

# Monetary Valuation of German Floodplain Ecosystem Services– a meta-analysis

## Evaluation monétaire des services écosystémiques des zones inondables allemandes – une méta-analyse

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### RÉSUMÉ

Les zones inondables fournissent une multitude de services écosystémiques (SE) et, en tant que telles, représentent l'un des écosystèmes les plus valorisés à l'échelle mondiale, lorsqu'ils sont évalués en termes monétaires. Cependant, nous demandons si cette analyse globale s'applique également aux zones inondables allemandes où les pertes sont très élevées et leur caractère naturel soit faible. Nous menons une méta-analyse des études d'évaluation des SE des zones inondables allemandes existantes. Nous utilisons l'ensemble des données produits par van der Ploeg et de Groot (2010), Förster et al. (2019) et Perosa et al. (2021) qui ont posé une question similaire pour une couverture géographique plus grande que l'Allemagne seule. Cela a été ensuite complété par une recherche systématique à l'aide de Web of Science et par la «littérature grise» pour avoir une taille suffisante de l'échantillon de méta-analyse. Parmi les études identifiées, 16 études avec 53 points de données étaient pertinentes pour l'inclusion dans la méta-analyse. La purification de l'eau, l'atténuation du changement climatique et la biodiversité sont les SE les mieux représentés. Généralement, la plupart des études portent sur plusieurs SE, avec une valeur monétaire moyenne de 677 €<sup>2015</sup> ha<sup>-1</sup> an<sup>-1</sup>. La variance des estimations d'évaluation est élevée et la volonté de payer diffère des approches fondées sur les coûts. Par conséquent, il y a une valeur ajoutée significative à mener une telle méta-analyse pour comprendre cette variation et créer une valeur monétaire robuste des SE clés.

### ABSTRACT

Floodplains provide a multitude of ecosystem services (ES) and as such represent one of the most valued ecosystems globally, when assessed in monetary values. However, we ask if this global analysis also applies to German floodplains where floodplain losses are very high, and naturalness is low. We conduct a meta-analysis of the existing German floodplain ES valuation studies that used willingness to pay or cost-based approaches. To conduct the required systematic literature review for a meta-analysis, we use the datasets produced by van der Ploeg and de Groot (2010), Förster et al. (2019), and Perosa et al. (2021) who asked a similar question for a larger geographical coverage than just Germany. This was then complemented by a systematic search using Web of Science and by the relevant “grey literature” to have a sufficient meta-analysis sample size. Out of the studies identified, only 16 studies with 53 data points were relevant for inclusion in the meta-analysis. Water purification, climate mitigation, and biodiversity are the best represented ES. Generally, most studies look at several ES, with an average monetary value of 677 €<sup>2015</sup> ha<sup>-1</sup> yr<sup>-1</sup>. The variance in valuation estimates is high and the willingness to pay differs from cost-based approaches. Therefore, there is a significant value added to conduct such a meta-analysis to understand this variation and to create a robust monetary value of key ES.

### KEYWORDS

Ecosystem service, floodplain, Germany, meta-analysis, monetary valuation

## 1 INTRODUCTION

Floodplains provide multiple ecosystem services (ES), e.g., biodiversity, flood protection, carbon sequestration, water purification, recreational and amenity values, flood protection, food production etc. These ES cover the range of ES categories of Provisioning, Regulating, Cultural, and Supporting services, due to the complex ecological-human interaction occurring in floodplains as a nexus of land and water interactions. It is often argued that out of the ES provided by floodplains biodiversity and flood protection are the most socially valued, whereas recreational use and water purification are among the most frequent cited in literature. For floodplains to be able to provide these ES that enhance human wellbeing, the ecological status of the floodplain must be in a sufficiently good status.

However, the potential for floodplains to provide this key wellbeing-enhancing ES can be negatively affected by human impacts. In the past land-use changes and overall environmental degradation has rendered 70-90% of Europe's floodplains in a degraded status. These competing pressures lead to a series of complex trade-offs that must be made during the process of governing how floodplains are used to help create a sustainable and high level of human wellbeing. This is particularly relevant as floodplains are one of the ecosystems from which humans receive the highest share of benefits. Therefore, understanding how humans value the ES provided by floodplains is particularly important. As seen from the recent Dasgupta report on the Economics of Biodiversity, the natural capital that generates ES should be measured and considered as part of a nation's or community's assets. This requires an evaluation of quantity of ES provided by a particular natural area, as well as a monetary valuation of benefits received so that they can be included in the political decision-making process. However, many of the benefits provided by floodplains are not tangible and are non-marketed, with no immediate monetary values.

For this reason, there have been many studies on ES overall, e.g., see van der Ploeg and de Groot (2010), Förster et al. (2019), and Perosa et al. (2021) but there are hardly any focused on Germany, resulting in the observation that an exhaustive analysis of ES and decisive parameters is missing. Furthermore, there is an additional difficulty regarding floodplain ES, as the definition of floodplains is fuzzy, comprising many different land-uses for which different ES are reported. Therefore, we aim to address this gap by aiming to produce a systematic meta-analysis of the both the scientific and grey literature databases on the topic of German floodplain ES to try and synthesize the current knowledge and to better understand how and why variation between estimated ES values has occurred. So far a comparison of different valuation methods for different ES, at least on the basis of Germany is missing. If data is scarce methodological approaches, which as a meta-analysis, are needed so that values can be transferred across studies to help decision-makers carefully consider the multifunctionality of floodplains when considering the restoration, conservation, or transformation of floodplains. We hypothesise significant differences in monetary values due to different valuation methods. Moreover, this difference could also vary across individual ES and valuation method. We also suppose a difference between localised and national studies.

