


# Effects of plant species identity override diversity effects in explaining sedimentation within vegetation in a flume experiment

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## Abstract

During floods, sediments suspended in river water deposit on floodplains. Thus, floodplains are a key to improving river water quality. Yet, the factors that determine the amount of fine sediment that deposits on floodplains are largely unknown. Plant diversity typically increases structural diversity, whereas the vegetation structure and the structural characteristics of individual species are known to influence sedimentation. We hypothesised that species diversity, in addition to species identity, may promote sediment retention. Our study aimed to disentangle the effects of species richness and species identity, via differences in vegetation structure, on sediment retention within herbaceous vegetation patches. In a flume experiment, we investigated sedimentation on 30 vegetation patches (40 × 60 cm<sup>2</sup>). We created patches with five different species-richness levels (3, 4, 6, 8, and 11 species), each replicated six times. Species were randomly selected from 14 common floodplain species. We inundated the patches with silt- and clay-rich water and measured the amount of accumulated sediment on the vegetation and on the ground underneath it. Species richness significantly increased sedimentation underneath the vegetation ( $R^2 = 0.17$ ). However, including species identity effects in a structural equation model, we showed that individual species' presence largely drove these effects. *Alopecurus pratensis* had a direct negative effect on sedimentation on the vegetation, whereas *Bromus inermis* and *Elymus repens* had indirect positive effects through an increase in total biomass ( $R^2 = 0.42$ ). *Elymus repens* had a direct negative, and *Urtica dioica* a direct positive effect on sedimentation underneath the vegetation ( $R^2 = 0.38$ ). Our results indicate that selecting the most effective species, rather than as many species as possible, may have the greatest benefits for promoting sedimentation. Overall, we conclude that floodplain management that aims to increase sediment retention should alter the vegetation structure of meadows by increasing vegetation biomass.

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## KEYWORDS

floodplain, leaf surface, sediment retention, structural diversity, traits

## 1 | INTRODUCTION

Sediment and nutrient loads of streams and rivers are increasing worldwide, largely due to anthropogenic activities (Hunter & Walton, 2008; Sharma et al., 2008; Tockner et al., 2010). Industrial agriculture and forestry are responsible for soil erosion and over fertilisation (Hancock, 2002). This overload of sediment and nutrients causes eutrophication and siltation in river catchments (Carpenter et al., 1998; Habersack et al., 2016) or sediment accumulation upstream of barriers, such as hydro-engineering infrastructures (Habersack et al., 2016). A natural floodplain, however, retains sediment and the associated nutrients during floods (Naiman & Décamps, 1997; Noe & Hupp, 2005). Thus, natural floodplains reduce sediment transport to downstream areas and, thereby providing an important ecosystem function (Conte et al., 2011; Hopkins et al., 2018). However, most natural floodplains are decoupled from their rivers due to anthropogenic activities such as channelisation, embankments, and river straightening (Naiman & Décamps, 1997; Tockner & Stanford, 2002), which impair their contribution to sediment and nutrient retention.

In recent decades, efforts to restore floodplains have increased, focusing on reconnecting rivers to their floodplains. Thus, more attention has been given to floodplain management and its vegetation with the goal to increase their capacity to buffer high-water peaks and retain sediment and nutrients (Wolf et al., 2013). In addition to floodplain topography, the vegetation is also a relevant driver for sediment retention. During floods, the vegetation can filter sediments and nutrients from the river water (Corenblit et al., 2011; Gurnell et al., 2012). However, to manage floodplains for optimal sediment retention, we need to understand how floodplain vegetation influences sedimentation.

Different vegetation types (trees, shrubs, herbs, and macrophytes) are known to have strong but contrasting effects on sediment retention capacity via their biomass or structural parameters such as density, height, and volume (Corenblit et al., 2009; Elliott, 2000; Gurnell et al., 2012; Västilä & Järvelä, 2018). However, thus far, sedimentation has only been measured in front or behind vegetation patches, although data on sedimentation on, within, or beneath vegetation is scarce (but see Kretz et al., 2021).

