Floodplain inundation in Germany –
an empirical modelling approach with current discharge data
how much water is enough for natural processes?

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Institute of Environmental Sciecne and Geography

Funded by
DFG Deutsche Forschungsgemeinschaft
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Background and aim

- "*Defining **floodplain boundaries** considering hydraulic and ecologic aspects as basis for the development of an integrated approach to **quantify ecosystem services** of floodplains on the **landscape scale***"
- https://gepris.dfg.de/gepris/projekt/390612937?language=en

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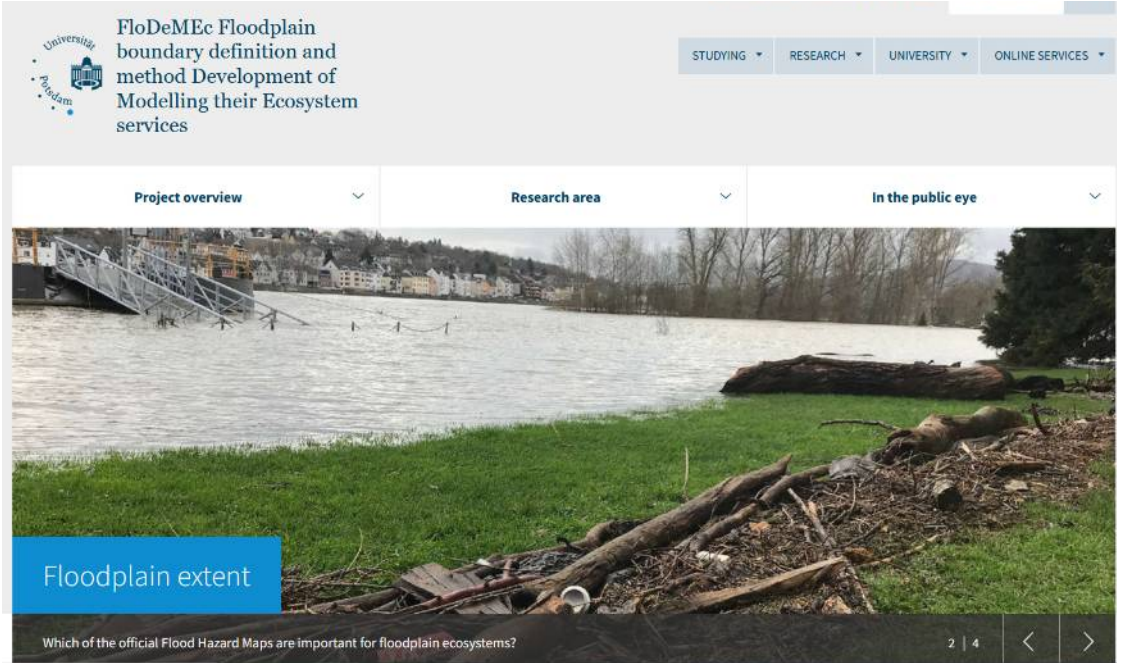

- FloDeMEc
- https://www.uni-potsdam.de/en/flodemec/

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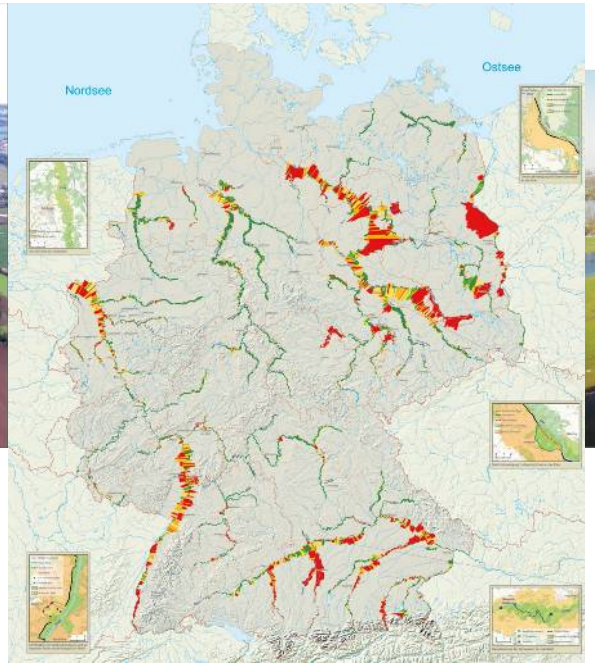
Background and aim

- Floodplain status reports (2009, 2021) reveal: floodplain losses of up to 90% of morphological floodplain.
- Basis: T100-floodplain
- **Reason:** river regulation (e.g. dikes)
- **Problem:** unfrequent/no inundation
- **Solution:** restoration (e.g. dike relocations, creation of secondary floodplains, reconnection of side-arms)
- **BUT:** flow regime has changed for most rivers due to additional flow regulation & river bed incision



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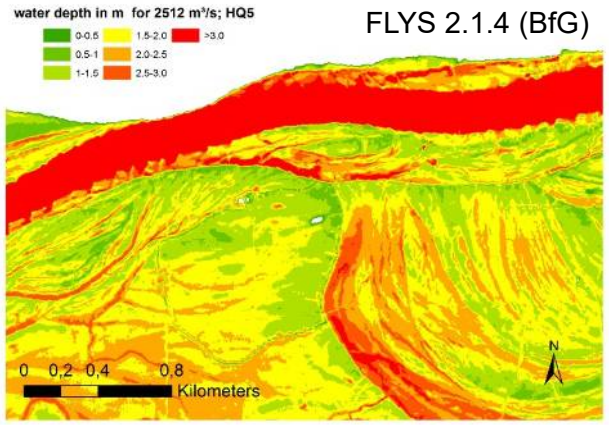
Background and aim

1. Which information is available on floodplain inundation on a landscape scale?
2. How often are floodplains inundated?



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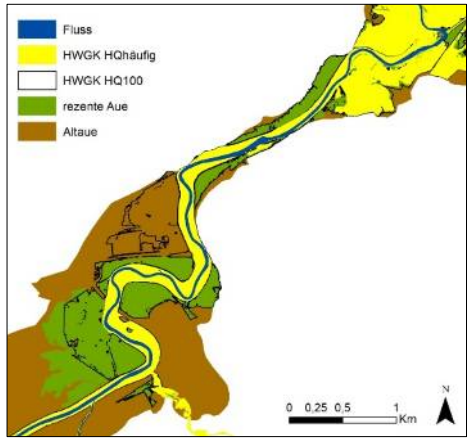

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Background and aim

1. Which information is available on floodplain inundation on a landscape scale?
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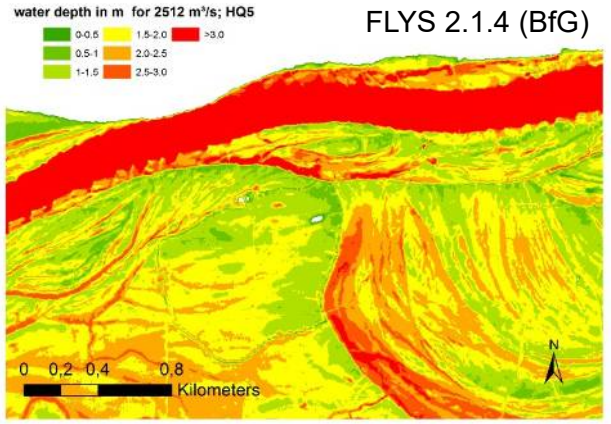
3. How can available data be coupled to semi-empirical inundation-discharge relations obtained from different rivers?



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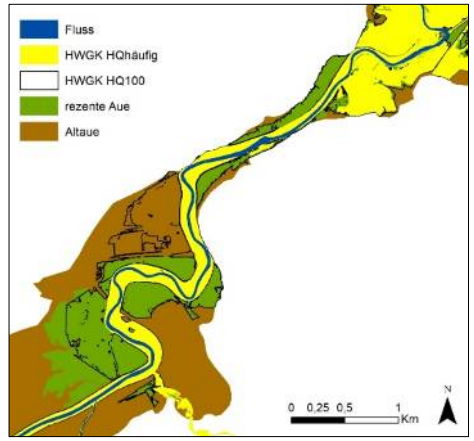
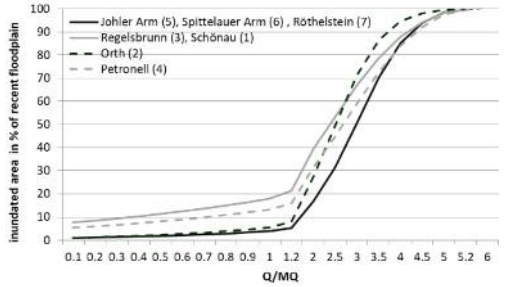
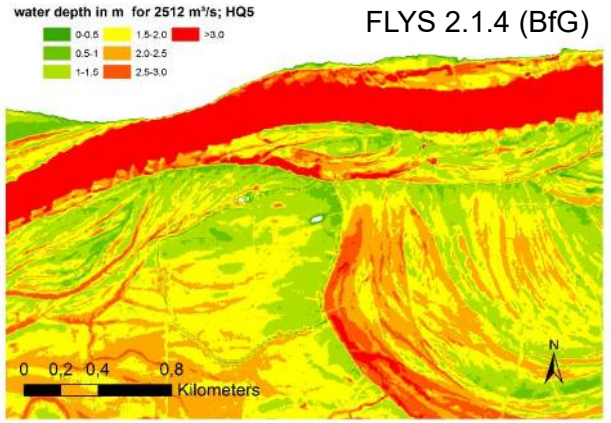




Natho et al. 2020

Background and aim

1. Which information is available on floodplain inundation on a landscape scale?
2. How often are floodplains inundated?
3. How can available data be coupled to semi-empirical inundation-discharge relations obtained from different rivers?
4. Will this information be enough for nutrient retention modelling in floodplains depending on inundation and load entering the floodplain?



