment trapping behind dams in the whole catchment.

Given the large variability of floodplain conditions across Europe and the limited availability and resolution of European-wide input data, it is evident that the assessment results cannot reflect all specific conditions and must not be used at the basis of single FECs. However, since the plausibility check revealed a good match between assessment results and actual conditions visible on satellite images in general, the results are most probably suited to give an overview on the habitat conditions of floodplains on a European scale.

4.2 Floodplain extent

4.2.1 Habitat area loss

Indicator description

The indicator 'habitat area loss' directly quantifies to which extent the area covered by natural floodplain habitats has been reduced in size. It describes the habitat area loss as a consequence of either non-natural land cover or absence of natural floodplain vegetation. The habitat area loss is expressed as the share of non-natural floodplain habitats in the flood-prone area excluding the water surface area. It is a rather conservative estimate of loss.

Indicator quantification

Copernicus RZLC/LU MAES level 3 land use classes were grouped as potentially being natural floodplain habitats or clearly representing other habitats and non-natural land uses (Table 4.2) based on the detailed description of the land use classes given in the respective nomenclature guideline (Tamame et al., 2018). The percentage cover of the non-natural land used classes in the floodplain was summed up and considered as habitat area loss, i.e. values range from 0 % (no habitat area loss) to 100 % (no natural habitats occurring, whole floodplain covered by non-natural MAES level 3 classes). Since in case of doubt land use classes have been considered as floodplain habitats, this again was a conservative estimate.

The assessment of habitat area loss is floodplain type-specific because what was considered natural floodplain habitat differs between floodplain types:

The three different MAES level 3 forest classes (broadleaved, coniferous, mixed) were grouped as potentially being natural floodplain habitats based on the following assumptions:

- Broadleaved forests were considered being natural floodplain habitats in the floodplain of all FECs because they naturally occur in the frequently flooded lower part of the floodplain in virtually all of Europe and all floodplain types.
- Coniferous forests were considered being natural floodplain habitats in the floodplain of FECs where the potential natural vegetation mainly consists of coniferous forests. The map of the European potential natural vegetation was used (Bohn et al., 2007, BfN, 2020). Spatial data on potential vegetation is available in "EuroVegMap 2.0" (BfN, 2020). All vegetation formations selected where coniferous forests occur naturally (A 'Subnival-nival vegetation of high mountains', B 'Arctic tundras and alpine vegetation', C 'Subarctic boreal and nemoral-montane as well as subalpine and oro-Mediterranean vegetation', D 'Mesophytic and hygromesophytic coniferous and mixed broadleaved-coniferous forests', K 'Xerophytic coniferous forests and scrub' and S 'Mires'). The percentage cover of these vegetation formations in the floodplain of the FECs was calculated. Coniferous forests were considered being natural habitat in FECs where these formations covered more than 50 % of the floodplain.
- Mixed forests were considered natural habitats in floodplain Types 3 to 7 even if the FECs were not dominated by coniferous formations because these types mainly occur in boreal and mountain regions or occur at higher altitudes and have steeper valley floors (i.e. lower groundwater levels), allowing single coniferous trees to grow in the floodplain. Mixed forests were not considered natural habitat in the wide flat floodplains of floodplain Types 1 and 2, because broadleaved trees were assumed to outcompete coniferous trees in the whole floodplain.

Given that large parts of the forests in Europe are used for silviculture, most probably only small parts of the floodplain covered by MAES level 3 forest classes actually are real natural floodplain forests. This again makes the assessment a conservative estimate.

In addition, the assessment of the MAES level 3 class ‘lakes and reservoirs’ differed between floodplain types. Unfortunately, this MAES land use class does not distinguish between natural lakes and artificial reservoirs. Natural lakes are much more widespread in glacial landscapes, especially in Fenno-Scandinavia and the Baltic region. To minimize misclassifications, the MAES level 3 class ‘lakes and reservoirs’ was considered natural in these areas (floodplain Type 7 and Fenno-Scandinavian and Baltic countries and ecoregions) but non-natural elsewhere.

Finally, sclerophyllous vegetation was considered potentially being natural in floodplain Types 3 to 7 because due to the rather narrow valleys, the flood-prone area partly includes rather elevated areas. Especially in the Mediterranean region and in FECs of intermittent rivers, the presence of sclerophyllous vegetation cannot necessarily be considered non-natural in these floodplain types. In contrast, groundwater levels usually are high and sclerophyllous vegetation should not occur in the flat floodplain of large to very large, usually permanent rivers of floodplain Types 1 and 2.

A detailed sensitivity analysis was not performed but the results of preliminary runs prior to the plausibility check were compared to final results which showed surprisingly small differences. This indicates that the assessment results were not very sensitive to whether single MAES land use classes were considered natural floodplain habitat or not. This might partly be due to the use of the three rather gross assessment classes.

Table 4.2 Grouping of Copernicus Riparian Zone LC/LU MAES level 3 land use classes

	MAES level 3 land use classes	Considered natural floodplain habitats					
		Broadleaved FECs			Coniferous FECs		
		Type 1 & 2	Type 3 to 6	Type 7	Type 1 & 2	Type 3 to 6	Type 7
Urban	101 Urban areas, 111 Dense to medium dense urban fabric, 112 Low density urban fabric, 121 Transport infrastructure, 131 Mineral extraction, dump and construction sites, 142 Sport and leisure facilities	0	0	0	0	0	0
	132 Land without current use, 141 Green urban areas	0	0	0	0	0	0
Agriculture	211 Non-irrigated arable land, 212 Greenhouses, 213 Irrigated arable land and rice fields, 214 Complex patterns of irrigated and non-irrigated arable land, 221 Vineyards, 222 Fruit tree and berry plantations, 223 Olive groves, 230 Heterogeneous agricultural area, 231 Annual crops associated with permanent crops, 232 Complex cultivation patterns	0	0	0	0	0	0
	233 Land principally occupied by agriculture with significant areas of natural vegetation, 234 Agro-forestry	0	0	0	0	0	0
	411 Managed grassland	0	0	0	0	0	0

Table 4.2 Cont.

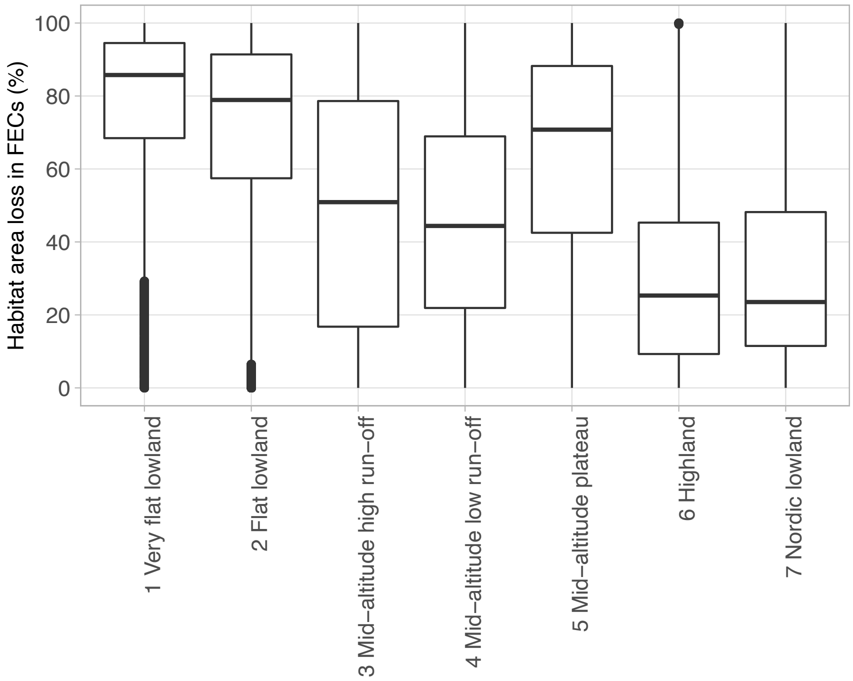
	MAES level 3 land use classes	Considered natural floodplain habitats					
		Broadleaved FECs			Coniferous FECs		
		Type 1 & 2	Type 3 to 6	Type 7	Type 1 & 2	Type 3 to 6	Type 7
Forest	315 Highly artificial broadleaved plantations	0	0	0	0	0	0
	341 Transitional woodland and scrub, 351 Damaged forest	0	0	0	0	0	0
	321–324 Coniferous forest	0	0	0	1	1	1
	331–334 Mixed forest, 300 Woodland	0	1	1	1	1	1
	311–314 Broadleaved forest	1	1	1	1	1	1
Water bodies (artificial)	921 Lakes and reservoirs	0	0	1	0	0	1
	811 Salt marshes & salines	0	0	0	0	0	0
	922 Artificial standing water bodies	0	0	0	0	0	0
Non-forest natural vegetation and water bodies	521 Sclerophyllous vegetation	0	1	1	0	1	1
	421 Natural grassland prevailingly with trees and scrubs, 422 Natural grasslands without trees and scrubs, 420 Natural grassland, 511 Moors and heathland, 500 Heathland, 611 Sparsely vegetated areas, 621 Beaches, dunes, sands, 622 Bare rocks, burnt areas, glaciers and perpetual snow,700 Wetland, 711 Inland freshwater marshes, 712 Inland saline marshes, 721 Peat bogs, 722 Unexploited peat bog, 812 Intertidal flats, 821 Coastal lagoons, 822 Estuaries, 889 Natural coastal ecosystems, 912 Separated water bodies belonging to the river system (dead side-arms, flood ponds), 991 Marine (other)	1	1	1	1	1	1

Note: Grouping of Copernicus Riparian Zone LC/LU MAES level 3 land use classes as natural floodplain habitats (1) or clearly representing other habitats and non-natural land uses (0) for the different floodplain types and depending on whether pure coniferous forests are the dominant potential natural vegetation.

Indicator assessment results

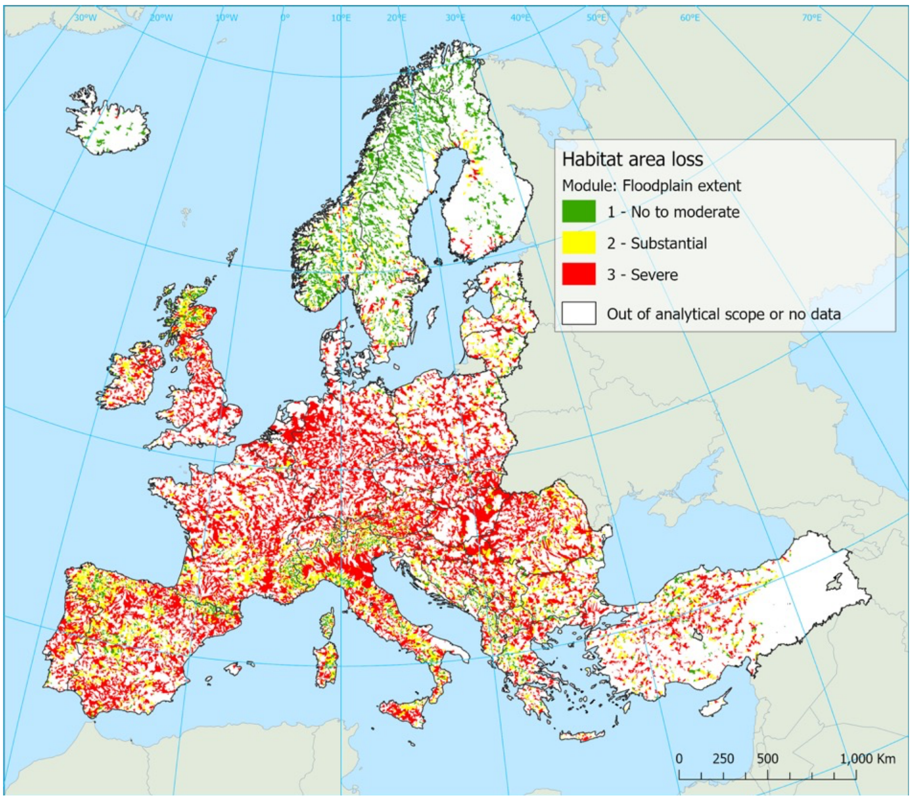
The median habitat area loss per FEC is 75.4 % but differences between floodplain types are large. These differences between types are reasonable and clearly reflect the general naturalness of the landscapes (Figure 4.1): Median habitat area loss is rather low in the Type 7 'Nordic floodplains' (23.5 %) and the Type 6 'Highland floodplains' (25.3 %), moderate in the 'Mid-altitude mountain floodplains' of Type 4 (44.4 %) and Type 3 (50.9 %), higher in the more intensively used 'Mid-altitude plateau' Type 5 (70.8 %), and highest in the intensively used Type 2 (78.9 %) and Type 1 (85.7 %) floodplains. Given that this is a very conservative estimate (see section on indicator quantification above), especially the high habitat area loss in the iconic wide floodplains of Type 1 must be considered dramatic.

Figure 4.1: Median and range of habitat area loss in the different floodplain types



Most of the analysed FECs (60 %) have a habitat area loss > 66 %, hence the fall in Class 3. These severely degraded FECs occur in most parts of Europe but are particularly common in the Central Plains and Hungarian Lowlands ecoregions but also in the Central and Western Highlands ecoregions (Map 4.1). Only 18 % of the FECs fall in Class 1, which mainly occur where coniferous forests are part of the potential natural vegetation: In the boreal biogeographic region and most of the higher mountain regions like the Alps and Pyrenees. But habitat area loss is also low in some FECs where broadleaved forests are dominant (e.g. parts of the Apennine Mountains and Cantabrian Mountains).

Map 4.1: Spatial distribution of FECs with different habitat area loss across Europe



4.3 Floodplain structures

4.3.1 Indicators description

For the assessment of floodplain structures, we used two indicators:

- Large scale floodplain structures or distinct 'large fluvial floodplain features' like oxbow lakes, bars and wetlands; can be identified by remote sensing and are often represented in land use datasets as distinct land use classes.
- Floodplain topography and microhabitats or 'small scale floodplain structures' where patchy habitat mosaic is formed. This is a result of small local differences in terrain height (topography) and substrate of floodplains, both causing local differences in temperature and soil-moisture; the floodplain topography and habitat patchiness substantially contribute to the high habitat complexity. They are expected to exist in floodplain forest, meadow areas and other large scale floodplain habitats. In urbanized or intensively farmed area, no small scale floodplain structures are expected to exists.

While the large floodplain features were assessed by the indicator 'floodplain features', floodplain topography and microhabitats were assessed by the indicator 'land use pressure'.

4.3.2 Land use pressure quantification

Indicator description

The indicator is a proxy for anthropogenic changes of floodplain topography and forms, hence, floodplain structures. It was assumed that alterations of floodplain morphology and forms (structures) increase with increasing land use pressure. For example, extensive grassland farming probably has a lower impact on floodplain forms than intensive cropland, which often entails changes in floodplain topography due to tillage and terracing, which adjust small local differences in height, substrate and soil moisture conditions. These adjustments result in a less patchy habitat mosaic even after abandoning agriculture. In urban areas floodplain topography is usually completely modified and destroyed, so no small structures exist there. We considered this a reasonable first assumption, which is supported by studies on the long-term smoothing of the relief caused by changing land use from forest to arable land (Rejman et al., 2014) caused by tillage (Van Oost et al., 2005). However, we are not aware of any specific empirical study on the effect of different land uses on floodplain topography. Further testing this assumption for a sub-dataset of FECs using high resolution data on height and substrate data would be a necessary next step.

Besides being a proxy for alterations of floodplain topography and forms, land use pressure is a proxy for the naturalness and patchiness of the floodplain ecosystem, i.e. for floodplain habitat quality.

Indicator quantification

A land use pressure value ranging from 0 (low) to 1 (high) was assigned to each Copernicus Riparian Zone LCLU MAES level 3 land use class (Table 4.3). The weighted mean land use pressure was calculated in each FEC using the area covered by each land use class in the floodplain as a weight. For example, if managed grassland, with a land use pressure of 0.6, was covering 75 % and urban areas (with a land use pressure of 1.0) 25 % of the floodplain, the land use pressure was calculated as 0.6 x 0.75 + 1.0 x 0.25 = 0.7. The resulting land use pressure values range from 0 (completely covered by natural vegetation and water bodies) to 1 (completely covered by urban areas).

The assessment of habitat area loss is floodplain type-specific because the land use pressure values assigned to some land use classes differ between floodplain types.

The three different MAES level 3 forest classes (broadleaved, coniferous, mixed) were grouped as potentially being natural floodplain habitats based on the same assumptions as for the indicator 'habitat area loss':

- Broadleaved forests were considered being natural floodplain habitats in the floodplain of all FECs because they naturally occur in the frequently flooded lower part of the floodplain in virtually all of Europe and all floodplain types.
- Coniferous forests were considered being natural floodplain habitats in the floodplain of FECs where the potential natural vegetation mainly consists of coniferous forests (see description of the indicator 'habitat area loss' for details).
- Mixed forests were considered natural habitats in floodplain Types 3 to 7 even if the FECs were not dominated by coniferous formations. These types of floodplains in fact mainly occur in boreal and mountain regions or at higher altitudes and have steeper valley floors (i.e. lower groundwater levels), allowing single coniferous trees to grow in the floodplain. Mixed forests were not considered natural habitat in the wide flat floodplains of floodplain Types 1 and 2 because broadleaved trees were assumed to outcompete coniferous trees in the whole floodplain.

Given that large parts of the forests in Europe are used for silviculture, a land use pressure value of 0.1 was assigned to land use classes representing forest types that naturally can occur in the FEC instead of using the lowest value of zero.

As for the indicator 'habitat area loss', the MAES level 3 class 'lakes and reservoirs' was considered natural (to minimize misclassifications) with a land use pressure value of zero in floodplain Type 7 and Fenno-Scandinavian and Baltic countries and ecoregions but having a moderate land use pressure value of 0.4 elsewhere.

A detailed sensitivity analysis was not performed but the results of preliminary runs prior to the plausibility check were compared with final results which showed surprisingly small differences. This indicates that the assessment results were not very sensitive to moderate changes in the land use pressure values. This might partly be due to the use of three rather gross assessment classes. We only checked if the land uses in FECs falling in a respective assessment class corresponded to the normative description in Table 4.1. A detailed analysis on the effect of increasing land use pressure on floodplain topography was beyond the scope of this project (i.e. testing the underlying assumption of decreasing naturalness of floodplain topography with increasing land use pressure).

Table 4.3 Land use pressure values ranging from 0 (low) to 1 (high)

	MAES level 3 land use classes	Considered natural floodplain habitats					
		Broadleaved FECs			Coniferous FECs		
		Type 1 & 2	Type 3 to 6	Type 7	Type 1 & 2	Type 3 to 6	Type 7
Urban	101 Urban areas, 111 Dense to medium dense urban fabric, 112 Low density urban fabric, 121 Transport infrastructure, 131 Mineral extraction, dump and construction sites, 142 Sport and leisure facilities	1.0	1.0	1.0	1.0	1.0	1.0
	132 Land without current use, 141 Green urban areas	0.8	0.8	0.8	0.8	0.8	0.8
Agriculture	211 Non-irrigated arable land, 212 Greenhouses, 213 Irrigated arable land and rice fields, 214 Complex patterns of irrigated and non-irrigated arable land, 221 Vineyards, 222 Fruit trees and berry plantations, 223 Olive groves, 230 Heterogeneous agricultural area, 231 Annual crops associated with permanent crops, 232 Complex cultivation patterns	0.8	0.8	0.8	0.8	0.8	0.8
	233 Land principally occupied by agriculture with significant areas of natural vegetation, 234 Agro-forestry	0.6	0.6	0.6	0.6	0.6	0.6
	411 Managed grassland	0.6	0.6	0.6	0.6	0.6	0.6
Forest	315 Highly artificial broadleaved plantations	0.6	0.6	0.6	0.6	0.6	0.6
	341 Transitional woodland and scrub, 351 Damaged forest	0.4	0.4	0.4	0.4	0.4	0.4
	321-324 Coniferous forest	0.6	0.4	0.4	0.1	0.1	0.1
	331-334 Mixed forest, 300 Woodland	0.4	0.2	0.2	0.1	0.1	0.1
	311-314 Broadleaved forest	0.1	0.1	0.1	0.1	0.1	0.1
Water bodies (artificial)	921 Lakes and reservoirs	0.4	0.4	0	0.4	0.4	0
	811 Salt marshes & salines	0.2	0.2	0.2	0.2	0.2	0.2
	922 Artificial standing water bodies	0.8	0.8	0.8	0.8	0.8	0.8
Non-forest natural vegetation and water bodies	521 Sclerophyllous vegetation	0	0	0	0	0	0
	421 Natural grassland prevailingly with trees and scrubs, 422 Natural grasslands without trees and scrubs, 420 Natural grassland, 511 Moors and heathland, 500 Heathland, 611 Sparsely vegetated areas, 621 Beaches, dunes, sands, 622 Bare rocks, burnt areas, glaciers and perpetual snow, 700 Wetland, 711 Inland freshwater marshes, 712 Inland saline marshes, 721 Peat bogs, 722 Unexploited peat bog, 812 Intertidal flats, 821 Coastal lagoons, 822 Estuaries, 889 Natural coastal ecosystems, 912 Separated water bodies belonging to the river system (dead side-arms, flood ponds), 991 Marine (other)	0	0	0	0	0	0

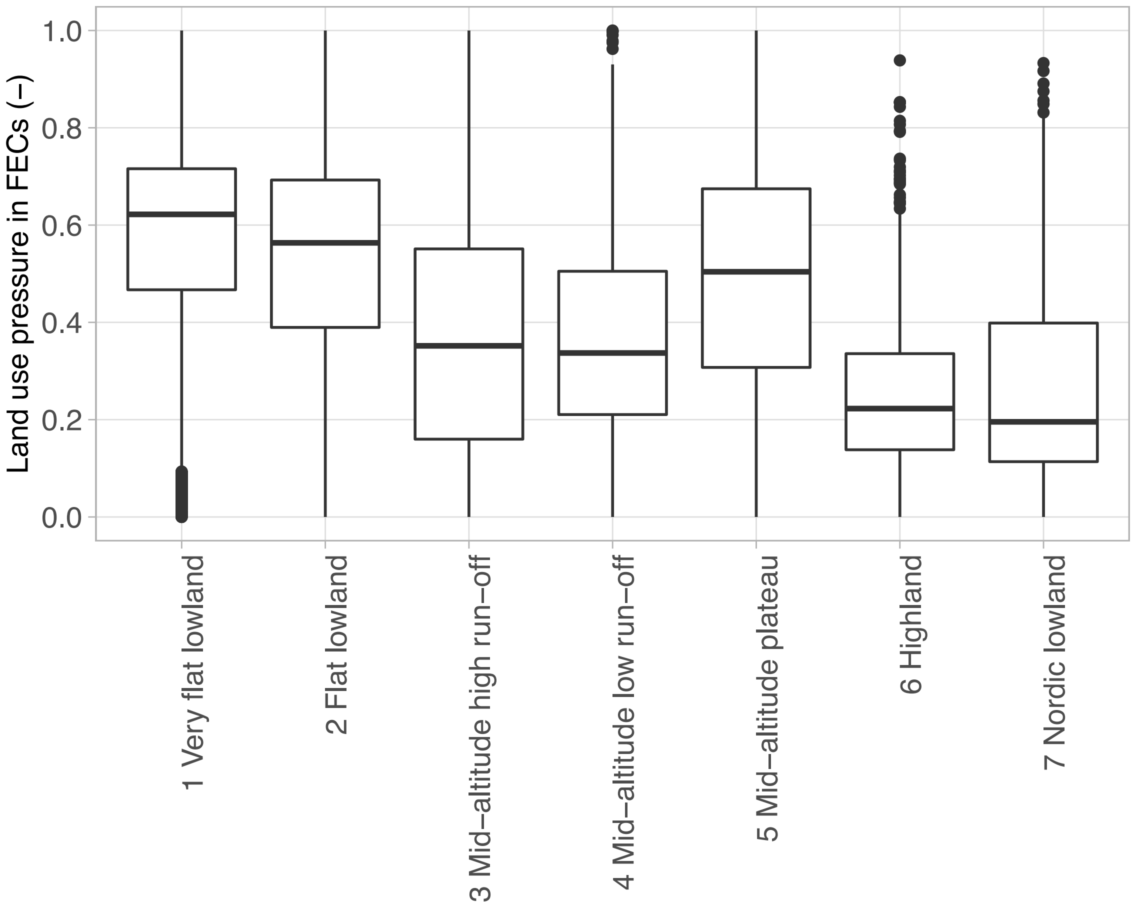
Note: Land use pressure values were assigned to the Copernicus Riparian Zone LC/LU MAES level 3 land use classes for the different floodplain types and depending on whether pure coniferous forests are the dominant potential natural vegetation.

Indicator assessment results

The median land use pressure per FEC is 0.54 but floodplain types strongly differ. These differences between types are reasonable and clearly reflect the general land use pressure in the different landscapes (Figure 5.2): land use pressure is lowest in Type 7 Nordic lowland floodplains (0.20) and Type 6 Highland floodplains (0.22), moderate in the mid-altitude mountain floodplains of Type 4 (0.34) and Type 3 (0.35), higher in the more intensively used mid-altitude plateau Type 5 (0.50), and highest in the intensively used Type 2 (0.56) and Type 1 (0.62) floodplains.

Compared to the indicator 'habitat area loss', differences between floodplain types are smaller, which is reasonable since the highest land use pressure of 1.0 only occurs if the floodplain is completely urbanized (which rarely occurs even in Type 1 'Very flat lowland' and Type 2 'Flat lowland floodplains'). On the other hand, natural floodplain habitats are completely lost in many FECs of Type 1 and Type 2, resulting in the maximum habitat area loss of 100 %. The typical land use in the floodplain types with the highest land use pressure (Type 1 and Type 2) corresponds to what has to be expected at the upper threshold of Class 2 (0.66), according to the normative description given in Table 5.1: intensive agriculture and managed grassland are dominant, with larger patches of urban areas, some small forest patches and only remnants of natural vegetation. Given this mix of land uses, it seems likely that floodplain topography has been substantially to severely changed, with most small local differences in height and substrate conditions and related microhabitats being lost.

Figure 4.2: Median and range of land use pressure in the different floodplain types

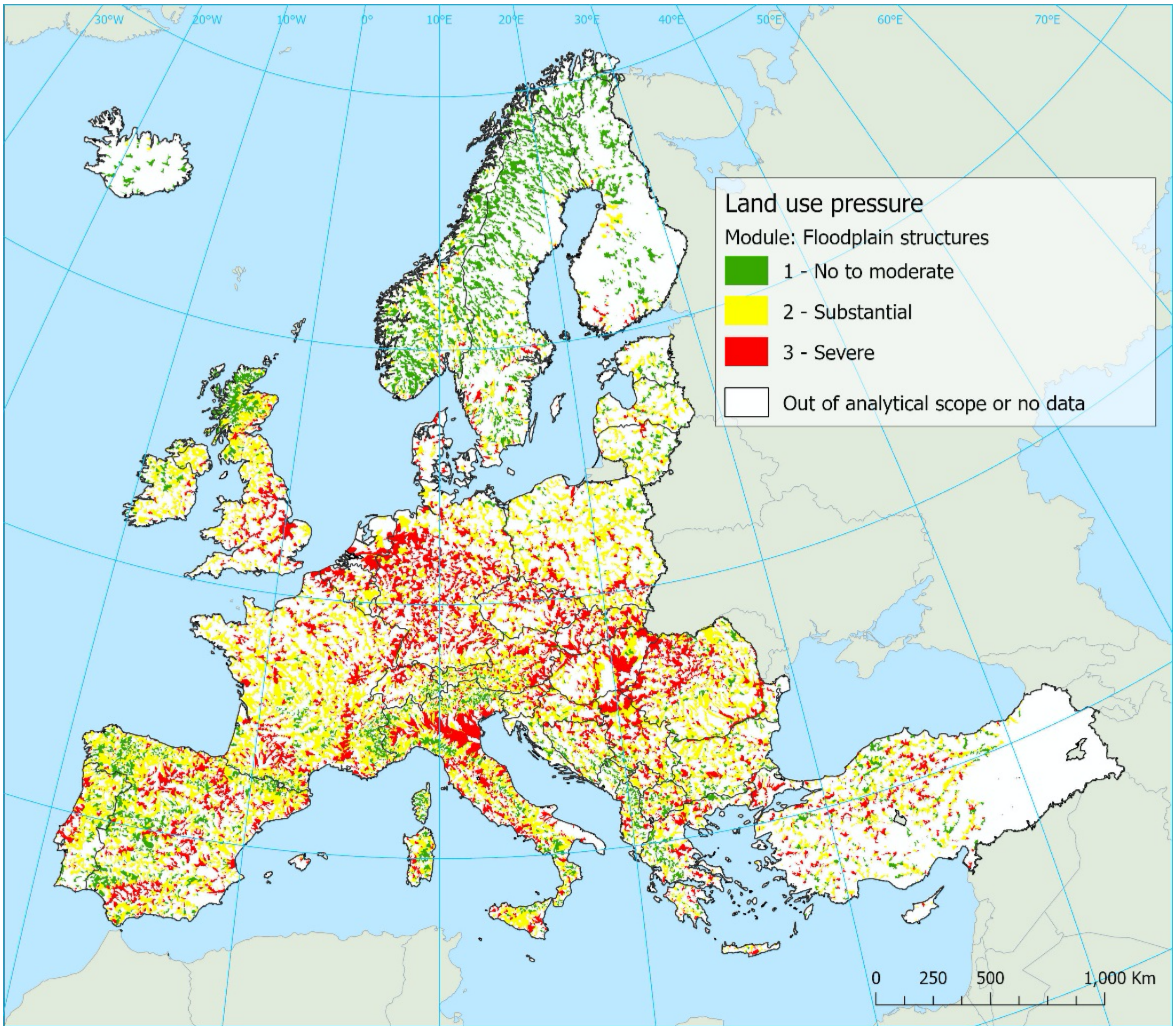


Most of the FECs (46 %) have land use pressure values ranging from 0.33 to 0.66 and, hence, fall in Class 2. Compared to the indicator 'habitat area loss' (60 %), less FECs (29 %) are severely degraded in respect to land use pressure (Class 3) and they mainly occur in Central Europe (Central Plains and Central Highlands, Map 4.2).

In these ecoregions, habitat area loss is high (> 66 %) and the natural habitats have obviously been replaced by land uses with a high land use pressure, resulting in large land use pressure values (> 0.66). In contrast, there are other regions like the Western Highlands, where habitat area loss is also high (> 66 %) but land use pressure is lower (mainly 0.33–0.66).

These results indicate that although the assessment results of the two indicators 'habitat area loss' and 'land use pressure' was based on the same land use data, and therefore potentially correlated, the two indicators provide different and complementary information. This is also reflected by the increase in the variability of land use pressure values with increasing habitat area loss: in FECs where a large part of the natural floodplain habitats are lost, they may have been replaced by land uses with a very different land use pressure (e.g. either by urban areas or managed grassland). This can result in a large variability of land use pressure values, which is an important information besides habitat area loss. At the same time, only looking at land use pressure might give a wrong impression on floodplain habitat conditions since a low land use pressure can result from very different combinations of land uses, even if typical floodplain habitats are absent. Therefore, it's only the combination of the two indicators 'habitat area loss' and 'land use pressure' that provides the full picture.

Map 4.2: Spatial distribution of FECs with different land use pressure across Europe



4.3.3 Floodplain features

Indicator description

The indicator 'floodplain features' directly measures and assesses the type and extent of large distinct natural fluvial floodplain features. The extent of oxbow lakes, bars and wetlands in the floodplain are compared to floodplain type-specific natural reference conditions.

For the assessment of the fluvial floodplain features of the FECs belonging to one floodplain type, no information was available on the specific channel pattern of the FECs. Therefore, it was not possible to assign each FEC to one specific channel pattern. Alternatively, we assumed that any of the channel patterns typical for a floodplain type can potentially occur. As a consequence, FECs were assigned to Class 1 in case any of the thresholds of the floodplain type was passed. For example, FECs of Type 1 'Very flat lowland floodplains' were assigned to Class 1 if the percentage cover of oxbow lakes was > 0.5 % or wetlands > 12 % or bars and dunes > 10 %. This gave reasonable results since it is very unlikely that the floodplain features occur at such a high percentage cover due to anthropogenic degradation.

Indicator quantification

Copernicus RZ LC/LU MAES level 3 land use data were used. MAES level 3 land use classes were identified to represent specific fluvial floodplain features based on the feature names, information in the EEA nomenclature guideline (2015) and visual inspection in GIS (Table 4.4). The percentage cover of each fluvial floodplain feature in the floodplain was quantified for all FECs.

Table 4.4 MAES level 3 land use classes corresponding to fluvial floodplain features

MAES level 3 land use class name	MAES level 3 code	Floodplain feature
Separated water bodies belonging to the river system	912	Oxbow lakes
Beaches, dunes, sands	621	Bars
Inland freshwater marshes	711	Wetlands
Wetlands	700	Wetlands

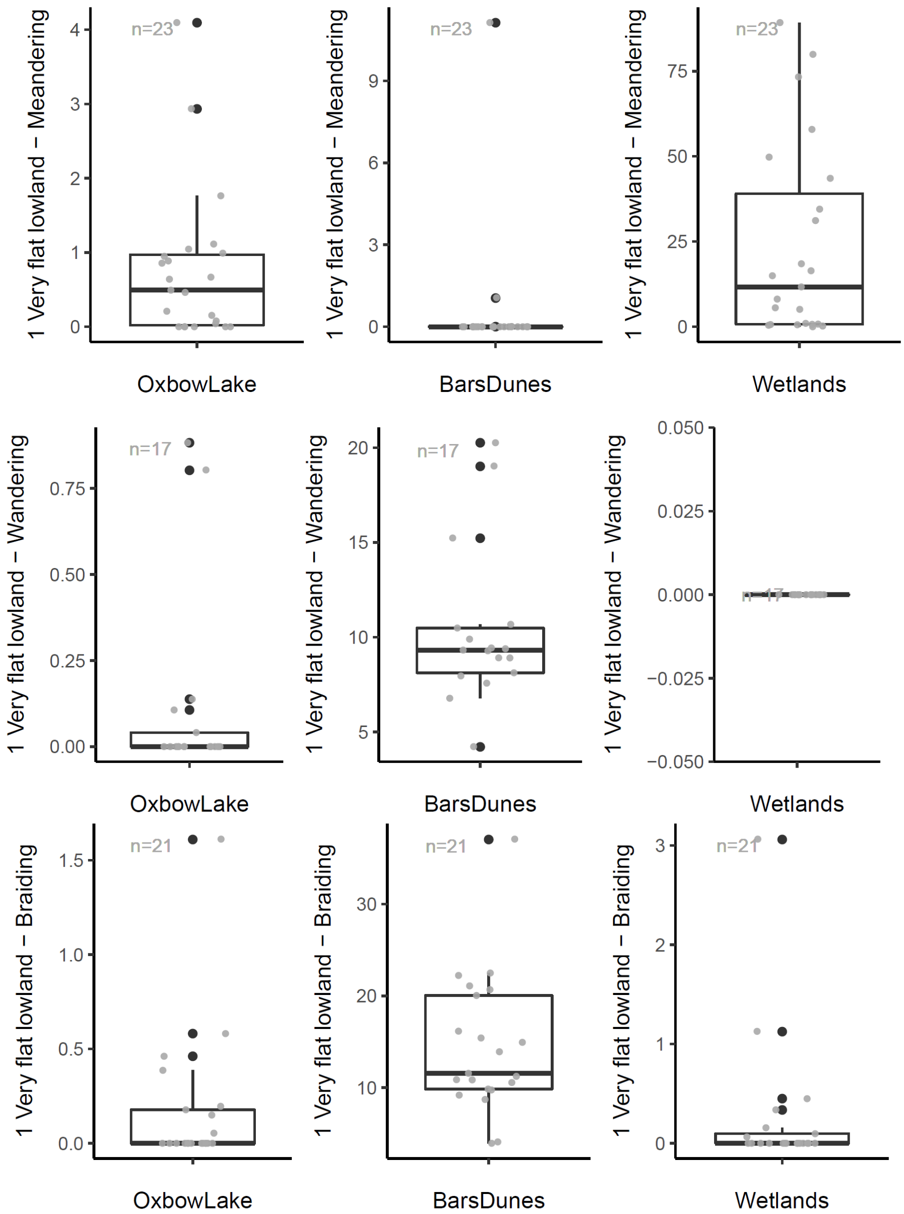
As already described in detail in Section 3.5, the most natural FECs were pre-selected using a data-driven approach and visually checked to identify a number of least-disturbed FECs for each floodplain type. Different channel patterns naturally occur in the single floodplain types, and the least-disturbed FECs of each floodplain type were grouped according to five general channel patterns (confined single-thread, braiding, meandering, sinuous, wandering). For each channel pattern in each floodplain type, the median percentage cover of the fluvial floodplain features in the floodplain was calculated and displayed in box plots (floodplain Type 1 given as example in Figure 4.3).