Existing studies have focussed on identifying structural parameters that reduce the flow velocity causing sediment to sink and deposit either on the soil or on the vegetation (Akram et al., 2014; Asselman & Middelkoop, 1995). For example, a recent study showed that increasing structural diversity using a mixture of different plant heights increases sediment retention within vegetation patches (Kretz et al., 2021). As species richness often increases the structural diversity of herbaceous vegetation (Proulx et al., 2014; Schuldt et al., 2019), the species richness of natural floodplains may indirectly increase sedimentation. At the same time, characteristic

features of dominant plant species at the leaf, plant, or stand level may exert strong identity effects on sedimentation within and underneath the vegetation.

In the context of sediment retention, species-richness effects are rarely studied, even though riparian zones and floodplain meadows are biodiversity hotspots (Tockner & Stanford, 2002), while simultaneously belonging to the most threatened habitats worldwide (Olson & Dinerstein, 1998). From grassland studies, we know that biomass, stand density, and canopy height positively correlates with species diversity (Cardinale et al., 2007; Marquard et al., 2009; Schulze et al., 2009) and, therefore, reflect enhanced ecosystem functions such as productivity and nutrient acquisition (Tilman et al., 2014). However, the only experimental study exploring the effects of species richness on sediment retention in herbaceous vegetation did not find a significant difference between monocultures and three-species mixtures (Kervroëdan et al., 2019).

Total biomass can also increase sedimentation (Elliott, 2000; Gurnell et al., 2012) by two mechanisms. First, more biomass directly increases sedimentation due to overall larger leaf surface area, where sediment can settle. The second mechanism acts indirectly. Biomass increases with structural characteristics of the vegetation, such as height or density (Marquard et al., 2009; Schulze et al., 2009), which both have been found to increase sedimentation (Kretz et al., 2021). As biomass often increases with species diversity (Cardinale et al., 2007), it may link sedimentation processes with plant species richness.

In addition to species richness and total biomass, identity effects of individual species may also drive sedimentation. In many floodplain meadows, single species, especially grasses, tend to reach dominance, and species-specific characteristics, such as stature, density, and leaf surface structure, are likely to have strong effects on the sedimentation process (Corenblit et al., 2011; Elliott, 2000; Kretz et al., 2020). Thus, the structural characteristics of individual species may influence overall sedimentation. For example, a species such as the herb *Artemisia vulgaris* is likely to capture high amounts of sediment on its surface, i.e., on the vegetation, due to its hairy leaves (Kretz et al., 2020). It may also capture a lot of sediment underneath the vegetation due to its tall and dense growth, lowering flow velocities and allowing sediments to sink and deposit (Kretz et al., 2021). The herb *A. vulgaris* can build a canopy-like stature and, thus, open space directly above the ground where sediment can settle. Paul et al. (2014) separated species into two groups, crown-building species (herbs building a canopy) and meadow-building species (grasses), to distinguish different plant shapes that influence the water flow pattern. In contrast to *A. vulgaris*, *Phalaris arundinacea*, a grass species, may reduce overall sedimentation. The dense swards produced by *P. arundinacea* lower the flow velocity and, thus, increase sedimentation. However, these swards may be too dense for sediment to settle underneath the vegetation. For sedimentation on

**TABLE 1** Species selection (grasses and herbs) for the experiment

	Probability to be drawn (%)
<b>Grasses</b>	
<i>Alopecurus pratensis</i> L.	11.05
<i>Arrhenatherum elatius</i> (L.) J. Presl & C. Presl	12.11
<i>Bromus inermis</i> Leyss.	8.42
<i>Calamagrostis epigejos</i> (L.) Roth	17.89
<i>Elymus repens</i> (L.) Gould	18.42
<i>Phalaris arundinacea</i> L.	6.32
<i>Phragmites australis</i> (Cav.) Trin. ex Steud.	0.53
<b>Herbs</b>	
<i>Artemisia vulgaris</i> L.	1.05
<i>Galium mollugo</i> L., s. str.	7.37
<i>Glechoma hederacea</i> L.	1.05
<i>Rumex acetosa</i> L., nom. cons.	3.68
<i>Tanacetum vulgare</i> L.	2.11
<i>Urtica dioica</i> L., s. l.	8.95
<i>Viola tricolor</i> L.	1.05

Note: Probability to be selected for patches (based on their frequency in the inventories). Grey-coloured species did not germinate.

the vegetation, its relatively large, but nonhaired leaves, are likely to capture only little sediment (Kretz et al., 2020).