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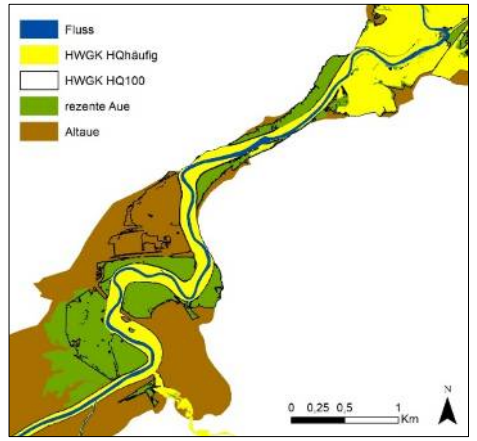
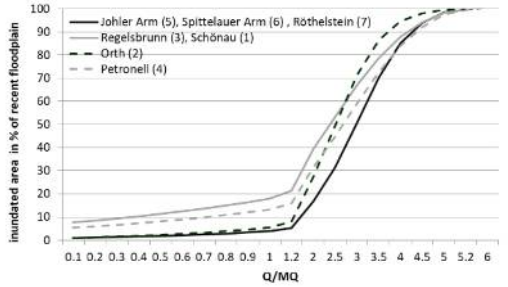
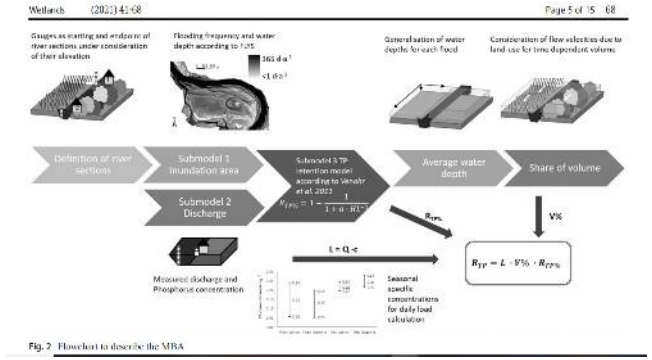




Natho et al. 2020



Schulz-Zunkel et al. 2021

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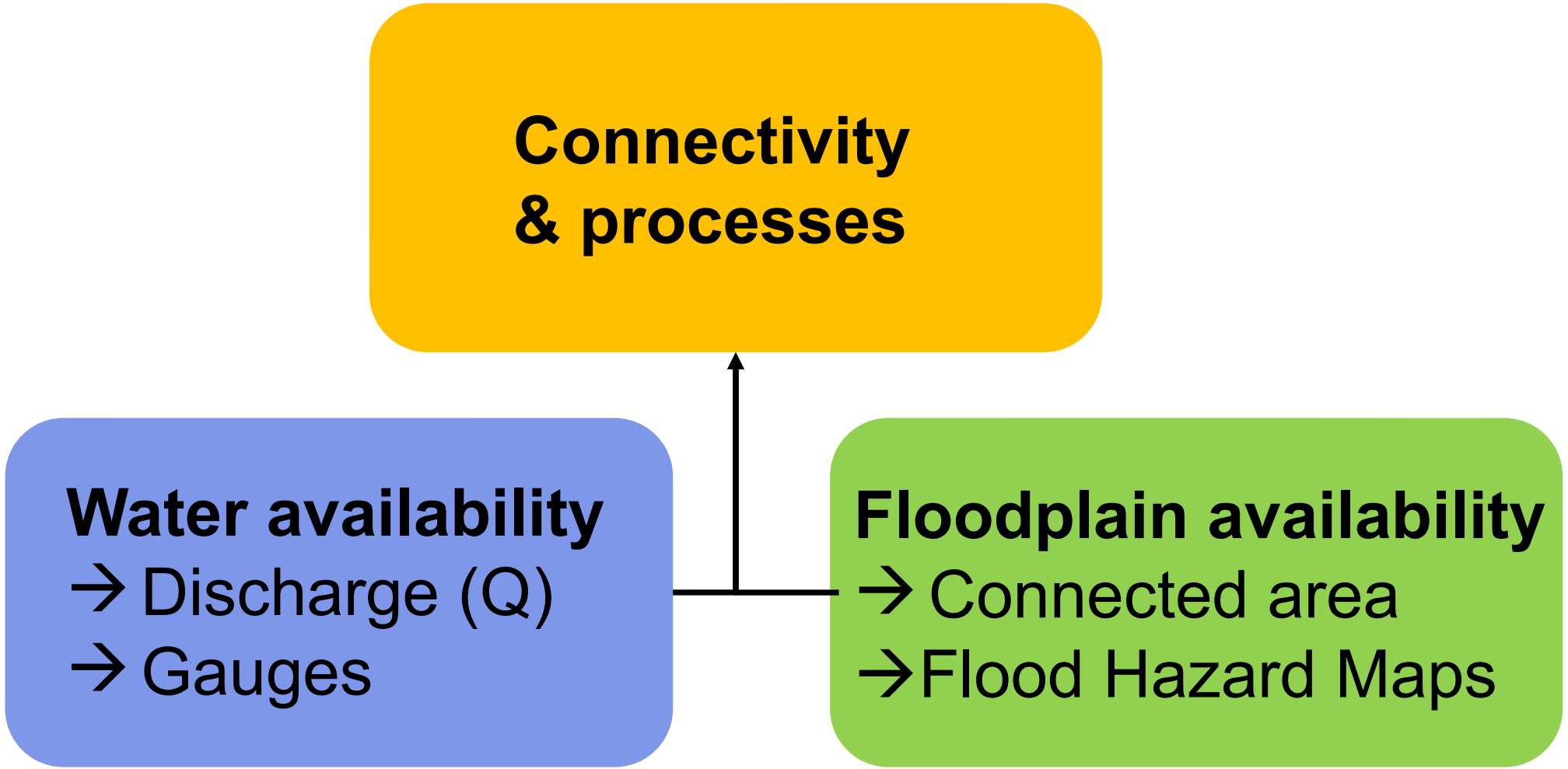
Methods & Data



Data & Study Site

- Flood Hazard Maps (FHM) of frequent and medium floods of German Federal States

Natho 2021

Applied Nomenclature in This Study		German	English	
Inundation Frequency According to FHM	T-Year Recurrence Interval	Statistic Main Values as HQT	T-Year Recurrence Interval	Annual Exceedance Probability
		HQ1	1	1
		HQ2	2	0.5
T-frequent	T-5	HQ5	5	0.2
	T-10	HQ10	10	0.1
	T-20	HQ20	20	0.05
	T-25	HQ25	25	0.04
	T-50	HQ50	50	0.02
T-medium	T-100	HQ100	100	0.001

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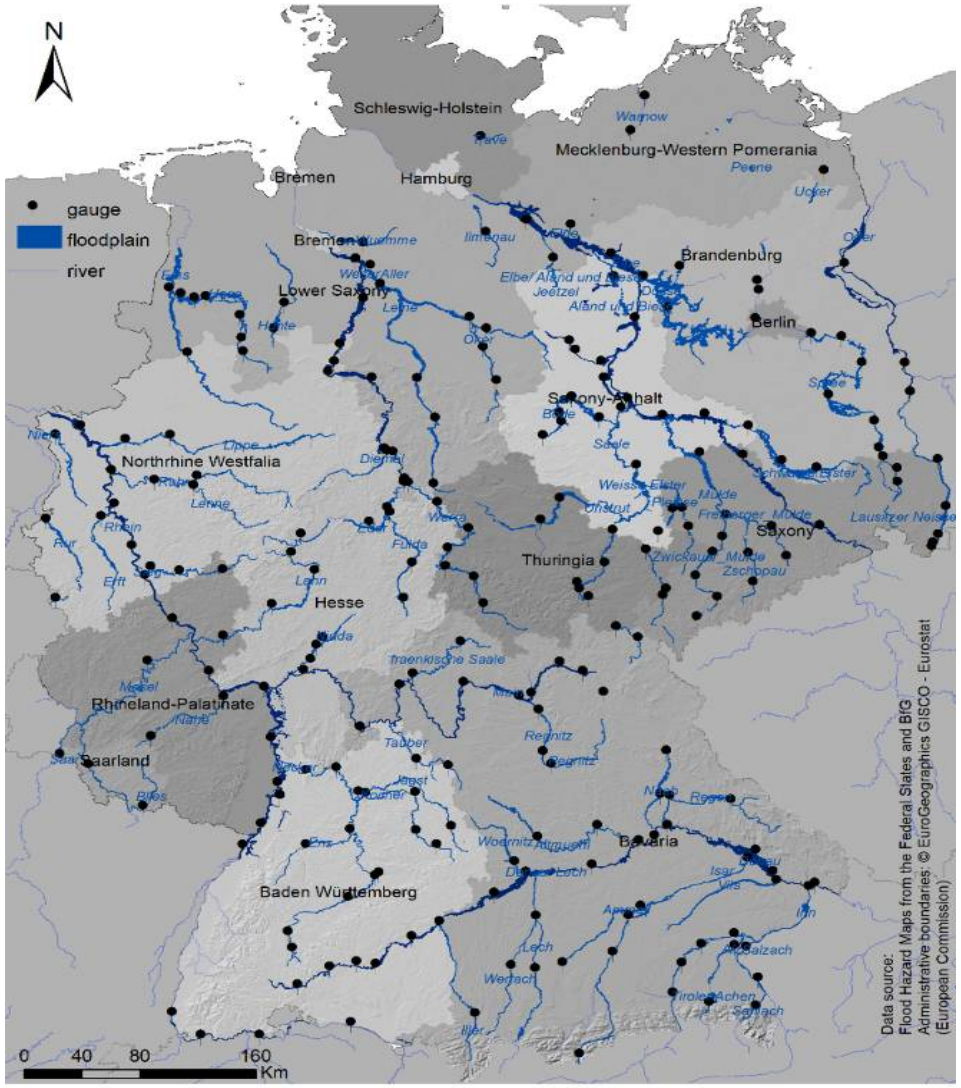
Data & Study Site