For each floodplain type, typical fluvial floodplain features were identified, based on the box plots and expert knowledge. In the example on floodplain Type 1 given in Figure 4.3, oxbow lakes and wetlands typically occur in FECs with a meandering channel pattern, whereas bars and dunes were typical floodplain features of FECs with a wandering and braiding pattern. The median values of these typical fluvial floodplain features in the least-disturbed FECs were used as thresholds for the floodplain type specific reference conditions. FECs where the percentage cover of one of the typical fluvial floodplain features passes the respective threshold were assigned to Class 1. Here, at least one of the typical floodplain features occurs to an extent comparable to what can be expected under natural to moderately disturbed conditions (Table 4.1, Table 4.5).

For values below the Class 1 threshold, we did not further distinguish between Class 2 and Class 3 for two reasons: First, the range of values was too small to separate two classes which clearly differ (conditions in the FECs below the threshold were too similar to distinguish between substantially and severely degraded conditions). Second, the assessment results for the indicator 'floodplain features' were finally used to upgrade the assessment of the land use pressure indicator in case the Class 1 threshold was passed to come to an assessment of the module 'floodplain structures' and, hence, a further distinction between Class 2 and Class 3 was not needed (see Section 4.3.4 for more details).

It is important to note that the threshold values for Class 1 do not necessarily correspond to the typical extent of the fluvial floodplain features in the field but rather reflect the typical percentage cover given the resolution of the Copernicus Riparian Zone LCLU MAES level 3 land use data, i.e. they can only be applied to this specific land use dataset. For example, the meandering channel pattern frequently occurs in floodplain Type 2 'Flat lowland floodplains'. However, the oxbow lakes are too small to be mapped and included in the land use dataset and, hence, cannot be used for assessing the naturalness of fluvial floodplain features in this specific floodplain type. Furthermore, none of the fluvial floodplain features can naturally develop in floodplains of confined rivers (see also Section 4.4.2 and 4.4.3) and, hence, Type 6 'Highland floodplains' cannot be assessed since only the confined channel pattern occurs in this floodplain type.

Figure 4.3: Percentage cover of the three different fluvial floodplain features in the floodplain of the least-disturbed FECs



Note: Example for floodplain Type 1 'Very flat lowland floodplains' is given where the three different channel patterns meandering, wandering and braiding naturally occur.

Table 4.5 Floodplain type-specific thresholds for fluvial floodplain features

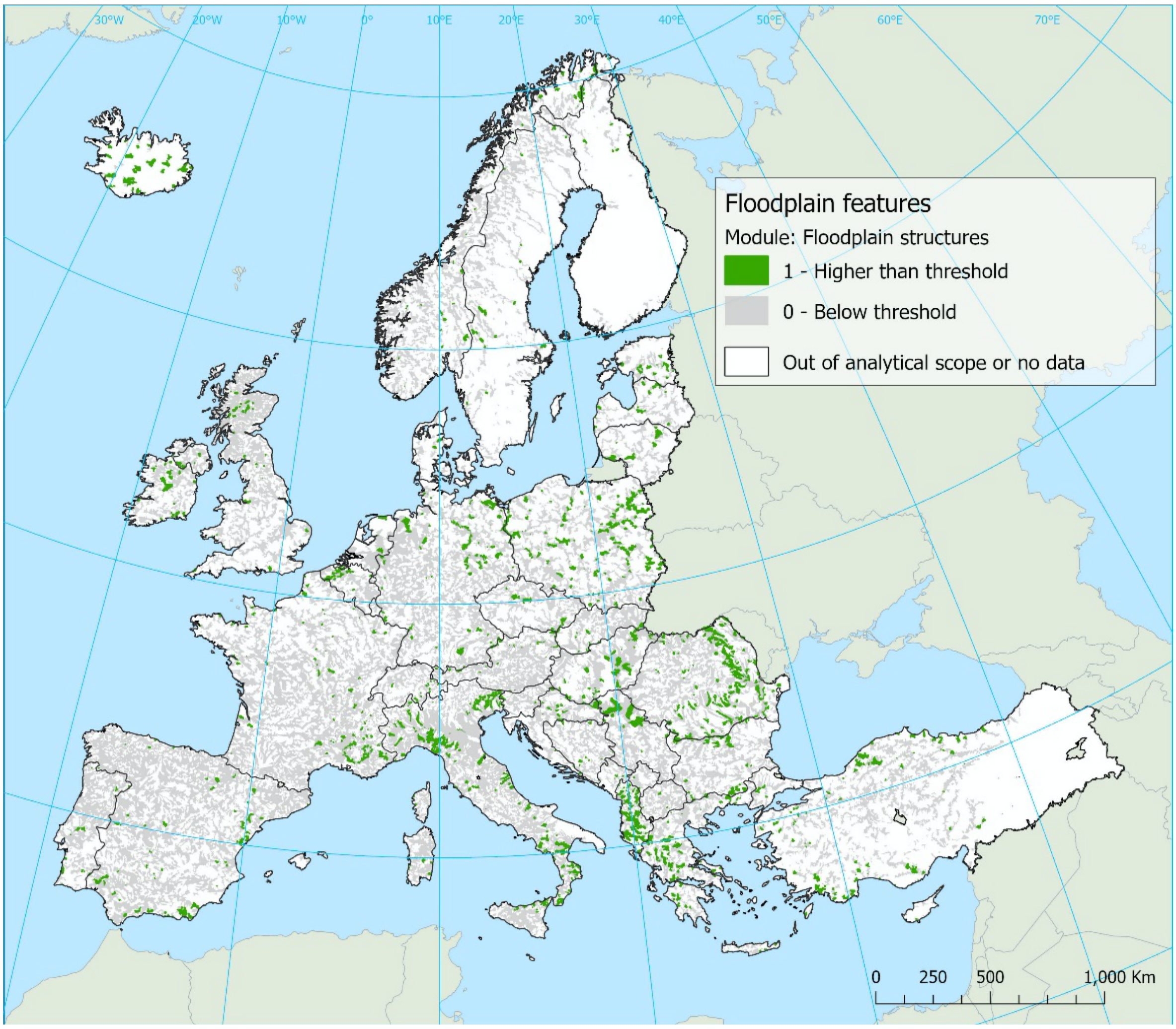
Floodplain type	Channel pattern	Floodplain feature	Class 1 threshold (% cover)
1 Very flat lowland	Meandering	Oxbow lakes	> 0.5
		Wetlands	> 12
	Wandering	Bars and dunes	> 10
	Braiding	Bars and dunes	> 12
2 Flat lowland	Wandering	Bars and dunes	> 4
	Braiding	Bars and dunes	> 11
3 Mid-altitude high run-off	Wandering to braiding	Bars and dunes	> 4
4 Mid-altitude low run-off	Wandering to braiding	Bars and dunes	> 18
5 Mid-altitude plateau	Wandering to braiding	Bars and dunes	> 27
6 Highland	Confined	*None of the floodplain features occurs naturally.*	
7 Nordic lowland	Sinuous	*Floodplain features too small to be mapped in MAES land use dataset.*	

Note: The "Class 1 threshold (% cover)" field presents the percentage cover of the respective land use class in the flood-prone area.

Indicator assessment results

Out of the 36 888 FECs included in the analysis, only 2 329 or 6.3 % passed the floodplain type-specific thresholds and, hence, at least one of the fluvial floodplain features occurs to an extent comparable to the least-disturbed conditions. Most of these FECs had a high percentage cover of bars and dunes but about 25 % (n = 607) passed the threshold for oxbow lakes and about 15 % (n = 357) the wetland threshold. The plausibility check revealed that there are some misclassifications like dry sediments of reservoirs being mapped as bars and dunes, but most of these fluvial floodplain features were natural. When considering that floodplain features might also be absent naturally (see Section 2.1.2) and smaller features were not mapped and did not appear in the land use dataset, the number of FECs in Class 1 (Figure 4.4) is extremely low, indicating that European floodplains are severely degraded in respect to the presence of large-scale floodplain features (Map 4.3).

Map 4.3 Spatial distribution of the FECs with any of the fluvial floodplain features (oxbow lakes, wetlands, bars and dunes) occurring to an extent comparable to least-disturbed conditions



Note: FECs are only partly shown. Border of the floodplain is symbolized as a white line, percentage cover of oxbow lakes and bars/ dunes in whole FEC is 1.1 % and 11.8 %, respectively. Other FECs in Class 1 are more degraded.

Figure 4.4: Examples of the most natural FECs in Class 1 of Type 1 Very flat lowland floodplains with a meandering (left) and braiding (right) channel pattern

Source: Google Maps (2020)

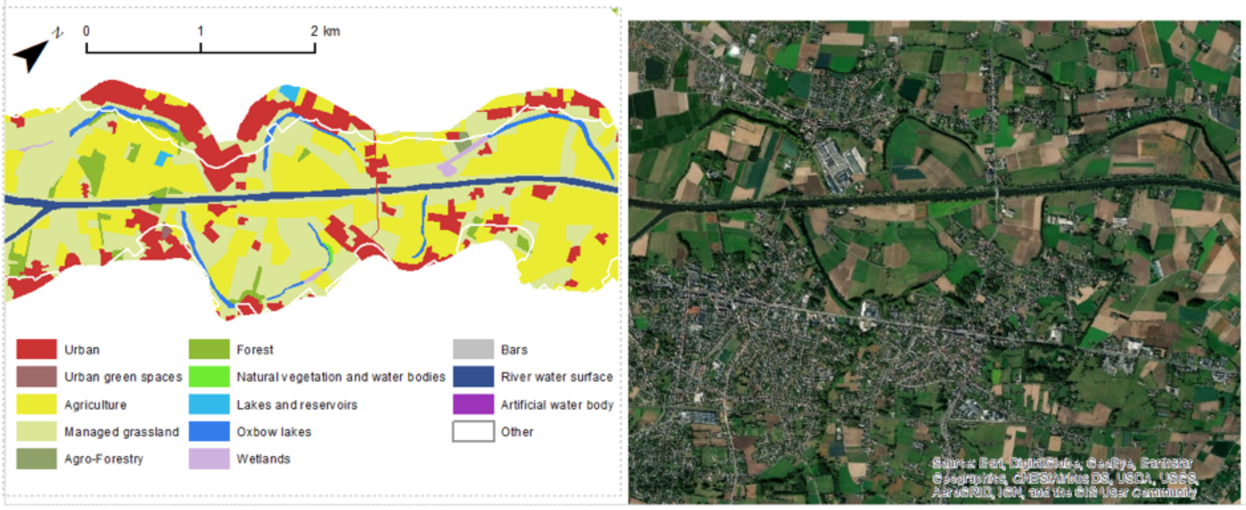
4.3.4 Floodplain structures: module assessment

For an assessment of the module 'floodplain structures', the assessment results of the two indicators 'land use pressure' and 'floodplain features' were combined.

Although FECs within each floodplain type are similar in respect to factors governing the formation of floodplains (see Section 3.2), there is still some variability among FECs in respect to the natural extent of floodplain features like oxbow lakes and bars. For example, the valley floor of FECs of Type 1 'Very flat lowland floodplains' might be somewhat narrower, limiting the formation of large meanders, meander cut-offs and oxbow lakes. At the same time, sediment load might naturally be lower due to differences in geology, limiting the occurrence of braiding channel patterns and large braid bars. For this reason, while the presence of the floodplain features clearly indicates naturalness of floodplain forms/ habitats, it is not necessarily an indicator of floodplain degradation if they are absent.

Therefore, the two indicators were not combined by calculating the mean value, but the indicator 'floodplain features' was used to upgrade the assessment of the land use pressure indicator in case the type-specific floodplain features were present to an extent comparable to natural or to moderately disturbed conditions. If a FEC did fall in Class 1 for the indicator 'floodplain features', the land use pressure assessment was upgraded by one class (Figure 4.5). For example, if the 'floodplain features' indicator was in Class 1 and the 'land use pressure' indicator in Class 3, this resulted in a final assessment of floodplain forms in Class 2. In more than half of the 2 329 FECs, for which the 'floodplain features' indicator was in Class 1, there was an upgrading of the land use pressure assessment since this was in Class 2 or Class 3. In the other FECs, the land use pressure indicator was not upgraded since it already was in Class 1. The results are shown in Map 4.4.

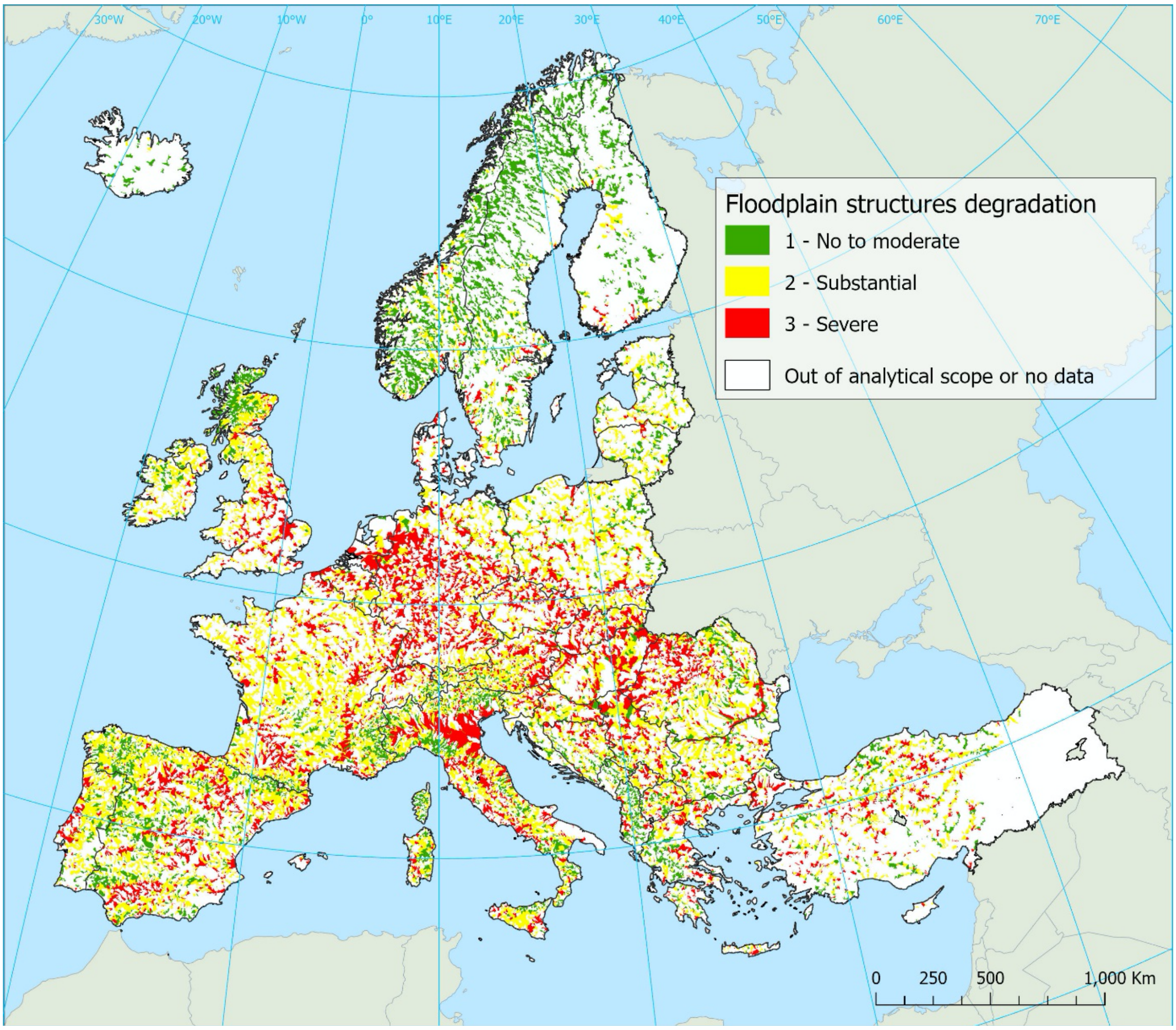
Figure 4.5: Example for a FEC with the indicator land use pressure in Class 3 upgraded to Class 2



Source: Left map**:** CLMS (2019); right map: Google Maps (2020)

Note: In the assessment of floodplain structures, FECs with the indicator land use pressure in Class 3 are upgraded to Class 2 due to the presence of oxbow lakes and indicator floodplain features in Class 1.

Map 4.4: Spatial distribution of the FECs with different structures condition classes across Europe



4.4 Floodplain processes

Processes determine structural and functional elements of river floodplains. They are driven by erosion, transportation and deposition of sediments, physical connectivity of channels, floodplain topography and subsurface exchange of water. The floodplain is flooded when water flow (discharge) exceeds river bankfull capacity. In the absence of engineering interventions, the river banks are eroded due to increased friction at high water flow. Consequently, the river's efficiency to transport material is reduced and results in the increased levels of sediment deposition. The deposited load on the floodplain is known as alluvium. Dynamics for channel and floodplain formations are therefore characterised by flow of sediment and high-water flows.

Water is constantly exchanged between the river and the floodplain even in periods when there are no floods. It is a subsurface water exchange between the river channel and floodplain groundwater, which is important especially in periods of low water flows. Floodplain groundwater is an important ecological factor for floodplain habitats.

We selected three indicators to assess the degradation of processes that sustain floodplain habitats:

- base flow and groundwater alteration;
- channel- and floodplain forming discharge alteration;
- sediment transport alteration by dams.

4.4.1 Base flow and groundwater alteration

Indicator description

In natural river-floodplain systems, there is a permanent exchange between streamflow and floodplain groundwater, which in turn has important consequences for floodplain vegetation (Poff et al., 1997; Shafroth et al. 1998; Tockner et al., 2000; Ward et al., 2002). Flow in the channel, if higher than base flow, recharges floodplain groundwater and side arm channels. When the floodplain groundwater level is higher than streamflow level, water from the floodplain aquifers flows into the river and contributes to the base flow. The exchange of water between streamflow and floodplain groundwater depends on the water level in the river channel, the topography of river channels, the permeability of channel banks and the hydrogeological characteristics of floodplain sediments. At larger streamflow, the water level in the channel is higher, increasing the exchange of water and soil wetness, and as such improves the ecological conditions of the floodplain.

Streamflow in general, and base flow, depend on climatic and physiographic characteristics of the catchment. The most important climate driver is precipitation, whereas catchment geology, soil, topography, and vegetation (land cover) are among the most important physiographic characteristics of a catchment that affect base flow (Beck et al., 2013). Both, vegetation changes and human water uses can alter the base flow. Loss of large forest areas are in fact often linked with increased run-off as evapotranspiration drops and human abstractions and diversions of water can substantially alter stream flow. We used the Base Flow Index alteration (BFA) as a proxy indicator for base flow and groundwater alteration. It is the ratio of long-term mean Base Flow Index to total streamflow (i.e. annual average flow). It is calculated from daily run-off at each FEC (substitute for discharge) for a selected period of time for two, disturbed and undisturbed, water and land use scenarios.

Indicator quantification

The BFA was quantified for each FEC as described in Panagopoulos et al. (2019). The global hydrologic model PCR-GLOBWB was used for the simulation of daily run-off, presenting river flows (discharges) in Europe for two scenarios under the same climate: a) the present situation (anthropogenic), and b) for the situation under Least Disturbed Conditions (LDC). In the LDC scenario, no water use, irrigation, abstractions, industry or water reservoir management was considered, and only natural surface water bodies were included. Both LDC and the anthropogenic scenario were projected with the climate of the period 2001–2010. Thus, differences in the two scenario outcomes are attributed only to water use, irrigation and reservoir management. The Base Flow Index (BFI) was calculated with the Indicators of Hydrologic Alterations (IHA) software (The Nature Conservancy, 2009):

$$\mathrm{BFI} = \frac{\mathrm{Q_{baseflow}}}{\mathrm{MeanAnnualFlow}}\text{, where}$$

$Q_{baseflow}$: Average of annual 7-day minimum flows in a period defined as flows less than or equal to the 50-percentile of daily flows;
$M_{ean}A_{nnual}F_{low}$: Mean Annual Flow (MAF) calculated as the mean of the annual river flows.

The ratio of the BFI calculated for the LDC and the anthropogenic scenario represents the BFA. If the ratio is equal to 1, there is no alteration of this indicator due to anthropogenic pressures. If the ratio is very low (e.g. lower than 0.10) or very high (e.g. higher than 1.90), the alteration is severe. For our purposes, we normalized the BFA values into the range from 0 to 100, with 'no alteration' having a BFA = 0 and increasing values indicating the increasing level of alteration (irrespective of the direction of alteration).

Indicator assessment results

The average BFA for the present situation in Europe is 9.7 (Table 4.6). Fifteen percent of FECs show no alteration of base flow. Fifty percent of FECs have BFA values lower than 1.2. Ninety percent of FECs have BFA values below 30.

The highest average BFA values were found for Type 1 'Very flat lowland floodplains' (mean BFA = 13.9) and Type 2 'Flat lowland floodplains' (mean BFA = 12.2). These types feature alluvial aquifers with significant groundwater-surface water exchange processes in the natural state; thus, alterations of base flow due to catchment water use have the highest impact. In addition, changes in annual run-offs (long term average flow) due to significant water use, urbanization and intensive agricultural production may generally be larger in large catchments than in medium or small catchments.

The two lowest base flow alterations were found in Type 7 'Nordic lowland floodplains' (mean BFA = 2.3) and Type 3 'Mid-altitude high run-off floodplains' (mean BFA = 4.7). Though the groundwater-surface water exchange is important in 'Nordic floodplains', water abstraction is low in comparison to water availability as shown by the water exploitation index for the Nordic countries (EEA, 2020b)[1]. The low base flow alteration in Type 3 'Mid-altitude high runoff floodplains' can be explained with their type-specific lower groundwater storage capacities and therefore generally weak groundwater-surface water exchange processes.

Table 4.6 Mean and selected percentile values of Base Flow Index alteration (BFA) by floodplain type

	Type 1	**Type 2**	**Type 3**	**Type 4**	**Type 5**	**Type 6**	**Type 7**	**All types**
				All FECs				
Mean	13.9	12.2	4.7	8	5.3	6.1	2.3	9.7
75th percentile	15.8	10.7	2.1	5.2	4.1	3.8	0.7	7.7
90th percentile	42.4	39.9	9.1	20.9	13.5	16.1	4.9	28.3
Least-disturbed FECs								
Mean	7.6	7.8	1.4	4.5	1.2	4.3	2.8	5.2
75th percentile	6.6	5.2	2.8	3.5	1	9.2	1.8	3.9
90th percentile	17.4	21.8	4.6	13.8	3.7	13.7	14.5	11.4
Natura 2000 habitat types (mean BFA values)								
6430([a])	11.7	8.9	3.8	5.3	4.0	6.2	1.7	7.5
6440([b])	7.7	6.9	1.8	2.2	0.5	1.4	-	6.9
6450([c])	9.6	1.3	0.2	1.3	0.5	0.3	3.0	0.4
91e0([d])	11.0	10.8	5.5	7.5	4.6	7.0	1.6	8.8
91f0([e])	10.7	9.7	9.7	8.1	4.9	-	-	10.1
mean BFA	10.1	7.5	4.2	4.9	2.9	3.7	2.1	6.7

Note: The table rows are separated by (1) all FECs, (2) least-disturbed FECs and (3) Natura 2000 habitat types.

([a]) Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels.
([b]) Alluvial meadows of river valleys of the Cnidion dubii.
([c]) Northern boreal alluvial meadow.
([d]) Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae).
([e]) Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (Ulmenion minoris).

[1] WEI in Nordic countries is not larger than 1 %, whereas in two continental European catchments (Elbe and Rhine) the water exploitation index is 16.6 % and 13.2 %, respectively.

The BFA values are much lower for floodplains in least-disturbed conditions (see Section 3.5.2) and for FECs featuring Natura 2000 floodplains-related habitats (which depend on high groundwater level; Table 4.6). As an example, the mean of BFA at least-disturbed Type 5 'Mid-altitude plateau floodplains' is only one fifth of the total average for this type. The BFA mean of floodplains with a high proportion of Natura 2000 floodplain-related habitats is only half of the total average for this type. Based on this analysis, we consider BFA values below 10 as an indication of existing groundwater-surface water exchange. The results also validate BFA as a proxy indicator for groundwater alterations caused by catchment water uses. Threshold values for the three alteration classes of alteration the mean BFA values at floodplains in least-disturbed conditions and the 75th percentile values of all FECs with BFA alterations (Table 4.7).

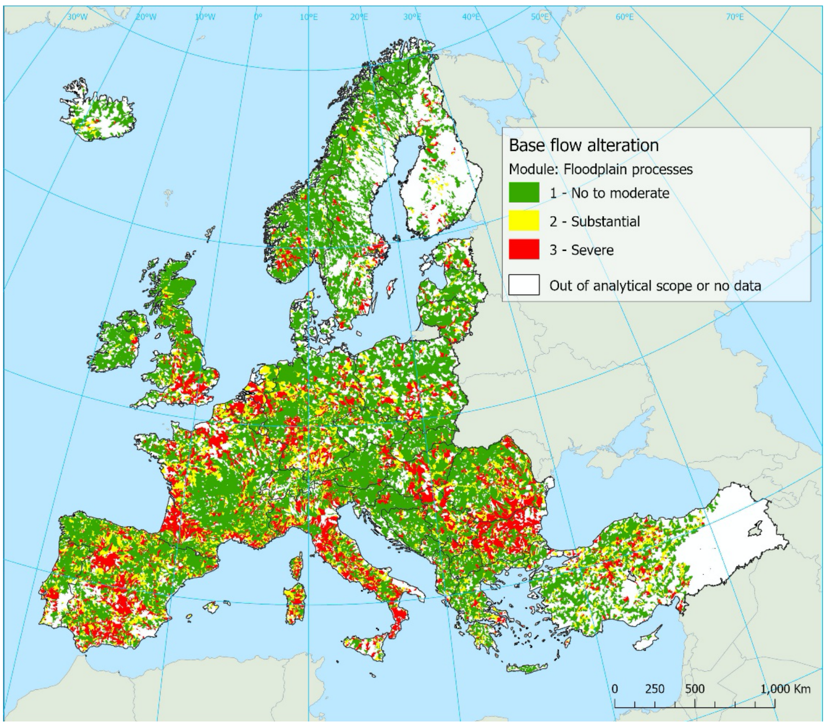
Table 4.7 Floodplain type-specific threshold values of the Base Flow Index alteration (BFA)

	Class 1 No to moderately degraded	Class 2 Substantially degraded	Class 3 Severely degraded
Types 1&2	≤ 8	> 8 to 20	> 20
Types 3&5	≤ 1	> 1 to 5	> 5
Type 4&6	≤ 5	> 5 to 10	> 10
Type 7	≤ 2	> 2 to 5	> 5

About one third of Europe's floodplains show significantly altered base flow (substantial alteration: 13.6 %; severe alteration: 17.7 %). Type 7 'Nordic low-land floodplains' are the least altered (15 % of FECs), while the Type 5 'Mid altitude plateau floodplains' are the most altered (57 % of FECs).

The occurrence of severe base flow alteration shows a distinct spatial distribution (Map 4.5): Pannonian lowlands (Burgenland in Austria, Central Hungary, Vojvodina in Serbia), lowlands in Romania and Bulgaria (river Danube, Kamchia, Maritsa/Evros), north-eastern Romania, the Wroclav area (Odra/Oder) and the Lodz region in Poland, Middle Bohemia in Czechia, Strasbourg-Mannheim area (Neckar, Rhine) and Brandenburg in Germany, south-western and western France (Aquitaine, Poitou-Charentes region, Seine), Walloon region in Belgium (Scheldt) and Meuse river in the Netherlands, south-east England, the Italian regions Emilia Romana, Toscana, Lazio (Rome), Campania and Calabria, the Spanish regions Castilla-La Mancha (Guadiana and Tajo/Tagus) and Andalusia (Guadalquivir), and the Alentejo region in Portugal.

Map 4.5: Spatial distribution of FECs with different base flow alteration across Europe



4.4.2 Channel- and floodplain-forming river discharge alteration

Indicator description

If there are dams on a river, the water is temporarily stored and released following management schedules of dam operations. Accordingly, the magnitudes, timing, frequency, and duration of flow are changed downstream. Hydrographs (a graph showing the rate of river flow in time - discharge at a specific river location) become more uniform and usually have lower and fewer peak flows, as water is collected in reservoirs. Consequently, there are fewer events when water moves sediments in the channel, initiates inflows to secondary channels or, when discharging higher than bankfull, water then inundates the floodplains. We call such discharges ‘channel- and floodplain-forming discharges’ and characterise them as high discharges. In a hydrological sense, these discharges are usually higher than the mean annual flow. We assume that morphologically less degraded floodplains also correspond to lower alterations of higher discharges caused by the damming of water in the catchment. The frequency, duration, and magnitude of floods and therefore flooding have traditionally been reduced by constructions of dams upstream with the purpose to ‘catch’ and ‘store’ water at high flow peaks. Since flood hazard in Europe was significantly reduced downstream of dams constructed in Europe in the last century, a large share of floodplains has been converted to urban and agricultural land. Where the conversion was not so severe, typical floodplain habitats and forms still exist at present.

Indicator quantification

The proxy indicator for alteration of channel- and floodplain-forming discharges by dams in the catchment is the Degree of Flow Regulation (DFR). It is assigned to all main drains as a weighted average of the Degree of Regulation Index (DOR) of river sections forming them. DOR values were calculated by Grill et al. (2019) as:

$$\mathrm{DOR}_j = 100 \times \frac{\sum_{i=1}^{n} \mathrm{svol}_i}{d_{\mathrm{vol}}}$$

, where

DOR_j: degree of water flow regulation index at river reach j;
$svol_i$: storage volume of any reservoir;
i: upstream of river reach j;
n: the total number of reservoirs upstream of river reach j;
d_{vol}: natural average discharge volume per year at river reach j.

The underlying assumption is that a large reservoir with low annual discharge will generally have a larger regulatory effect on the natural river flow regime than a small reservoir with higher flow rates. If there are dams with multi-year reservoirs in the catchment (i.e. water stays in the reservoir for more than a year before it is released), DOR is set to a maximum of 100.

Reservoir storage capacities and river network used for determination of DOR in the study by Grill et al. (2019) were taken from the GOODD database (Mulligan et al., 2020). The calculation of DOR has not taken into account any river typology.

For the purpose to quantify the degree of flow regulation indicator for each FEC, we filtered river and stream reaches lying on main drains and averaged their DOR values. The result is one DFR value for each FEC. DFR values were calculated for 64 363 FECs in the range from 0 to 100, where 0 corresponds to no, and 100 to full flow regulation by dams upstream.

The three condition classes of DFR, which are used as a proxy indicator for the severity of channel- and floodplain-forming discharge alterations, were defined floodplain type-specific. The DFR threshold between Class 1 and Class 2 was defined in relation to DFR values of floodplains in a least-disturbed condition (see Section 3.5.2), excluding least-disturbed FECs of floodplain types with a confined single-thread pattern[3]. In non-confined least-disturbed floodplain FECs, the high flow is still able to sustain channel and floodplain forms to a certain degree. We thus assume that these floodplains show lower DFR values. This assumption was validated by comparing the mean DFR values at all FECs with the mean of DFR values of least-disturbed FECs (Table 4.8). When only FECs with positive DFR values are compared (i.e. excluding FECs with DFR = 0), the mean DOFR values of least-disturbed FECs fall below the mean DOR values of all FECs in each floodplain type.

We selected the floodplain type-specific mean DFR values of least-disturbed FECs as the upper Class 2 threshold, demarking the boundary between moderately and substantially degraded floodplains for the Degree of Regulation Index (see Table 4.1). The lower Class 2 threshold (demarking the boundary between substantially and severely degraded floodplains) was selected based on the type-specific mean DFR values including all FECs of a type. In both cases, we combined types with similar threshold values and equalled the threshold values (Table 4.9).

Table 4.8 Mean and selected percentile values of Degree of Flow Regulation (DFR) by floodplain type

	Type 1	Type 2	Type 3	Type 4		Type 5	Type 6	Type 7	All types
	All FECs								
Mean	8.2	6.2	3.6	4.5		8.9	3.6	3.1	6.3
75th percentile	6.8	0.0	0.0	0.0		0.5	0.0	0.0	6.8
90th percentile	22.8	18.1	7.3	4.7		34.3	1.9	0.0	22.8
	FECs with DOR > 0								
Percentage of all FECs	91 %	32 %	16 %	15 %		35 %	12 %	10 %	25 %
Mean	17.2	25.5	26.7	35.4		34.2	32.7	34.0	25.5
	Least-disturbed FECs(a)								
Mean	4.6	7.0	9.7	2.9		0.6	0.0	0.6	5.6
	Least-disturbed FECs with DFR > 0								
Mean	7.7	12.3	14.9	22.0		12.0	-	9.1(b)	13.2

Note: The table rows are separated by (1) all FECs, (2) FECs with DFR > 0, (3) least-disturbed FECs and (4) least-disturbed FECs with DFR > 0.

(a) Excluding FECs with 'confined single-thread pattern.
(b) Only one single FEC.

Table 4.9 Floodplain type-specific threshold values of the Degree of Flow Regulation (DFR)

	Class 1 No to moderately degraded	Class 2 Substantially degraded	Class 3 Severely degraded
Types 1&2	≤ 5	> 5 to 10	> 10
Types 3,6,7	≤ 1	> 1 to 5	> 5
Type 4	≤ 3	> 3 to 5	> 5
Type 5	≤ 1	> 1 to 10	> 10

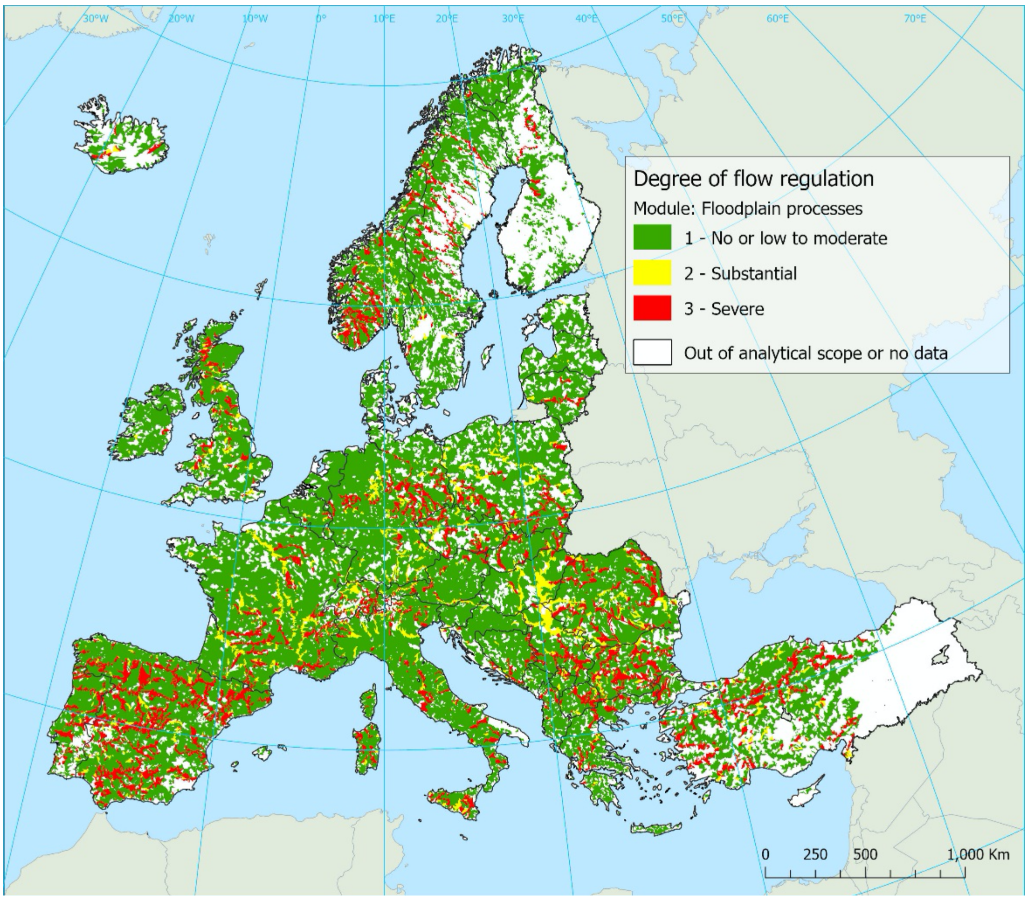
[3] This type of channel pattern is not relevant for defining type-specific thresholds, as floodplains are not formed at high flow due to confinement.