This study investigated to what extent species richness and dominant species' identity influence sedimentation on and underneath vegetation patches. We experimentally designed a gradient in species richness of herbaceous plant patches. We inundated these patches in a flume to measure how much sediment these patches trapped on and underneath the vegetation under highly controlled conditions. We analysed the effects of species richness, species identity, and the mediating effect of total vegetation biomass on sedimentation on and underneath the vegetation.

We hypothesised that:

**H1:** Patches with higher species richness accumulate more sediment on and underneath the vegetation.

**H2:** The identity of the species, especially of dominant species, influences sedimentation on and underneath the vegetation.

**H3:** The effects of species richness and identity on sedimentation are, in part, driven by vegetation biomass, as this is a proxy for various structural properties.

## 2 | METHODS

### 2.1 | Experimental design

We planted 30 patches with herbaceous vegetation spanning a species-richness gradient of 3 to 11 species found in natural floodplain meadows of German lowland rivers. We designed representative levels of species richness for the floodplains along the River Mulde (3, 4, 6, 8, and 11 species). In total, we selected the

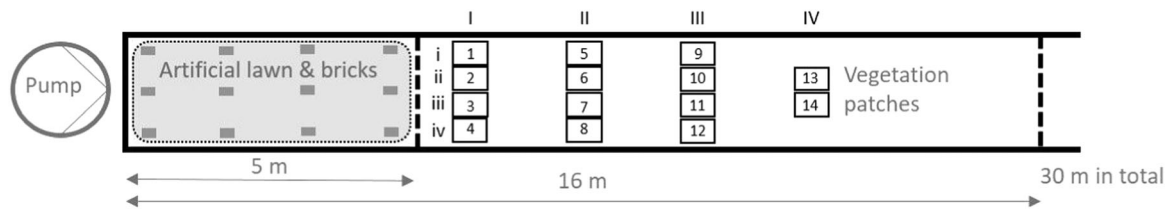
14 most frequently occurring species for our species pool (seven grass species and seven herbs; Table 1) based on a vegetation survey on 90 plots (0.25 m<sup>2</sup>) of three floodplain meadows along the River Mulde between Raguhn and Dessau, Germany (51°43'–46' N, 12°17'–18'E) in 2017. Each species richness level was replicated six times with randomly selected species combinations. Table 1 gives the probability that any given species is drawn based on its abundance in the vegetation survey along the River Mulde. We drew the patches-species mixtures without replacement, and identical patches were discarded.

### 2.2 | Experimental set-up

In June 2018, we seeded the patches in trays (40 × 60 cm<sup>2</sup>) on 3 cm sand mixed with fertiliser (Osmocote Exact Standard [5–6M]; Meyer). The sand layer was covered with a fleece (Thermos-Fleece 85 g/m<sup>2</sup>; Meyer) on which we spread the seeds evenly but randomly. We seeded 1,000 seeds per tray, with the same number of seeds for each species (thousand divided by the species-richness level). For promoting germination, we covered the seeds with an additional thin layer of sand and turf. For the first 9 weeks, the patches grew in the greenhouse of the Leipzig Botanical Garden (Figure S1a). We watered the trays twice per day and moved them outside in the shade for additional 2 weeks (Figure S1b). We ran the actual sedimentation experiment in a flume (Stahl-Technik-Straub GmbH & Co KG) at the Leichtweiß-Institute for Hydraulic Engineering and Water Resources (TU Braunschweig). The flume (30-m-long, 2-m-wide and 80-cm-deep) had a closed water cycle powered by a pump with a water discharge of 24–25 L s<sup>-1</sup>. The water level in the flume was regulated to a height of 45 cm. To create the sediment component, we mixed the whole waterbody of 28,000 L with 7.5 kg clay (Ø < 2 µm) and 7.5 kg silt (90% with Ø 2–63 µm). The first 5 m were covered with artificial lawn and bricks to roughen the surface and ensure a fully developed flow upstream of the first vegetation patches (Figure 1).