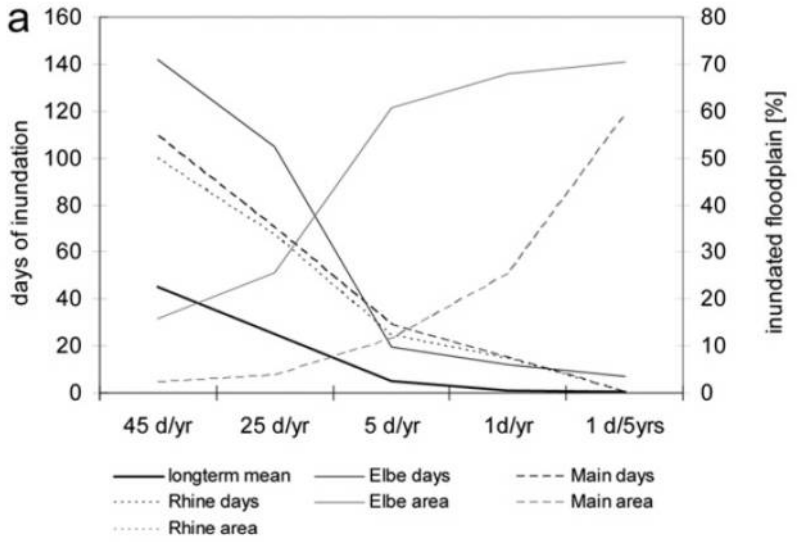
- Flood Hazard Maps (FHM) of frequent and medium floods of German Federal States
- Gauge data from more than 200 locations for the years 2000-2019

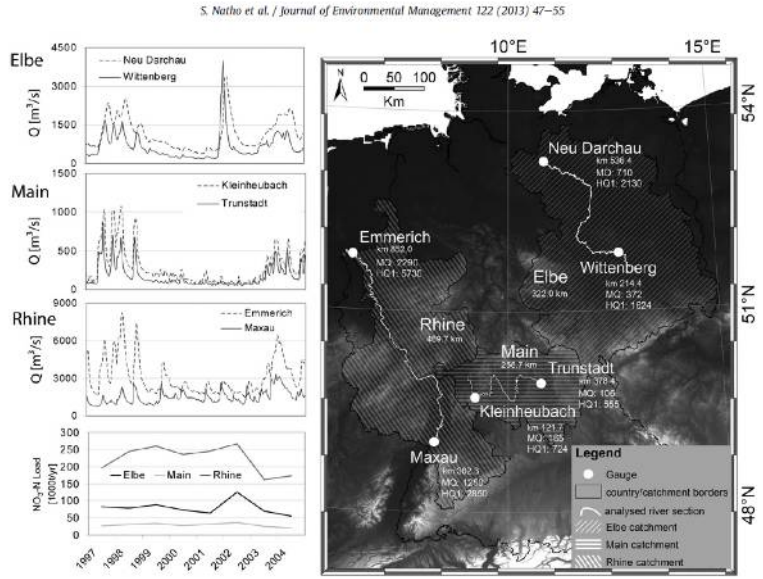


Data & Study Site

- Flood Hazard Maps (FHM) of frequent and medium floods of German Federal States
- Gauge data from more than 200 locations for the years 2000-2019
- Empirical discharge-inundated area relations from different rivers derived from the Software FLYS (BfG)

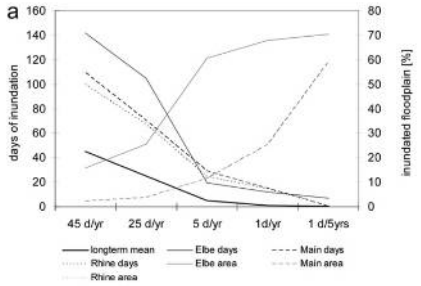
Natho et al. 2013





Methods

Identification of **inundation extents** of any floods **< T-frequent**



Transfer of known relations of Q and A

Comparing daily **discharges (Q)** with statistical discharge thresholds representing different flood magnitudes for each gauge

→ identification of **actual floods** (2000 to 2019)
→ Identification of **floodplains** being **inundated more or less frequent**

Comparing **inundation extent (A)** of frequent and medium floods

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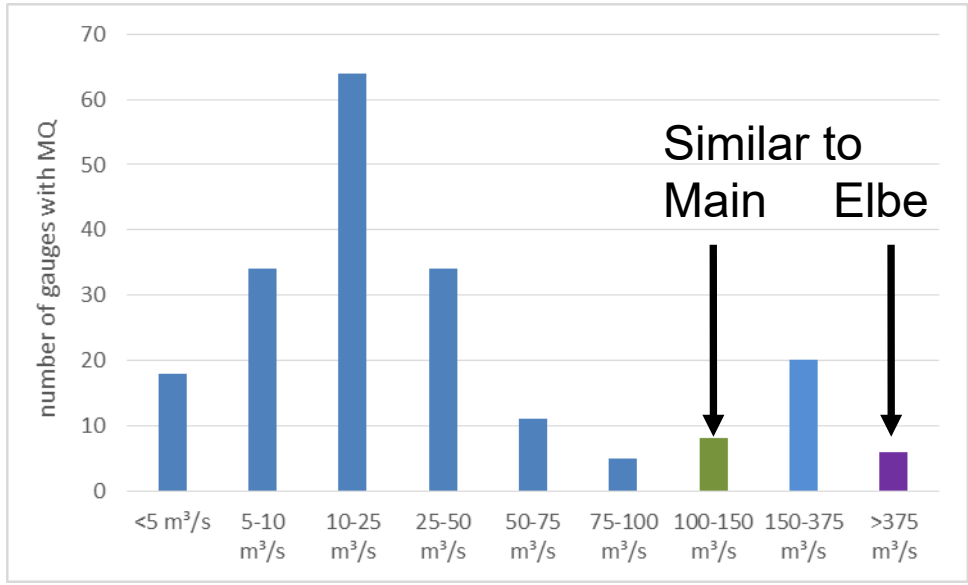
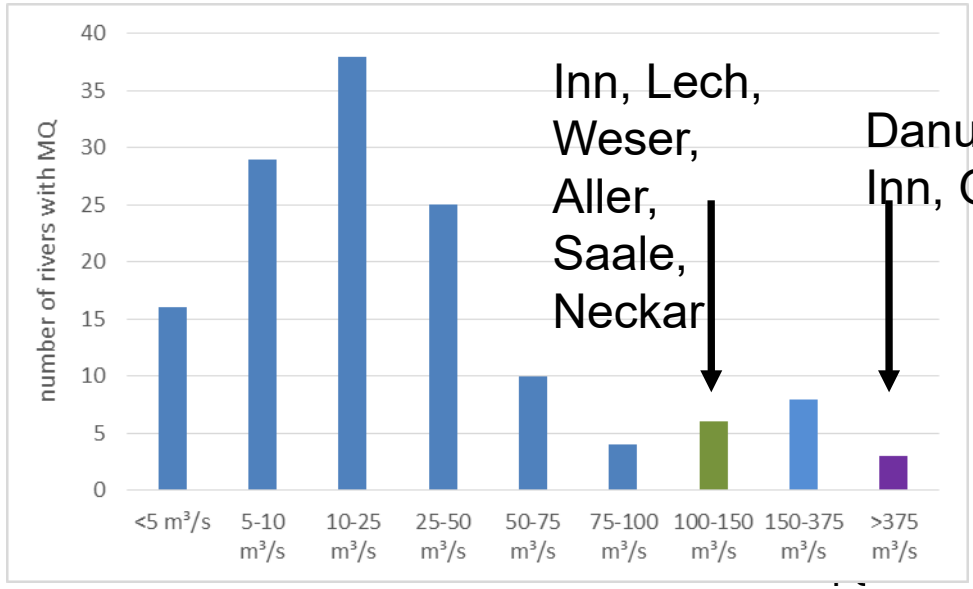
Methods

Challenges:

- Large reference rivers
  - Main (MQ 106-165 m³/s),
  - Elbe (MQ 372-710 m³/s),
  - Rhine (MQ1250-2290 m³/s),
- Study rivers include large variation in MQ