Indicator assessment results
The average DFR for all FECs is 6.3 (scale from 0 to 100; Table 4.8). The highest value of DOR occur at Type 5 ‘Mid-altitude plateau floodplains’ and Type 1 ‘Very flat lowland floodplains’ (8.9 and 8.2, respectively). This average is rather low due to the fact that 75 % of the FECs show DOR = 0, leaving one quarter of FECs with channel- and floodplain-forming discharge alterations due to dam operations. Amongst these, almost all Type 1 ‘Very flat lowland floodplains’ (91 %) experience flow alteration by dams, while this is true for only one third of Type 2 ‘Flat lowland floodplains’ and Type 5 ‘Mid-altitude plateau floodplains’. In other floodplain types, the percentage of altered FECs is between 10 % and 16 %, though the degree of alteration at those sites is high (31 % on average) compared to Type 1 ‘Very flat lowland floodplains’ (17 % on average).

With almost 20 % of floodplains being substantially altered, Type 1 ‘Very flat lowland floodplains’ show the largest share of channel- and floodplain-forming discharge alteration, followed by Type 5 ‘Mid-altitude plateau floodplains’ (16 % substantially altered). In contrast, mid-altitude, highland and Nordic floodplains all feature no to moderate discharge alterations for > 83 % of floodplains.

Channel- and floodplain-forming discharges are severely altered at Type 1 ‘Very flat lowland floodplains’ of Wisla, San, Varta and Odra in Poland, Labe and Vlatva in Czechia, Elbe (Labe), Saale and Spree in Germany, Danube tributaries in Austria (Morava), Hungary (Vah, Tamiš), Western Balkans (Drina and Velika Morava) and Romania (Jiu, Olt, Arges, Siret, Prut). Discharges are substantially altered along the Danube and Tisza. In Bulgaria and Greece, the most altered river is Maritsa and its tributary Ergene. In France, high water flow is substantially altered in the floodplains of the Marne, Yonne and Seine in the western part and in two tributaries of the Garonne (Dordogne and Olt). Substantially altered are also Type 2 ‘Flat lowland floodplains’ and Type 5 ‘Mid-altitude plateau floodplains’ in Spain: Ebro, Guadiana, Guadalquivir, Tagus and Douro with two tributaries (Esla and Pisuerga) (Map 4.6).

Map 4.6: Spatial distribution of FECs with different channel- and floodplain-forming discharge alteration across Europe indicated by the Degree of Flow Regulation (DFR)



4.4.3 Sediment flow alteration

Indicator description

Sediment flow is a key driver for the process of sediment dynamics in rivers and floodplains. Dams capture large amounts of sediments in their reservoirs and can trigger a cascade of impacts on fluvio-morphological dynamics far downstream. The 'Sediment Trapping Index' (SED) (Grill et al. 2019) is a proxy of dam impacts on the longitudinal sediment flows in river networks. The SED quantifies the proportion of potential sediment load trapped by dams at any given point in the river system. It focuses on suspended loads and provides a lower-bound estimate for dam impacts on river sediment budgets. Sediment trapping of 30 % or more is likely to negatively impact on aquatic ecosystems.

Based on preliminary analysis comparing the occurrence of bars and/or dunes across FECs with (SED > 0) and without (SED = 0) sediment trapping, we found on average fewer occurrences of these features in floodplains with SED > 0. This difference was largest for Type 3 'Mid-altitude high-runoff floodplains' and lowest for Type 2 'Flat lowland floodplains'. For Type 6 'Highland floodplains', the sediment trapping index did not influence the occurrence of bars, presumably caused by the generally high sediment supply irrespective of damming effects. This finding supports the assumption that SED is directly related to the floodplain forms.

Indicator quantification

Grill et al. (2019) used a high-resolution erosion map as a proxy to calculate sediment supply to rivers. Based on a routing model, the Potential Sediment Load (PSL) was quantified for each river reach in a river system, accounting for both natural and artificial sediment trapping in lakes and reservoirs by multiplying the PSL with the respective trapping efficiencies. The PSL was calculated in a recursive process from upstream to downstream reaches. Then the Modified Sediment Load (MSL) was calculated, which represents the sediment load after trapping in reservoirs, using a recursive upstream-to-downstream approach. For this purpose, the trapping sediment efficiencies for lakes and reservoirs were calculated using (1) local residence time change at each river reach, (2) total storage capacity of all lakes and/or reservoirs at a reach and (3) the discharge at the mouth of each reach. The SED in Grill et al. (2019) was calculated as:

$$\mathrm{SED}_j = \frac{\mathrm{PSL}_j - \mathrm{MSL}_j}{\mathrm{PSL}_j} \times 100$$

, where

SEDj: sediment trapping index at river reach j,
PSLj: potential sediment load at river reach j,
MSLj: modified sediment load at river reach j.

The Sediment Trapping Index was calculated for all river and stream reaches in the GOODD database not taking into account any river typology.

For the purpose to quantify the Sediment Flow Alteration (SEA) indicator for each FEC, we filtered river and stream reaches lying on main drains and averaged their Sediment Trapping Index. The result is one SEA value for each FEC. SEA values were calculated for 64 363 FECs in the range from 0 to 100, where 0 corresponds to no, and 100 to complete trapping of sediments by dams upstream.

The three condition classes of SEA were defined floodplain type specific. The SEA threshold between Class 1 and Class 2 was defined in relation to the SEA values of floodplains in least-disturbed conditions (Table 5.10). We selected the floodplain type-specific mean SEA values of least-disturbed FECs as the upper Class 2 threshold, demarking the boundary between moderately and substantially degraded floodplains for the Sediment Trapping Index (see Table 4.1). The lower Class 2 threshold (demarking the boundary between substantially and severely degraded floodplains) was selected based on the type-specific mean SEA values including all FECs of a type. In both cases, we combined types with similar threshold values and equalled the threshold values (Table 4.11).

Table 4.10 Mean and selected percentile values of the Sediment Flow Alteration (SEA) by floodplain type, separated between (1) all FECs, (2) FECs with SEA > 0, (3) least-disturbed FECs and (4) least-disturbed FECs with SEA > 0

	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7	All types
All FECs								
Mean	12.2	8.7	4.6	5.4	9.4	4	3.4	8.3
75th percentile	14.1	0.3	0	0	0	0	0	0.7
90th percentile	45.3	35.1	12.4	10.5	39.7	6	0	31.6
all FECs with SEA > 0								
Percentage of all FECs	91 %	32 %	16 %	15 %	35 %	12 %	10 %	25 %
Mean	25.3	33.4	33.9	40.6	34.8	25.0	39.1	31.8
Least-disturbed FECs								
Mean	14	16.3	8.0	1.0	0.0	2.5	0.0	8.9
Least-disturbed FECs with SEA > 0								
Mean	23.7	45.6	16.5	14.3	0.7	-	0.3([a])	30.9

Note: The table rows are separated by (1) all FECs, (2) FECs with SEA > 0, (3) least-disturbed FECs and (4) least-disturbed FECs with SEA > 0.

([a]) Includes only one FEC.

Table 4.11 Floodplain type-specific threshold values of the sediment flow alteration (SEA)

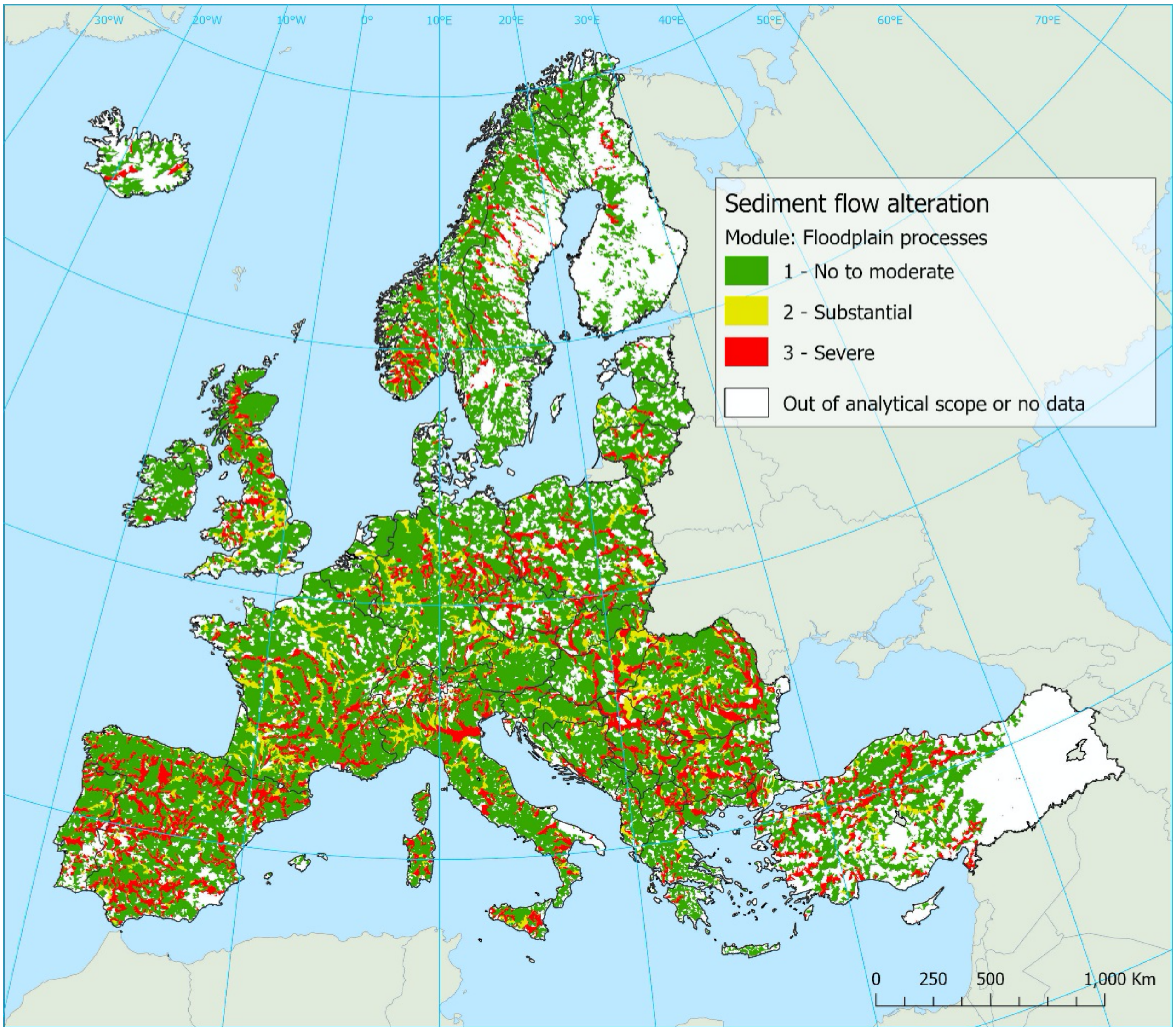
	Class 1 Natural to moderately degraded	Class 2 Substantially degraded	Class 3 Severely degraded
Types 1, 2, 5	≤ 1	> 1 to 10	> 10
Types 3, 4, 6, 7	≤ 1	> 1 to 5	> 5

Indicator assessment results

The average SEA for all classified FECs amounts to 8.3, ranging from 3.4 (Type 7 'Nordic floodplains') to 12.2 (Type 1 'Very flat lowland floodplains', Table 4.10). The presence of sediment trapping is related to the presence of dams, thus only 25 % of FECs show SEA values above zero (the same as for the DOR index). Almost all Type 1 'Very flat lowland floodplains' (91 %) experience sediment trapping by dams, while this is true for only one third of Type 2 'Flat lowland floodplains' and Type 5 'Mid-altitude plateau floodplains'. Amongst all floodplains with SEA > 0, the average SEA amounts to 31.8. The highest sediment flow alteration occurs at Type 4 'Mid-altitude low-runoff floodplains' (40.6). Across the FECs of Type 1 'Very flat lowland floodplains' with SEA > 0, the average SEA amounts to 25.3, which is among the smallest average SEA of all floodplain types. The lowest share of altered sediment flow is at Type 7 'Nordic lowland floodplains' (10 %), but with on average very high SEA values (39.1). This means that when sediment flow is altered at Nordic lowland floodplains, this alteration is very high (75th percentile SEA value = 71). To compare, the 75th percentile value at Type 1 'Very flat lowland floodplains' is half this size.

Overall, the severity of the sediment flow alteration (SEA) and the Degree of Flow Regulation (DFR) (see Section 4.4.2) is comparable. For about 10 % of the floodplains, however, the severity of the sediment flow alteration is higher. The sediment flow is substantially or severely altered for 43 % of Type 1 'Very flat lowland floodplains', whereas less than 30 % floodplains in this type are in the same Class 3 regarding channel- and floodplain-forming discharge alteration. Severe alteration of sediment flow occurs at floodplains along the Danube and its tributaries (Tisa, Sava and Drava); Po and Adige in Italy; Rhone, Loire, Cher and Tarn in France; Varta and Vistula in Poland, Weser and Rhine in Germany, Meuse in Belgium and floodplains along rivers in the United Kingdom such as the Severn, Wye, Usk, Trent and Mersey (Map 4.7).

Map 4.7: Spatial distribution of FECs with Sediment Flow Alteration (SFA) across Europe



4.4.4 Floodplain processes assessment

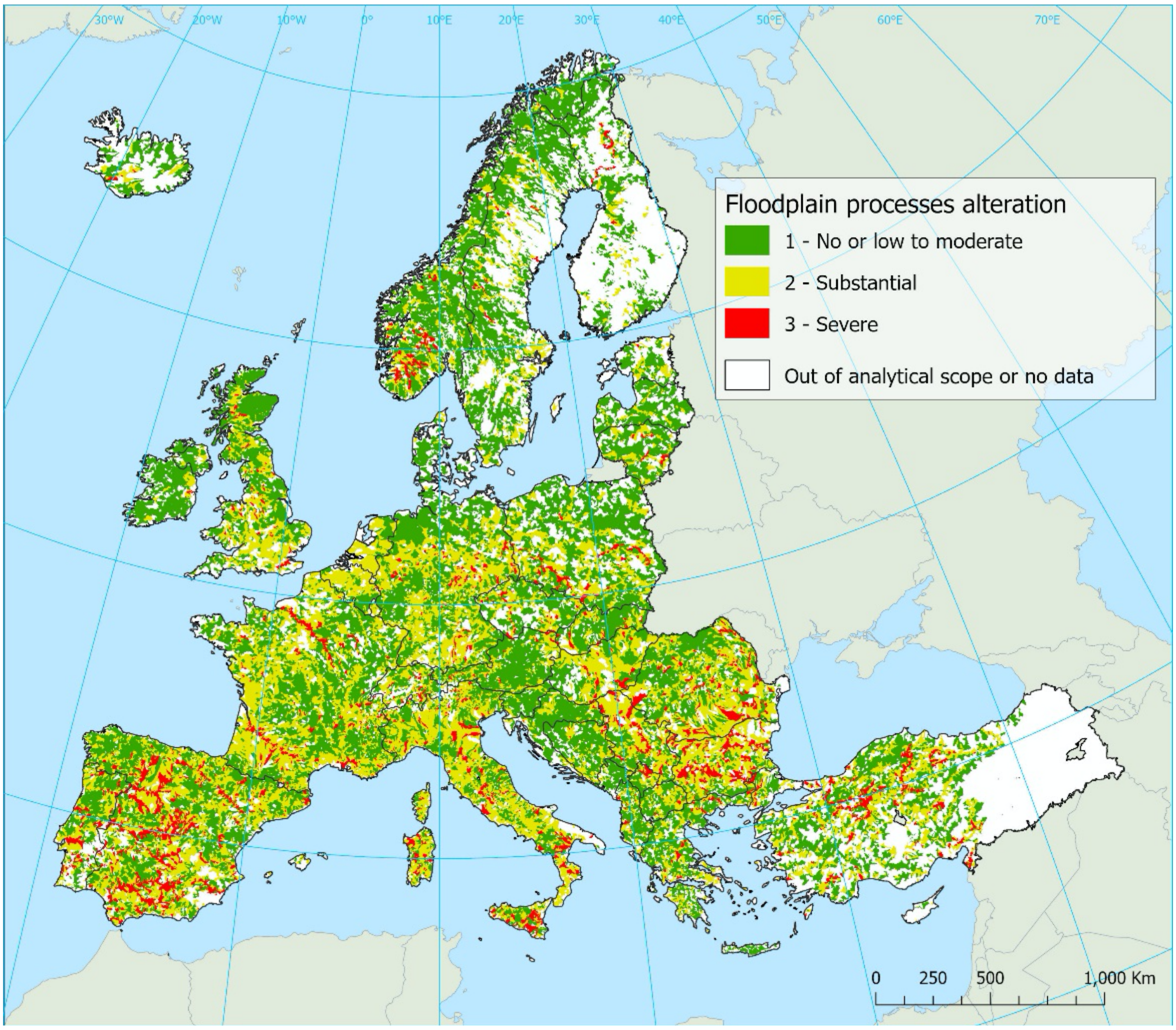
The classes resulting from the assessment of the three aforementioned process indicators are combined into assessment of the floodplain processes condition, according to the formula:

$FPA = 0.5 * BFA_{class} + 0.5 * (DFR_{class} + SEA_{class})/2$, where

FPA: floodplain processes alteration,
BFA_{class}: assessment class of the Base Flow Alteration,
DFR_{class}: assessment class of the Degree of Flow Regulation,
SEA_{class}: assessment class of the Sediment Flow Alteration.

The formula was derived on assumption that alteration of base flow (expressed as Base Flow Index alteration – BFA) and alteration of high flow are equally important, therefore we are averaging both or giving them the equal weight (0.5 low flow and 0.5 high flow). The high flow alteration due to dams in the upstream catchment has two components, high water flow expressed as the Degree of Flow Regulation (DFR) and Sediment Flow Alteration (SEA), we are averaging them (or taking the weight 1/4 of each indicator in a formula). With such an approach, we reduced redundancy, since both indicators are derived from the same e-data source. They are significantly correlated, but still provide different and complementary information referring to either water flow or sediment flow baselines. In the assessment, their combined weight is equal to the weight of the Base Flow Alteration Index (BFA), which addresses a different component (groundwater) of the range of relevant floodplain processes (Map 4.8).

Map 4.8: Spatial distribution of FECs with floodplain processes alteration across Europe



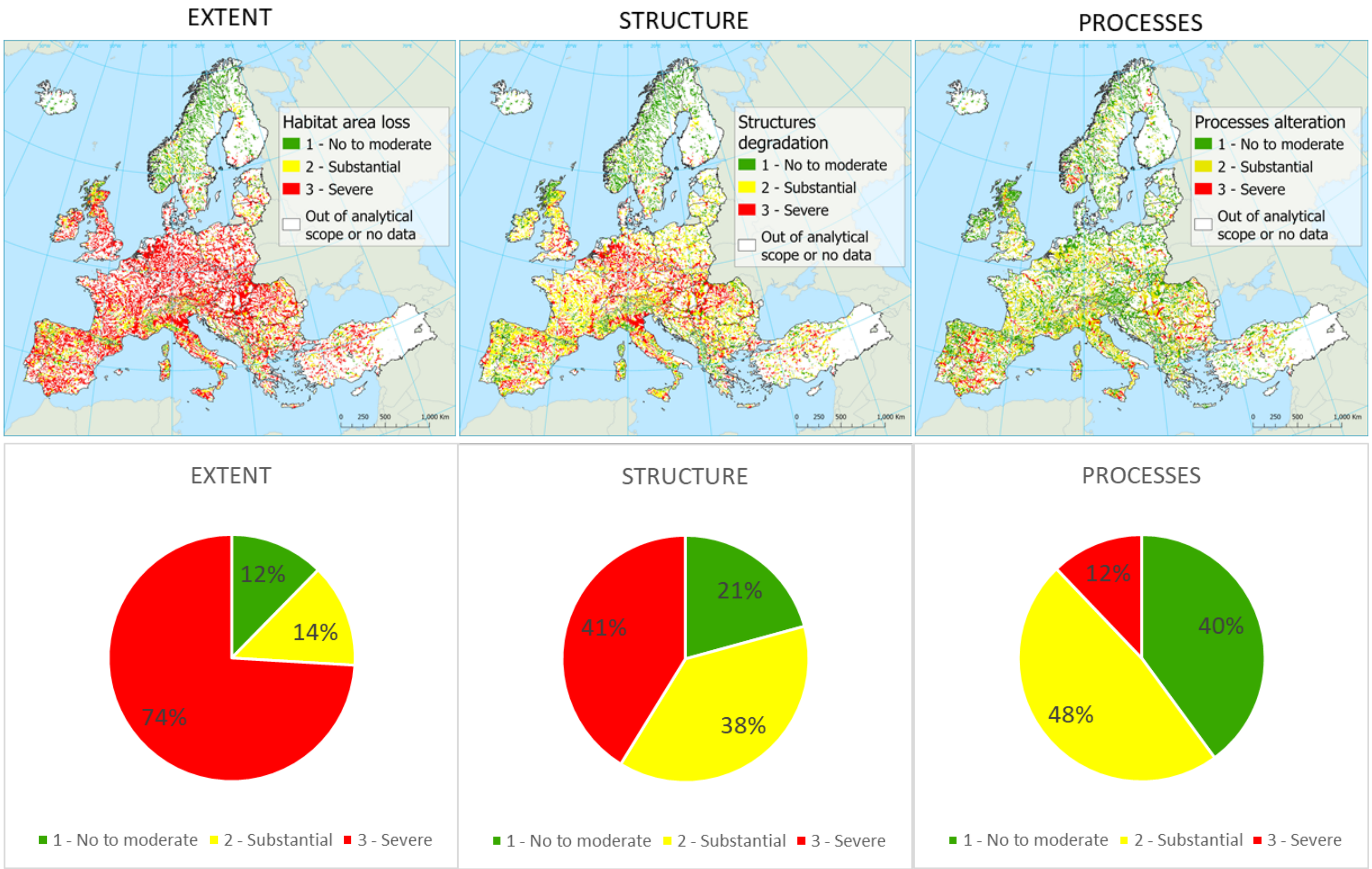
4.5 Overview of module results

In summary, comparing the assessment results reveals clear differences between the modules: Extent shows widespread degradation. While 74 % of Europe's floodplain area shows severe habitat area loss, and additional 14 % show substantial loss. Only a small share of floodplain area (12 %) features no to moderate habitat loss (Figure 4.6 – left). The assessment of the floodplain structures reveals 41 % severely degraded structure and 38 % significantly degraded structure. Severely degraded structure occurs where land use is almost entirely characterized by urban areas and agriculture, both of which contribute strongly to degrading floodplain structures as a consequence of modified river channel, drainage and flood protection. In the substantially and moderately to no degradation the land use intensity decreases gradually towards more extensive forms of land use – (Figure 4.6 middle). The assessment of the specific indicator 'floodplain features' (included into the module classification) shows that only a small fraction of floodplains (6 %) still features typical habitats (e.g. bars and dunes, oxbow lakes, wetlands) occurring to an extent comparable to least-disturbed conditions.

The floodplain processes show the smallest degree of alteration amongst the module assessments. The combined classification of base flow alteration, degree of flow regulation and sediment flow alteration reveals severe and substantial alterations for 60 % of Europe's floodplain area, whereas 40 % of the area shows no to moderate alterations (Figure 4.6 – right). The floodplain processes module captures three processes which are important for maintaining floodplain integrity and support the lateral connection between river and floodplain. Yet, it was not possible to include the actual flooding into this indicator as flooding is regulated by flood protection structures, for which data were not available for this study.

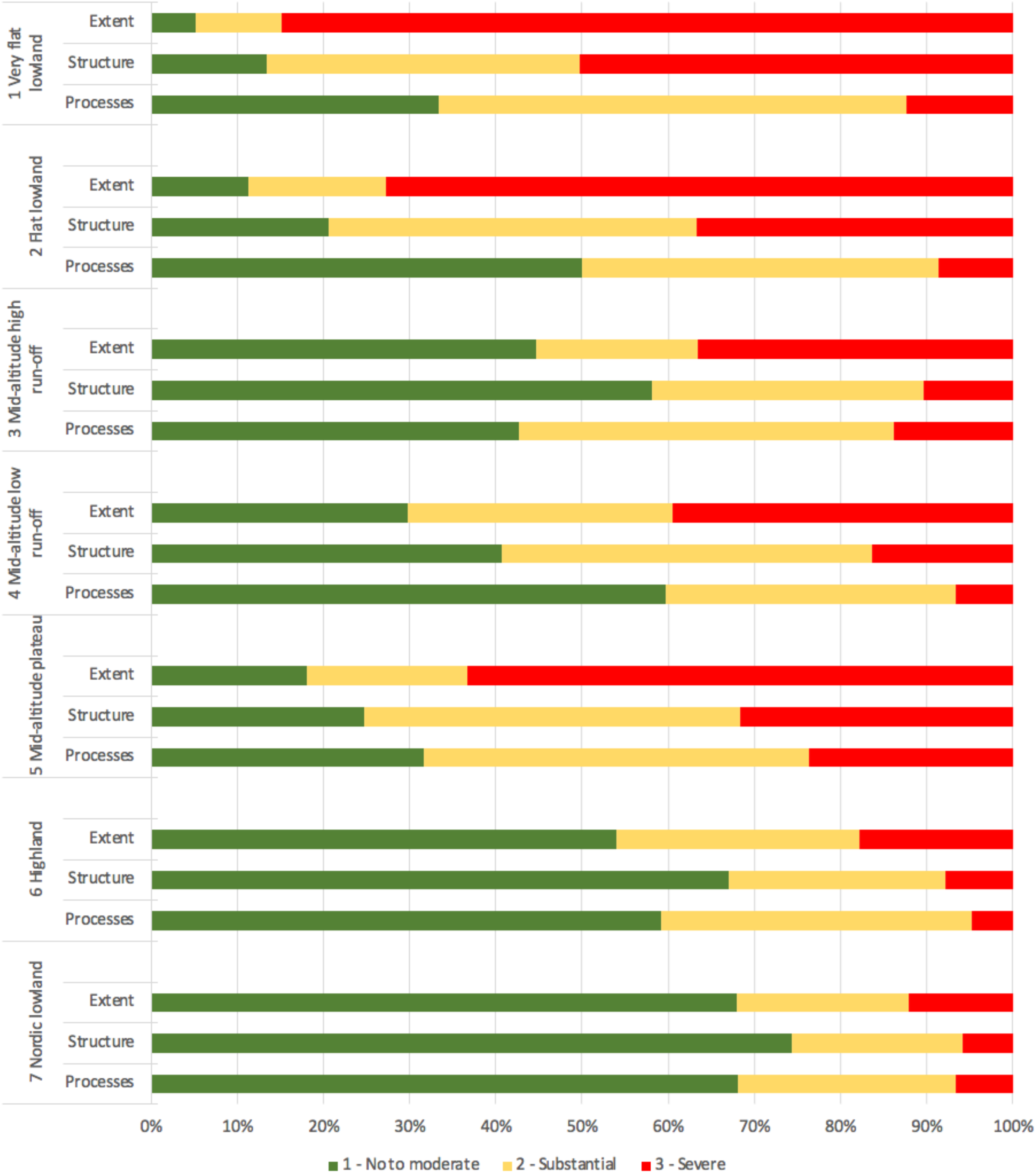
However, results of both the floodplain extent and structure modules depend critically on the lateral connection between river and the floodplain being in place, which allows for the transfer of both water and sediment between river and floodplain, and lateral movement of the channel. This is crucial for the natural floodplain habitats and relates to flooding and riverbank erosion usually not desired when floodplains are used by humans. This means that riverbanks are usually stabilized; channels are deepened and other flood protection structures (e.g. dikes) are put in place. In addition to these, floodplains are commonly drained to improve agricultural conditions. All of these interventions occur together with land use and increase with the intensity of land use. Hence, the extent and structural modules are indicators of the degree to which natural processes are impaired. In addition, the assessment results were compared with a national German assessment (Brunotte et al., 2009; Scholz et al., 2012). The comparison is shown in Annex 6.

Figure 4.6 Assessment of European floodplains by the three modules extent, structure, and processes



Note: Values in the pie charts present the share of assessed area.

Figure 4.7: Floodplain type-specific assessment by the three modules extent, structure, and processes



The habitat condition assessments clearly differ between floodplain types. The flat lowland floodplain types and the mid-altitude plateau floodplains are the most degraded among all floodplain types (Figure 4.7). For these types, less than 20 % of floodplains show no to moderate habitat loss, accompanied by a similarly small percentage of floodplains with no or moderate structural degradation. Most of the floodplains in these types are impacted by intensive land uses such as agriculture or settlements. At the other end of the scale, the Nordic lowland and highland floodplains feature large areas of unspoiled habitat conditions, owing to their often-remote location away from areas of high population densities.

5 Conclusions and outlook

This report presents a typology for floodplains and a methodological approach for the assessment of floodplain condition in Europe, together with first ever results. The assessment was performed using datasets available with Europe wide coverage, analysed at the sub-catchment level.

The typology established in this report categorizes the floodplain diversity at pan-European level and delivers insight into the highly diverse river-floodplain systems across Europe. The accompanying fact sheets illustrate the main characteristics and highlight remaining least disturbed and highly valuable floodplains. These fact sheets generally serve to raise the awareness for the uniqueness and high value of European floodplains as well as their distinctive natural features. The examples selected to represent each floodplain type showcase the supporting value of least disturbed floodplain sections for Natura 2000 sites and biodiversity.

The report presents a preliminary pan-European assessment of floodplain condition by addressing the degradation of floodplain extent, structure, as well as processes. It documents that floodplains suffer from wide-spread degradation in particular very flat lowland, flat lowland and mid altitude plateau types. These correspond to areas where land use activities are intense and urbanisation is present. This is also where the lateral connection between rivers and floodplain, which is fundamental for their condition, has been most impaired.

These preliminary assessment results point to extensive restoration needs if floodplains are to support achieving water and conservation policy objectives. It is critical for restoration efforts to tackle improving the lateral connectivity between rivers and floodplains. Such improvements are needed in the upcoming process of implementing the 2030 Biodiversity Strategy under the European Green Deal. It includes a target to achieve 25 000 km of free-flowing rivers through the removal of barriers and restoration of floodplains and wetlands.

Floodplain assessments, together with plans for restoration, could also be more systematically included into the River Basin Management Plans of the WFD, as their condition is a critical contribution to achieving good status. A link from WFD objectives to conservation objectives of the Habitats and Birds Directives would allow for a holistic and target-oriented planning of restoration measures. Floodplains constitute the interface between rivers and their catchments. Thus a 'functioning' floodplain supports the status of water bodies, biodiversity, water retention and flood risk reduction, through many ecosystem services.

Furthermore, this preliminary assessment of floodplain condition will help to establish a framework for a structured discussion about knowledge and information gaps on a European scale. For example, this study did not have access to datasets on flood protection structures or other hydromorphological pressures, hampering an explicit assessment of lateral connectivity. Future availability of such data will improve the assessment.

Future restoration objectives for floodplains should target re-establishing lateral connectivity with rivers, as this is a fundamental property for improving its condition. It also needs a broad approach to establish space for rivers by considering improvements to floodplain extent and structures as well as the integrity of natural processes. Which is more important depends on local conditions. This analysis points to wide ranging restoration being necessary.

6 Abbreviations

BFA	Base Flow Alteration
BFI	Base Flow Index
CCM	Catchment Characterisation and Modelling
CIC	Common Implementation Strategy
CLARA	Clustering Large Applications
CLMS	Copernicus Land Monitoring Service
CORINE	Coordination of Information on the Environment
DOR	Degree of Regulation
EEA	European Environment Agency
EEA-38	The EEA-32 countries plus six collaborating countries (Albania, Bosnia and Herzegovina, North Macedonia, Serbia and Kosovo (under UN Security Council Resolution 1244/99)
ECRINS	European Catchments and Rivers Network System
EFTA	European Free Trade Area
EU-27	the 27 EU Member States
ETC/ICM	European Topic Centre on Inland, Coastal and Marine Waters
FAO	Food and Agriculture Organization
FEC	Functional Elementary Catchment
HMPA	Hydromorphological processes alteration
IHA	Indicators of Hydrologic Alterations
IHME	International Hydrogeological Map of Europe
JRC	Joint Research Centre (of the European Commission)
LDC	Least Disturbed Conditions
LiDAR	Light Detection and Ranging data
MAES	Mapping and Assessment of Ecosystems and their Services
MARS	Managing Aquatic Ecosystems and Water Resources Under Multiple Stress
MSL	Modified Sediment Load
PCA	Principal Component Analysis
PCR-GLOBWB	PCRaster Global Water Balance
PSL	Potential Sediment Load
RZLC/LU	Riparian Zone Land Use/Land Cover
SED	Sediment Trapping Index
SGDBE	Soil Geographical Database of Eurasia
WFD	Water Framework Directive
WISE	Water Information System for Europe

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Annex 1 Compilation of candidate typology factors

Typology factors represent different environmental characteristics at the spatial resolution of FEC and their flood-prone area extent. They reflect basic abiotic conditions, which are considered to be the main drivers for floodplain characteristics under natural conditions.

The list of candidate typology factors included 24 parameters (Table A1.1) obtained from numerous sources (e.g. ECRINS, MARS, FAO, Copernicus, WorldClim, IHA, IHME), which we compiled to check data coverage across Europe. Depending on the factor, data were aggregated at the level of the FEC, the hinterland and the flood-prone area within the FEC or the FEC's maindrain. Spatial relations between ECRINS data and data distribution of typology factors were established using different geoprocessing methods (e.g. intersections and aggregations).

We grouped factors into the following thematic categories: region, altitude, climate, geology, morphology, hydrology, river dynamics (Table A1.1). Most of the factors cover 95 to 99 % of the assessment area comprising 104 685 FECs in total. However, some factors could not be calculated for about 3 300 FECs located in eastern Turkey. In particular, this applies for the hydrological parameters where the data could be obtained only for those parts of Turkey, which are draining into the Mediterranean and Black Sea. Moreover, 163 FECs in north-eastern Turkey had also incomplete ECRINS information, which is why the FEC-to-hinterland relation could not be established. Hinterland information for these FECs could not be calculated and is thus incomplete. Factors applied to the FEC maindrain (e.g. average floodplain width) could not be applied to about 1 200 FECs with direct outflow to the sea where the maindrain information is incomplete within the ECRINS database.

Both factors in the category "River dynamics" showed low data coverage. Information was available for less than 30 % of FECs, because it could be calculated only for FECs where 'gravel', 'sand' or 'fine sediments' were the prevailing substrate in the flood-prone area, and where the mean annual flow was known.