### 2.3 | Experiment conduction

The individual patches per run and also their position in the flume were randomly selected. We prepared the patches by washing out the sand between the roots. The fleeces with their aboveground parts above the fleece and the roots remaining below were fixed on a metal plate (40 × 60 cm<sup>2</sup>) with magnets. Then, we inundated the patches in the flume (Figure 1). Each run was equipped with 14 metal plates (Figure 1), where four were control patches with blank fleeces and 10 were vegetation patches. Each row and line had a control patch, but its position was shifted for each run (Figures 1 and S1c). We took four reference water samples (100-ml each) 3 h before each run's end. At the end of each run (after 21 ± 1 h), we stopped the flow, the vegetated area was slowly drained, and we removed the patches from the flume. We did an additional control run with only control fleeces as references. After removal from the flume, the



**FIGURE 1** Top view sketch of flume with pump, inlet section to roughen the flow (artificial lawn and bricks), closable walls to drain the vegetated section (dashed lines), and positions of the patches in lines (capital Roman numerals) and rows (lowercase Roman numerals)

**TABLE 2** Descriptive statistics of all variables

Variables	Unit	Min	Max	Mean	Median	SD	Occurrence
Sediment on vegetation	g patch <sup>-1</sup>	1.05	15.86	6.19	5.41	3.21	
Sediment on fleece	g patch <sup>-1</sup>	1.65	9.98	5.00	4.82	2.19	
Sown species richness		3.0	11.0	6.40	6.0	2.92	
Realised species richness		1.0	7.0	4.07	4.0	1.57	
Biomass	g patch <sup>-1</sup>	20.06	65.45	38.16	37.70	10.53	
<i>Alopecurus pratensis</i>	g patch <sup>-1</sup>	0.47	10.36	5.68	5.64	3.07	8
<i>Arrhenatherum elatius</i>	g patch <sup>-1</sup>	0.62	27.89	11.17	8.10	8.47	18
<i>Bromus inermis</i>	g patch <sup>-1</sup>	9.21	55.11	21.63	13.43	14.47	19
<i>Elymus repens</i>	g patch <sup>-1</sup>	0.12	12.37	3.79	2.11	3.92	17
<i>Galium mollugo</i>	g patch <sup>-1</sup>	0.01	0.42	0.07	0.02	0.11	15
<i>Glechoma hederacea</i>	g patch <sup>-1</sup>	0.01	0.15	0.08	0.08	0.10	2
<i>Phalaris arundinacea</i>	g patch <sup>-1</sup>	7.91	39.04	22.14	23.25	8.04	15
<i>Rumex acetosa</i>	g patch <sup>-1</sup>	0.18	8.88	3.25	2.57	2.89	10
<i>Urtica dioica</i>	g patch <sup>-1</sup>	0.04	5.06	0.61	0.22	1.23	18

Note: Occurrence is the number of patches with a species out of the 30 patches.

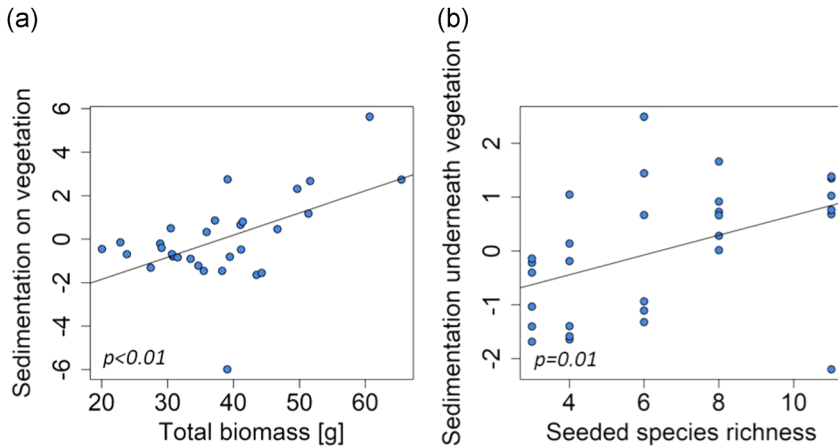
Abbreviations: Max, maximum; Min, minimum; SD, standard deviation.

plants on each patch were carefully harvested, washed to collect the accumulated sediment and sorted by species (Figure S1a,e). The species biomass was dried (110°C) for 24 h the same day but the washing water was stored. The fleeces were also washed to collect the sediment that accumulated underneath the vegetation, and the sediment water from these fleeces was stored as well. The water samples were kept cool for a few days in the laboratory and afterwards for a maximum of one month at 4°C until all samples were processed. We then filtered the sediment-rich water (2-mm pore size) to remove coarse sediment, turf and organic material. We dried the sediment-rich water in glass beakers at 110°C and weighed the absolute amount of sediment per fleece (per 0.24 m<sup>2</sup>) and per total biomass. The dried species biomass was also weighed.