- Though not Q but Q/MQ is used: variation of smaller rivers is much higher

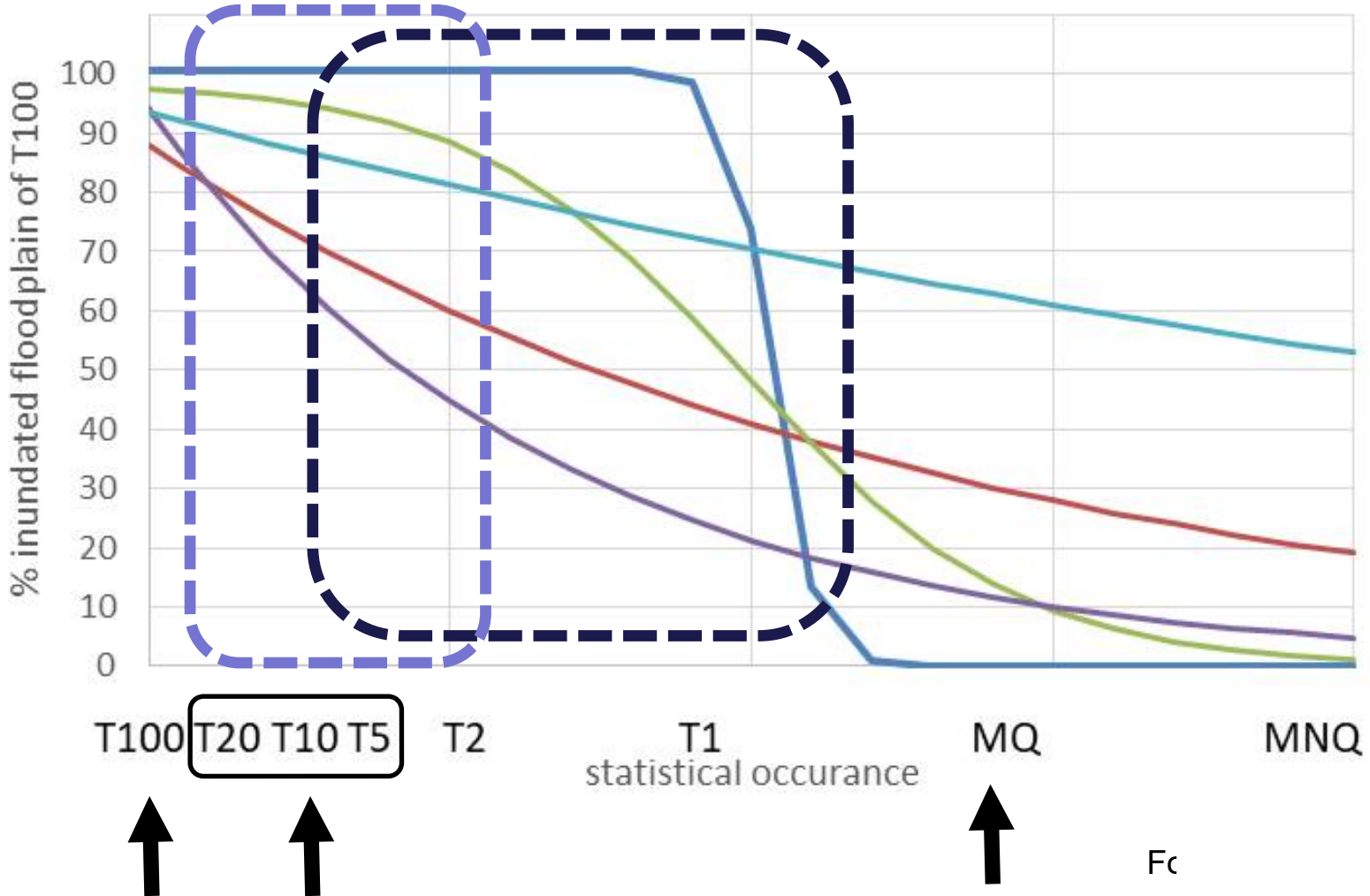




Methods

Solution:

- Working with statistical frequencies
- Identification of crucial discharges
- Comparison with available floodplain data
- Applying SigmaPlot 14.0 for 3-parameter sigmoid functions for each gauge
- Calculating maximum and average inundated areas for each gauge



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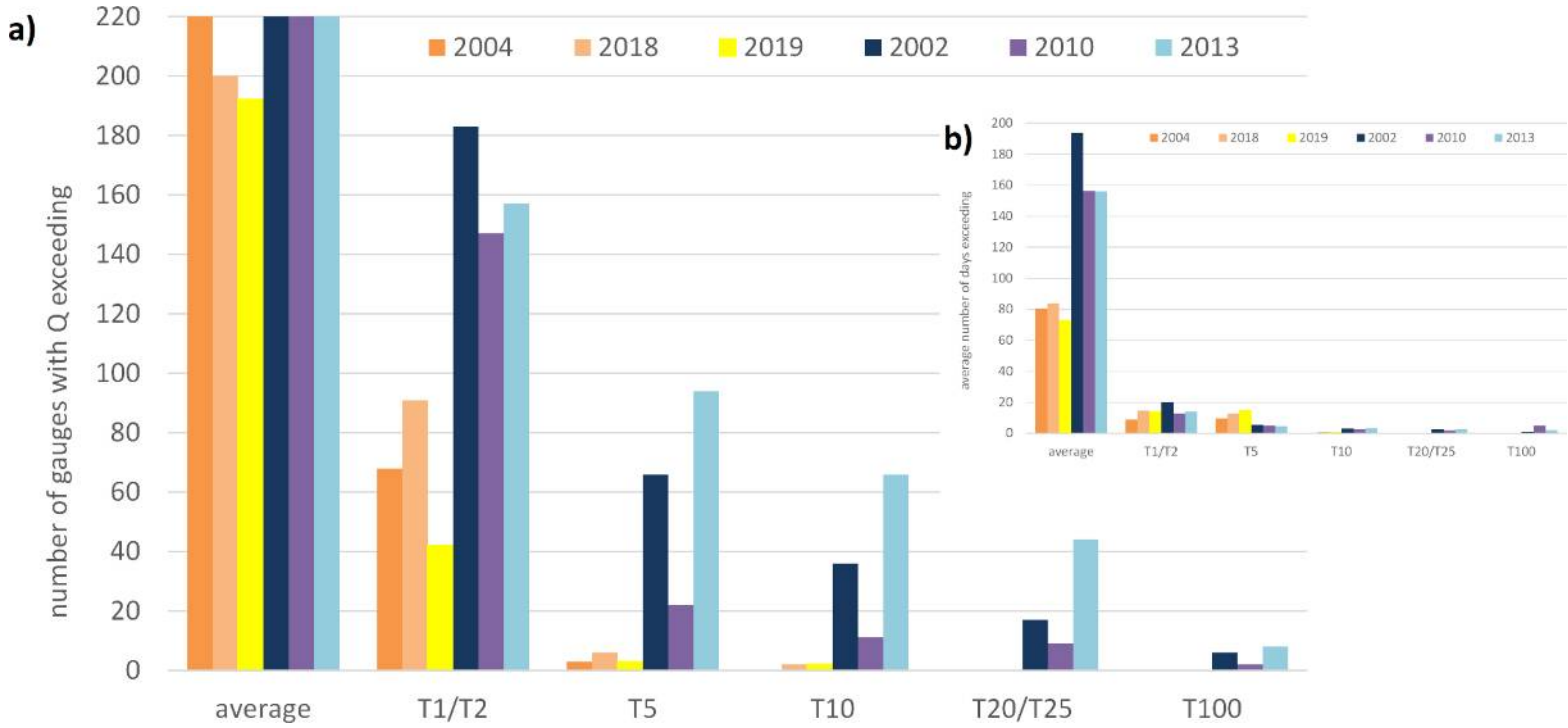
Results I: water availability

a) Hardly any floods in the past 20 years

→extremely wet years with 100-year floods (2002, 2013)

→ other years with few gauges noticing floods exceeding T5

b) Number of days with floods exceeding T1/T2 below 20!



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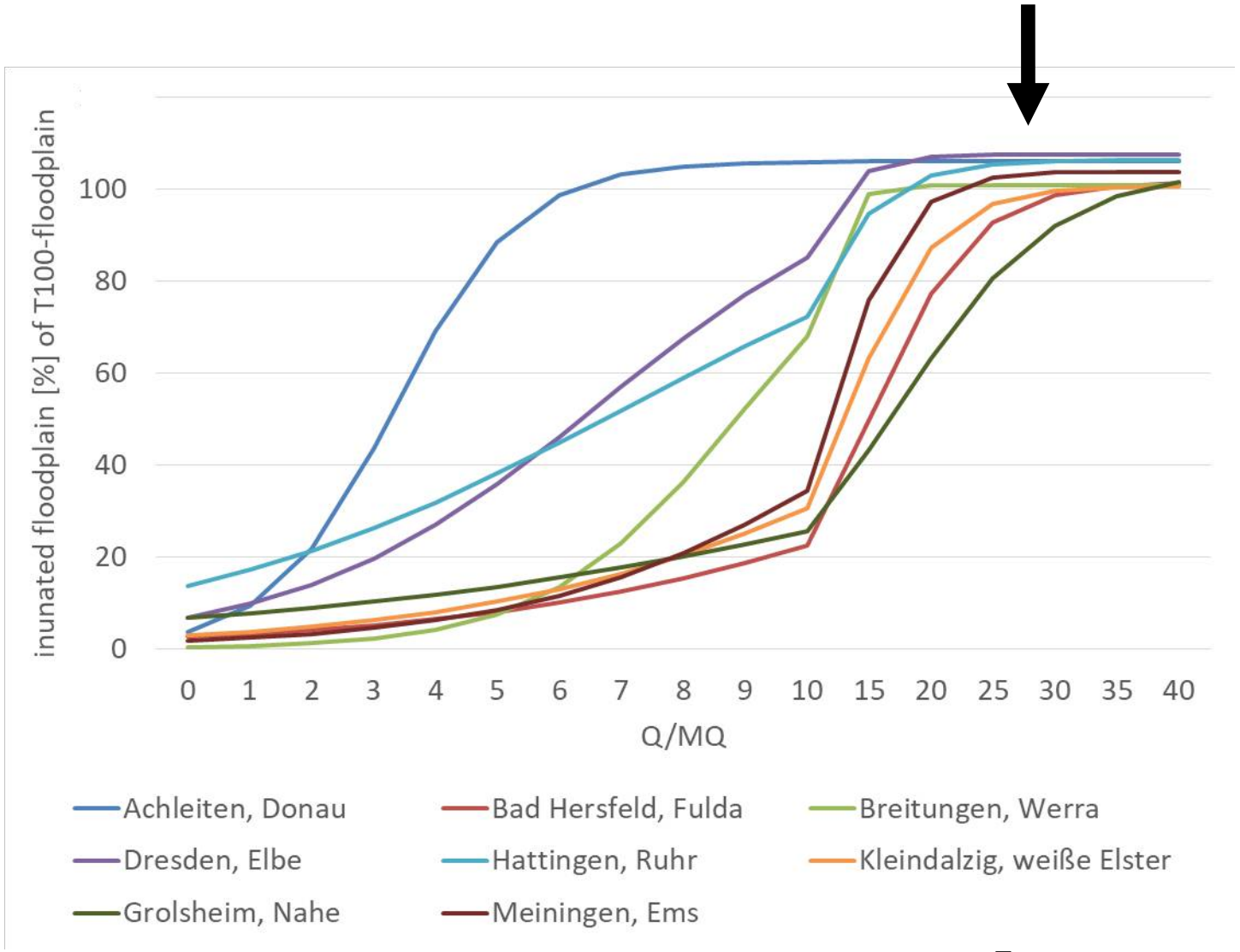
Results II: Inundation