Table A1.1 List of candidate typology factors for floodplains

Category	Field name	Description	Data type	Unit	Coverage
Region	fr_biogreg	Biogeographical regions used in the Habitats Directive (92/43/EEC)	text	-	100.0 %
Region	fr_ecolreg	Ecological regions used in WFD	text	-	88.7 %
Region	fr_brhyreg	Broad hydro regions (MARS project)	text	-	100.0 %
Region	fm_bt20	Broad type (20 categories)	text	-	95.1 %
Region	fm_bt12	Broad type (12 categories)	text	-	95.1 %
Altitude	fm_altavg	Average altitude of river maindrain in FEC	int	m	98.5 %
Climate	hc_meanpr	Average annual precipitation for the period 1960 to 1990 in hinterland	numeric	mm/year	95.7 %
Climate	fc_meanpr	Average annual precipitation for the period 1960 to 1990 in FEC	numeric	mm/year	95.4 %
Climate	hc_meantem	Average annual temperature for period 1950 to 2000 in hinterland	numeric	°C	96.6 %
Climate	fc_meantem	Average annual temperature for period 1950 to 2000 in FEC	numeric	°C	96.6 %
Geology	fg_substr	Dominant (prevailing) geology substratum in flood-prone area within FEC	text	-	75.5 %
Geology	fg_subsha	Dominant (prevailing) geology substratum share in flood-prone area within FEC	float	share	75.5 %
Geology	hg_calsilo	Dominant (prevailing) geo-chemistry in hinterland	text		96.6 %
Morphology	fm_pfaw	Average floodplain width in FEC	numeric	km	76.6 %
Morphology	fm_slopdr	Slope of FEC maindrain	numeric	m/km	98.5 %
Morphology	hm_area	Catchment size upstream (hinterland) including FEC	numeric	km^2	99.8 %
Morphology	hm_areacat	Catchment size upstream (hinterland) including FEC (3 classes)	text	km^2	99.8 %
Morphology	hm_slopedr	Slope of hinterland maindrain	numeric	m/km	98.4 %
Hydrology	fh_mfnd	Mean annual flow (modelled run-off without abstractions). Average of all daily flows for the period 2001 to 2010	numeric	m^3/s	95.7 %
Hydrology	fh_bfnd	Base flow index: seven consecutive days with a minimum flow in a year divided by a mean annual flow (without abstractions)	numeric	-	95.7 %
Hydrology	fh_hfdnd	High flow duration: days with hydrological flow greater than 75th percentile of daily flows (without abstractions)	numeric	number of days	91.7 %
Hydrology	fh_hfpnd	High flow pulses: number of events in year, when daily run-off is greater than 75th percentile (without abstractions)	numeric	number of events	95.7 %
River dynamics	fp_widref	Reference channel width calculated by method described by Kleinhans & van den Berg (2011)	numeric	m	28.6 %
River dynamics	fp_spstpo	Specific stream power ω calculated by method described by Kleinhans & van den Berg (2011)	float	kg m^2/s^2	28.3 %

Note: Coverage is calculated in respect to 104 685 FECs within EEA-38 and UK territory.

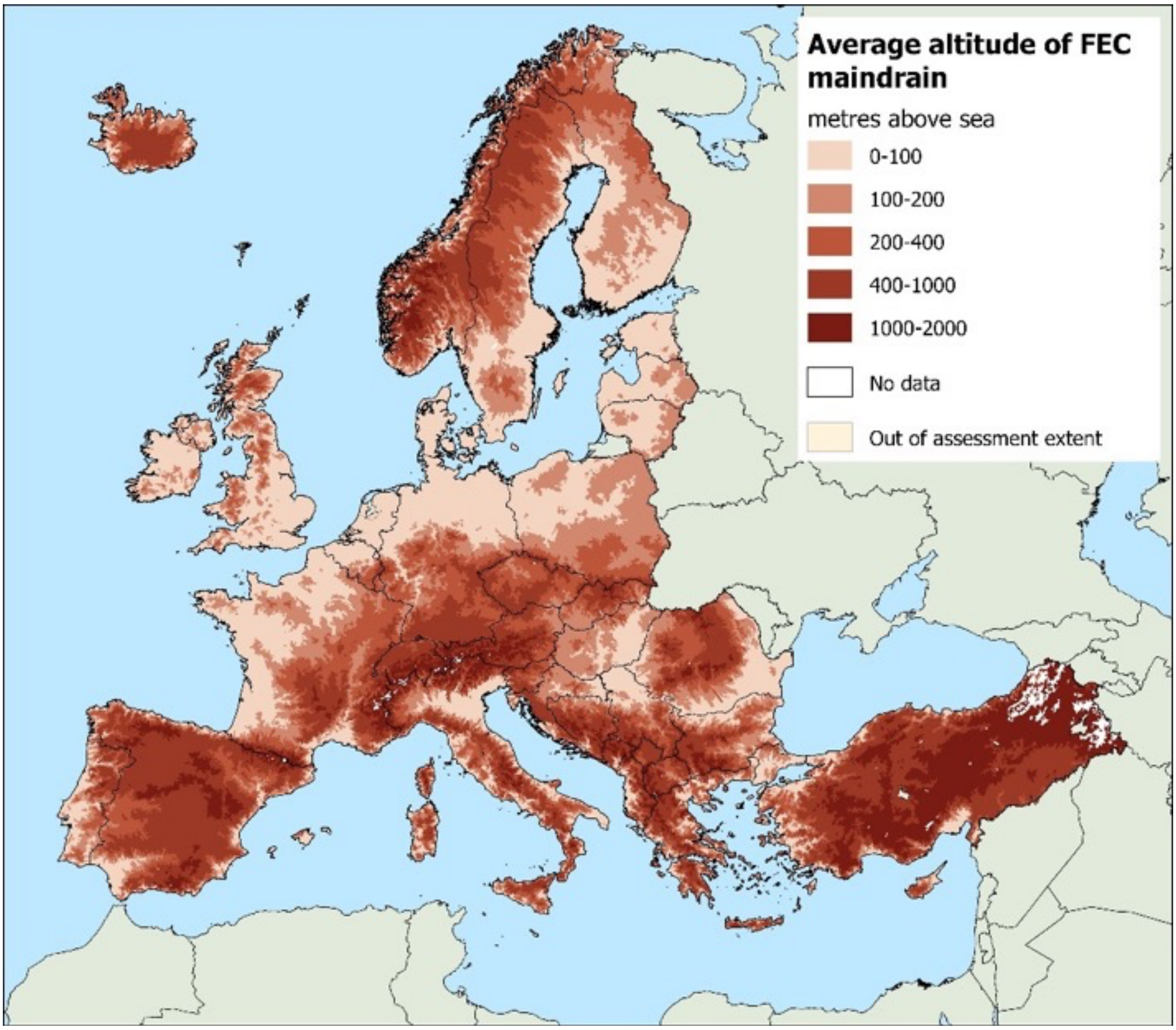
Annex 2 Detailed information on typology factors

Average altitude of FEC maindrain (morphology)

The average altitude of the FEC maindrain was assigned to each FEC by calculating the average value of inflow and outflow altitude of maindrain river segment in each FEC.

Coverage: Almost complete (Map A2.1). Information could not be applied to 1 428 FECs because the maindrain information in the ECRINS database is incomplete. These were mostly coastal FECs with relatively small catchments and direct outflow to the sea and about 170 FECs in north-eastern Turkey.

Map A2.1: Average altitude of FEC maindrain



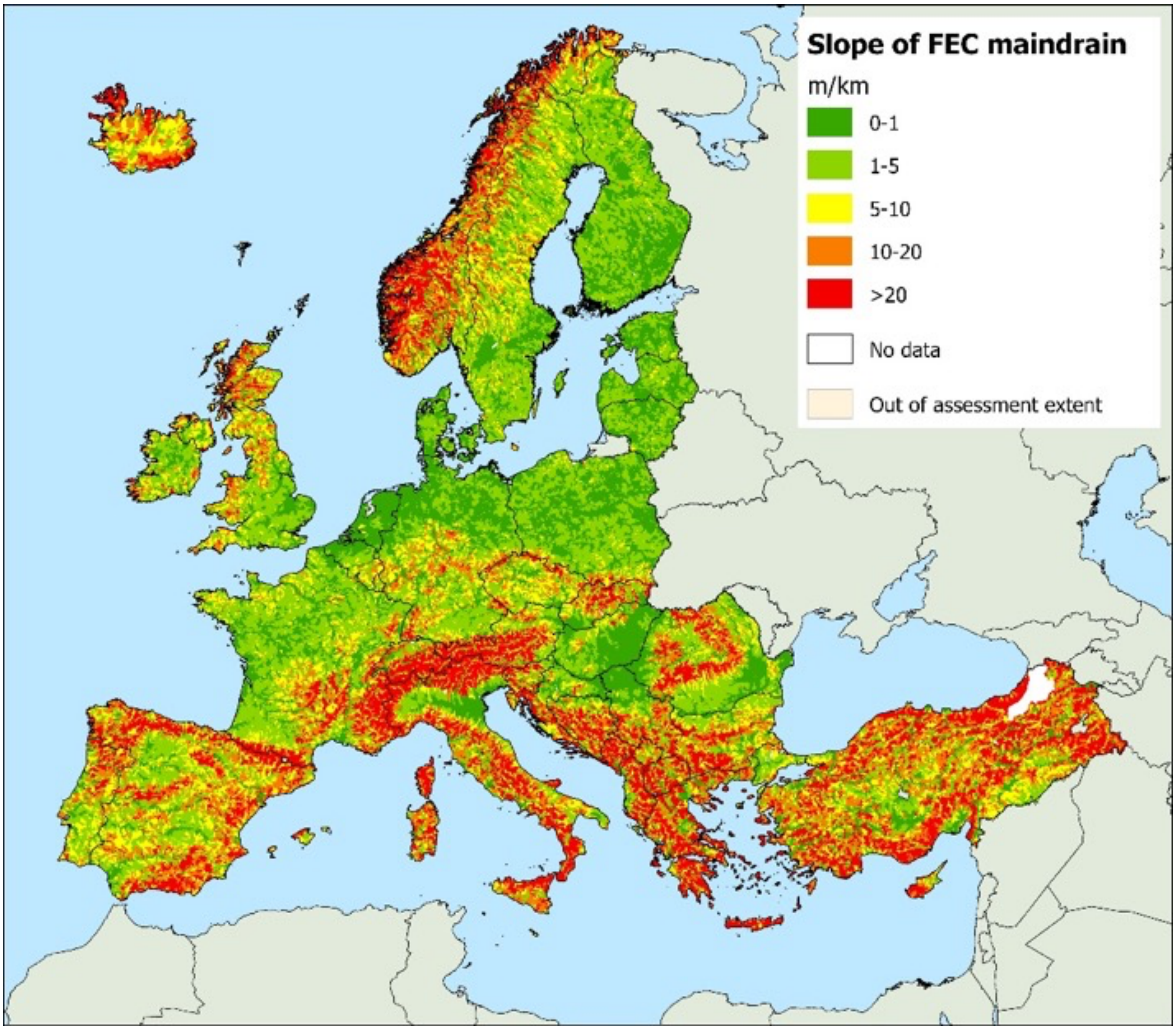
Slope of FEC maindrain (morphology)

The slope of the FEC maindrain was assigned to each FEC by dividing the difference of inflow and outflow altitude of the maindrain river in the FEC with maindrain length.

Coverage: Almost complete (Map A2.2). Information not applied to 1 428 FECs (maindrain information not available in ECRINS). These were mostly coastal FECs with rather small catchments with direct outflow to the sea and about 170 FECs in north-eastern Turkey with incomplete ECRINS information.

The average slope of FEC maindrain in Europe amounts to 20 ‰ (m/km). Higher maindrain gradients (> 40 ‰) are significant for Alpine region (Switzerland, Austria, France and Italy), Pyrenees (Spain, France), the Dinaric Arc (Bosnia and Herzegovina, Albania, Montenegro and Greece) and Norway. Rivers with very small gradient (< 0.05‰) are flowing in northern and north-eastern Europe (e.g. Lithuania, Latvia, Estonia, northern Poland, northern Germany, the Netherlands, Belgium). These rivers are draining to the Baltic Sea and the North Sea. Lower maindrain altitudes are significant also for the River Po and the Pannonian Basin (Danube, Tisa, Prut).

Map A2.2: Slope of FEC maindrain

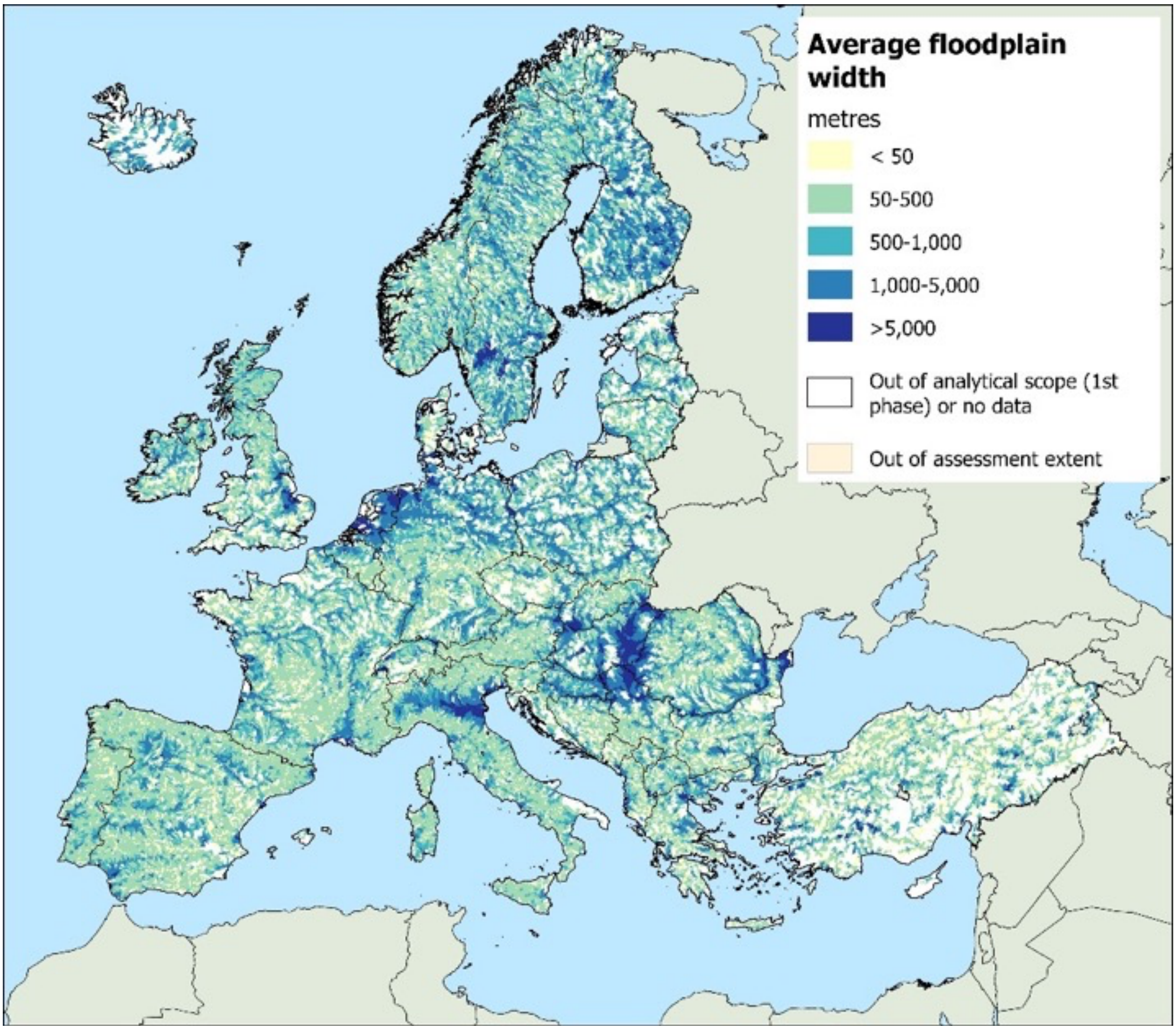


Average floodplain width

The average floodplain width in a FEC is calculated using (1) the flood-prone area extent in the FEC, (2) the share of the maindrain within flood-prone area in the FEC and (3) the total length of the maindrain in the FEC. Flood-prone area in the FEC is divided by the share of the maindrain flowing within the flood-prone area and multiplied by the maindrain length.

Coverage: Extensive coverage (Map A2.3). Information were not applied to 21 210 FECs. 80 % of these FECs were not covered with potential flood-prone areas and are in most cases upstream FECs with Strahler orders 1 (831 FECs), 2 (12 730 FECs) and 3 (3 886 FECs). The remaining FECs (20 %) were mostly coastal FECs with relatively small catchments and direct outflow to the sea (maindrain does not exist) and about 170 FECs in north-eastern Turkey with incomplete ECRINS information.

Map A2.3: Average floodplain width

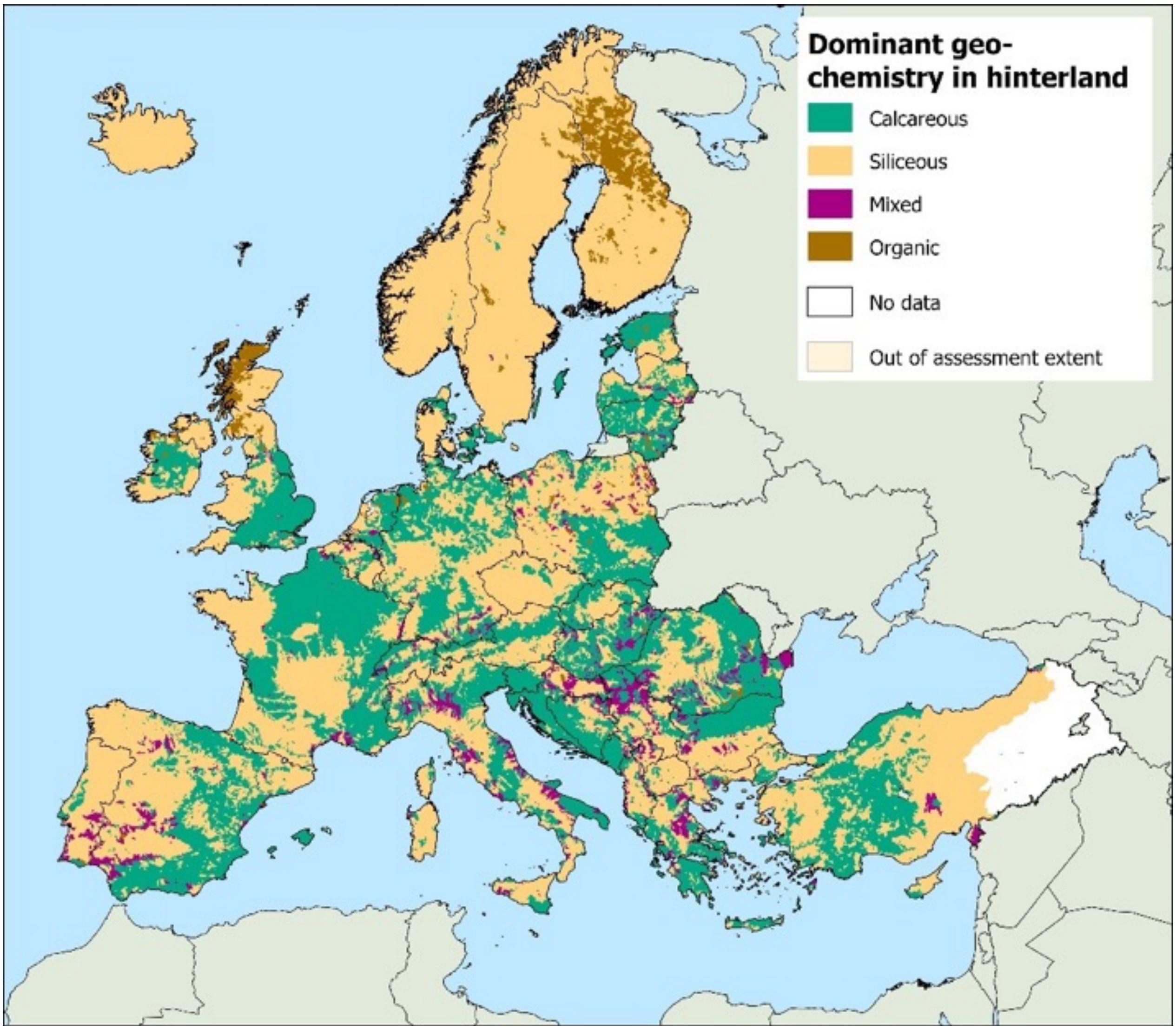


The average floodplain width in the EEA-38 and UK amounts to 507 m. Wider floodplains (> 1 000 m) can be found on the Danube River and its tributaries (Drava, Sava, Tisza, Mures, Morava, Prut, Siret), numerous rivers flowing into the Greater North Sea and the Atlantic Ocean (Loire, Rhine, Elbe). Baltic rivers with wider floodplains can be found on the Vistula, Odra and its tributaries (Warta, Noteć). On the other hand, only a few Mediterranean rivers (Po, Rhone) have floodplains wider than one kilometre.

Dominant geology (geochemistry) in the catchment

The methodology for the Dominant Catchment Geology (geochemistry) category map is described in Lyche Solheim et al. (2019) and was developed in the MARS project to establish the broad river typology in Europe. It was defined in two steps: a base map of the four geological categories (i.e. siliceous, calcareous, mixed and organic) was produced from two thematic maps: the bedrock map "International Hydrogeological Map of Europe (IHME 1500_v11)" (BGR, 2019; Duscher et al., 2015) and the Soil Geographical Database of Eurasia (SGDBE) (JRC, 2016). In the second step, the prevailing catchment area geology for each FEC was calculated. Data on alkalinity from the Geochemical Atlas of Europe (Salminen et al., 2005) and Waterbase – Water Quality Database (EEA, 2016), as well as type information from Water Information System for Europe (WISE) WFD Database (EEA, 2015; EEA, 2019b) was used to validate the geochemical categories derived from the bedrock and soil maps, applying an alkalinity threshold of 60 mg HCO_3/L (corresponding to 1 meq/L) to distinguish calcareous from siliceous FECs. In a few FECs where data on bedrock or soil types were missing, the dominant catchment geology category was assigned using alkalinity data.

Map A2.4: Dominant geo-chemistry in hinterland



Coverage: Almost complete (Map A2.4). Information could not be applied to 3 222 FECs, which are not draining to European seas (eastern Turkey). The prevailing geochemistry for these catchments could not be identified since they are outside the extent of the IHME map.

Almost 60 % of all hinterlands, for which prevailing geology could be defined, are siliceous. Catchments with prevailing siliceous geo-chemistry are in Scandinavia, parts of Central Europe, the western part of the Iberian Peninsula, the central part of Italy and eastern Turkey. Catchments with prevailing calcareous geochemistry (34 %) are situated in the south-eastern Europe (Dinaric Arc), northern France, south-eastern Spain, the Baltic countries and elsewhere in central Europe. Relatively low share of hinterlands (3.9 %) was assigned “mixed” geological class. These are present mostly in southern Europe (Spain, Portugal, Greece and Italy) and south-eastern Europe (Croatia, Serbia and Romania). Hinterlands with mainly organic geo-chemistry (2.3 %) are located in Scandinavia (Finland, Sweden) and northern Scotland.

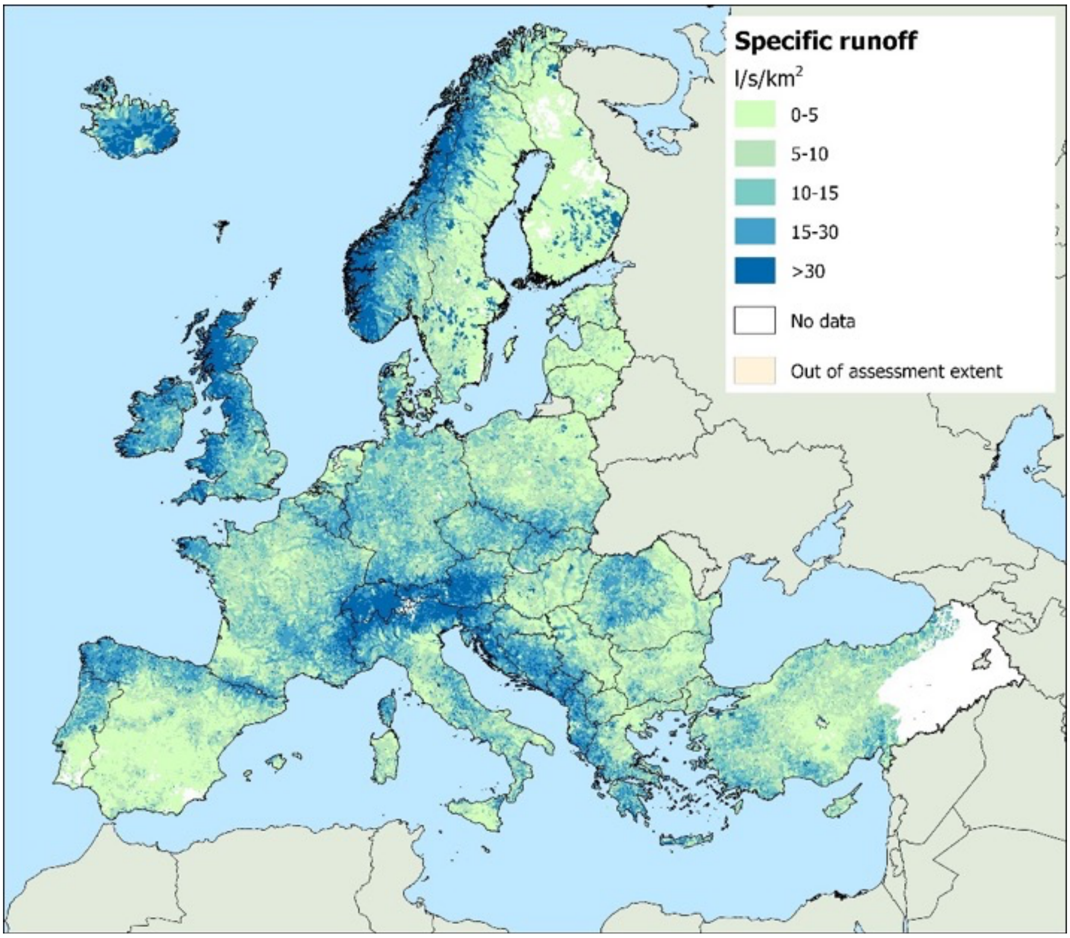
Hydrology

Hydrological parameters calculated per FEC and used in floodplain typology cluster analyses were obtained from the MARS project and are documented in Panagopoulos et al. (2019). Time series on daily run-off modelled with the global water balance model PCR-GLOBWB were provided in raster format. By linking the FEC outlet to corresponding grid cells, daily time series for semi-natural conditions (water abstraction and effects of reservoirs operations are eliminated) were derived. Time series for a period 2001–2010 were prepared in MARS project with a free software tool developed by The Nature Conservancy, ‘Indicators of Hydrologic Alteration’ (IHA, 2020). Data are available in MARSgeoDB (Globevnik et al., 2017). The indicators of hydrologic alteration were developed by Richter et al. (1996) to assess the degree of hydrologic alteration caused by human intervention on rivers. The hydrologic parameters are computed with the use of a free software tool developed by The Nature Conservancy. Out of numerous parameters calculated with this software, three were used in the floodplain cluster analyses: mean annual flow (used to calculate specific run-off), high flow duration and high flow pulses.

Specific run-off

The specific run-off gives information about how many litres of water drain per second from 1 km^2 of catchment. Contrary to river discharge, the specific run-off is the highest in the upstream catchments and gradually decreases downstream. Specific run-off is calculated by dividing mean annual flow (modelled discharge without abstractions for the period 2001 – 2010) in the FEC's maindrain with its hinterland area.

Map A2.5: Specific run-off in hinterland



Coverage: Almost complete (Map A2.5). Specific run-off could not be calculated for 4 124 FECs. More than 80 % of these FECs are situated in eastern Turkey. Since the hydrological model included only sub-catchments draining to European seas, the mean annual flow and specific run-off for these FECs could not be defined. The remaining 20 % of FECs for which specific run-off could not be calculated are situated in Finland (217 FECs), Spain (214 FECs), Portugal (102 FECs) and a few other countries. Hydrological parameters for these FECs could not be calculated because the global water balance model PCR-GLOBWB, which is based on raster data, could not be aggregated to FEC sub-catchment level due to spatial constrains.

Higher specific run-offs (>30 l/s/km^2) were calculated for approximately 20 % of all FECs. They are significant for the Alpine region (Switzerland, Austria, France and Italy), Scottish Highlands, Iceland, western Norway, Pyrenees (Spain, France), Cantabrian Mountains and the Galician Massif in Spain and the Dinaric Arc (Bosnia and Herzegovina, Albania, Montenegro and Greece). Lower specific run-offs (< 5 l/s/km^2) are significant for the Baltic countries, western Poland, Finland, eastern Sweden, the Pannonian Basin, lower Danube, Anatolia (Turkey) and major parts of the Iberian Peninsula.

There are 2 267 FECS with implausible run-off rates as calculated from PCR-GLOBEWB that were not included into further analysis.

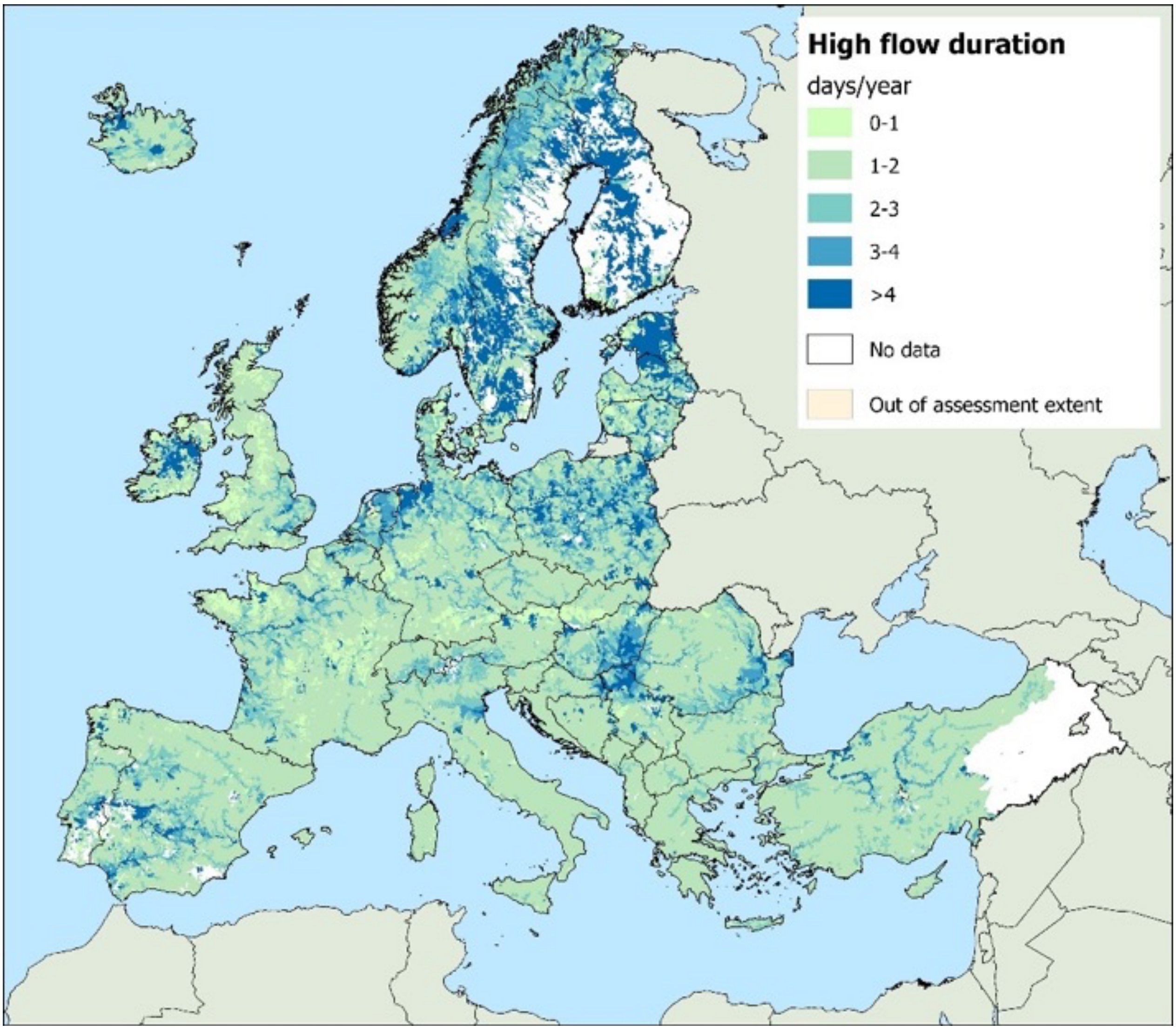
High flow duration

The high flow duration parameter was expressed as the number of days with discharges higher than the 75th percentile of all daily flows in one year.

Coverage: Almost complete (Map A2.6). The parameter could not be calculated for 7 798 FECs. About 45 % of these FECs are situated in Sweden and Finland. High flow duration for these FECs could not be calculated because the global water balance model PCR-GLOBWB, which is based on raster data, could not be aggregated to FEC sub-catchment level due to spatial constrains. An additional 40 % of FECs, for which high flow duration could not be calculated, are situated in parts of eastern Turkey draining to the Indian Ocean, which was not included in the PCR-GLOBWB model as applied in the MARS project.

More than four days per year when discharges are higher than 75th percentile of all daily flows are significant for the rivers Tisza (Hungary), lower Danube (Romania), Odra (Poland), Vistula (Poland), Loire (France), Ems (Germany), the Baltic countries and numerous rivers in Sweden and Finland.

Map A2.6: High flow duration



Note: High flow duration is defined as number of days with hydrological flow greater than the 75th percentile of daily flows (without abstractions).

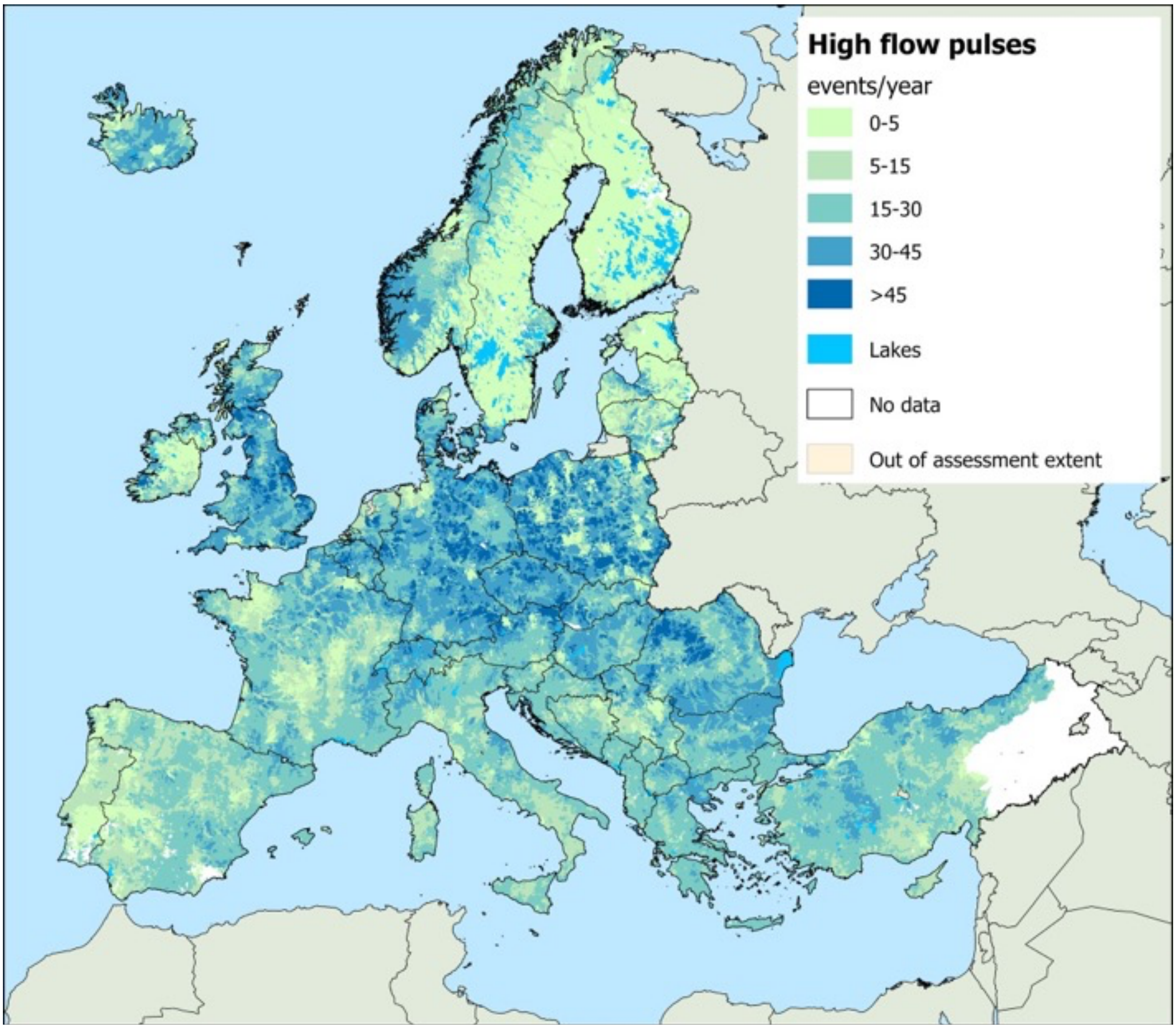
High flow pulses

The high flow pulse is an event when discharge reaches the 75th percentile of all daily discharges in the selected period. The parameter is expressed as number of events in a year when a daily discharge is greater than or less than a specified discharge threshold.