## 2.4 | Data analysis

All statistical analyses were carried out with the statistical software R (R Core Team, 2020). As a first step, we performed

simple linear models as an explorative analysis to investigate whether sedimentation changed over time (i.e., differed between later vs. earlier runs), and we detected a significant decrease with time. To correct for this trend, we ran mixed effect models (lmer function, lme4 library; Bates et al., 2015) with the run ID (day, thus accounting for time) as a fixed factor and the position in the flume as a random factor to explain sediment on and underneath the vegetation. We used the residuals of these first models as the response variables in all subsequent models that investigated how species richness, identity and total biomass drive sedimentation on and underneath the vegetation after correcting for time and position within the flume. First, we ran two models in which the residuals of the sediment (i) on vegetation and (ii) underneath the vegetation were modelled as a response to the total biomass, the sown species richness, and the realised species richness. We tested for multicollinearity by calculating the variance inflation factor, where a variance inflation factor below 5 (vif function, car library; Fox & Weisberg, 2019) signified that variables were not significantly collinear and selected the



**FIGURE 2** Significant linear models on variables explaining sedimentation

most parsimonious model based on the lowest AIC value, using the stepAIC function of the MASS library (Venables & Ripley, 2002). We additionally ran three separate linear models to explain (i) the residuals of the sediment on the vegetation, (ii) the residuals of the sediment underneath the vegetation, and (iii) the total biomass. We included the presence/absence of all species (excluding *Glechoma hederacea* due to its low occurrence), the biomass, and the sown and realised species richness as explanatory variables (Table 2). Here, we used a forward model selection to avoid multicollinearity. We first ran 12 simple linear models for each response variable to identify which variables had the strongest effects. Step by step, we added additional, most significant variables that had a variance inflation factor (VIF) below 5 (vif function, car library; Fox & Weisberg, 2019) until no more significant variables could be added. Afterwards, we ran a piecewise structural equation model (pSEM function, piecewiseSEM library; Lefcheck, 2016) to examine the mechanistic links between the predictors. For the pSEM, we began with a model containing all significant variables that directly and indirectly explained sedimentation in the previous linear models.

### 3 | RESULTS

#### 3.1 | Descriptive statistical results

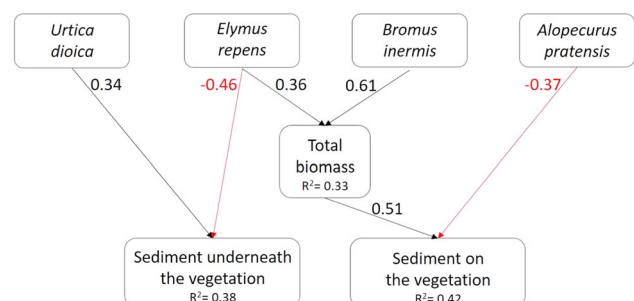
Five species did not germinate on any patches (*Artemisia vulgaris*, *Calamagrostis epigejos*, *Phragmites australis*, *Tanacetum vulgare* and *Viola tricolor*, Table 1). Thus, even though we seeded a species-richness gradient from 3 to 11 species, realised species richness varied from one to seven species, still spanning a considerable richness gradient in our experiment. In the end, species richness of one and seven species was replicated once, whereas species richness of two to six species was replicated between five and seven times. Sedimentation on the vegetation reached a mean of  $6.19 \pm 3.21$  g (Table 2), whereas sediment on the fleece (underneath the vegetation) reached a mean of  $5.00 \pm 2.19$  g (Table 2). More descriptive statistics are summarised in Table 2.