- Alternative functions for 176 gauges
- 65% of gauges with acceptable deviation
- deviation = difference calculated maximum floodplain and 100%



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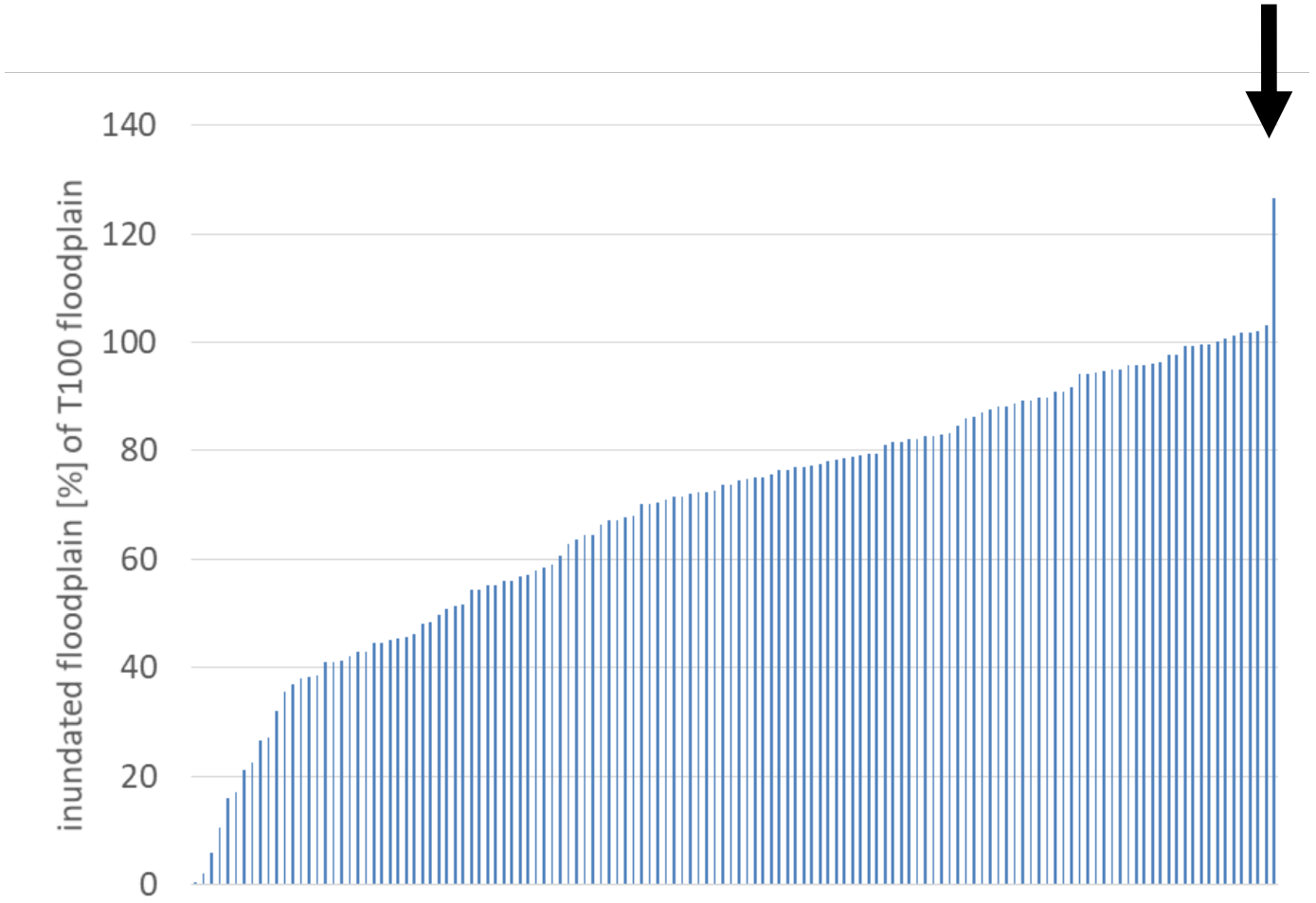
Results II: Inundation

- Alternative functions for 176 gauges
- 65% auf gauges with acceptable deviation
- deviation = difference calculated maximum floodplain and 100%
- Calculation of inundated floodplains for 140 gauges
- Maximum of the past 20 years between 0.2 and 126%, as yearly average 0-51%



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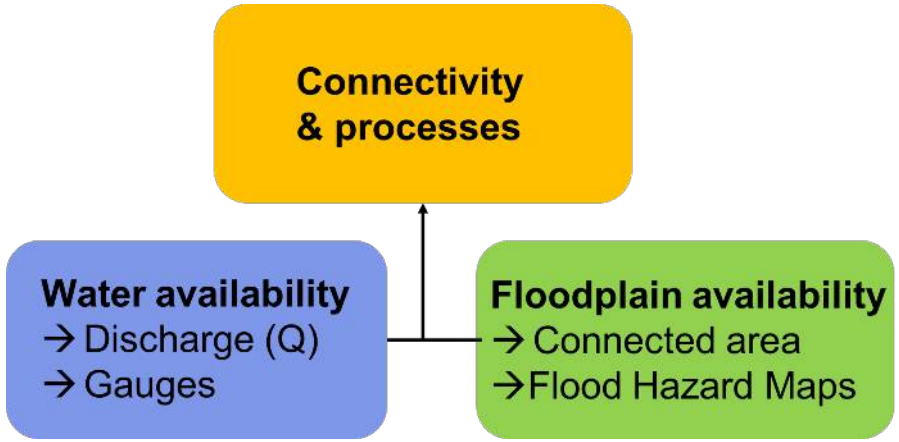
Discussion & Outlook

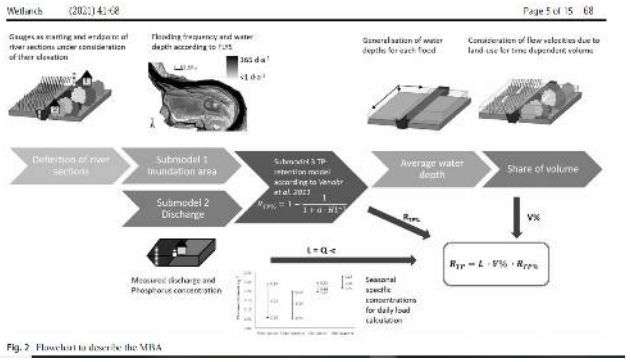
- Inundated floodplain extent can be estimated - at least for 140 gauges and thus river sections for daily discharge for various rivers
- T100 floodplains is hardly inundated in the past 20 years



- Coupling this knowledge with a nutrient retention model (Venohr et al. 2011)
- Need of daily NO_3-N and TP concentrations

→ Random forest with gauge and monitoring data on the basis of pubicly available data (approx. 45,000 data points).

→ Work in progress



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water

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Article

How Flood Hazard Maps Improve the Understanding of Ecologically Active Floodplains

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Abstract: Floodplains are threatened ecosystems and are not only ecologically meaningful but also important for humans by creating multiple benefits. Many underlying functions, like nutrient retention, carbon sequestration or water regulation, strongly depend on regular inundation. So far, these are approached on the basis of what are called 'active floodplains'. Active floodplains, defined as statistically inundated once every 100 years, represent less than 10% of a floodplain's original size. Still, should this remaining area be considered as one homogenous surface in terms of floodplain function, or are there any alternative approaches to quantify ecologically active floodplains? With the European Flood Hazard Maps, the extent of not only medium floods (T-medium) but also frequent floods (T-frequent) needs to be modelled by all member states of the European Union. For large German rivers, both scenarios were compared to quantify the extent, as well as selected indicators for naturalness derived from inundation. It is assumed that the more naturalness there is, the more inundation and the better the functioning. Real inundation was quantified using measured discharges from relevant gauges over the past 20 years. As a result, land uses indicating strong human impacts changed significantly from T-frequent to T-medium floodplains. Furthermore, the extent, water depth and water volume stored in the T-frequent and T-medium floodplains is significantly different. Even T-frequent floodplains experienced inundation for only half of the considered gauges during the past 20 years. This study gives evidence for considering regulation functions on the basis of ecologically active floodplains, meaning in floodplains with more frequent inundation that T-medium floodplains delineate.

Keywords: active floodplain; frequent flood; flood hazard map; inundation; land use

check for updates

Citation: Natho, S. How Flood Hazard Maps Improve the Understanding of Ecologically Active Floodplains. *Water* **2021**, *13*, 937. https://doi.org/10.3390/w13070937