Coverage: Almost complete (Map A2.7). The parameter could not be calculated for 3 993 FECs. More than 80 % of these FECs are located in parts of eastern Turkey draining into the Indian Ocean, which was not included in the PCR-GLOBWB model as applied in the MARS project. The majority of the remaining 20 % of FECs are located in Sweden, Finland, Spain and Portugal. The high flow pulses for these FECs could not be calculated because the global water balance model PCR-GLOBWB, which is based on raster data, could not be aggregated to FEC sub-catchment level due to spatial constrains.

FECs featuring more than 45 events per year, when discharges are higher than the 75th percentile of all daily flows, are located in central Europe, the United Kingdom, western Norway and northern Romania. These FECs are tributary FECs to the upper Danube, Odra, Elbe, Vistula, Rhine and other rivers. Less than five events per year, when discharges are higher than the 75th percentile, are representative for a major part of Sweden, Finland and the Baltic countries. Less than five events per year also occur on the Iberian Peninsula, particularly in the Guadiana, Tagus and Sorraia catchments.

Map A2.7: High flow pulses



Note: High flow pulses are the number of events in a year, when daily discharge is greater than the 75th percentile (without abstractions).

Annex 3 Details of statistical clustering, validation and aggregation

The data of the seven typology factors available for the 66 382 FECs were clustered using the *treeClust()* function of the R-package ‘treeClust’ (Buttrey & Whitaker, 2015). This cluster method produces pairwise dissimilarities arising from a set of classification or regression trees and allows to also include categorical variables. The approach was successfully applied in the typification of very large European rivers (Borgwardt et al., 2019). Clustering was done using the ‘CLARA’ algorithm (Kaufman and Rousseeuw, 2005) suited for treating more than several thousand observations.

Due to the large dataset, we controlled the output of the algorithm to produce clustering objects of manageable size, using the *treeClust.control()* function. Furthermore, we created an ‘inter-point distance matrix’ mirroring the *treeClust()* dissimilarities by using the *tcnewdata()* function, because in our dataset the vector of all pairwise distances was assumed to be too large to be readily handled (Buttrey and Whitaker, 2015).

To estimate the optimal number of clusters in our data, we used the average silhouette method, which allows for interpreting and validating the consistency within and between clusters. The 'silhouette value' obtained from the analysis is a measure of how similar an object is to its own cluster compared to other clusters (Rousseeuw, 1987).

We scrutinised the results of the cluster analysis by (1) applying a Principal Component Analysis (PCA) of the typology factors, followed by an overlay of the cluster-membership allocated to each FEC in the PCA-plot, (2) mapping the geographical distribution of the clusters, and (3) comparing the statistical descriptors (e.g. median, quartiles, range, outliers) of each typology factor among clusters. These steps allowed for checking the plausibility of the results obtained from the statistical clustering, and enabled merging of similar clusters and re-allocating of outlying FECs to more corresponding clusters. Based on statistical descriptors, we built type classes for each typology factor to specify differences between floodplain types (Table A3.1).

Table A3.1 European floodplain types and selected typology factors, including the main statistical descriptors and type-classes

Altitude (m)								
Type	*Min*	*10th perc*	*25th perc*	*Med*	*75th perc*	*90th perc*	*Max*	***Type-classes***
1 Very flat lowland floodplains	-5	5	25	79	144	217	510	Lowland (< 200)
2 Flat lowland floodplains	-15	37	81	170	293	405	510	Lowland (< 300)
3 Mid-altitude high run-off floodplains	1	122	228	422	688	957	1 486	Mid-altitude (200–800)
4 Mid-altitude low run-off floodplains	-1	250	402	619	878	1 121	2 032	Mid-altitude (200–1 000)
5 Mid-altitude plateau floodplains	150	515	577	708	756	1 085	1 838	Mid-altitude (500–800)
6 Highland floodplains	135	640	859.8	1 175.5	1 539	1 808	2 513	Highland (> 800)
7 Nordic lowland floodplains	-5	41	84	150	240	379	1 205	Lowland (< 300)
Slope (m/km)								
Type	*Min*	*10th perc*	*25th perc*	*Med*	*75th perc*	*90th perc*	*Max*	***Type-classes***
1 Very flat lowland floodplains	0.0	0.0	0.2	0.5	0.9	1.1	1.5	Very flat (< 1)
2 Flat lowland floodplains	0.0	1.5	2.3	4.3	8.3	12.8	23.5	Flat (1–10)
3 Mid-altitude high run-off floodplains	0.0	7.8	19.8	43.4	70.6	87.6	334.5	Steep (10–100)
4 Mid-altitude low run-off floodplains	10.1	21.3	25.1	34.2	49.9	66.2	143.8	Steep (10–100)
5 Mid-altitude plateau floodplains	0.0	0.7	2.3	6.6	12.2	16.8	20.6	Flat (1–10)
6 Highland floodplains	20.7	90.4	101.0	124.6	162.9	214.0	501.9	Very steep (> 100)
7 Nordic lowland floodplains	0.0	0.4	1.0	2.7	6.4	13.2	181.2	Flat (1–10)
Floodplain width (m)								
Type	*Min*	*10th perc*	*25th perc*	*Med*	*75th perc*	*90th perc*	*Max*	***Type-classes***
1 Very flat lowland floodplains	0.14	0.44	0.60	0.91	1.42	2.32	83.32	Very wide (> 0.6)
2 Flat lowland floodplains	0.00	0.04	0.13	0.29	0.51	0.79	51.11	Wide (0.1–1.0)
3 Mid-altitude high run-off floodplains	0.00	0.02	0.03	0.08	0.20	0.48	8.40	Narrow (0.04–0.25)
4 Mid-altitude low run-off floodplains	0.00	0.01	0.04	0.11	0.19	0.31	24.24	Narrow (0.04–0.25)
5 Mid-altitude plateau floodplains	0.00	0.04	0.17	0.31	0.55	0.89	23.86	Wide (0.1–1.0)
6 Highland floodplains	0.00	0.01	0.02	0.05	0.11	0.17	12.50	Very narrow (< 0.1)
7 Nordic lowland floodplains	0.00	0.05	0.14	0.43	0.78	1.23	27.61	Wide (0.1–1.0)

Table A3.1 Cont.

Run-off [l/s/km²]								
Type	*Min*	*10th perc*	*25th perc*	*Med*	*75th perc*	*90th perc*	*Max*	***Type-classes***
1 Very flat lowland floodplains	0.1	2.9	5.6	9.3	13.4	19.7	423.2	Low (< 20)
2 Flat lowland floodplains	0.1	3.1	6.0	10.5	17.2	28.2	492.2	Low (< 40)
3 Mid-altitude high run-off floodplains	37.5	54.1	59.7	76.0	115.2	197.8	497.3	High (> 50)
4 Mid-altitude low run-off floodplains	0.2	5.2	9.4	16.8	27.8	38.8	50.0	Low (< 40)
5 Mid-altitude plateau floodplains	0.1	2.4	5.1	9.4	17.5	29.9	381.9	Low (< 30)
6 Highland floodplains	0.8	21.6	36.8	67.2	122.5	205.5	500.0	High (> 40)
7 Nordic lowland floodplains	0.1	0.7	2.0	4.6	8.3	20.6	480.6	Low (< 20)
High flow pulse (number per year)								
Type	*Min*	*10th perc*	*25th perc*	*Med*	*75th perc*	*90th perc*	*Max*	***Type-classes***
1 Very flat lowland floodplains	1	6	13	21	30	38	56	High number, highly varying range (13–30)
2 Flat lowland floodplains	0	5	14	24	34	44	56	High number, highly variable range (14–34)
3 Mid-altitude high run-off floodplains	1	9	16	23	32	40	54	High number, highly variable range (16–32)
4 Mid-altitude low run-off floodplains	0	7	14	20	27	33	53	High number, moderately variable range (14–27)
5 Mid-altitude plateau floodplains	0	9	15	20	27	33	51	High number, moderately variable range (15–27)
6 Highland floodplains	0	13	17	22	28	34	49	High number, moderately variable range (17–28)
7 Nordic lowland floodplains	0	1	1	1	2	26	48	Low number, unvarying range (1–2)
High flow duration (duration of event in number of days)								
Type	*Min*	*10th perc*	*25th perc*	*Med*	*75th perc*	*90th perc*	*Max*	***Type-classes***
1 Very flat lowland floodplains	1	2	2	3	4	5	146	Short (< 5 days)
2 Flat lowland floodplains	1	1	2	2	2	3	185	Short (< 5 days)
3 Mid-altitude high run-off floodplains	1	2	2	2	2	3	181	Short (< 5 days)
4 Mid-altitude low run-off floodplains	1	2	2	2	2	3	132	Short (< 5 days)
5 Mid-altitude plateau floodplains	1	2	2	2	2	3	75	Short (< 5 days)
6 Highland floodplains	1	2	2	2	2	3	129	Short (< 5 days)
7 Nordic lowland floodplains	1	2	56	56	56	56	241	Long (> 50 days)

Note: The factor dominant geology (geochemistry) in the catchment as a categorical factor is not included here.

Annex 4 Share of floodplain features for least-disturbed FECs

Box plots showing the share of floodplain features per floodplain type and dominant channel feature for least-disturbed FECs, based on Copernicus RZ LC/LU MAES level 3 data analyses (Figure A4.1).

Figure A4.1: Box plots showing the share of floodplain features per floodplain type

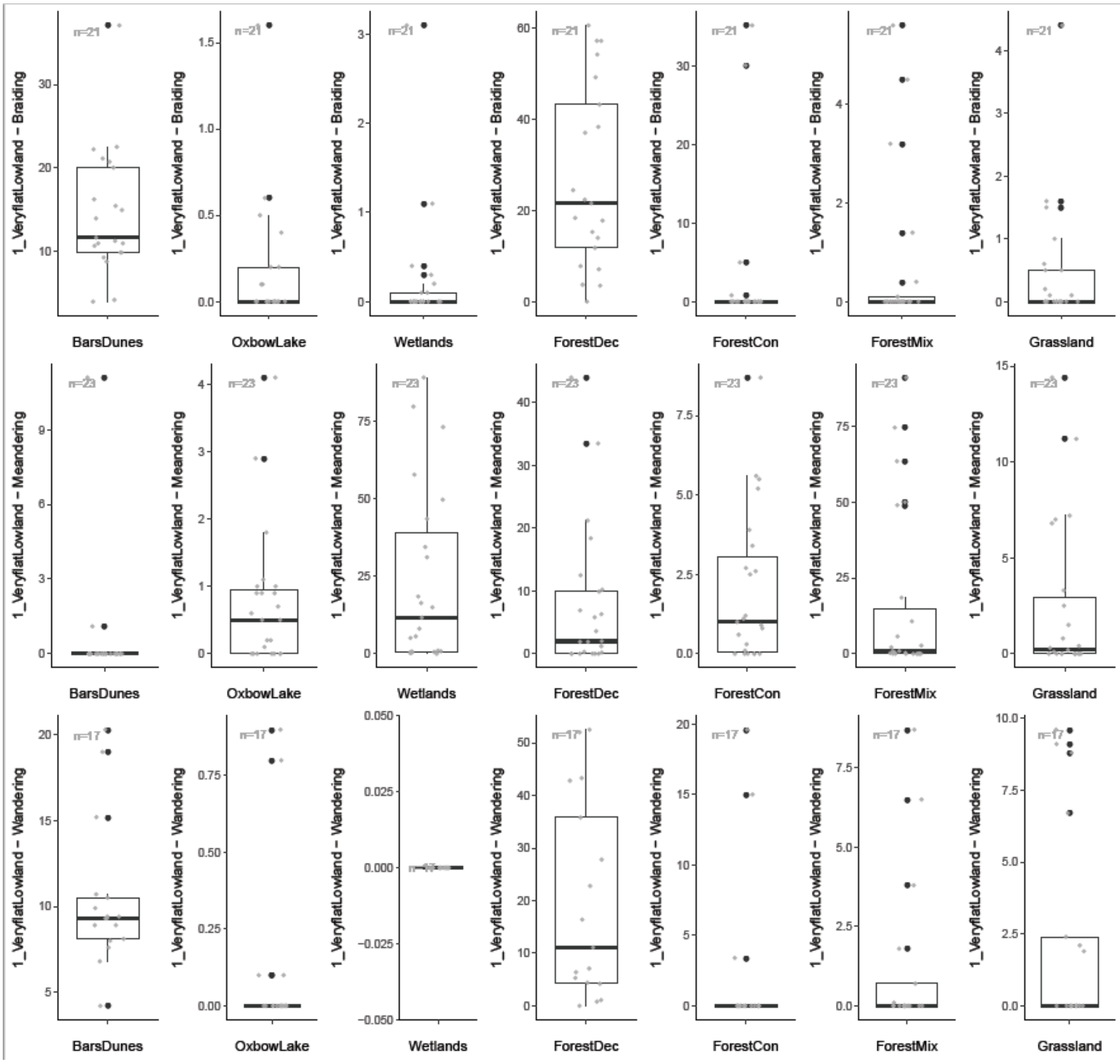


Figure A4.1: Cont.

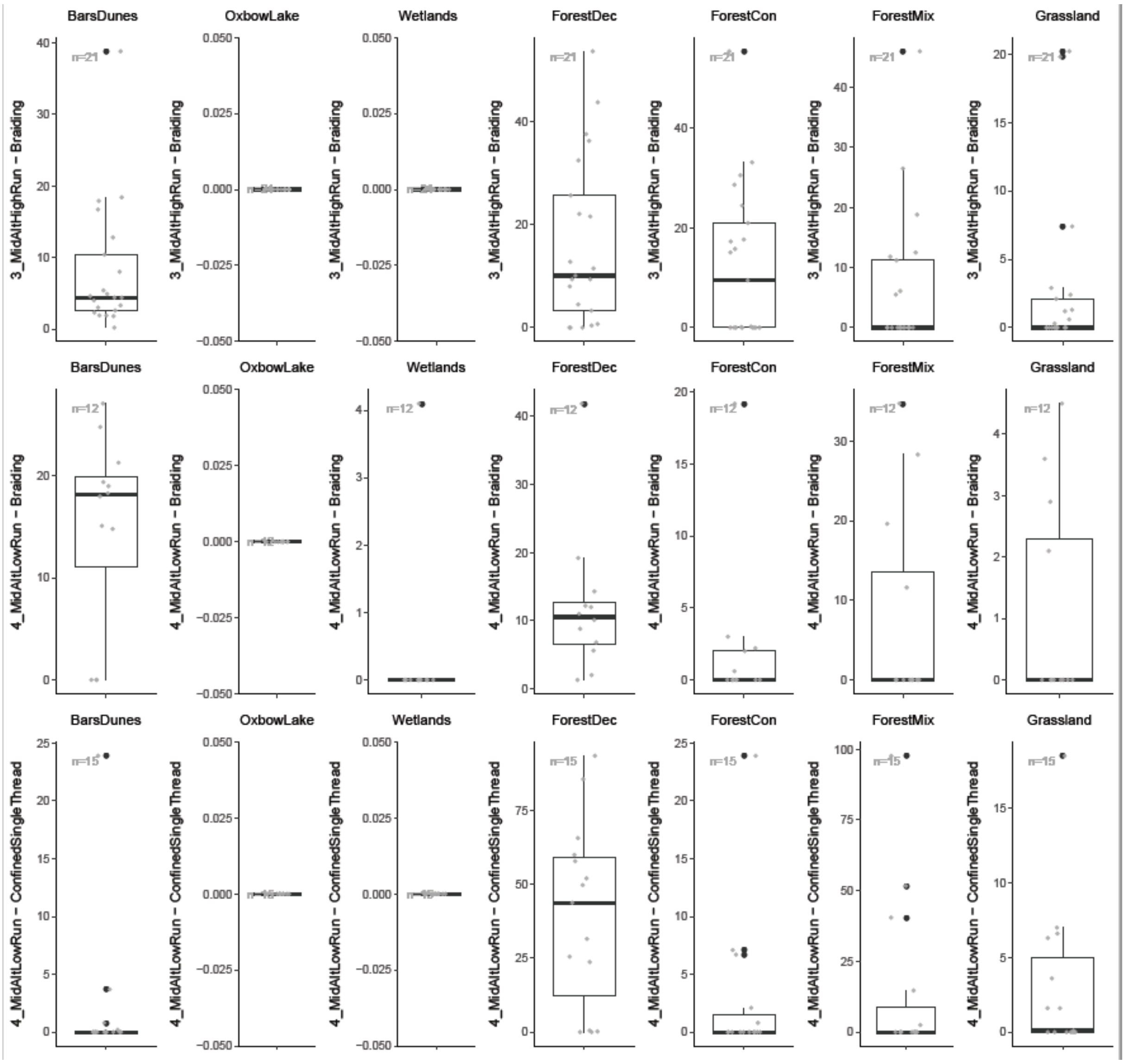


Figure A4.1: Cont.

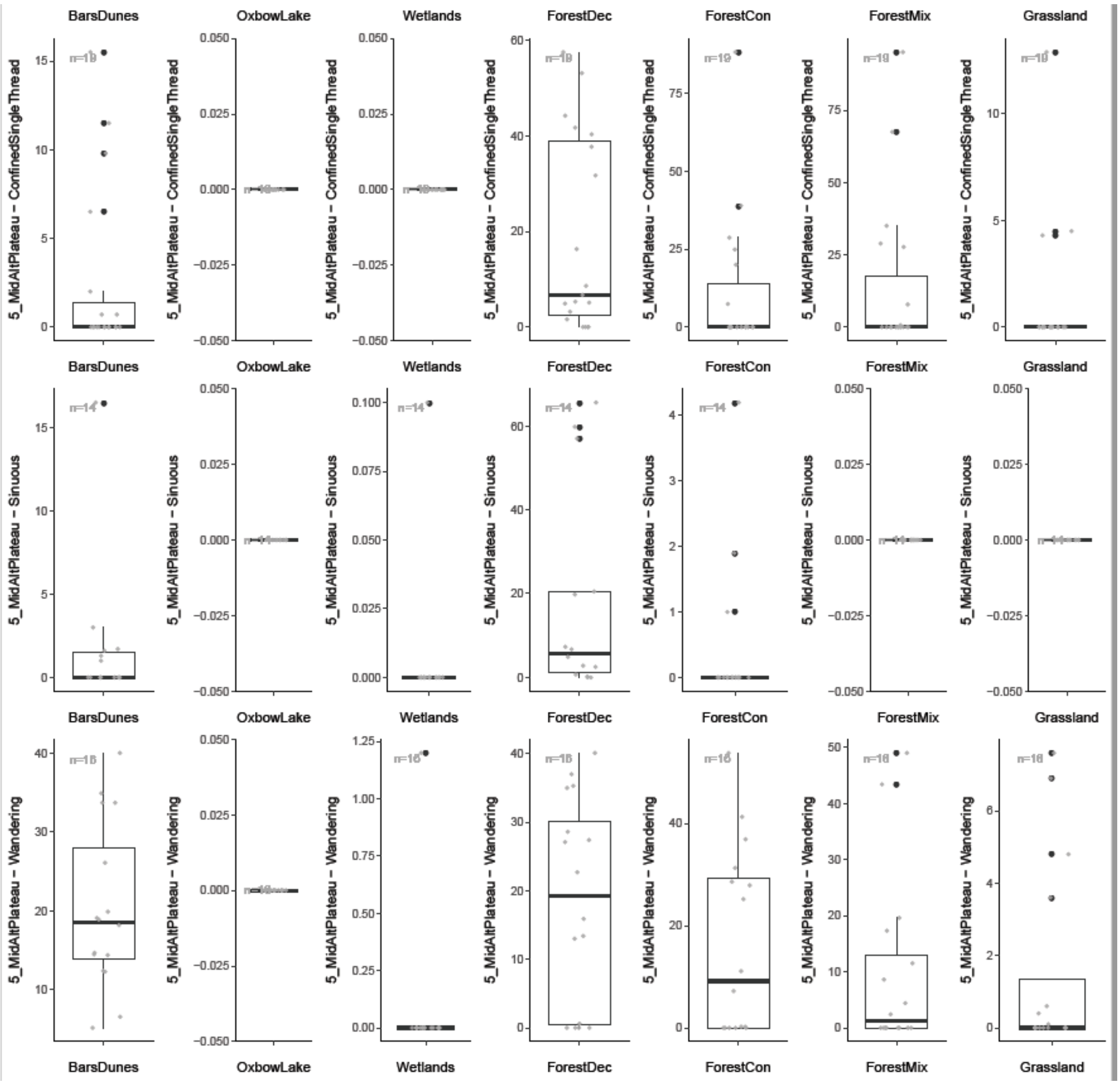
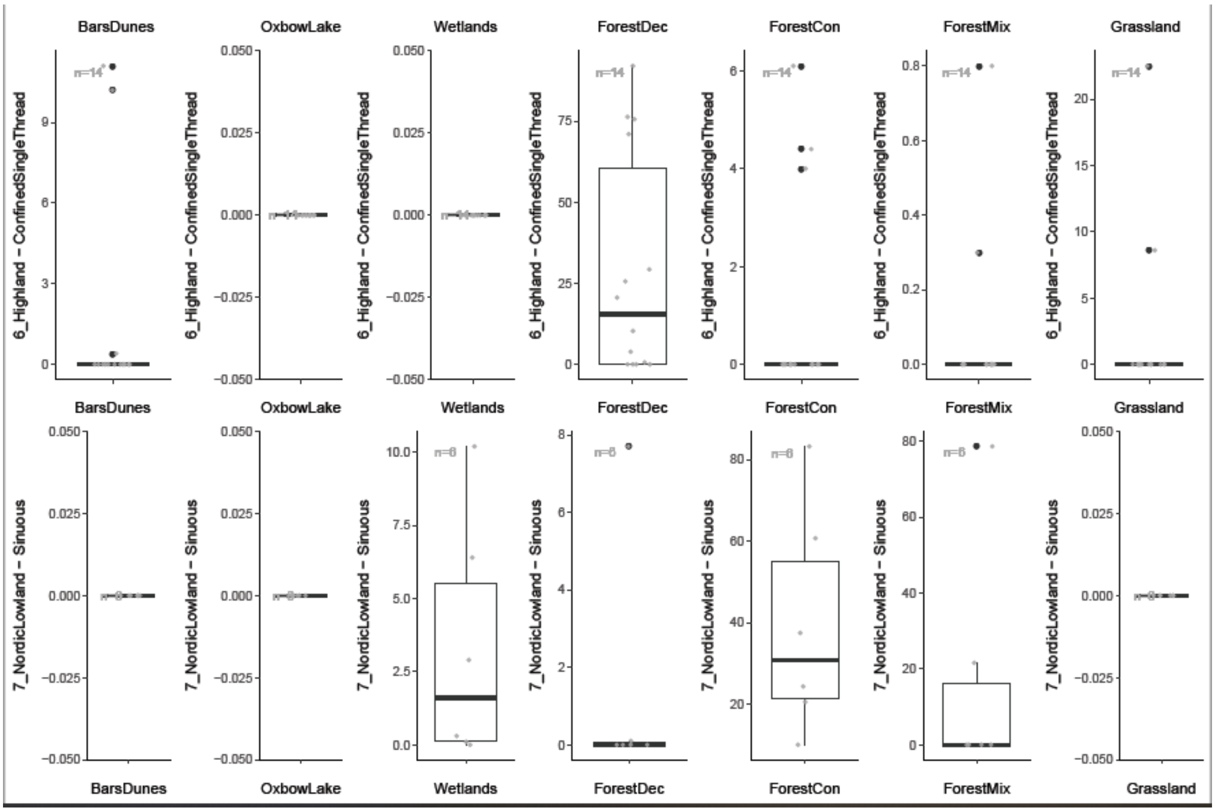


Figure A4.1: Cont.



Annex 5 Fact sheets

Floodplain Type 1: Very flat lowland floodplains

Very flat lowland floodplains are the largest floodplains across Europe with a potential floodplain width of more than 0.6 km up to 1.5 km. Mainly located in wide valleys and with very low slopes, rivers in this floodplain type show meandering, wandering or braided patterns and collect water from catchments up to 10,000 km². Floodplains with wandering or braided rivers are characterized by huge bars, floodplains with meandering rivers are characterized by oxbow lakes and wetlands. The run-off rate is generally low. High discharge events mainly occur in spring and flooding can persist for longer time spans.

Spatial distribution

Map A5.1: The European distribution of the floodplain type 1; number of FECs: 10,567

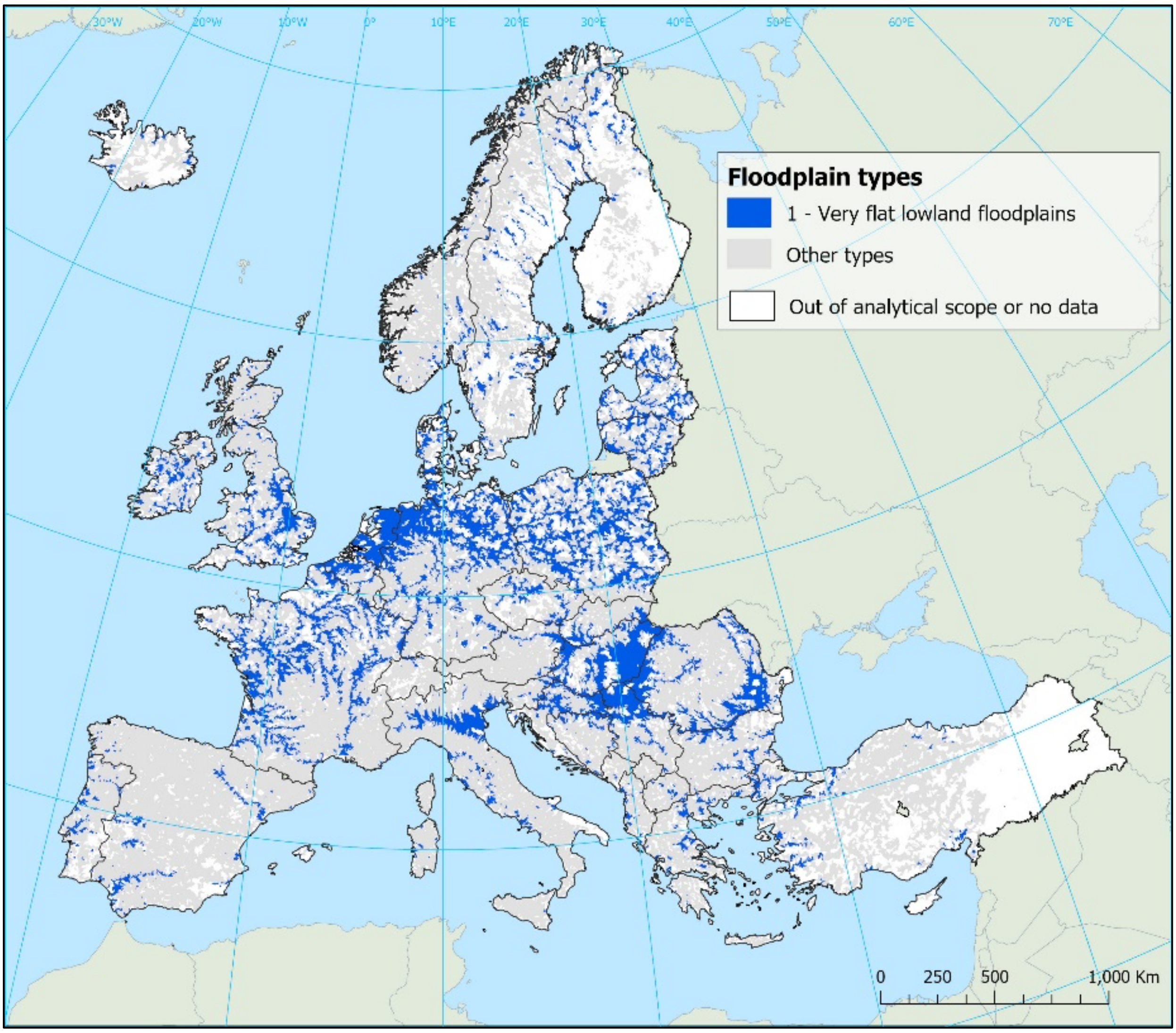
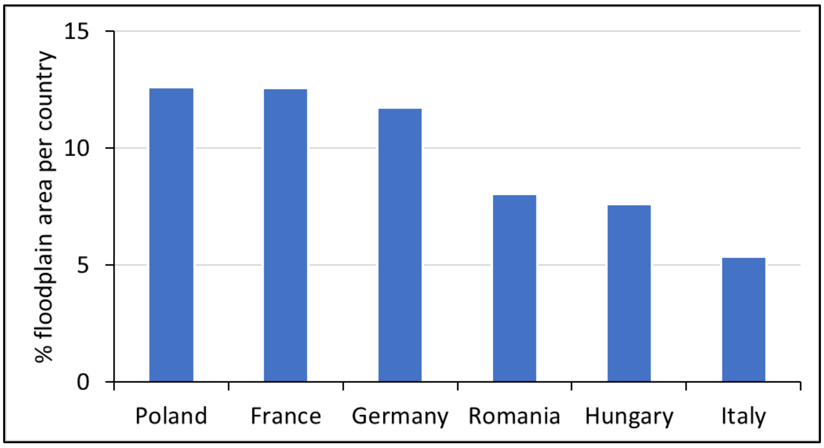


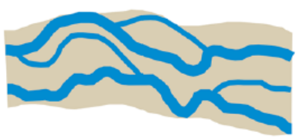
Figure A5.1: Distribution (% coverage) of floodplain type 1 within the EEA39 countries (countries shown with > 5 % of potential floodplain per country covered with relevant type)



Main characteristics

Altitude	Lowland (< 200 m a.s.l.)
Catchment size	Medium to very large (130-10,000 km²)
Slope	Very flat (< 1 m/km)
Potential width	Very wide (> 0.6 km)
Run-off rate	Low (< 20 l/s/km²)
Average flooding duration	< one month
Seasonality	High discharges in early spring (March to April)

Dominant channel patterns

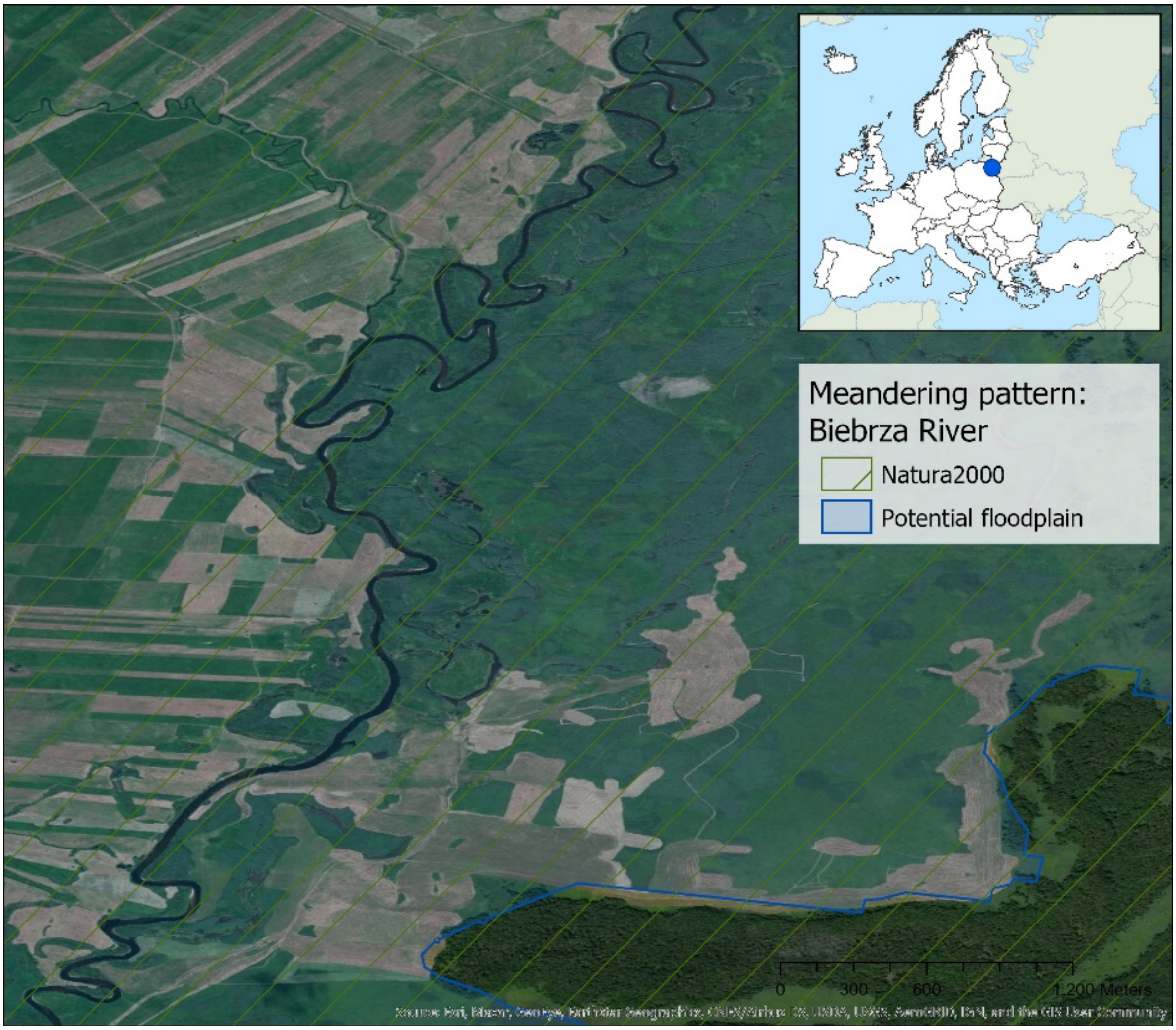
Confined single-thread	Sinuous	**Meandering**
		
Wandering	**Braided**	
		

Floodplain features (dark green = essential and dominant, light green = subdominant):

Channel pattern	Bars and dunes	Oxbow lakes	Wetlands	Deciduous forest	Coniferous forest	Mixed forest	Natural grassland
Meandering		dark green	dark green	dark green		dark green	
Wandering	light green			dark green			
Braided	dark green			dark green			

Meandering pattern: Biebrza River, Poland

Figure A5.2: Location of the Biebrza River (Poland) in Europe and satellite image of a meandering section



The Biebrza River (length: 164 km) and its floodplain are located in north-eastern Poland in the largest Polish national park, the Biebrza National Park. The huge floodplain wetland areas, peatbogs and marshes cover about 43 % of the total national park area (59 233 ha). In the designated Natura2000 sites (Dolina Biebrzy; natura2000 code PLH200008), the river shows typical near-natural meandering patterns. Here, the floodplain is up to 3 km wide. The meandering river typically consists of a single channel which forms a series of regular sinuous curves, bends, loops, turns, or windings in a wide floodplain. It is characterized by formations of highly curved meander bends with cut banks at the outer bends and the deposition of large point bars in the inner bends at the transition between the low-flow channel and the floodplain.