#### 3.2 | Total biomass and species richness

Results from the basic linear models showed that sedimentation on the vegetation significantly increased with total vegetation biomass ( $p < 0.01$ ,  $R^2 = 0.26$ ; Figure 2a and Table S1), whereas sedimentation underneath the vegetation significantly increased with sown species richness ( $p = 0.01$ ,  $R^2 = 0.17$ ; Figure 2 and Table S1).

#### 3.3 | Species identity effects

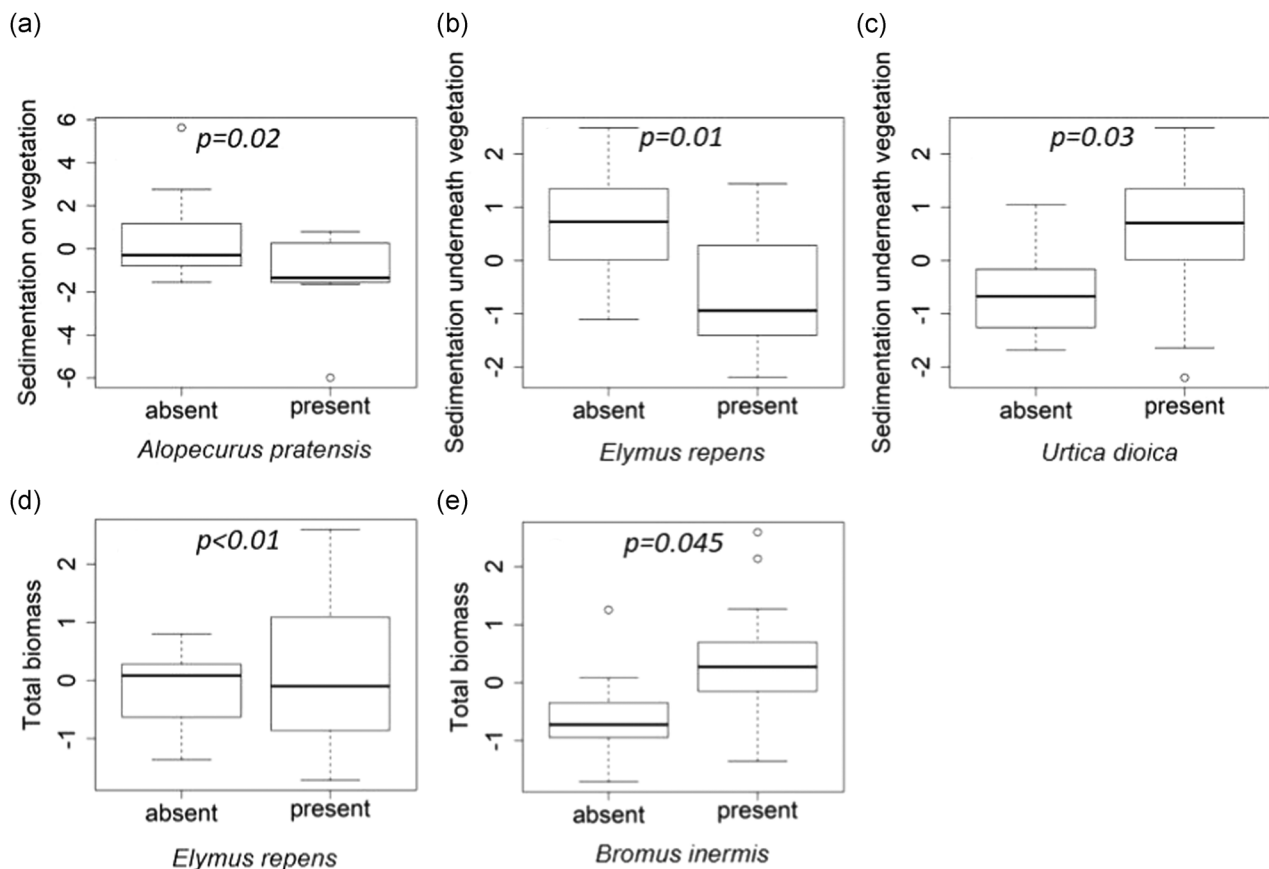
The global goodness-of-fit of the pSEM had a Fisher's C of 15.73 with  $p = 0.61$ , indicating an adequate model fit. Sedimentation on the vegetation was directly driven by the total biomass and the presence of the species *Alopecurus pratensis* ( $R^2 = 0.42$ ; Figure 3). The sediment on the vegetation increased with total biomass ( $p < 0.01$ ; Figure 2a and Table 3) and was lower when *A. pratensis* was present ( $p = 0.02$ ; Figure 4a and Table 3). Sedimentation underneath the vegetation was lower in the presence of *Elymus repens* ( $p = 0.01$ ) but higher when *Urtica dioica* was present ( $p = 0.03$ ,  $R^2 = 0.38$ ; Figures 3 and 4b,c; and Table 3). When *Bromus inermis* or *E. repens* were present, total biomass was significantly higher ( $p < 0.01$ ,  $p = 0.045$ , respectively,  $R^2 = 0.33$ ; Figures 3 and 4d,e and Table 3), thus these species also had indirect, positive effects on sedimentation on the vegetation.