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1. Introduction

Floodplains are transition zones between terrestrial and aquatic ecosystems and, as such, one of the ecosystems providing the most ecosystem services on earth [1]. From the ecological point of view, floodplains are "areas that are periodically inundated by lateral overflow of rivers or lakes" [2] (p. 112). This description underlines that floodplains do not comprise the permanent lotic system of a river, as they would from a hydrological point of view that defines riparian zones as areas of the stream channel "between the low and high water marks and that portion of the terrestrial landscape from the high water mark toward the uplands where vegetation may be influenced by elevated water tables or flooding and by the ability of the soils to hold water" [3] (p. 623). Thus, floodplains are understood as areas adjacent to riverbeds structured by natural disturbances (floods) [4], such that zonation is known to represent successional stages [5] because vegetation communities are controlled by environmental gradients [4,6] like inundation (frequency, duration, depth and timing) [7] and are adapted to it [8]. But, floodplain width is temporally and spatially complex to determine and different approaches have been developed [9,10], mainly based on defining an active floodplain as a 100-year return period flood zone. However, the degree of connectivity between rivers and floodplains is determined by flow, and thus by times of inundation when both systems share water, nutrients, organisms and sediment

https://doi.org/10.3390/w13070937

Thank you for your attention

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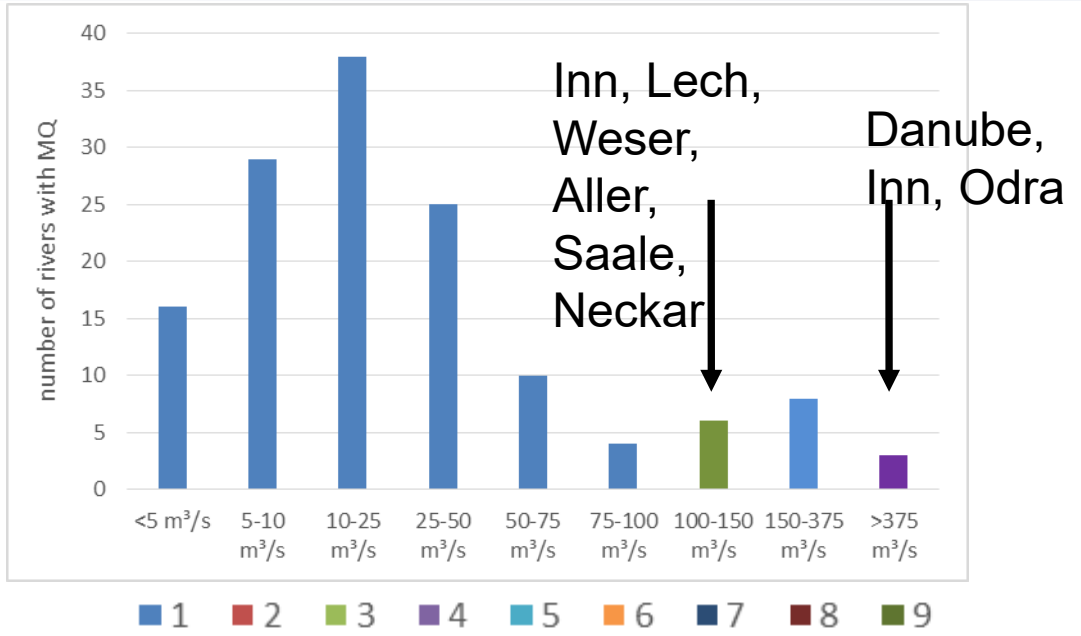
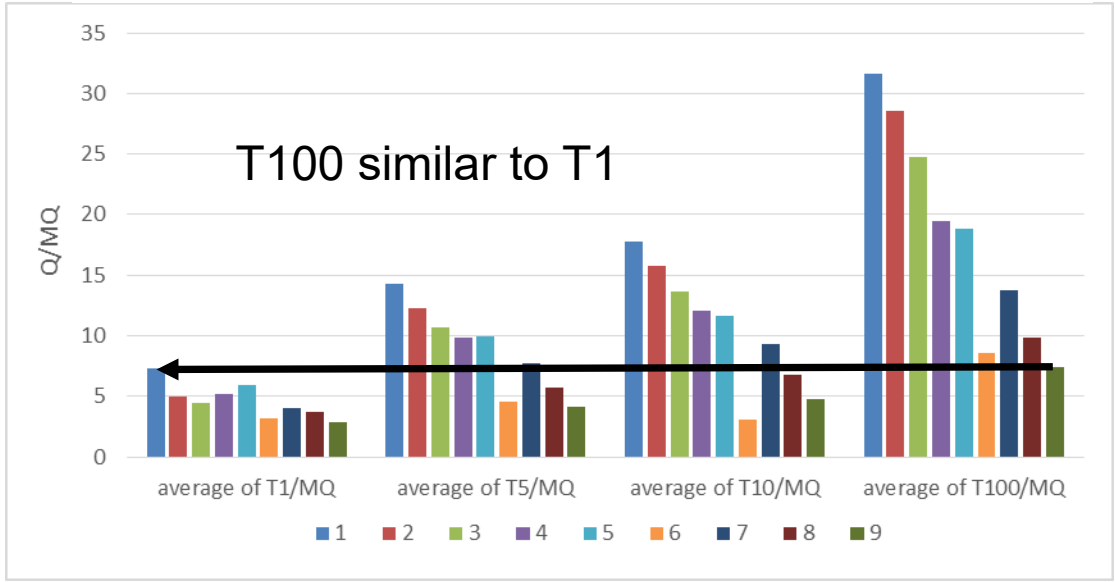
Back-up

Methods

Challenges:

- Study rivers include large variation in MQ
- Relation of Q/MQ as proxy of discharge dynamics
- 9 discharge classes reveal variation
- Small rivers (class 1) with high T100/MQ-values
- Big rivers (class 9) with low T100/MQ-values
- Class 6 only 3 rivers, Havel, Saale, Inn, heavily regulated

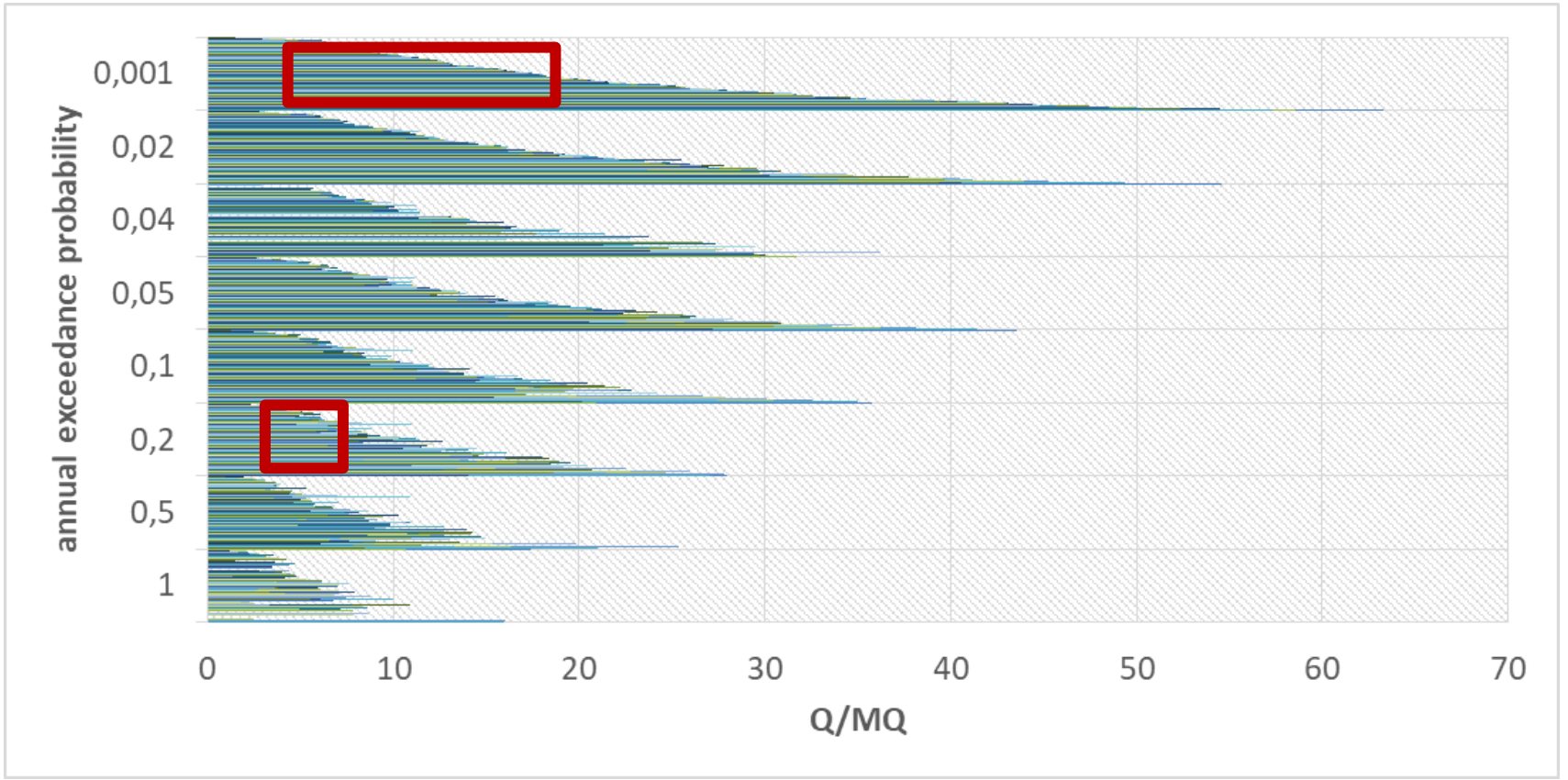




Methods

Challenges:

- How to transfer these relations to completely different discharges?



Range of Rhine, Elbe & Main

Methods

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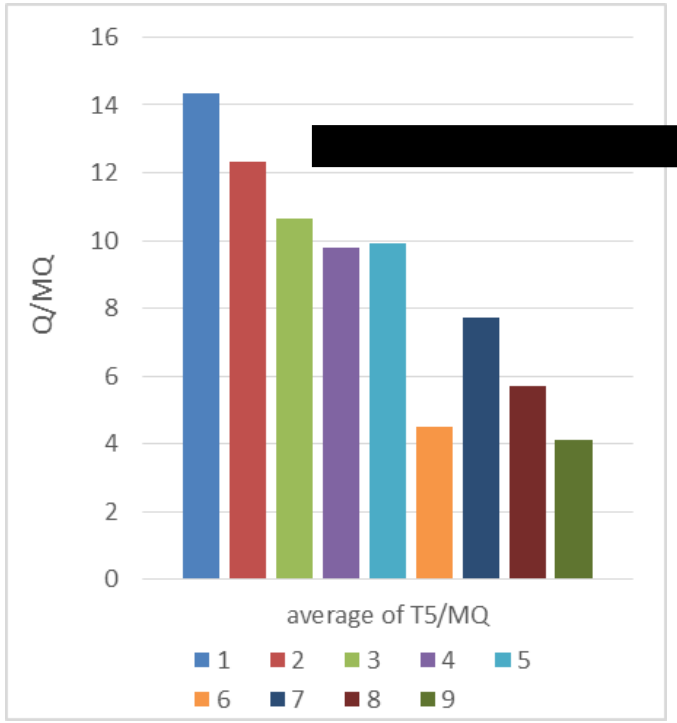