Continuous erosion and deposition lead to the lateral growth and downstream movement of the meander bends, re-working the floodplain sediments, development of floodplain features like meander scroll bars, natural levees, dunes, back-swamps, finally leading to meander cut-offs and the formation of oxbow-lakes. The Park has a high importance for nature conservation: it is a wetland site of global significance and under the protection of the RAMSAR Convention. As a designated Natura2000 area (special protected area for birds (SPA) and site of community importance (SCI)), it protects 21 habitat types of the Habitats Directive, whereas 7 are directly related to a near-natural river-floodplain system.

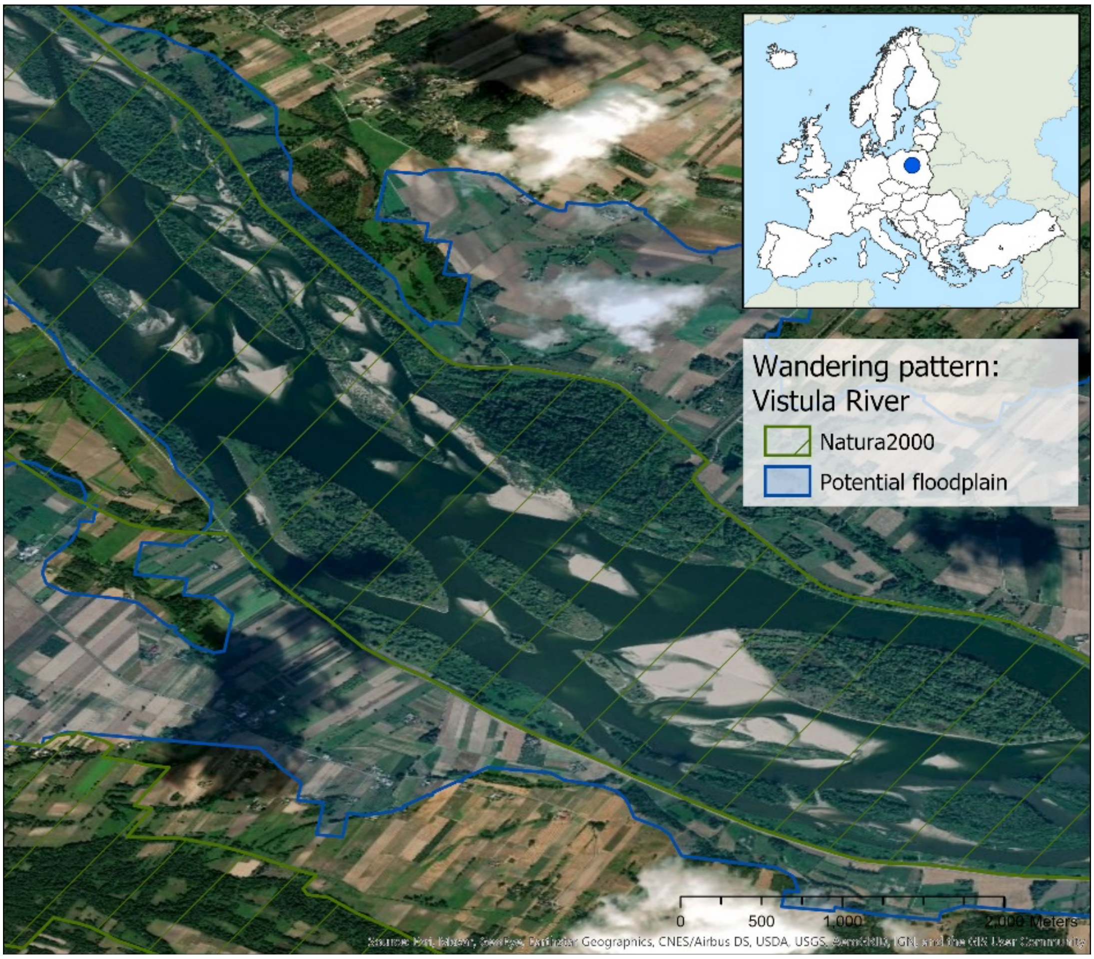
For the national park, about 900 vascular plants have been described, out of which 90 species are under strict protection. Most of them are well adapted to wet conditions, e.g. sedge and reed communities. Furthermore, it is colonized by 50 mammal species and 270 bird species. In the past, building of canals and drainage systems caused drastic changes in water supply conditions, which led to the degradation of the wetland ecosystem. Therefore, measures to reconstruct hydrological conditions were applied. Agricultural management was adopted to conservation principles and a public awareness campaign started to encourage organic farming in the area. In the park, guided tourism plays a significant role (e.g. in form of tourist footbridges, observational platforms, hiking trails and licensed guides).
Further information: https://www.biebrza.org.pl

Table A5.1 Protected natura2000 habitat types related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation
3160	Natural dystrophic lakes and ponds
3270	Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6440	Alluvial meadows of river valleys of the *Cnidion dubii*
91E0	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)
91F0	Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (Ulmenion minoris)

Wandering pattern: the Vistula river, Poland

Figure A5.3: Location of the Vistula River (Poland) in Europe and satellite image of a wandering section



The Vistula river (Polish: Wisla river; German: Weichsel; length: 1 047km) is the longest and largest river in Poland. The middle river sections up- and downstream from Warsaw show long, least-disturbed sections with a typical wandering channel pattern. The pattern is characterized by a multi-thread channel resulting from local avulsions caused by sediment overload or the periodic formation of large wood or ice jams, blocking and forcing the flow to pass on the floodplain where high flow channels form that finally develop into secondary channels and a multi-thread pattern. This anabranching results in rather stable islands at floodplain level separating dynamic channels with alternating side bars or braided bars and islands. Banks are vegetated with floodplain forest. Downstream from Warsaw, the Vistula river and its floodplain are part of an area of 207 km² designated as a Natura2000 protected area (Kampinoska Dolina Wisły; natura2000 code PLH140029)[4].

It protects 9 habitat types of the Habitats Directive, whereas 5 are directly related to a near-natural river-floodplain system. Furthermore, it protects 22 species, whereas about 15 are related to a natural river-floodplain system Mainly fish species benefit from these near-natural habitats (9 species).The history of floods of the Vistula is the focus of researches in several projects on historical hydrology as flooding in such a big river is a complex phenomenon depending on several natural and anthropogenic factors[5]: geomorphological processes over longer time spans, climate change, land use, development of dams and embankments and their maintenance.

[4] See NATURA 2000 – STANDARD DATA FORM https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=PLH140029&release=10

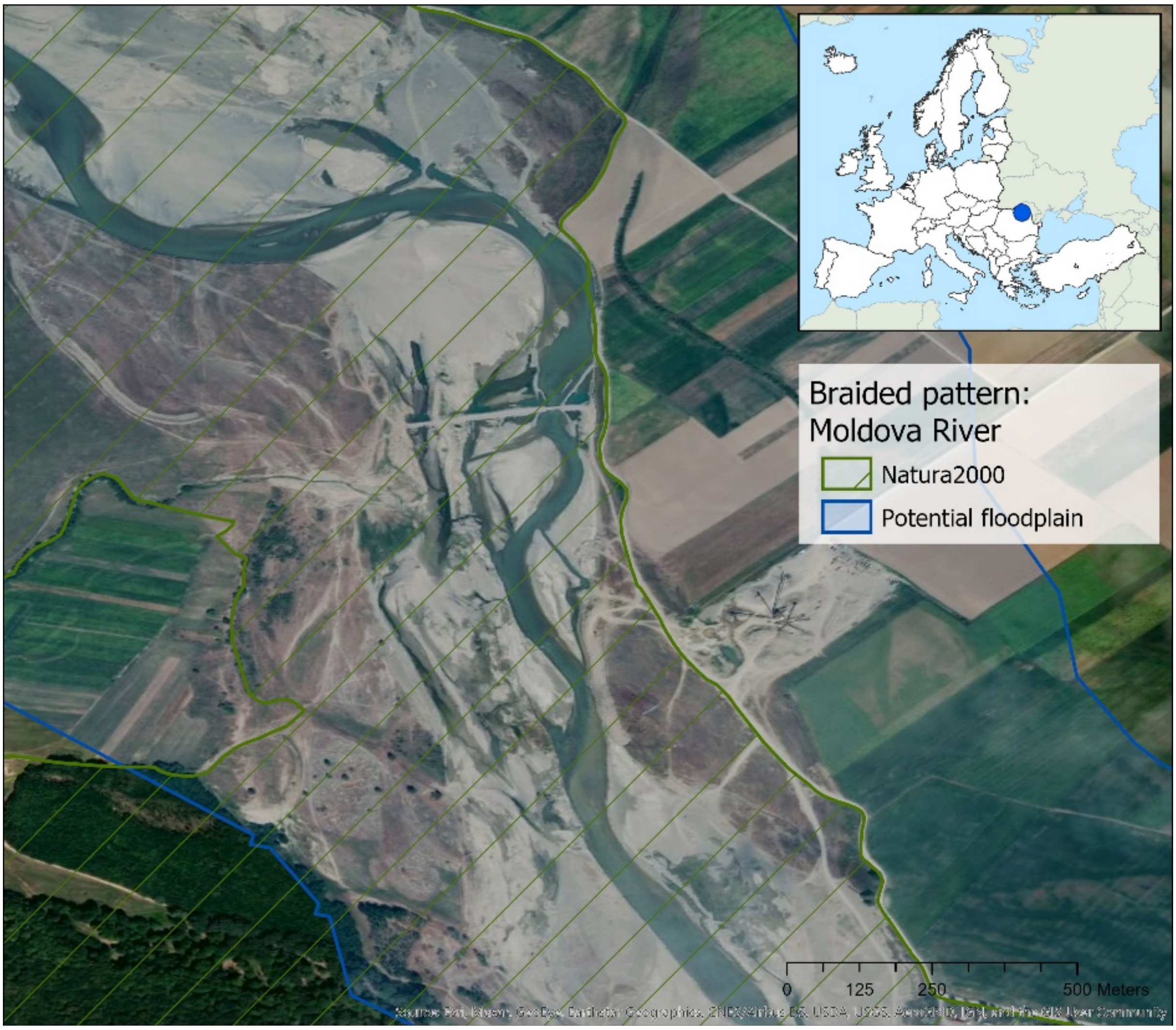
[5] E.g. Cyberski, J., Grześ, M., Gutry-Korycka, M., Nachlik, E., & Kundzewicz, Z. W. (2006). History of floods on the River Vistula. *Hydrological Sciences Journal*, *51*(5), 799–817. https://doi.org/10.1623/hysj.51.5.799.

Table A5.2 Protected natura2000 habitat types in 'Kampinoska Dolina Wisły' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation
3270	Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)
91F0	Riparian mixed forests of *Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus* excelsior or *Fraxinus angustifolia*, along the great rivers (Ulmenion minoris)

Braided pattern: Moldova river, Romania

Figure A5.4: Location of the Moldova River (Romania) in Europe and satellite image of a braided section



The Moldova river (length: 213 km) and its floodplain are located in the north-eastern part of Romania. The river originates from the Carpathian mountains and is known for the extent of its large floodplain and thickness of alluvial thickness.

Numerous large fossil trunks of oak, poplar and beech trees are buried in the alluvial sediments and become exposed at the riverbanks. The area is of high interest to geomorphologists who conducted detailed geomorphological, sedimentological and ^{14}C analyses of Late Holocene fluvial sequences[6].

The Moldova river is characterized by a braided channel pattern, which shows multi-thread channels building a complex river network with several bifurcations and longitudinal bars, frequent pioneer islands and some mature islands. This is due to high stream power, rapid and frequent variations in water discharge, high sediment loads and high and strong discharges, which result in small-scale sediment erosion and deposition dynamics. Braided channel patterns are typically accompanied by wide floodplains mainly dominated by huge gravel bars; banks at the outer areas of the floodplains are vegetated by floodplain forest. An area of 47 km² is designated as a Natura2000 protected site (Râul Moldova între Tupilați și Roman; natura2000 code ROSCI0364) due to the presence of 15 important species (e.g. amphibians: Crested Newt; fish: Spined Loach; mammals: Eurasion Otter)[7]. Furthermore, valuable freshwater habitats, grassland and broad-leaved deciduous woodland are present.

Although the hydromorphological characteristics show near-natural conditions, climate warming and direct human interventions on the river-floodplain-system e.g. gravel exploitation) are identified as the main causes for ongoing channel incision and narrowing of the river.

[6] Chiriloaei, F., Rădoane, M., Perşoiu, I., & Popa, I. (2012). Late Holocene history of the Moldova River Valley, Romania. *Catena*, *93*, 64–77. https://doi.org/10.1016/j.catena.2012.01.008

[7] See NATURA 2000 – STANDARD DATA FORM (https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ROSCI0364&release=10)

Floodplain Type 2: Flat lowland floodplains

Flat lowland floodplains are the most diverse floodplains across Europe and can have confined, meandering, or braided channel patterns, depending on the valley shape. In narrow valleys, rivers of this floodplain type feature confined single-thread patterns; in wider valleys, meandering or braided patterns are occurring and collect water from catchments up to 1 000 km²; in narrow valleys, confined single-thread patterns are present. Floodplains with meandering rivers are characterized by oxbow lakes and wetlands, floodplains with braided rivers are dominated by huge bars. The run-off rate is generally low. High discharge events mainly occur in spring, whereas flooding can persist for longer time spans.

Spatial distribution

Map A5.2: The European distribution of the floodplain type; number of FECs: 25 179

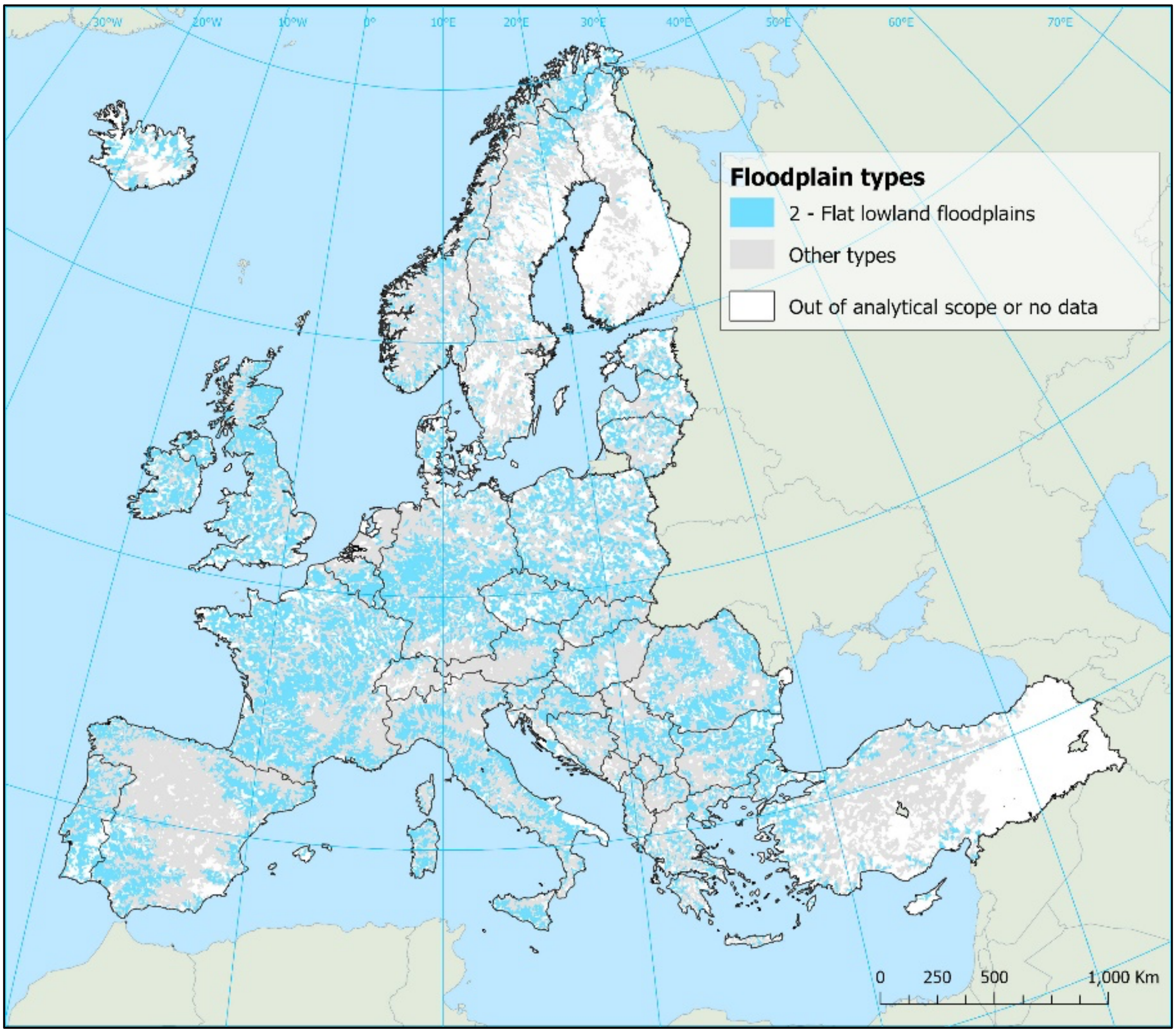
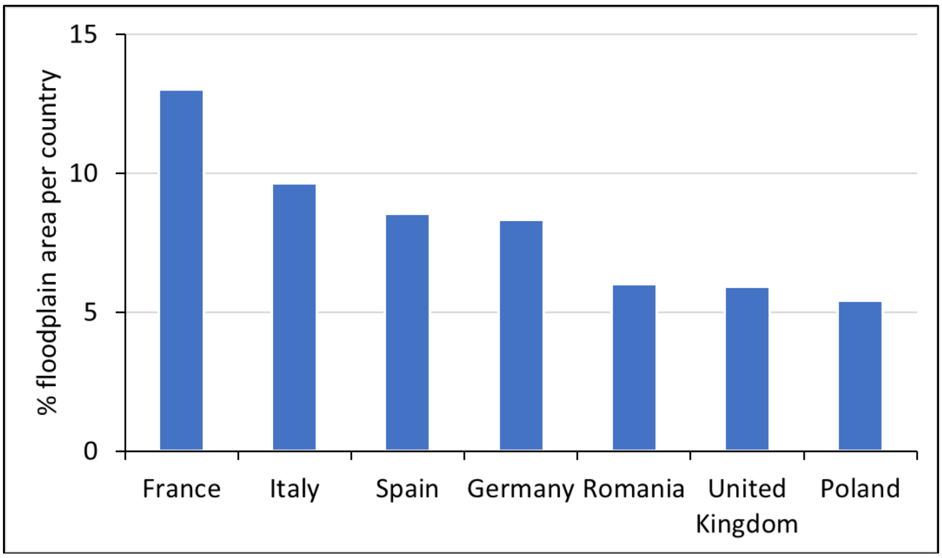


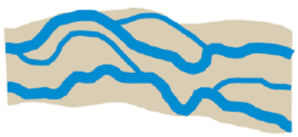
Figure A5.5: Distribution (% coverage) of floodplain type 2 within the EEA39 countries (countries shown with > 5 % potential floodplain per country covered with relevant type)



Main characteristics

Altitude	Lowland (< 300m a.s.l.)
Catchment size	Small to large (50–1 000 km²)
Slope	Flat (1-10 m/km)
Potential width	Wide (0.1-1.0 km)
Run-off rate	Low (< 40 l/s/km²)
Average flooding duration	< one month
Seasonality	High discharges in early spring (March to April)

Dominant channel patterns

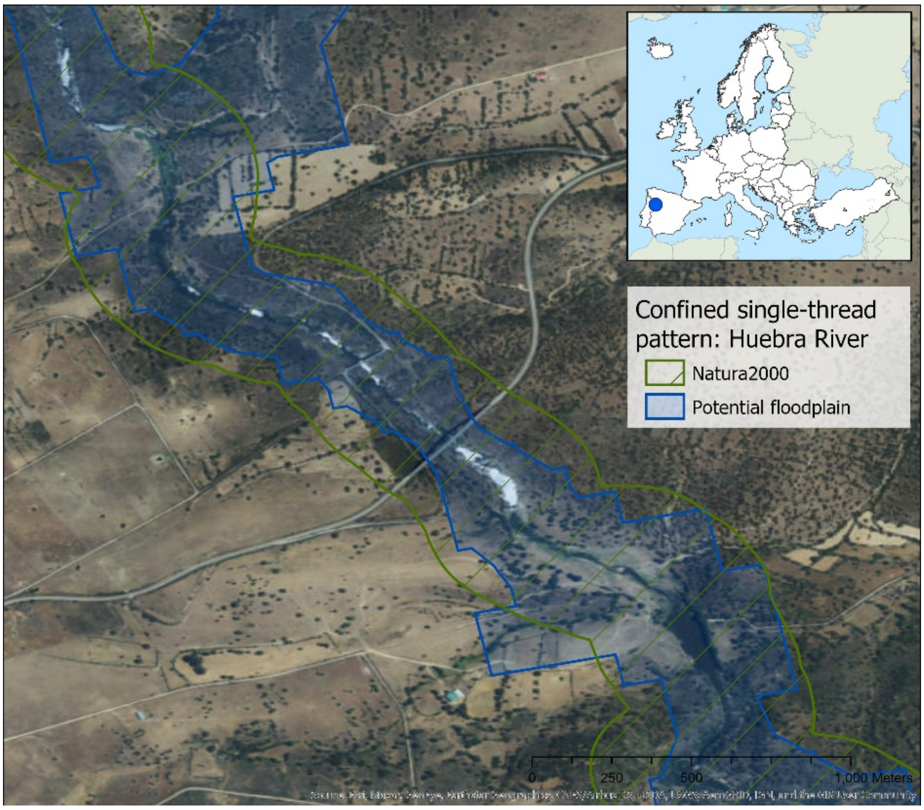
Confined single-thread	Sinuous	**Meandering**
		
Wandering	**Braided**	
		

Floodplain features (dark green = essential and dominant, light green = subdominant)

Channel pattern	Bars and dunes	Oxbow lakes	Wetlands	Deciduous forest	Coniferous forest	Mixed forest	Natural grassland
Confined single-thread							
Meandering							
Braided							

Confined single-thread pattern: the Huebra River and nearby confluences, Spain

Figure A5.6: Location of the Huebra River (Spain) in Europe and satellite image of a confined single-thread section



The Huebra River (length: 122 km) and its floodplain are located in western Spain. It flows from the village Escurial de la Sierra (in Salamanca province) into the Duero river which is the third largest river of the Iberian Peninsula. In least-disturbed conditions the river is characterized by a confined single-thread pattern. The river channel is naturally located in a narrow valley and the floodplain is small or absent due to the natural confinement by hillslopes or ancient terraces. Some small gravel or stone bars in the riparian zone occur. Most sections of the Huebra River and its narrow floodplain are undisturbed and therefore highly valuable for nature conservation. In total 52 km² of the Huebra river valley and nearby tributaries are designated as a Natura2000 site (Riberas de los Ríos Huebra, Yeltes, Uces y afluentes; Natura2000 code ES4150064)[8]. It protects 21 habitat types of the Habitats Directive, whereas 5 are directly related to a near-natural river-floodplain system. Furthermore, it protects 15 species, whereas six are strongly associated with rivers and floodplains, e.g. the Iberian painted frog, the fish species Southern Iberian spined loach, the Eurasion otter and the European pond terrapin.

[8] See NATURA 2000 – STANDARD DATA FORM (https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ES4150064)

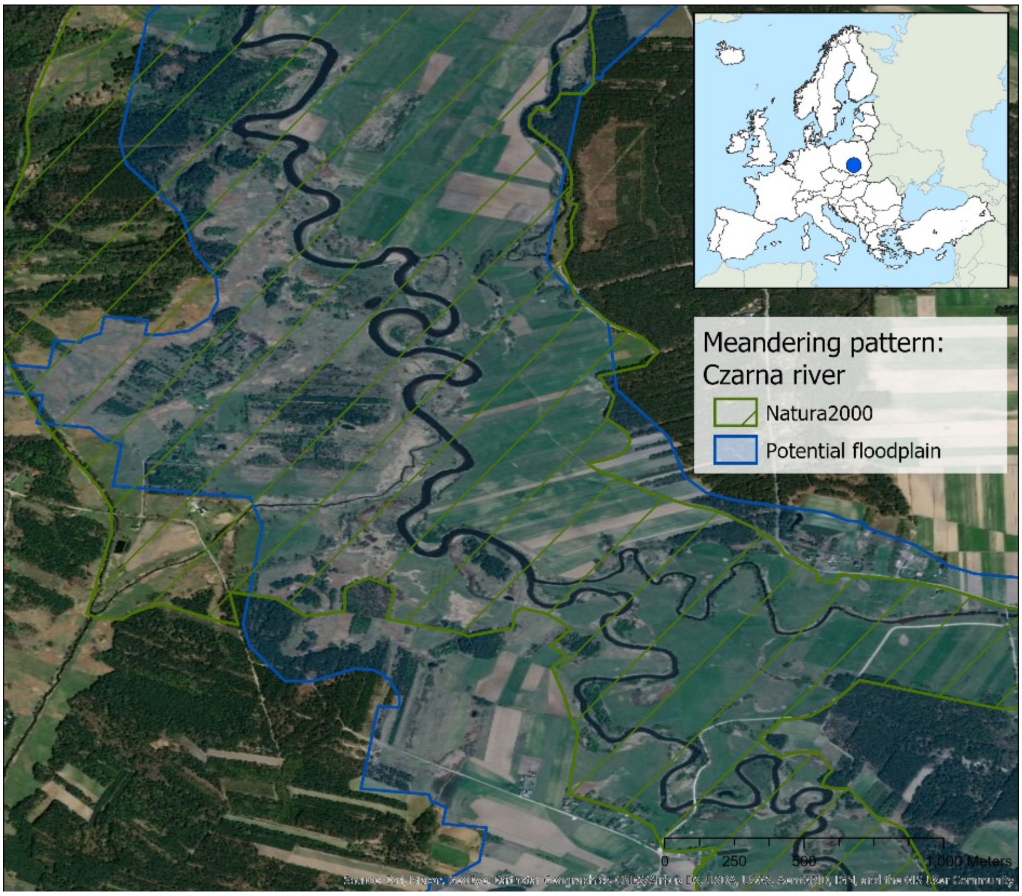
Table A5.3 Protected Natura2000 habitat types in the Natura2000 area 'Riberas de los Ríos Huebra, Yeltes, Uces y afluentes' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation
3250	Constantly flowing Mediterranean rivers with *Glaucium flavum*
3270	Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation

As a Special Protected Area (SPA) it is colonized by many bird species. Although the Huebra River and its floodplain are mostly least-disturbed and characterized by near-natural floodplain features and species, the river continuum was disrupted by a 2-metre-tall dam, built in 1958[9]. The dam supplied drinking water to local communities for half a century and was thought of as being responsible for the decline of endemic freshwater species. Due to the Water Framework Directive which aims at the improvement of the ecological status of rivers, the removal of the dam was conducted as one of the largest removal projects in Europe with high benefits for biodiversity [10].

Meandering pattern: Czarna River, Poland

Figure A5.7: Location of the Czarna River (Poland) in Europe and satellite image of a meandering section



[9] Schiermeier, Q. (2018): Dam removal restores rivers. Nature 557: 290–291. https://amber.international/wp-content/uploads/2018/06/2018-05-17_Nature.pdf

[10] https://www.damremoval.eu/portfolio/yecla-de-yeltes-dam-spain

The Czarna river (length: 198 km) and its floodplain is located in central Poland. It is a tributary to the Pilica river (a large lowland river), which is the longest tributary of the Vistula river. The least-disturbed sections of the Czarna River are characterized by meandering channel patterns. The river channel swings back and forth across the floodplain within in a wide valley with a width of appr. 0.7 km and builds a series of sinuous curves, loops, windings or turns. The meandering river typically consists of a single channel which forms a series of regular sinuous curves, bends, loops, turns, or windings in a wide floodplain. It is characterized by formations of highly curved meander bends with cut banks at the outer bends and the deposition of large point bars in the inner bends at the transition between the low-flow channel and the floodplain. Continuous erosion and deposition lead to the lateral growth and downstream movement of the meander bends, re-working the floodplain sediments, development of floodplain features like meander scroll bars, natural levees, dunes, back-swamps, finally leading to meander cut-offs and the formation of oxbow-lakes.

Together with the Pilica River and other tributaries, the Czarna River is designated as a Natura2000 site (Dolina Górnej Pilicy; Natura2000 code PLH260018) on a total area of 112 km² and highly valuable for nature conservation[11]. It protects 17 habitat types of the Habitats Directive, whereas five are directly related to a near-natural river-floodplain system. Additionally, different types of important natural grassland habitats occur, such as 'Inland dunes with open *Corynephorus* and *Agrostis* grasslands'. Furthermore, it protects 22 species, from which are the most bound to a natural river-floodplain-system: 11 invertebrate species (e.g. Green snaketail), five fish species (e.g. European weather loach) and two Amphibian species (e.g. Crested Newt).

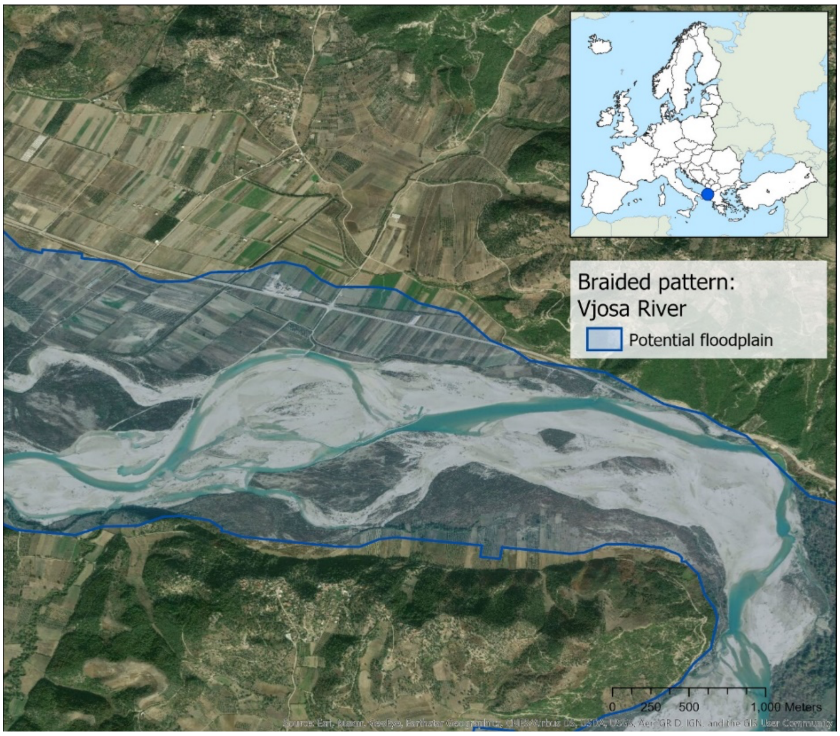
Table A5.4 Protected Natura2000 habitat types in the Natura2000 site 'Dolina Górnej Pilicy' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
3270	Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)

[11] See NATURA 2000 – STANDARD DATA FORM
https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=PLH260018

Braided pattern: Vjosa (Aoös) River, Albania

Figure A5.8: Location of the Vjosa River (Albania) in Europe and satellite image of a braided section



The Vjosa River (length: 270 km) and its floodplain are located in south Albania. It is one of the last remaining free flowing 'wild rivers' in Europe[12]. Especially the middle part of the river is characterized by natural braided river sections where the floodplain spans a width up to 2 km. The floodplain of these braided river sections shows the typical network of channels and islands. It is dominated by huge gravel bars due to high sediment load. In elevated zones of the floodplain deciduous floodplain forest is growing. The network of channels, bars and islands underlies frequent dynamic changes and is characterized by processes of strong sediment erosion and deposition. The floodplain underlies strong and rapid variation in water discharge. Frequent flooding and periods of water stress result in a very dynamic system and strong morphological processes of sediment erosion and deposition. Although the Vjosa River itself is not designated Natura2000, it borders many protected areas (three of which are designated as IUCN category II[13]and shows a high diversity of fauna and flora, which include many, often highly endangered species adapted to frequent flooding and habitat dynamics. It has a special importance for migratory fish and as a breeding ground for birds (e.g. the little ringed plover).

The large gravel bars are colonized by special pioneer vegetation. Furthermore, the Vjosa River and its floodplain has an importance for local fishermen and, increasingly, for recreational tourism, which is now partly converted into eco-tourism. The terraces of the floodplain are used for agricultural activities such as crop production and livestock farming. The biggest threat is the planned construction of 38 hydropower plants in the Vjosa catchment, which will have a severe impact on the hydrological regime and natural sediment transport. Therefore, an initiative was started by the local communities, scientists and support from all over Albania and Europe to save this unique river-floodplain system.[14]

[12] Miho, A., Beqiraj, S., Graf, W., & Schiemer, F. (2018). The Vjosa river system in Albania: a summary of actual challenges and agendas The Vjosa river system in Albania : a summary of actual challenges and agendas The Vjosa – a unique river – is threatened. *Acta ZooBot Austria*, *155*, 377–385.

[13] The IUCN Category II (national parks) labels protected large natural or near natural areas set aside to protect large-scale ecological processes and species and ecosystems characteristics of the area, under consideration of environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.

[14] https://balkanrivers.net/en/key-areas/vjosa-river

Floodplain Type 3: Mid-altitude high run-off floodplains

Mid-altitude high run-off floodplains are narrow, highly dynamic floodplains with a potential floodplain width of 0.04 to 0.25 km. Mainly located in valleys with high slopes, rivers in this floodplain type show braiding patterns and drain catchments ranging from 20 to 200 km². The floodplain is characterized by bars and forest. The run-off rate is generally high. High discharge events mainly occur in late spring, whereas flooding persists for shorter time spans.