**FIGURE 3** Piecewise structural equation models (pSEM) with all significant paths. Red colour indicates negative correlation

**TABLE 3** Statistical results of the piecewise structural equation models (pSEM) model

Response	Predictor	Estimate	Standard error	df	Critical value	p Value	Standard estimate	Significance
Sediment on vegetation	Total biomass	1.025	0.293	27	3.493	0.002	0.513	**
Sediment on vegetation	<i>Alopecurus pratense</i>	-1.624	0.652	27	-2.490	0.019	-0.365	*
Sediment underneath vegetation	<i>Elymus repens</i>	-1.093	0.369	27	-2.962	0.006	-0.456	**
Sediment underneath vegetation	<i>Urtica dioica</i>	0.835	0.373	27	2.238	0.034	0.344	*
Total biomass	<i>Bromus inermis</i>	1.247	0.348	27	3.584	0.001	0.611	**
Total biomass	<i>Elymus repens</i>	0.710	0.338	27	2.100	0.045	0.358	*

**FIGURE 4** Significant effects of absence and presence of plant species in the piecewise structural equation models

## 4 | DISCUSSION

The simple linear models showed that species richness significantly influenced the sedimentation underneath the vegetation, whereas total biomass explained sedimentation on the vegetation. Species richness, however, was no longer significant when species identity was included in the analyses. The presence of individual species explained total biomass and sedimentation on and underneath the vegetation, indicating that identity effects are of particular importance for sedimentation.

### 4.1 | Species richness

Our simple linear models indicated that species richness increased sedimentation underneath the vegetation significantly, as hypothesised in H1. However, this was only true when species identity effects were not considered. Species richness did not have any significant effect on sedimentation on the vegetation. The increase in sediment underneath the vegetation with increasing sown species richness could have two explanations. First, it could be explained by a selection effect because with increasing species richness, the

likelihood that a specific species is included also increases (Loreau, 1998). Second, it could be an artefact of the experimental design as patches with higher sown species richness had fewer seeds per species because the total sum of seeds was constant for all patches. If some species did not germinate, which was the case for five of our species, the occurring species had fewer individuals per species, which may open more space at the ground underneath the vegetation for sediment to settle. Further, a previous study showed that sedimentation underneath the vegetation increased with the vegetation's structural diversity (mixture of small and tall species; Kretz et al., 2021). This is probably caused by tall species reducing the flow velocity, whereas small species, especially small and hairy species, capture sediment. As correlations between species diversity and structural diversity have been found in observational studies (Proulx et al., 2014; Schuldt et al., 2019), species diversity likely increases sedimentation underneath the vegetation by increasing the structural diversity of the patches.

Sedimentation on the vegetation is explained by the total biomass but not by species richness. Even though there is evidence from grassland experimental studies that plant diversity often promotes productivity, measured as total biomass (Cardinale et al., 2007; Roscher & Schumacher, 2016), we did not find any significant link between species richness and sedimentation on the vegetation, neither directly nor indirectly via total biomass. One reason for this lack of a relationship could be that the community was only recently established. From grassland experiments, we know that the effects of diversity on productivity increase over longer periods (Tilman et al., 2014). Thus, in our case, the higher total biomass that led to increased sedimentation on the vegetation was not caused by species richness but rather by fast-growing individual species.