## 2 METHODS

### 2.1 Literature research and data processing

Search criteria were defined a) studies from the years 2000 to present b) spatial extent in Germany c) floodplain relevant ecosystems as the term floodplain itself is very fuzzy and comprises all different kinds of land use from arable land to Natura2000 protected wetlands d) reported/calculated/observed monetary values transferable to the unit  $\text{€ ha}^{-1} \text{ yr}^{-1}$ . Alternatively, condition d was replaced with that the study provided a willingness to pay estimate at the individual/household level. The popular databases from van der Ploeg and de Groot (2010) on the worldwide economics of ecosystems as well as two recent studies and their extensive databases on ES in Germany (Förster et al. 2019) as well as in European floodplains (Perosa et al. 2021) were searched and relevant studies were extracted and read. Further studies were selected by a systematic literature research using Clarivate Web of Science and 15 rounds with different combinations of the search terms (topics) "floodplain", "flood plain", "wetland", "water", "economic value", "recreational value", "replacement value", "economic valuation", "flood control", "Europe", "ecosystem". Additionally, "Germany" was used in the refinement option region. More than 1000 paper titles were checked revealing that most of the papers still contained other regions. Finally, 85 papers were read, and 27 papers/reports were included into this study. Since not all studies provided data in the format necessary for data processing, authors were contacted to obtain or recalculate all necessary parameters. As a result, 16 studies with 53 entries were considered in the meta-analysis. Monetary values of ES were reported in very different formats, e.g.,  $\text{€ yr}^{-1}$ ,  $\text{€ ha}^{-1} \text{ yr}^{-1}$ , or  $\text{€ household}^{-1}$

yr<sup>-1</sup>. To convert units into a common € ha<sup>-1</sup> yr<sup>-1</sup> metric, information on the study, e.g., relevant population, total size of the project, was used to convert an estimate to the common metric. In cases where data was missing similar studies were used to deduce missing information on e.g. average household size. All prices were transformed to 2015-year prices by the consumer price index baseline 2015. The transferred monetary values serve as the dependent variable. Further study-specific (e.g., year, valuation method) and site-specific (spatial extent) were extracted from the studies.

## 2.2 Meta-analysis approach

The meta-analytical regression model forms the core of this studies approach, as show in eq. (1):

$$(1): \text{Monetary value}_{i,j} = \alpha + \beta SD_{i,j} + \delta EC_{i,j} + \gamma SC_{i,j} + \varepsilon_{i,j}$$

This model will be estimated with the open source software R, as both a linear regression model, as well as a mixed-effects model to account for the observation that multiple studies provided more than one data point that can be considered as nested within each other. The regression states that the monetary value  $i$  from study  $j$  is a function of the study design (SD), the sample characteristics (SC), and the environmental characteristics (EC) variables. The objective of the meta-analytical is to be able to produce a model that can be used to create a hypothetical study for an area where there is limited data available. For the study design, we consider (as a series of dummy variables): does the value consider a regulating (0/1), provisioning (0/1), habitat (0/1) or cultural (0/1) ES; is the study locally (1) or nationally (0) focused; is the study WTP based (1) or cost-based (0); study was conducted after 2011 (1) or before (0). For EC, we consider: If the floodplain is located in the Elbe Biosphere/Catchment (1) or not (0), the floodplain was severely degraded at the time of the study (1) or not (0). SC are difficult to include given the differences between how a WTP and a cost-based study go about estimating a monetary value. Therefore, this is excluded from the main analysis of € ha<sup>-1</sup> yr<sup>-1</sup>, rather it is included when the analysis is repeated when only considering WTP / cost-based results independently. For the WTP estimates, we additionally include the response rate, the payment vehicle, as well as indicators of whether the sample considered only residents local to the area or from further afield. For the cost-based methods, this is instead broken down into more detail onto what costs they consider. In all cases, there is a small number of observations available for the analysis as compared to a larger number of variables that can explain the variation of monetary values. Therefore, the first step in this analysis will be to prioritise which variables should be included in the analysis before it is conducted to have the best model for this content.

## 3 PRELIMINARY RESULTS & CONCLUSIONS

The current state of research is focused on a preliminary explorative and descriptive analyses of the relevant 53 values (from 16 separate studies). In exploring the data set, 13 data points were located along the Elbe river, 9 data points for all of Germany, and the remaining 31 values are scattered across other German rivers (e.g., Weser, Fulda, Werra, Spree, etc). Regarding ES biodiversity is approached with 9 data points, whereas water purification is most often reported (24 data points) in the bundle of regulating ES with altogether 32 data points. Provisioning ES are represented by 2 values and recreation as a cultural ES by 3. After having all monetary values being homogenized and adjusted to 2015 prices, the frequency of standardized monetary values indicates that the values are distributed over a wide range with an average of 677 €<sup>2015</sup> ha<sup>-1</sup> yr<sup>-1</sup>, a median of 432 €<sup>2015</sup> ha<sup>-1</sup> yr<sup>-1</sup>. 80% of the values are between 125 and 1400 €<sup>2015</sup> ha<sup>-1</sup> yr<sup>-1</sup>.

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