Spatial distribution

Map A5.3: The European distribution of the floodplain type 3; number of FECs: 3,137

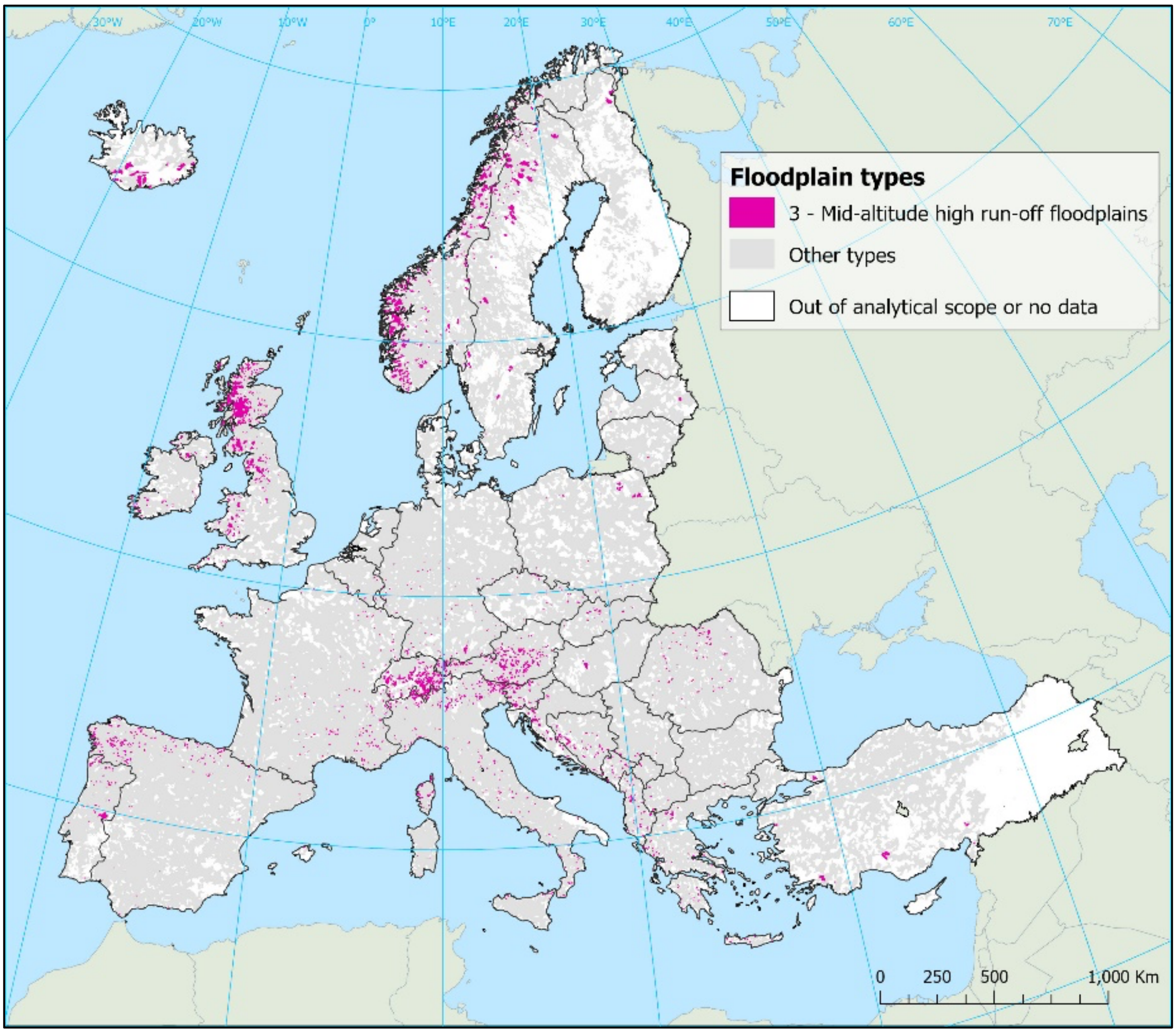
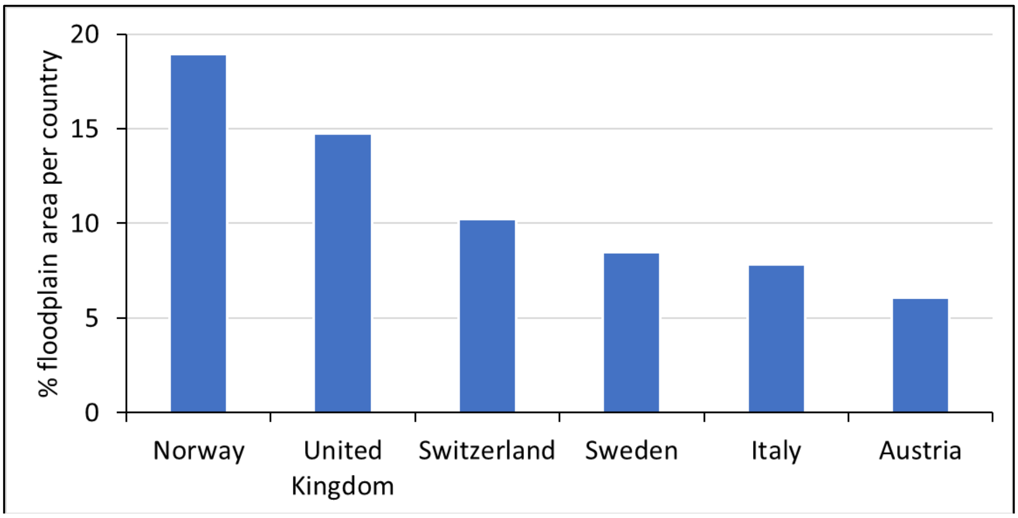


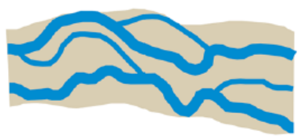
Figure A5.9: Distribution (% coverage) of floodplain type 3 within the EEA39 countries (countries shown with > 5 % of potential floodplain per country covered with relevant type)



Main characteristics

Altitude	Mid-altitude (200–800 a.s.l.)
Catchment size	Small to medium (20–200 km²)
Slope	Steep (10–100 m/km)
Potential width	Narrow (0.04–0.25 km)
Run-off rate	High (> 0.05 m³/s/km²)
Average flooding duration	< one month
Seasonality	High discharges in late spring (April to May)

Dominant channel patterns

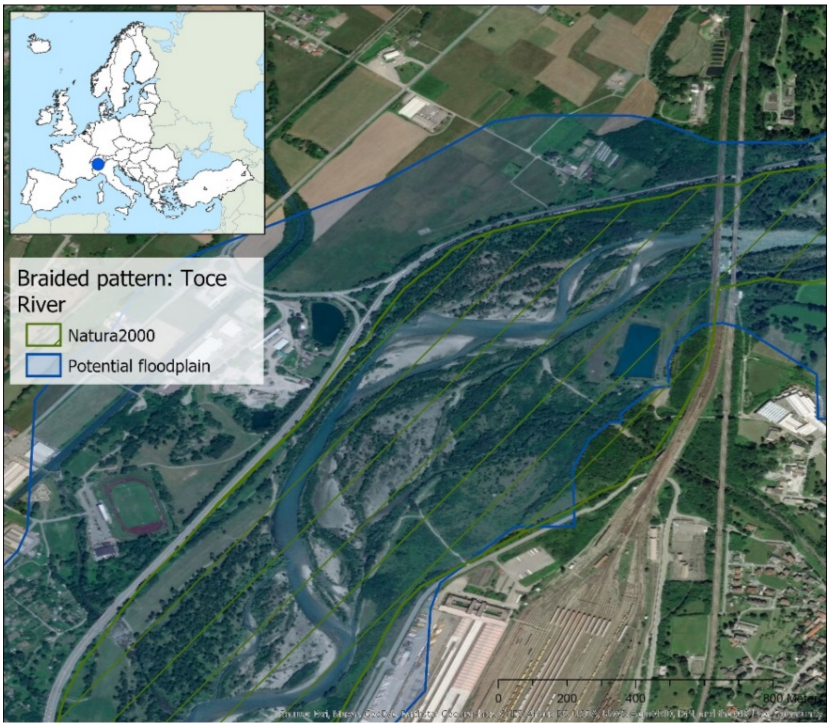
Confined single-thread	Sinuous	Meandering
		
Wandering	**Braided**	
		

Floodplain features (dark green = essential and dominant, light green = subdominant)

Channel pattern	Bars and dunes	Oxbow lakes	Wetlands	Deciduous forest	Coniferous forest	Mixed forest	Natural grassland
Braided							

Braided pattern: Toce River, Italy

Figure A5.10: Location of the Toce River (Italy) in Europe and satellite image of a braided section



The Toce River (length: 84 km) and its floodplain are located in the Alpine region of northern Italy. In this least-disturbed section it shows typical braided channel patterns with multi-thread channels building a river network with several bifurcations and longitudinal bars, frequent pioneer islands and some mature islands. This is due to high stream power, rapid and frequent variations in water discharge, high sediment loads and high and strong discharges resulting in intensive sediment erosion and deposition. Compared to braided patterns in other floodplain types (e.g., Type 1 or 2), the floodplain is narrower, typical for Alpine regions of higher elevation. The floodplain is dominated by huge gravel bars; banks at the outer areas of the floodplains are vegetated by floodplain forest. Most sections of the Toce River and its floodplain are designated as a Natura2000 site (Torrente Toce tra Domodossola e Villadossola; Natura2000 code IT1140006) on a total area of 746 km² and highly valuable for nature conservation[15]. It protects six habitat types of the Habitats Directive, four of which are directly related to a near-natural river-floodplain system. Additionally, 'Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*) as an important species-rich extensive grassland habitat is present. Furthermore, the area protects 40 species of the Nature Directives: 34 bird species (e.g. the Common Sandpiper which is dependent on sparsely vegetated bars), four fish species and four mammalian species.

Table A5.5 Protected Natura2000 habitat types in 'Torrente Toce tra Domodossola e Villadossola' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3230	Alpine rivers and their ligneous vegetation with *Myricaria germanica*
3240	Alpine rivers and their ligneous vegetation with *Salix elaeagnos*
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)

[15] https://eunis.eea.europa.eu/sites/IT1140006

Floodplain Type 4: Mid-altitude low run-off floodplains

Mid-altitude high run-off floodplains are the narrowest floodplains across Europe with a potential floodplain width of 0.04 to 0.25 km. They are mainly located in narrow valleys with confined single-thread patterns or braided sections. These floodplains have a high slope and feature upstream catchment sizes between 20 to 300 km². Deciduous forests are the dominating land cover, with coniferous forests being naturally present in the Nordic countries; natural grassland occurs in dry areas of the Mediterranean. The run-off rate is low. High discharge events mainly occur in late spring, whereas flooding persists in shorter time spans.

Spatial distribution

Map A5.4: The European distribution of floodplain type 4 (number of FECs: 10,654)

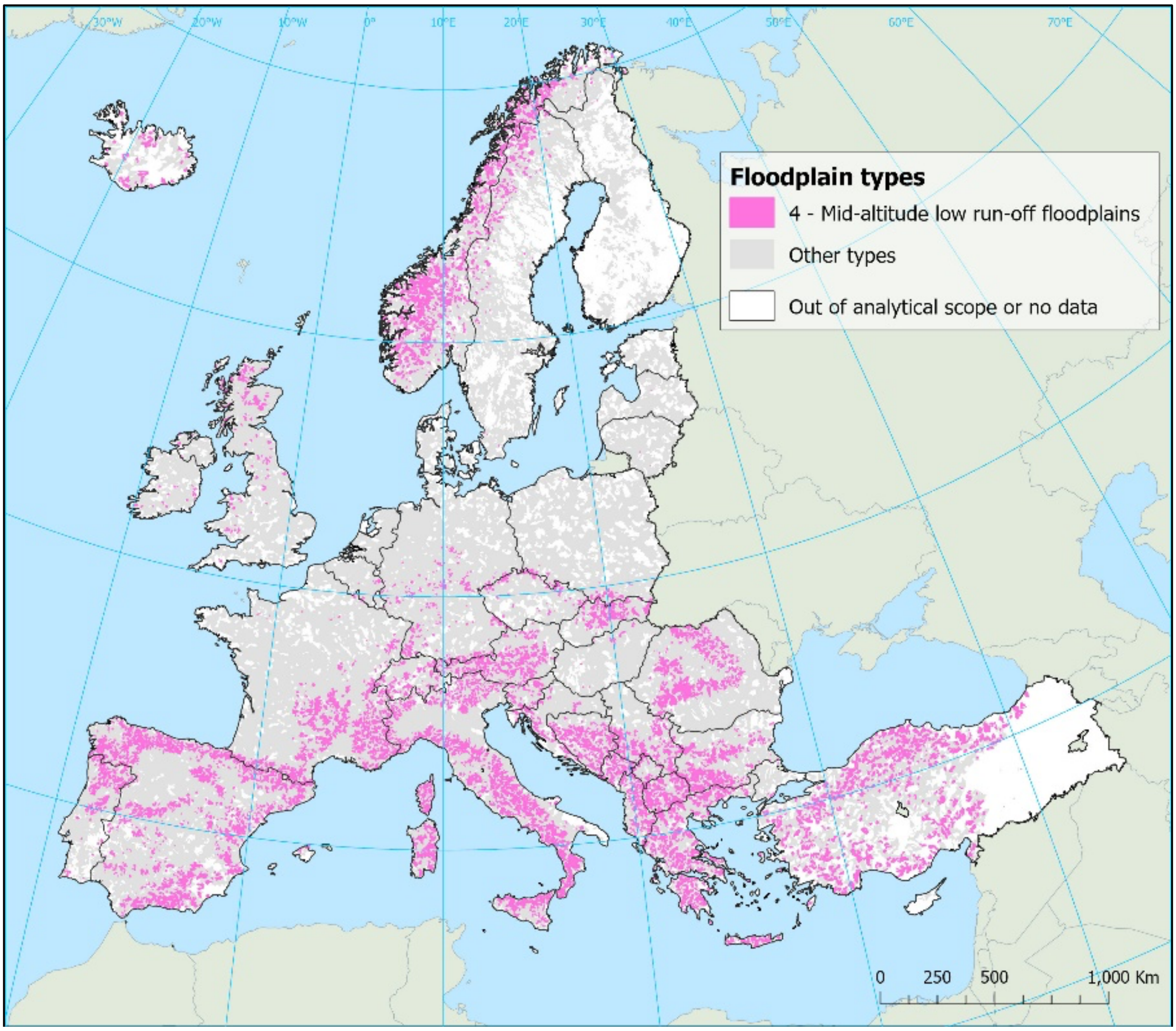
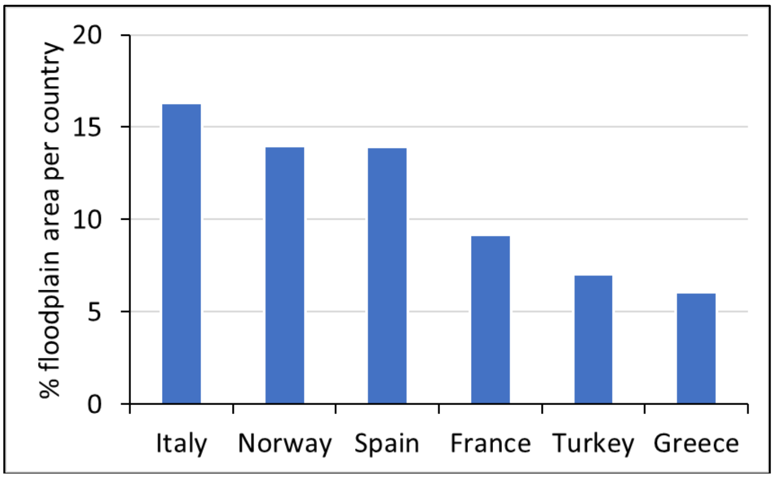


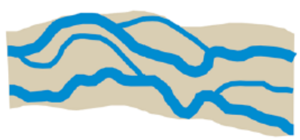
Figure A5.11: Distribution (% coverage) of floodplain type 4 within the EEA39 countries (countries shown with > 5 % of potential floodplain per country covered with relevant type)



Main characteristics

Altitude	Mid-altitude (200–1 000 a.s.l.)
Catchment size	Small to medium (20–300 km²)
Slope	Steep (10–100 m/km)
Potential width	Narrow (0.04–0.25 km)
Run-off rate	Low (< 20 l/s/km²)
Average flooding duration	< one month
Seasonality	High discharges in spring (March to May)

Dominant channel patterns

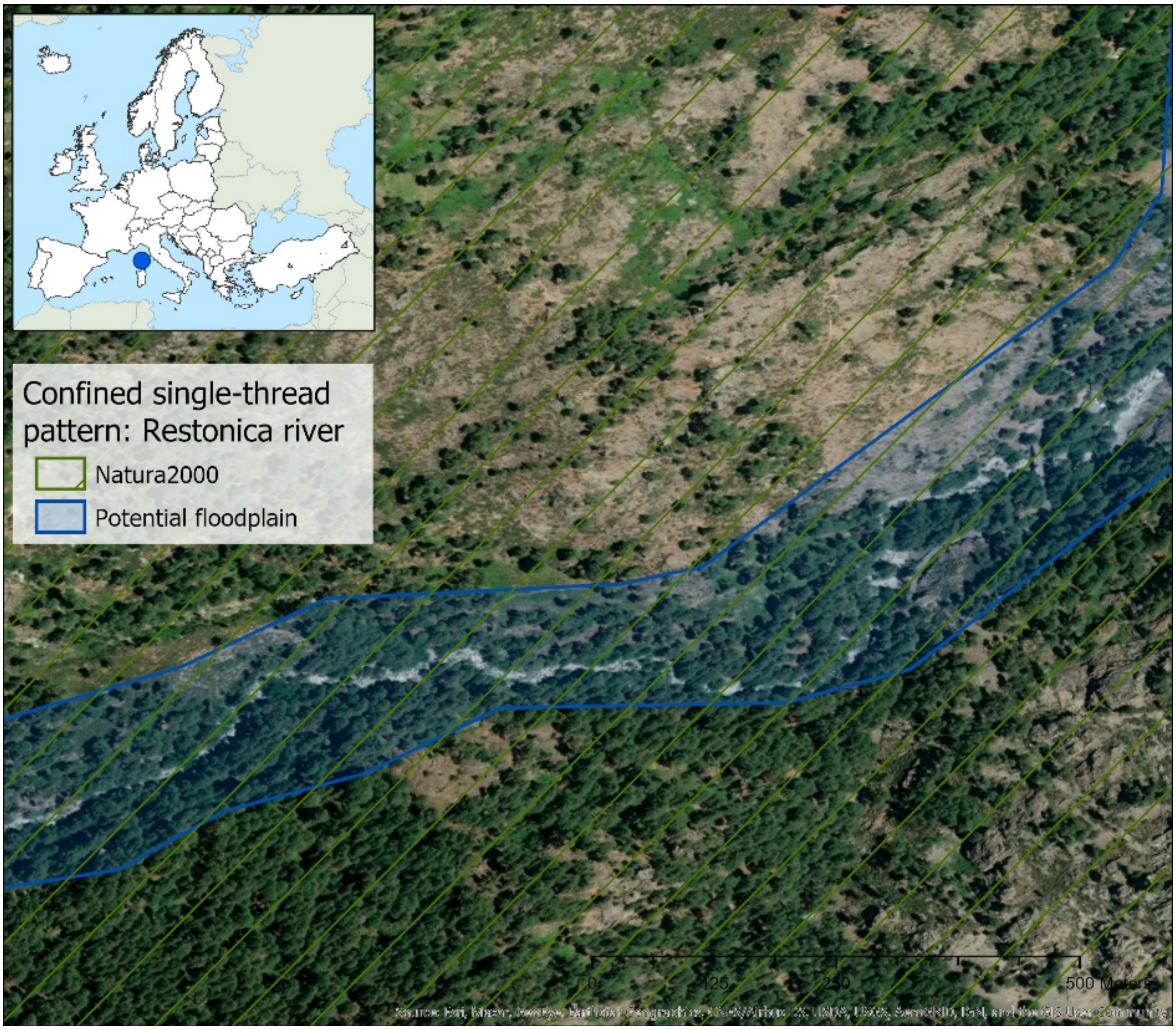
Confined single-thread	Sinuous	Meandering
		
Wandering	**Braided**	
		

Floodplain features (dark green = essential and dominant, light green = subdominant)

Channel pattern	Bars and dunes	Oxbow lakes	Wetlands	Deciduous forest	Coniferous forest	Mixed forest	Natural grassland
Confined single-thread	light green			dark green		dark green	
Braided	dark green			dark green		dark green	light green

Confined single-thread pattern: Restonica River, Corsica (France)

Figure A5.12: Location of the Restonica River (France) in Europe and satellite image of a confined single-thread section.



The Restonica river (length: 8 km) is located in the northern part of Corsica, France, and flows in a valley through granite cliffs and gorges. In least-disturbed conditions the river is characterized by a confined single-thread pattern. The river channel is naturally located in a narrow valley and the floodplain is small or absent due to the natural confinement by hillslopes or ancient terraces. Some small gravel or stone bars in the riparian zone occur.

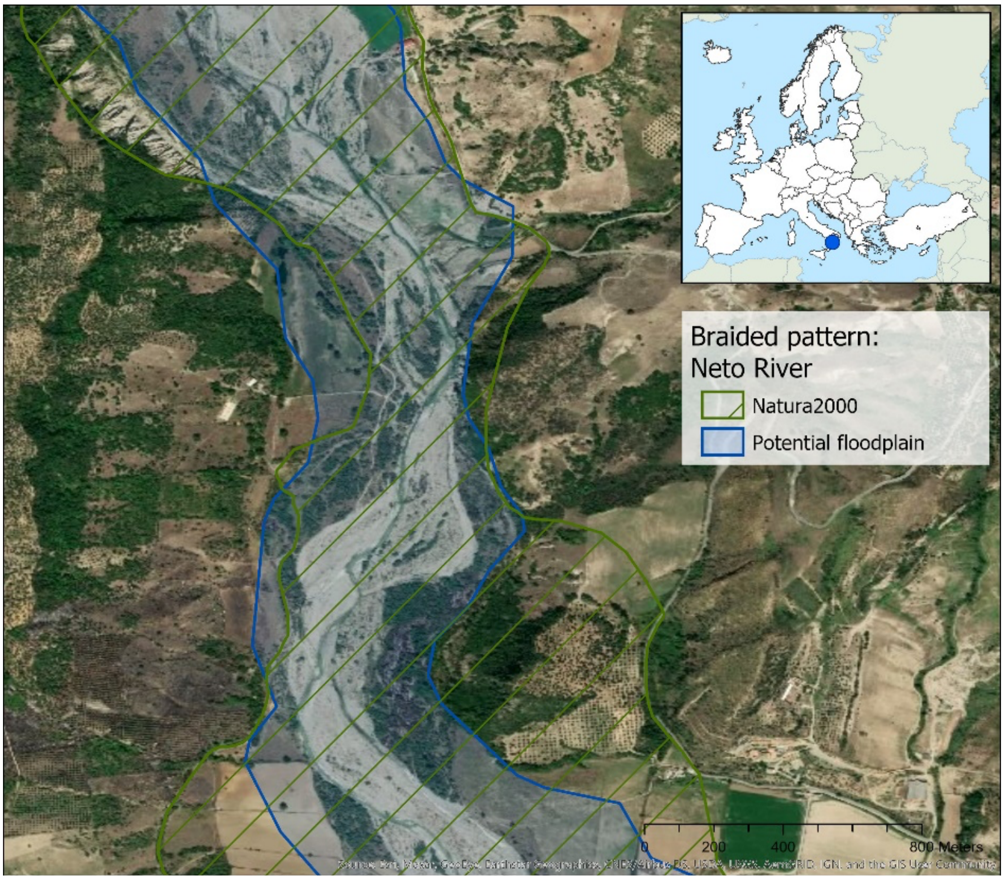
The Restonica river is located in an area designated as a Natura2000 site (Massif du Rotondo; Natura2000 code FR9400578), which has a total area of 153 km² and is highly valuable for nature conservation[16, 17]. In total, it protects 11 habitat types of the Habitats Directive; due to the low natural diversity of floodplain features only one of these is related to a natural river-floodplain system (habitat code 6430: 'Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels'). However, the designated area protects 15 species of the Nature Directives whereas three are bound to natural rivers: the Corsican painted frog, the Tyrrhenian painted frog and Mediterranean trout. Due to the isolated location in the mountains, the area has a high importance for local recreation and offers a variety of hiking trails.

[16] https://eunis.eea.europa.eu/sites/FR9400578

[17] See NATURA 2000 – STANDARD DATA FORM (https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=FR9400578&release=10)

Braided pattern: Neto River, Italy

Figure A5.13: Location of the Neto River (Italy) in Europe and satellite image of a braided section



The Neto river (length: 80 km) is the second largest river of Calabria, Southern Italy. It shows typical braided channel patterns with a typical network of channels and islands. It is dominated by huge gravel bars due to high sediment load. In elevated zones of the floodplain deciduous floodplain forest is growing. The network of channels, bars and islands underlies frequent dynamic changes and is characterized by processes of strong sediment erosion and deposition. The floodplain underlies strong and rapid variation in water discharge. Frequent flooding and periods of water stress result in a very dynamic system and strong morphological processes of sediment erosion and deposition.

Most sections of the Neto River and its floodplain are designated as a Natura2000 site (Fiume Lese; Natura2000 code IT9320122) on a total area of 12 km² with high nature conservation value[18, 19]. It protects 10 habitat types of the Habitats Directive, three of which are directly related to a near-natural river-floodplain system. Additionally, natural grasslands ('Pseudo-steppe with grasses and annuals of the Thero-Brachypodietea'; habitat code 6220) are present due to climatic conditions with heat and droughts. Furthermore, the designated area protects two species of the Nature Directives, one of which, the Long-fingered bat, is bound to natural wetlands.

Table A5.6: Protected Natura2000 habitat types in the Natura2000 site 'Dolina Górnej Pilicy' related to a natural river-floodplain system.

Natura2000 habitat code	Name of habitat type
3250	Constantly flowing Mediterranean rivers with *Glaucium flavum*
92D0	Southern riparian galleries and thickets (Nerio-Tamaricetea and Securinegion tinctoriae)

[18] https://eunis.eea.europa.eu/sites/IT9320122

[19] See NATURA 2000 – STANDARD DATA FORM (https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=IT9320122)

Floodplain Type 5: Mid-altitude plateau floodplains

Mid-altitude plateau floodplains are wide floodplains with a potential floodplain width of 0.01 to 1 km². They have low slope and upstream catchments ranging from 20 to 5 000 km². Rivers of this floodplain type show confined single-thread, sinuous or wandering channel patterns. Floodplains associated with confined single-thread and sinuous channel patterns are dominated by floodplain forest, whereas floodplains associated with wandering channel patterns are additionally characterized by bars and dunes. The run-off rate is low. High discharge events mainly occur in late spring and early summer, whereas flooding persists for longer time spans.

Spatial distribution

Map A5.5: The European distribution of the floodplain type 5 (number of FECs: 9,661)

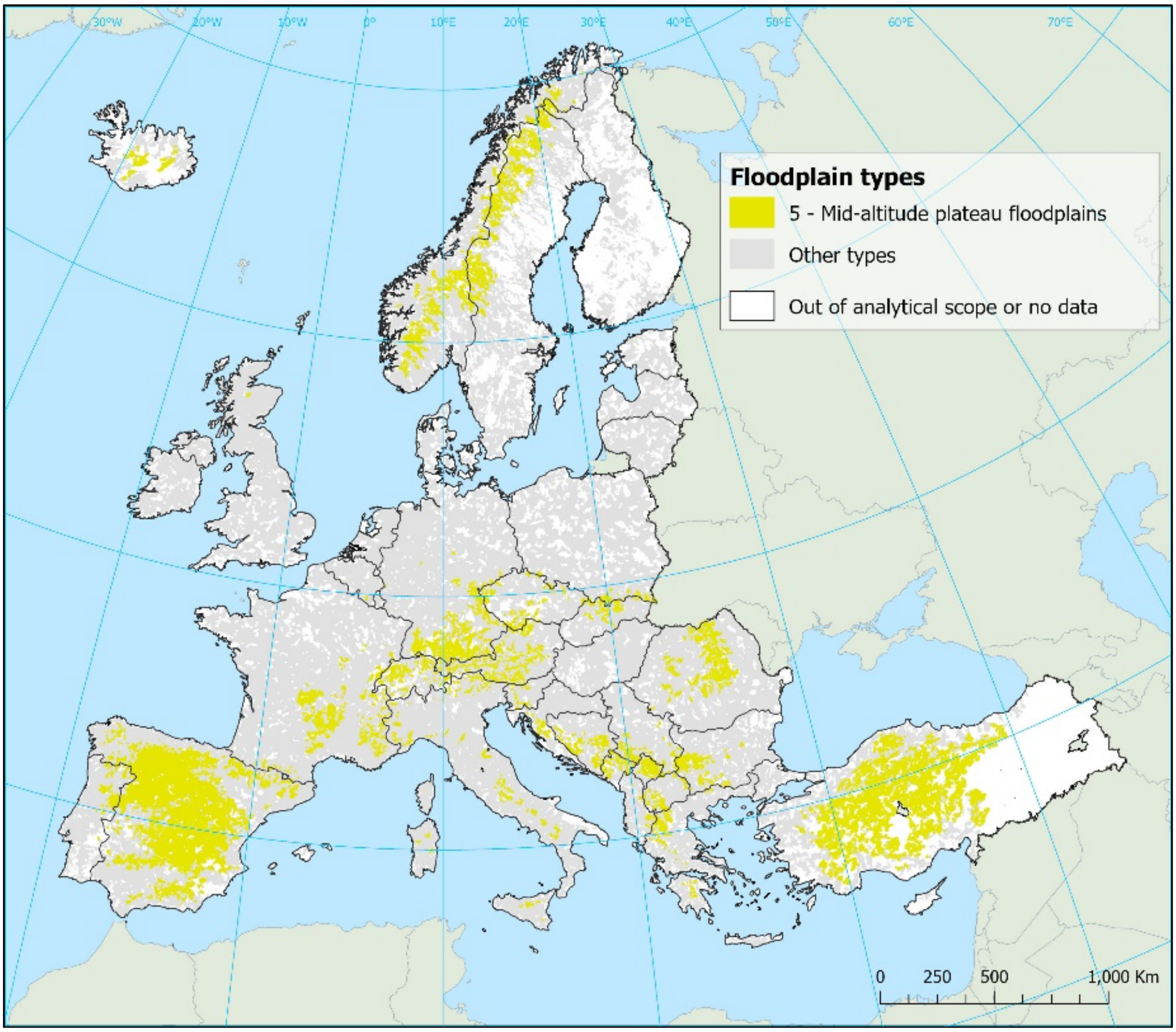
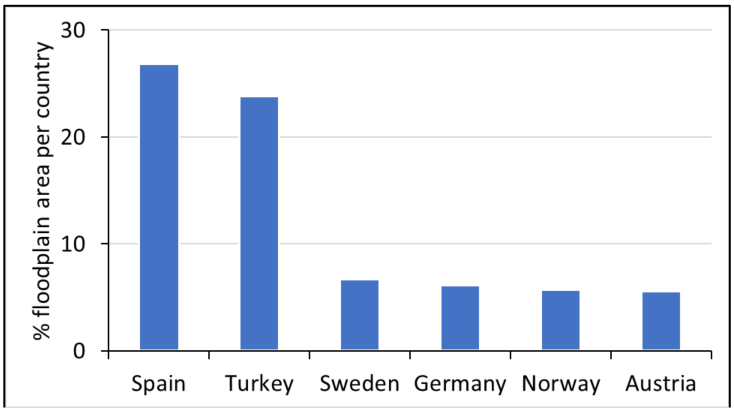


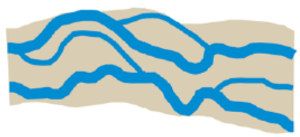
Figure A5.14: Distribution (% coverage) of floodplain type 5 within the EEA39 countries (countries shown with > 5 % of potential floodplain per country covered with relevant type)



Main characteristics

Altitude	Mid-altitude (500–800 a.s.l.)
Catchment size	Small to very large (20-5,000 km²)
Slope	Flat (1–10 m/km)
Potential width	Wide (0.1–1.0 km)
Run-off rate	Low (< 30 l/s/km²)
Average flooding duration	< one month
Seasonality	High discharges in late spring to early summer (April to June)

Dominant channel patterns

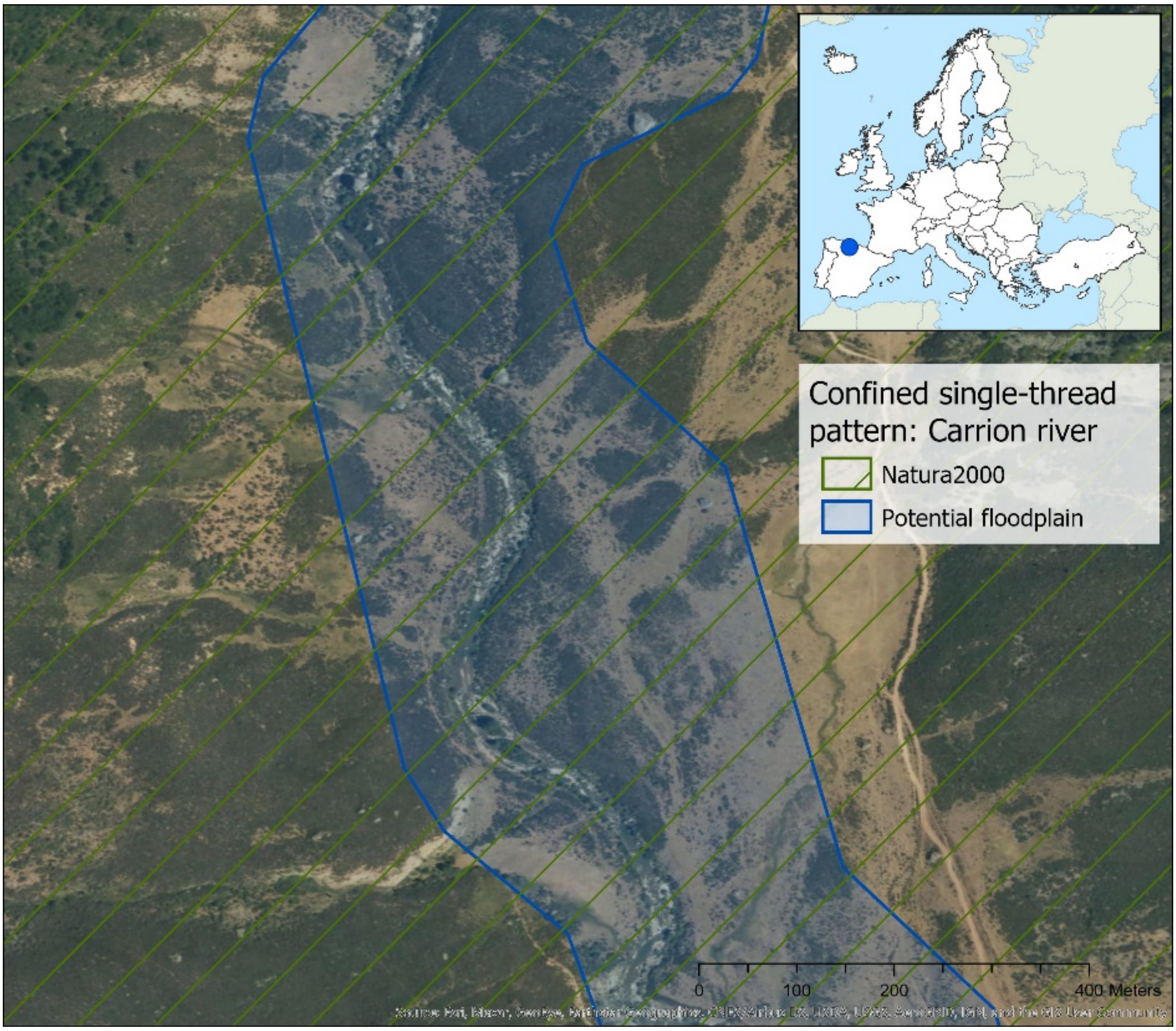
Confined single-thread	**Sinuous**	Meandering
		
Wandering	Braided	
		

Floodplain features (dark green = essential and dominant, light green = subdominant)

Channel pattern	Bars and dunes	Oxbow lakes	Wetlands	Deciduous forest	Coniferous forest	Mixed forest	Natural grassland
Confined single-thread							
Sinuous							
Wandering							

Confined single-thread pattern: Carrion River, Spain

Figure A5.15: Location of the Carrion River (Spain) in Europe and satellite image of a confined single-thread section



The Carrion River (length: 179 km) and its floodplain are located in northern Spain. The spring of the river is in the Cantabrian mountains from which it flows south through the province Palencia.

In least-disturbed conditions the river is characterized by a confined single-thread pattern. The river channel is naturally located in a narrow valley and the floodplain is small or absent due to the natural confinement by hillslopes or ancient terraces. Some small gravel or stone bars in the riparian zone occur. Most sections of the upper Carrion River and its narrow floodplain are undisturbed and therefore highly valuable for nature conservation. The river is located in the natural park Montaña Palentina which covers an area of 78 360 ha and is designated as a Natura2000 site (Fuentes Carrionas y Fuente Cobre-Montaña Palentina; Natura2000 code ES4140011)[20]. It protects 37 habitat types of the Habitats Directive, whereas 7 are directly related to a near-natural river-floodplain system. Furthermore, it protects 141 species, whereas 15 are strongly associated with rivers and floodplains, e.g. the Iberian painted frog, the Common Sandpiper, the Little Ringed Plover. As a Special Protected Area (SPA) 116 of the protected species are birds.