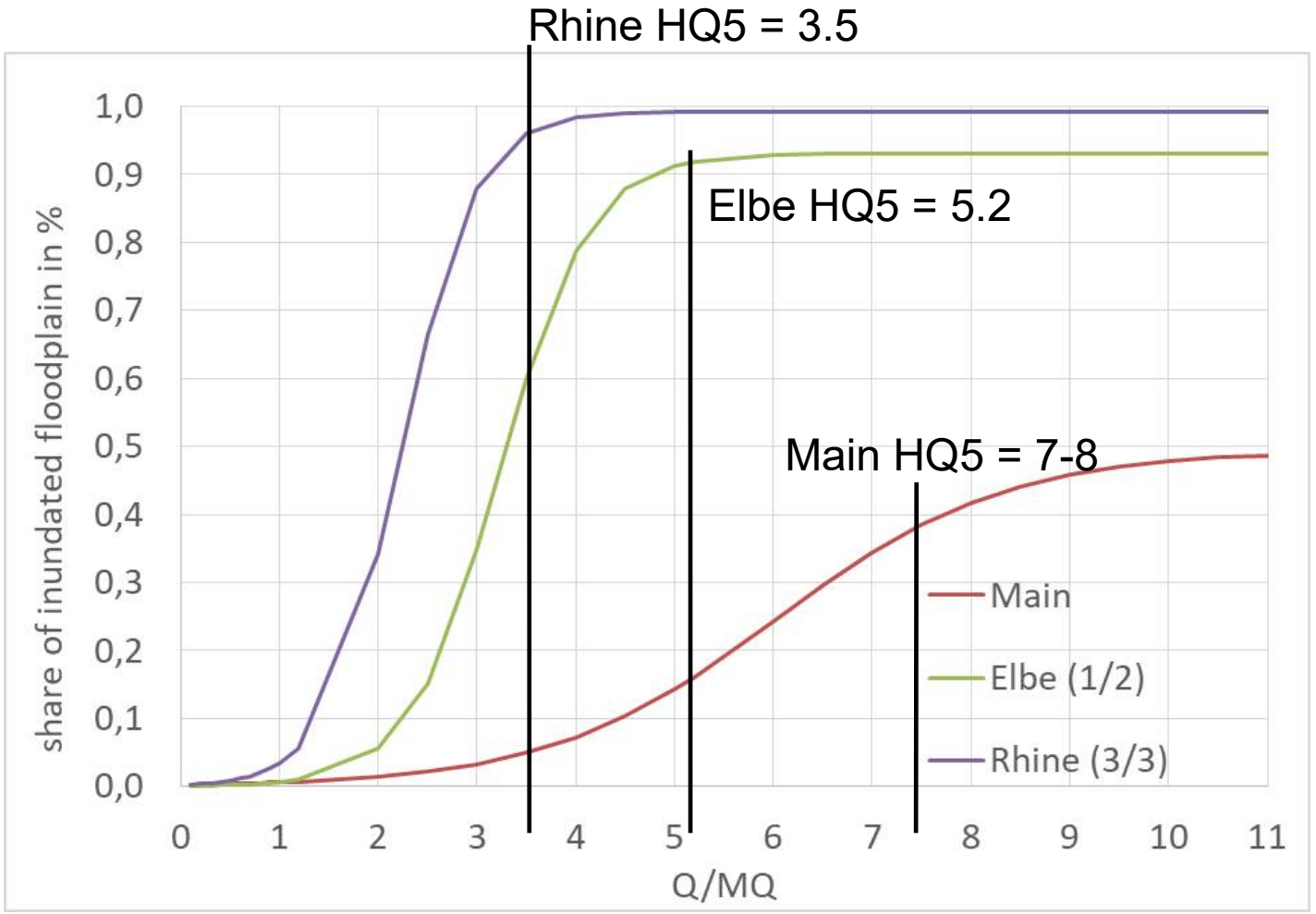

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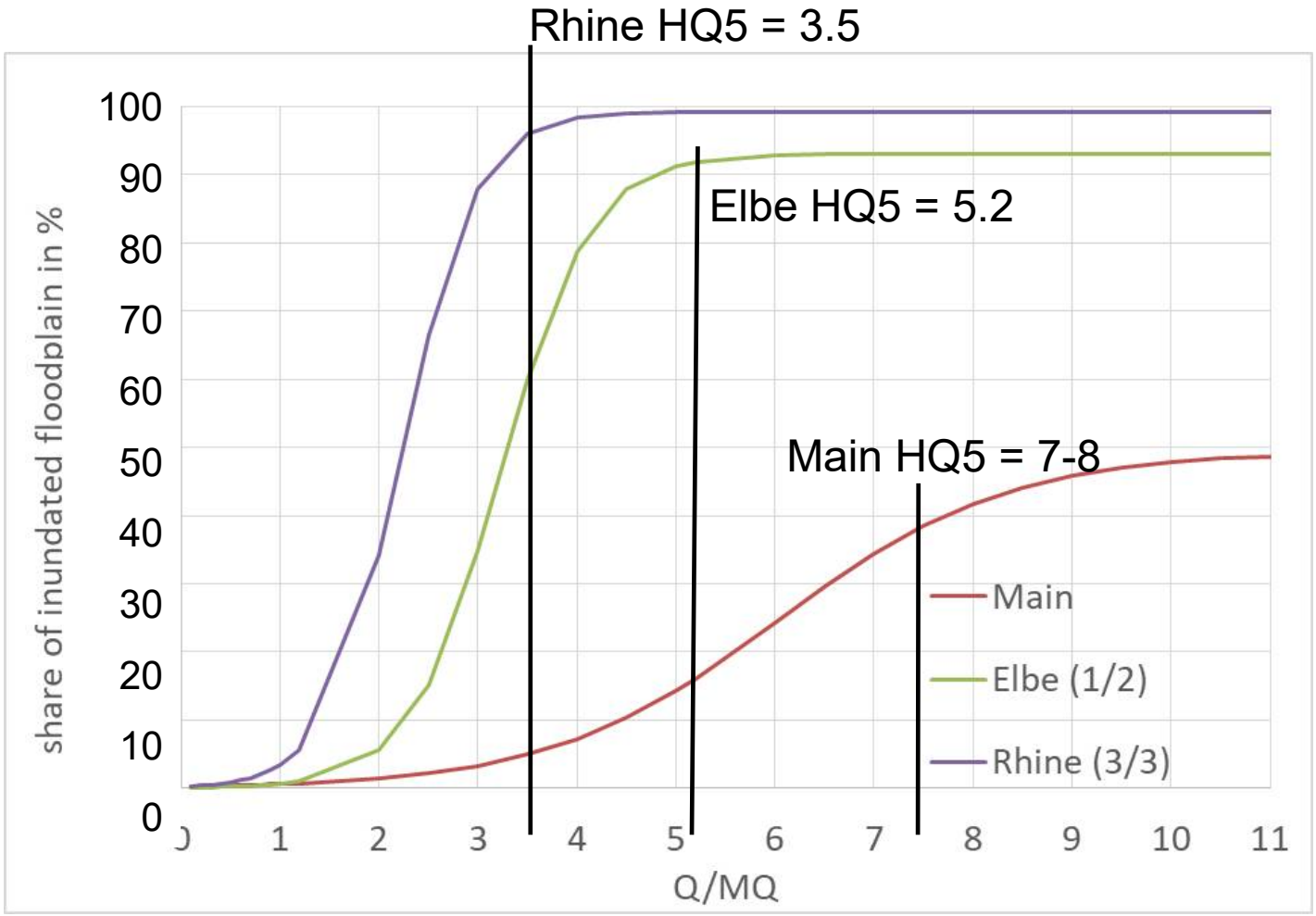
Methods

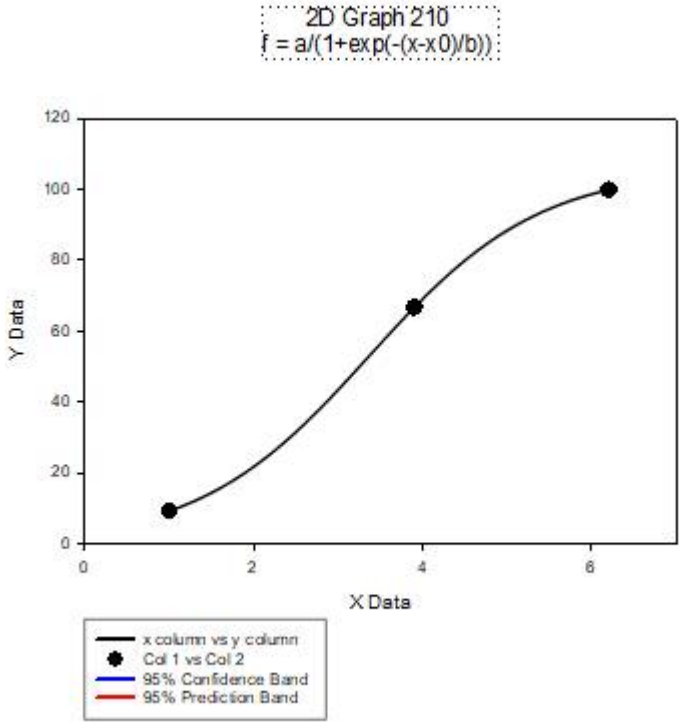
Solution:

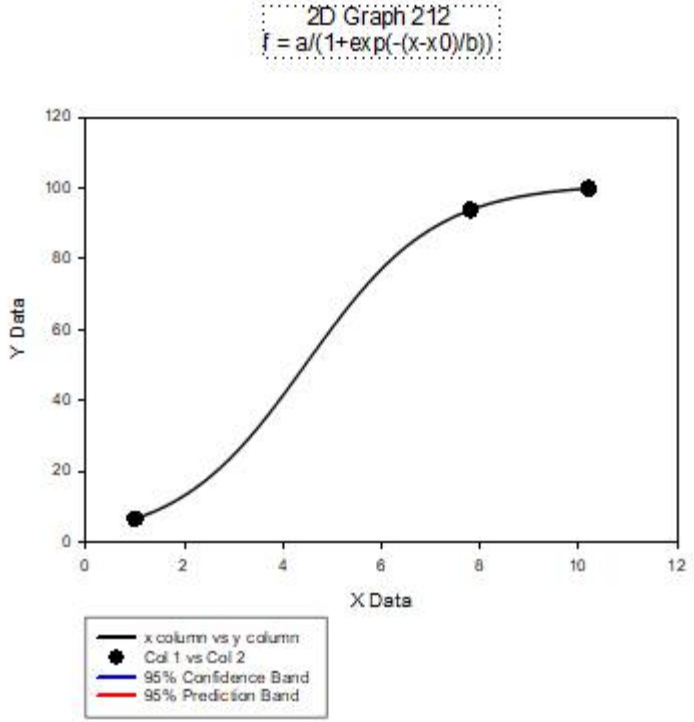
- Working with statistical frequencies

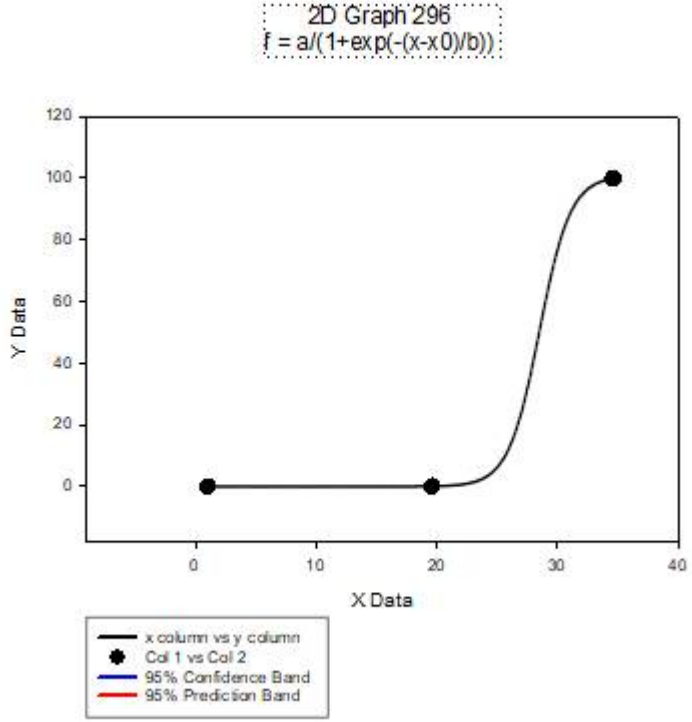


Methods

3-parameter sigmoid functions für different Q/MQ







Sigmaplot 14.0

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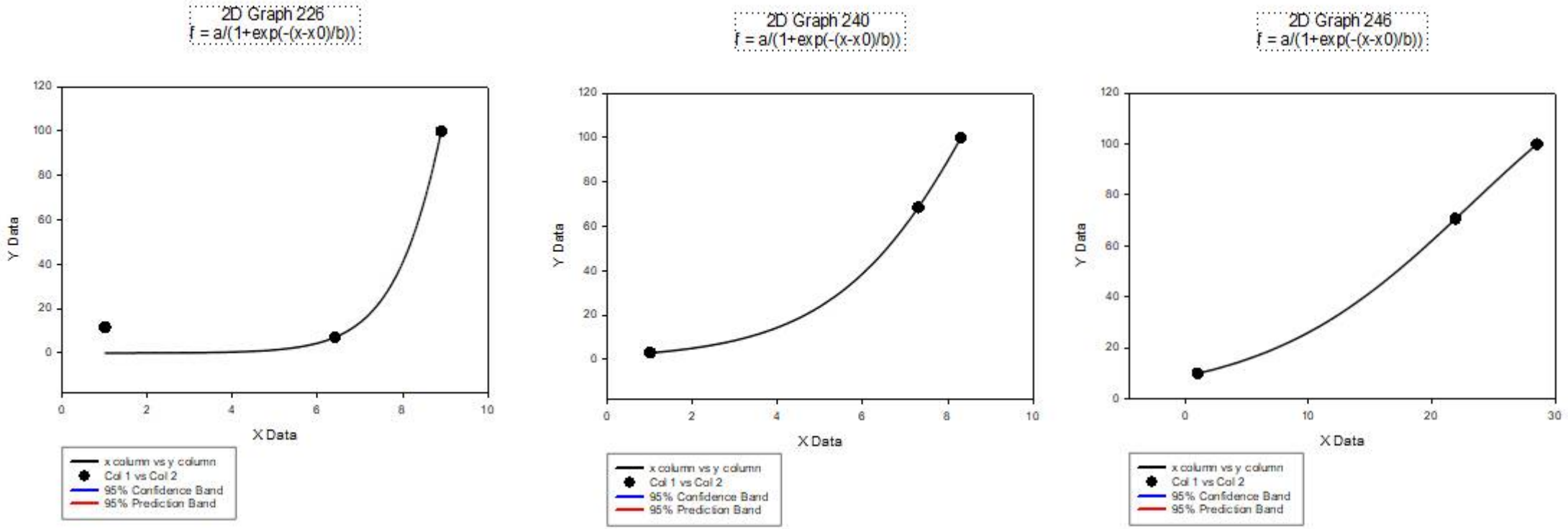
Methods

3-parameter sigmoid functions für different Q/MQ



Sigmaplot 14.0

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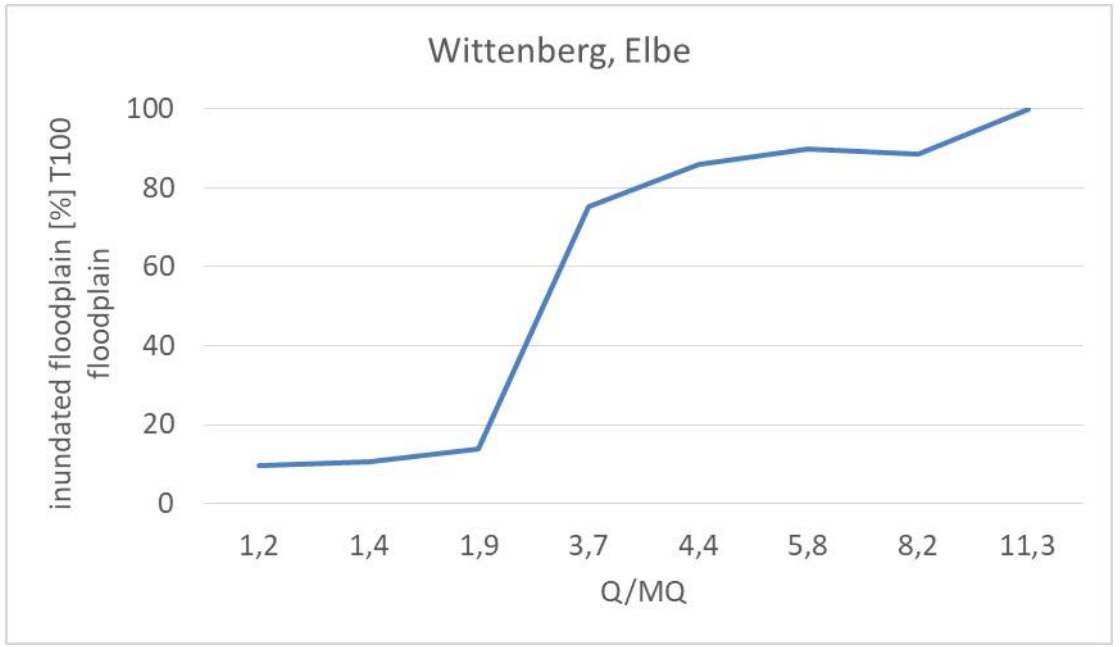
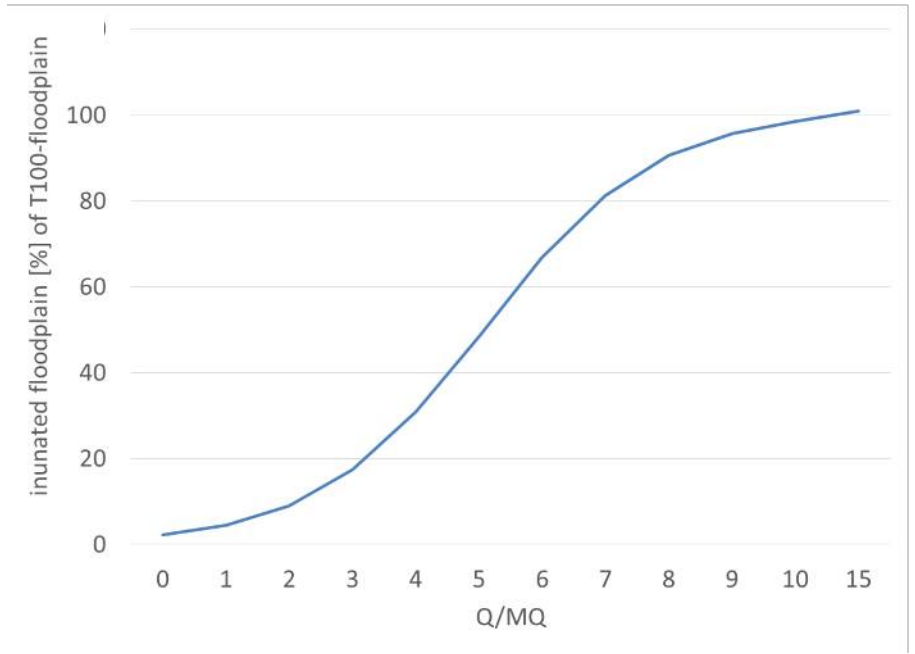
Results: Comparison of transfer functions

Full dataset



MQ & Tfrequent & T100



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