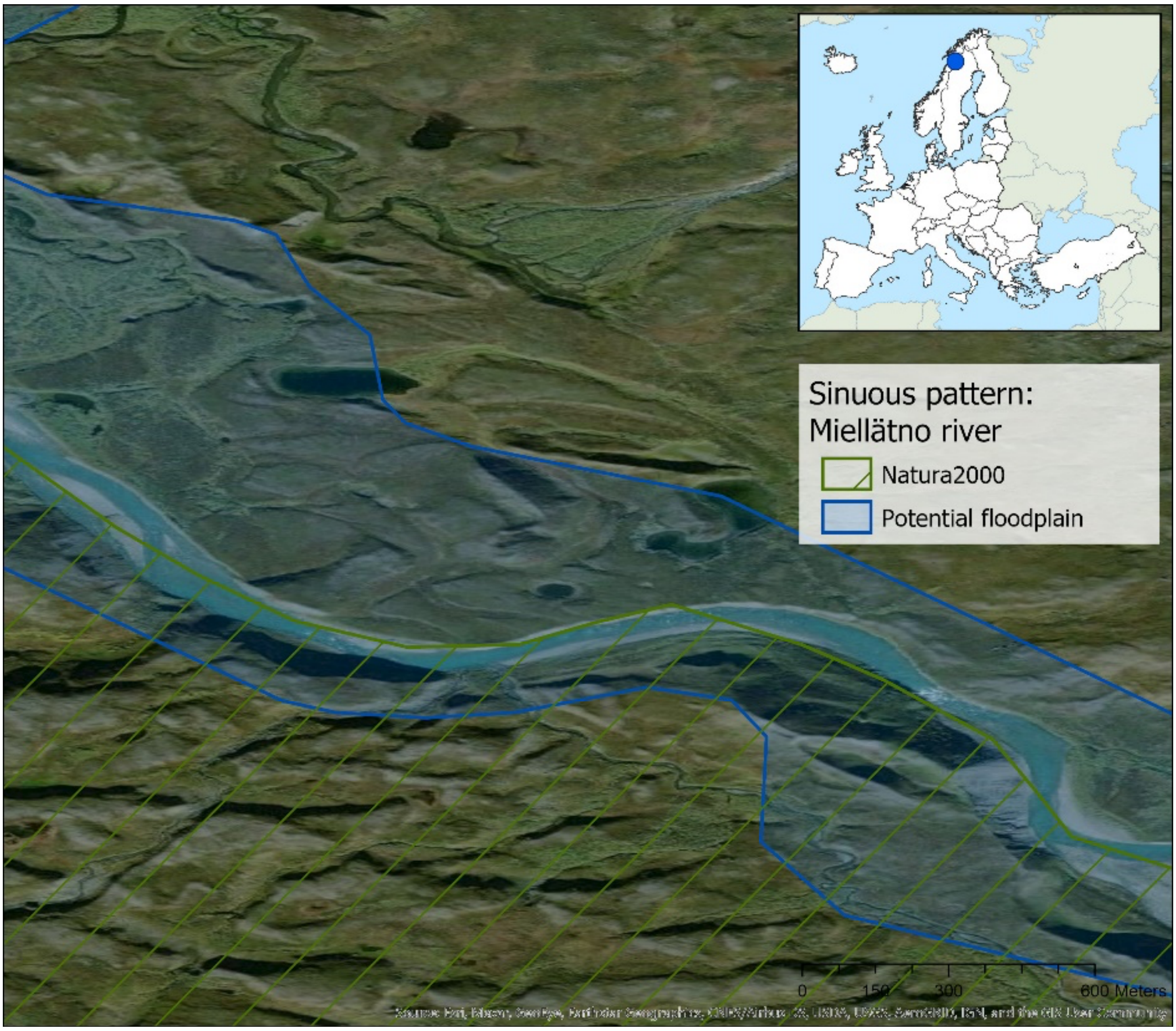
[20] See NATURA 2000 – STANDARD DATA FORM (https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=ES4140011)

Table A5.7 Protected Natura2000 habitat types in the Natura2000 area 'Fuentes Carrionas y Fuente Cobre-Montaña Palentina' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition - type vegetation
3160	Natural dystrophic lakes and ponds
3220	Alpine rivers and the herbaceous vegetation along their banks
3240	Alpine rivers and their ligneous vegetation with *Salix elaeagnos*
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)

Sinuous pattern: Miellätno River, Sweden

Figure A5.16: Location of the Miellätno River (Sweden) in Europe and satellite image of a sinuous section



The Miellätno River (length: 30 km) and its floodplain are located in the mountain plateau area in north-eastern Sweden. The river is lake-fed and flows into the lake Virihaure, which is 112 km², the largest natural lake in the Swedish national park Padjelanta. The upper part of the Miellätno river shows a typical sinuous channel pattern. Thereby, lateral channel dynamics like bank erosion and deposition of side bars are limited due to a somewhat wider but still narrow (partly confined) valley floor with high bank stability. This results in a sinuous channel, typically with alternating side bars in the transitional zone between the low-flow channel and a narrow alluvial floodplain with few floodplain features such as bars and floodplain forest. The upper part of the Miellätno River is located at the border between the Padjelanta and the Sarek national park. The latter is one of the oldest national parks in Europe, established in 1909. Both parks are designated as Natura2000 sites (Padjelanta: Natura2000 code SE0820201, total area of 1 999 km²; Sarek: Natura2000 code SE0820185, total area of 1 980 km²).

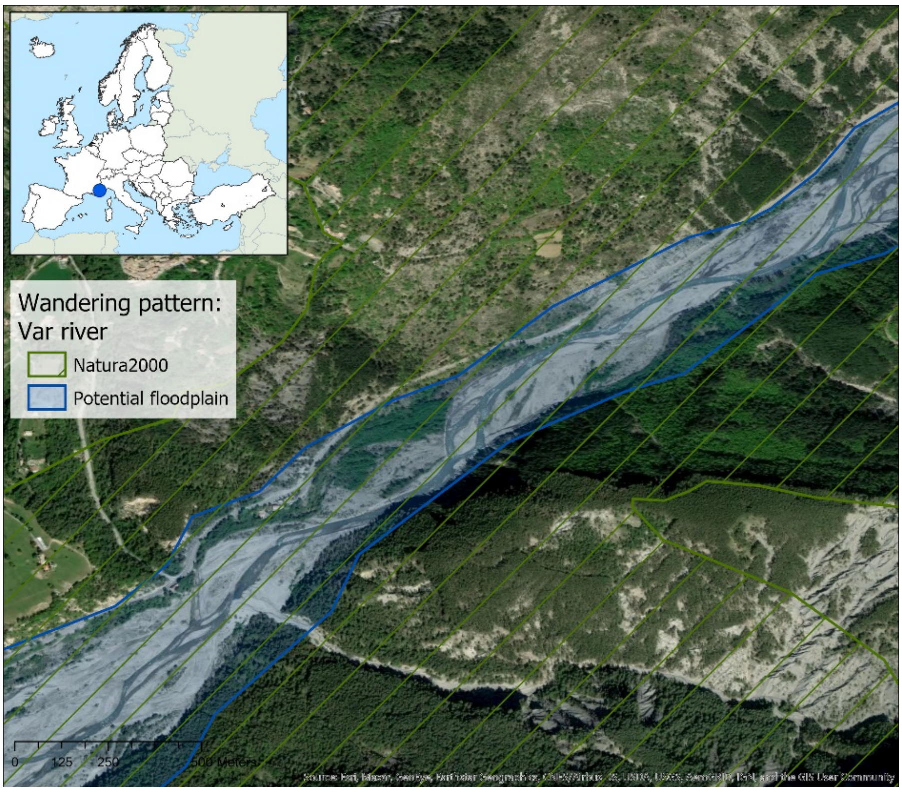
Being completely roadless and without any anthropogenic influence, the whole area offers wilderness and natural rivers, lakes surrounded by mountains, all being highly valuable for nature conservation[21]. In total, the Padjelanta site protects 19 habitat types of the Habitats Directive[22] whereas four of them are directly related to a near-natural river-floodplain system. Furthermore, it protects 41 species of the Nature Directives, 28 of which are bird species including highly endangered river and wetland species like the Wood Sandpiper.

Table A5.8 Protected Natura2000 habitat types in the Natura2000 area 'Padjelanta' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3140	Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
3220	Alpine rivers and the herbaceous vegetation along their banks
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
7240	Alpine pioneer formations of the Caricion bicoloris-atrofuscae

Wandering pattern: Var River, France

Figure A5.17: Location of the Var River (France) in Europe and satellite image of a wandering section



[21] https://eunis.eea.europa.eu/sites/SE0820201
[22] See NATURA 2000 – https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=SE0820201

The Var River (length: 114 km) and its floodplain are located in the south-east of France. The upper part shows a typical wandering channel pattern whereas the floodplain builds some kind of plateau with a low slope surrounded by mountains. The floodplain consists of multi-thread channels and the continuous presence of alternate side bars. This results from local erosion caused by sediment overload or the periodic formation of large wood or ice jams, blocking and forcing the flow to pass on into the floodplain, where high flow channels are formed that finally develop into secondary channels and a multi-thread pattern.

Pioneer and mature islands are present; small strips of the outer banks are vegetated with floodplain forest. On a total area of 34 km² the undisturbed upper part of the Var River and its floodplain is designated as a Natura2000 site (Sites à chauves souris – Castellet-Les-Sausses et Gorges de Daluis; Natura2000 code FR9301554), being highly valuable for nature conservation[23]. It protects 22 habitat types of the Habitats Directive[24], seven of which are directly related to a near-natural river-floodplain system. Furthermore, it protects 26 species, out of which two fish species are bound to natural river-floodplain systems: Mediterranean barbel and the Western Vairone.

Table A5.9 Protected Natura2000 habitat types in the Natura2000 area 'Riberas de los Ríos Huebra, Yeltes, Uces y afluentes' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3220	Alpine rivers and the herbaceous vegetation along their banks
3230	Alpine rivers and their ligneous vegetation with *Myricaria germanica*
3240	Alpine rivers and their ligneous vegetation with *Salix elaeagnos*
3250	Constantly flowing Mediterranean rivers with *Glaucium flavum*
3280	Constantly flowing Mediterranean rivers with Paspalo-Agrostidion species and hanging curtains of *Salix* and *Populus alba*
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)

The complete lower valley of the Var River was channelized along a length of 22 km in the first half of the 19th century and fitted with weirs and dams. Furthermore, the densely populated Nice Côte d'Azur metropolitan area is located in the direct surrounding of the river, including considerable human pressure exerted on the floodplain. However, in the thirty-years project 'Reconect'[25], which started in 2019, the whole region of Plaine du Var (also called the 'Var Eco Valley') will be redesigned, taking into account several important ecosystem services. It is a flagship project of the French Government that represents an innovative approach to manage and combine different environmental challenges, including the hydro-meteorological events in suburban and urban areas. The key aspects for the next 15 years are (i) restoration, preservation and valuation of the altered region, (ii) sustainable development, and (iii) support of strong economic and social dynamics throughout the metropolitan area.

[23] https://eunis.eea.europa.eu/sites/FR9301554
[24] See See NATURA 2000 – https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=FR9301554)
[25] http://www.reconect.eu/network-of-cases/var-river-basin/

Floodplain Type 6: Highland floodplains

Highland floodplains are the least structured and narrowest floodplains amongst the European floodplain types with a potential floodplain width of less than 0.1 km. Mainly located as small strips in narrow valleys and having a very high slope, rivers in this floodplain type show confined single-thread patterns with upstream catchments between 20 and 700 km². Floodplains are dominated by deciduous forest, whereas small patches with gravel bars and stones often occur. The run-off rate is high. High discharge events mainly occur in late spring and early summer. Flooding usually occurs for short time spans.

Spatial distribution

Map A5.6: The European distribution of the floodplain Type 6 (number of FECs: 3 308)

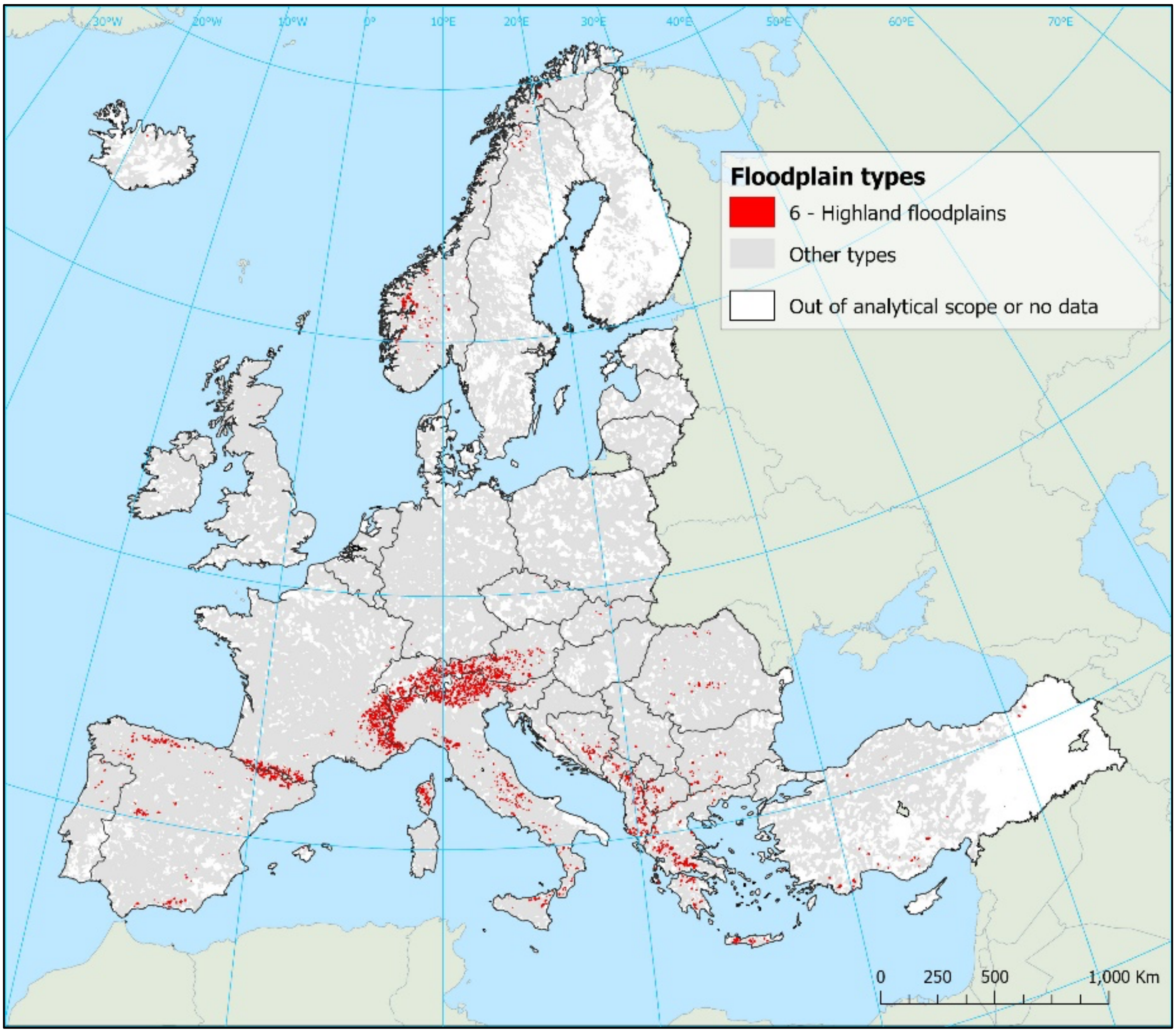
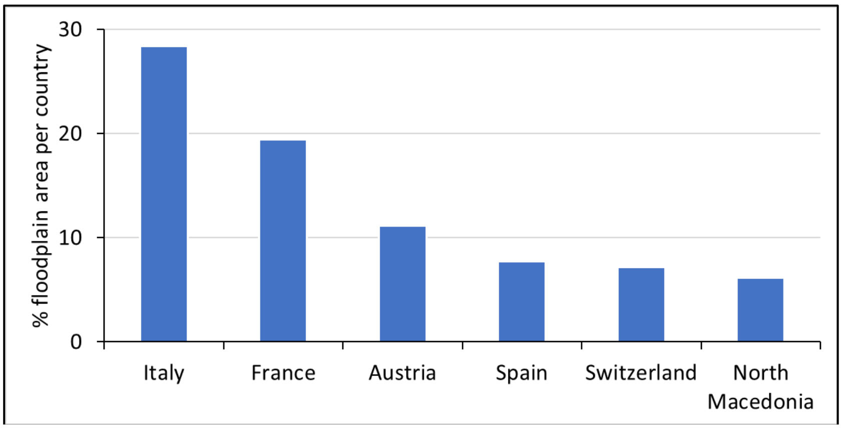


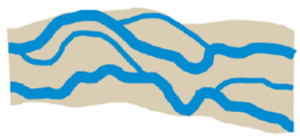
Figure A5.18: Distribution (% coverage) of floodplain Type 5 within the EEA39 countries (countries shown with > 5 % of potential floodplain per country covered with relevant type)



Main characteristics

Altitude	Highland (> 800 a.s.l.)
Catchment size	Small to large (20–700 km²)
Slope	Very steep (> 100 m/km)
Potential width	Very narrow (< 0.1 km))
Run-off rate	High (> 40 l/s/km²)
Average flooding duration	< one month
Seasonality	High discharges in late spring to early summer (April to June)

Dominant channel patterns

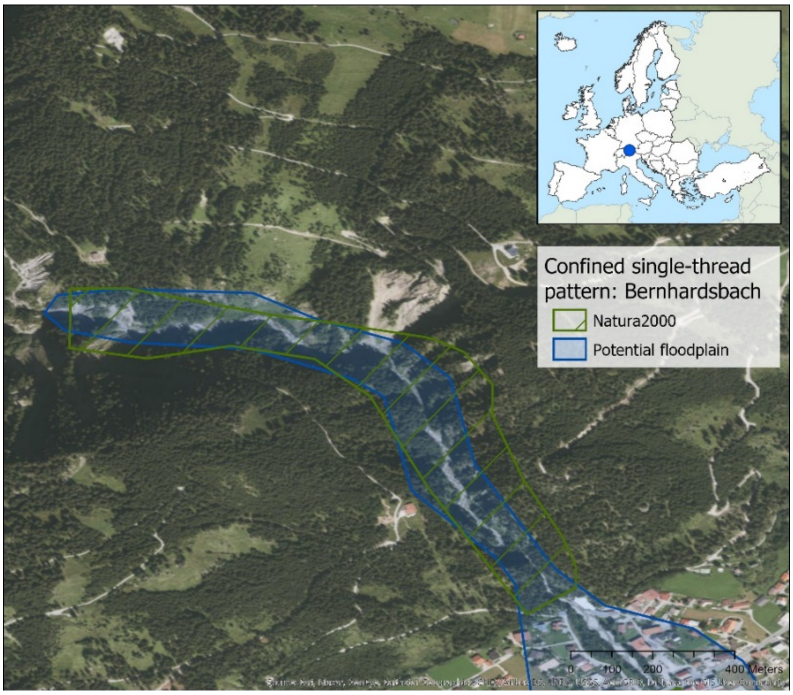
Confined single-thread	Sinuous	Meandering
		
Wandering	**Braided**	
		

Floodplain features (dark green = essential and dominant, light green = subdominant)

Channel pattern	Bars and dunes	Oxbow lakes	Wetlands	Deciduous forest	Coniferous forest	Mixed forest	Natural grassland
Confined single-thread							

Confined single-thread pattern: Bernhardsbach, Austria

Figure A5.19: Location of the Bernhardsbach (Austria) in Europe and satellite image of a confined single-thread section



The Bernhardsbach (length: 8 km) and its really narrow floodplain are located in eastern Austria. The spring of the river is in the Austrian alps from which it flows into the river Lech, a tributary of the Danube. In least-disturbed conditions the river is characterized by a confined single-thread pattern. The river channel is naturally located in a narrow valley and the floodplain is small or absent due to the natural confinement by hillslopes or ancient terraces. Some small gravel or stone bars in the riparian zone occur. The river is, together with other tributaries and the river Lech itself part of an area designated as a Natura2000 site (Tiroler Lech; Code AT3309000)[26, 27]. It protects 34 habitat types of the Habitats Directive, whereas 9 are directly related to a near-natural river-floodplain system. It protects 74 species, with several species strongly associated with rivers and floodplains, e.g. the Great crested newt (amphibian), the Little Ringed Plover (bird), the Freshwater sculpin (fish) or the Stone Crayfish.

Table A5.10 Protected Natura2000 habitat types in the area 'Tiroler Lech' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3140	Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.
3160	Natural dystrophic lakes and ponds
3220	Alpine rivers and the herbaceous vegetation along their banks
3230	Alpine rivers and their ligneous vegetation with *Myricaria germanica*
3240	Alpine rivers and their ligneous vegetation with *Salix elaeagnos*
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
7240	Alpine pioneer formations of the Caricion bicoloris-atrofuscae
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)

[26] See NATURA 2000 - https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=AT3309000
[27] https://eunis.eea.europa.eu/sites/AT3309000

Floodplain Type 7: Nordic lowland floodplains

Nordic lowland floodplains are the floodplains with the longest flood duration among the European types. This type features potential floodplain widths of up to 1 km. Mainly located in broad lowland valleys or planes with a low slope, rivers in this floodplain type show sinuous patterns with upstream catchment areas between 20 and 700 km². Floodplains are dominated by coniferous forest and wetlands occur very often. The run-off rate is low. High discharge events mainly occur in late spring and early summer. Flooding events usually last for longer time spans.

Spatial distribution

Map A5.7: The European distribution of the floodplain Type 7 (number of FECs: 3 004)

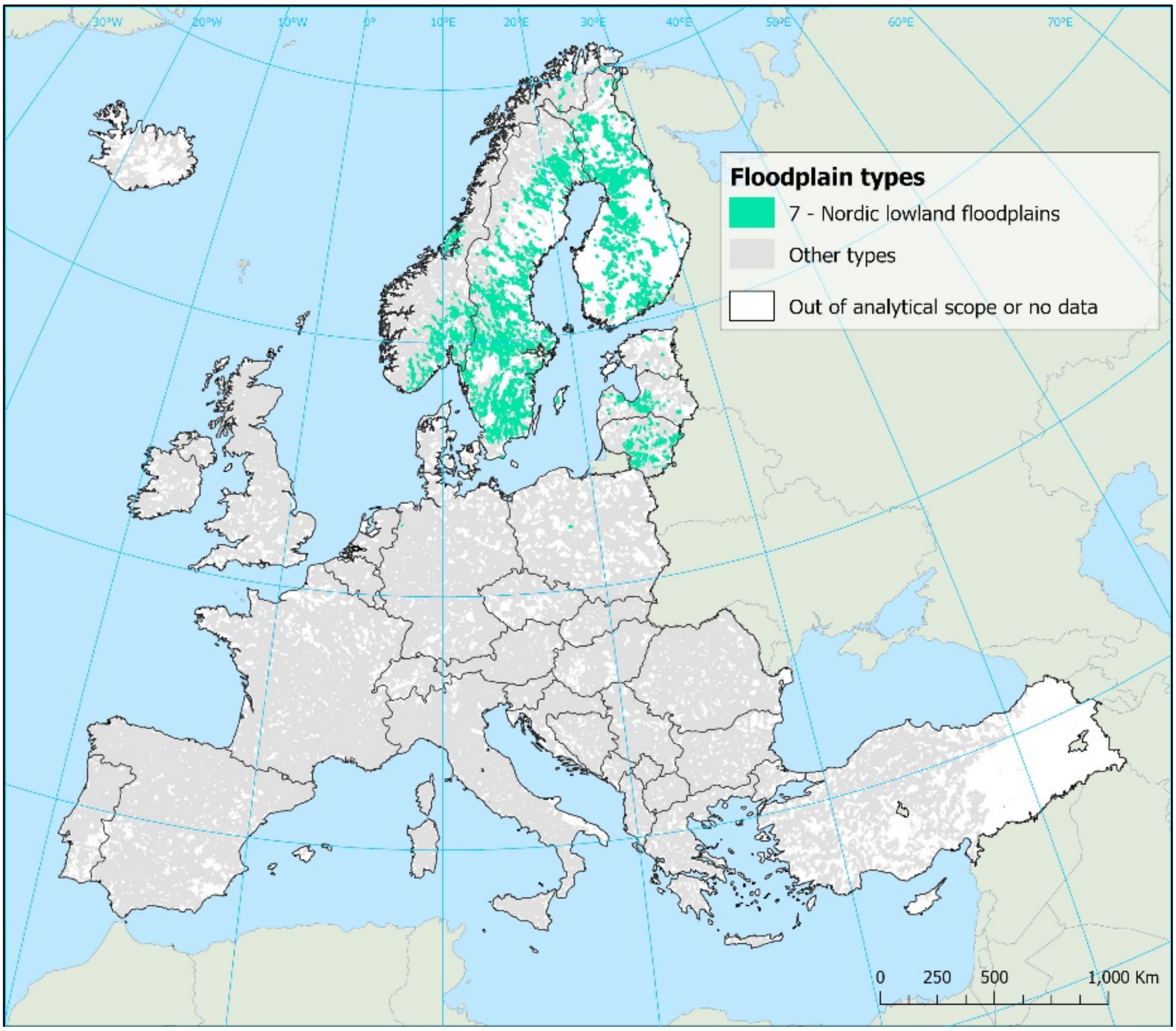
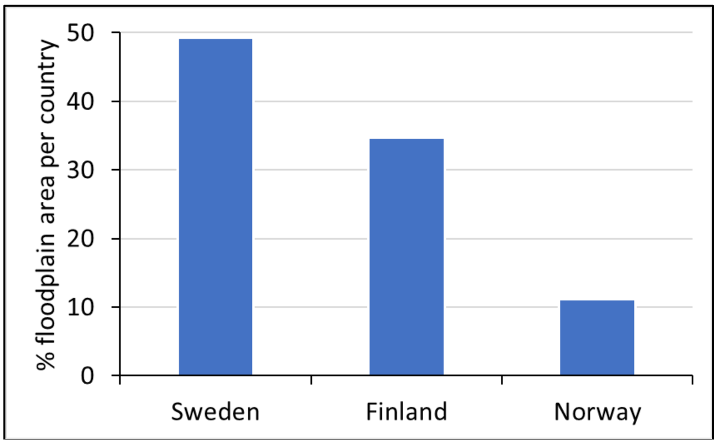


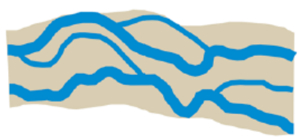
Figure A5.20: Distribution (% coverage) of floodplain Type 7 within the EEA39 countries (countries shown with > 5 % of potential floodplain per country covered with relevant type)



Main characteristics

Altitude	Lowland (< 300 a.s.l.)
Catchment size	Small to large (20–700 km²)
Slope	Flat (1–10 m/km)
Potential width	Wide (0.1–1.0 km)
Run-off rate	Low (< 20 l/s/km²)
Average flooding duration	> one month
Seasonality	High discharges in late spring to early summer (April to June)

Dominant channel patterns

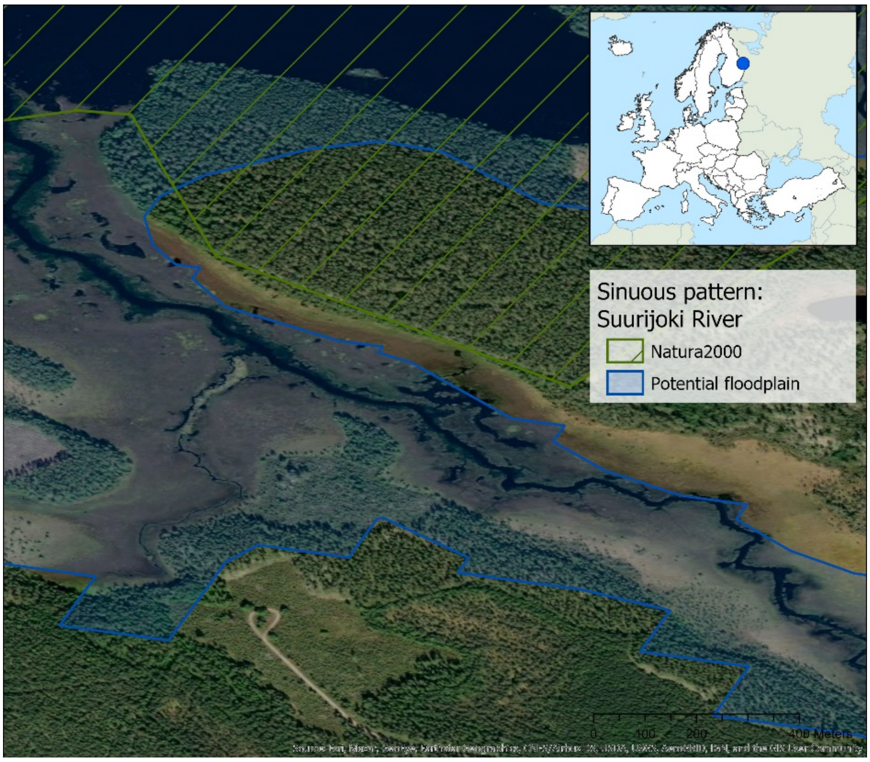
Confined single-thread	**Sinuous**	Meandering
		
Wandering	Braided	
		

Floodplain features (dark green = essential and dominant, light green = subdominant)

Channel pattern	Bars and dunes	Oxbow lakes	Wetlands	Deciduous forest	Coniferous forest	Mixed forest	Natural grassland
Sinuous							

Sinuous pattern: Suurijoki River, Finland

Figure A5.21: Location of the Suurijoki River (Finland) in Europe and satellite image of a sinuous section



The Suurijoki River (length: about 1 km) and its floodplain are located in the south-eastern part of Finland near the border with Russia. The river shows a sinuous pattern where the river channel is located in a wide groundwater-determined wetland area with alluvial sediments. Lateral channel dynamics like bank erosion and deposition of side bars is low due to very a low slope, low flow velocity and long-lasting periods of flooding. This results in a sinuous channel with huge wetland areas and forest patches. The Suurijoki River and its floodplain border an important area designated as Natura2000 site (Ruunaa: Natura2000 code FI0700045, total area of 119.8 km²). Located in a scarcely populated area, it offers wilderness and natural rivers, wetlands and lakes, all being highly valuable for nature conservation[28, 29]. In total, the Padjelanta site protects 13 habitat types of the Habitats Directive whereas four of them are directly related to a near-natural river-floodplain system. Furthermore, it protects 35 species, 14 of which are bird species including endangered river and wetland species like the Red-throated Diver or the Wood Sandpiper. Moreover, it offers habitats for the European otter.

Table A5.11 Protected Natura2000 habitat types in the Natura2000 area 'Ruunaa' related to a natural river-floodplain system

Natura2000 habitat code	Name of habitat type
3160	Natural dystrophic lakes and ponds
3210	Fennoscandian natural rivers
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)

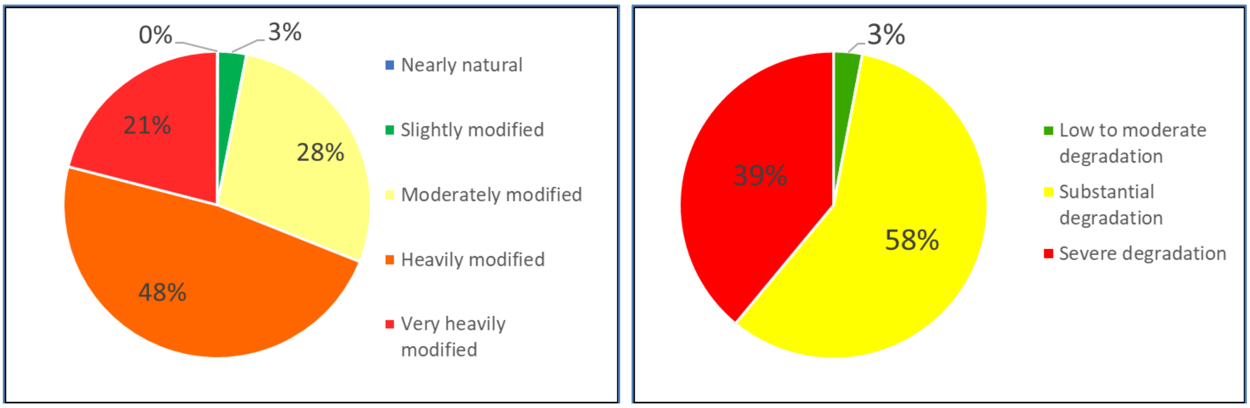
[28] https://eunis.eea.europa.eu/sites/FI0700045
[29] https://natura2000.eea.europa.eu/Natura2000/SDF.aspx?site=FI0700045

Annex 6 Comparison of preliminary assessment results with the national German assessment

The preliminary assessment results for the European floodplain were tested against the German national assessment of floodplain status, which is one of the few national floodplain condition assessments currently existing in Europe (Brunotte et al., 2009; Scholz et al., 2012). The German assessment classifies the floodplain status into five classes regarding the modification of ecological functions: Class 1 – Nearly natural, Class 2 – Slightly modified, Class 3 – Moderately modified, Class 4 – Heavily modified and Class 5 – Very heavily modified. This assessment was done for river segments covering lengths ranging between 1 km and 90 km, separately for both riverbanks and for active and former floodplains along both sides of the river. The German floodplain assessment classes were aggregated to FEC level (described by Scholz et al., 2018[29]). There are around 5 000 FECs in Germany, but a national floodplain assessment class was assigned to less than half of them.

For the comparison with the national German assessment, the preliminary European floodplain habitat condition overall assessment is developed for 1 432 FECs in Germany (FigureA6.1). FECs with unknown floodplain typology were excluded from the comparison. The overall assessment class was calculated as the mean of the three individual modules 'extent', 'structures', and 'processes' rounded to the next integer. With this approach all three modules are treated equally important for sustaining floodplain habitat condition since they are in permanent interaction and of interchanging dominance.

Figure A6.1: Floodplain condition assessment for German floodplains derived by two methods



Note: Assessment for 1 432 FECs in Germany. Left-hand chart: German method for floodplain modification of ecological functions; right-hand chart: European method for habitat condition degradation as developed in this study.

Both assessments show that 3 % of floodplains are not degraded or only slightly modified. According to the German assessment, 28 % of floodplains are moderately modified and 69 % are heavily or very heavily modified. The European assessment applied to the German FECs shows 38 % severely degraded and 58 % substantially degraded floodplains.

We assume that Class 1 and Class 2 in the German classification system is similar to the 'Low to moderate degradation' class in the European classification system. The German Classes 3 and 4 are similar to the European 'Substantially degraded' class, and the German Class 5 is similar to the European 'Severely degraded' class. Table A6.1 shows how results differ between the German and the preliminary European assessment for each compared FEC in Germany. Based on the alignment of classes described above, 77 %

[29] Scholz, M., Bonilha, O.T.M., Globevnik, L., Snoj, L., Schulz-Zunkel, C., Henle, K., Schmedtje, Ul, Blatter, A., 2018. European Floodplain assessment. Report summarising methodology for floodplain status assessment and recommendations for further work. EEA/NSV/13/002. ETC/ICM task 1.5.3a. Copenhagen. 15.10.2018. https://www.researchgate.net/publication/348437255_ETCICM_European_Floodplain_assessment_Report_summarising_methodology_for_floodplain_status_assessment_and_recommendations_for_further_work

of FECs were equally classified. In general, the European assessment seems more lenient than the German assessment when classifying floodplains into Class 1 ‘Low to moderate degradation’. But given the different data bases and assessment methodologies, these results support the validity of the European floodplain preliminary overall assessment results.

Table A6.1 Comparison of the European floodplain habitat condition assessment with the German floodplain assessment

Comparison	**German floodplain assessment**		**European floodplain assessment**					
			Low to moderate degradation		**Substantial degradation**		**Severe degradation**	
	no. FEC	% FEC	no. FEC	% FEC	no. FEC	% FEC	no. FEC	% FEC
Class 1 – Nearly natural	1	0 %	1	2 %	0	0 %	0	0 %
Class 2 – Slightly modified	37	3 %	11	23 %	26	3 %	0	0 %
Class 3 – Moderately modified	398	28 %	13	27 %	282	34 %	103	19 %
Class 4 – Heavily modified	688	48 %	21	44 %	368	44 %	299	54 %
Class 5 – Very heavily modified	308	22 %	2	4 %	159	19 %	147	27 %
Sum of FECs	**1 432**	100 %	**48**	100 %	**835**	100 %	**549**	100 %
FECs with same class	1 108	77 %	12	25 %	650	78 %	446	81 %
FECs with different class	324	23 %	36	75 %	185	22 %	103	19 %

European Topic Centre European Topic Centre on Inland, Coastal and Marine waters (ETC/ICM)
c/o Helmholtz Centre for Environmental Research – UFZ
Brückstraße 3a
39104 Magdeburg

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