## 4.2 | Total biomass

As hypothesised (H3), we found statistical evidence for increasing sedimentation on vegetation with increasing total biomass in the basic model as well as when including species identities. This finding is in line with another experimental study (Kretz et al., 2021). Two reasons may explain this result. First, more total biomass is likely to provide a larger leaf surface, thus providing a larger area for sediment to settle. Second, a vegetation patch with more total biomass is likely to be taller and denser (Schulze et al., 2009). A taller and denser canopy more strongly reduces the flow velocity and, thus, increases sedimentation (Fathi-Maghadam & Kouwen, 1997).

## 4.3 | Species identities

Our results show that species identity significantly affects sedimentation on and underneath the vegetation, either directly or via the effect of individual species on total biomass (H2). This is highly relevant for sedimentation in natural floodplains as our patches were designed to depict natural meadow communities occurring along the

River Mulde. The identity effects of single species can be explained by the structural characteristics of individual species that are likely to influence sedimentation.

When *Bromus inermis* was present, total biomass was significantly higher, thus indirectly increasing sedimentation on the vegetation. This annual species builds dense sods and can dominate locally across patches. *Elymus repens* also increased the total biomass significantly when present, even though it had the lowest mean dry biomass in the experimental patches (Table 2). However, in floodplain meadows, it can be highly competitive and dominant (Beltman et al., 2007). Moreover, *E. repens* decreased sedimentation underneath the vegetation, which can be explained by its relatively unstable stature that we observed under wet conditions. *E. repens* frequently bent upon inundation and covered the ground, thus leaving the ground less open for sedimentation when present. In contrast to *E. repens*, the presence of *Urtica dioica* increased sedimentation underneath the vegetation. Though *U. dioica* was never dominant in our experiment (Table 2), we assume that the stable upright herb stature of *U. dioica* already acts like a canopy (crown-building-species; Paul et al., 2014). That is, *U. dioica* reduces the flow velocity and opens space below it, where sediment can settle. *U. dioica* is a common species, especially in anthropogenically influenced floodplains. However, it is not a preferred species from a conservation perspective due to its ability to build dominant stands (Taylor, 2009). Finally, the presence of *A. pratensis* significantly decreased sedimentation on the vegetation. The structure of the leaf surface likely explains this decrease. *A. pratensis* is classified as a water repellent species (Neinhuis & Barthlott, 1997). This water repellence can be caused by wax layers or ultrastructural roughness (Bhushan et al., 2009) so that the water never reaches the leaf surface to deposit sediment before it drips off the leaf.

## 4.4 | Floodplain management

We can derive several management strategies from our results that may increase the sediment retention capacity of floodplains. First, more biomass increases sedimentation. Management that promotes biomass during the flood season is, therefore, favourable. As our results indicate, this could be accomplished by promoting single, highly productive species. However, promoting single, dominant species would reduce species diversity in the floodplain and, consequently, most likely reduce other ecosystem functions and management goals. This is due to the well-established negative effect of biodiversity loss on many important ecosystem functions, such as productivity, stability or nutrient cycling (Cardinale et al., 2007; Ebeling et al., 2008; Roscher & Schumacher, 2016; Tilman et al., 2006). As an alternative management strategy, the promotion of species richness would increase biomass production (Cardinale et al., 2007; Roscher & Schumacher, 2016), which would likely increase sediment retention together with other ecosystem functions. Second, changing the mowing strategy (earlier last cut, less frequent or omitting sites in the lower floodplain with a higher likelihood to

get flooded) would also increase the standing biomass during the flood season and would additionally minimise the expansion of *A. pratensis*, which often occurs in hay meadows and decreases sedimentation on the vegetation. By omitting sites in the lower floodplain from mowing, local conditions can be considered, and differentiated management is possible. Third, the occurrence of herbs with canopy building statures, such as *Artemisia vulgaris*, *Lythrum salicaria*, and *Veronica maritima*, would resemble the function of *U. dioica* in our experiment. Thus, they are likely to increase the structural diversity of grass-dominated meadow stands and, thus, increase sediment retention (Kretz et al., 2021). In general, it is important to realise that sediment retention is one of many ecosystem functions floodplains provide, and every trade-off and interference needs to be weighted in the context of local conditions (flooding frequency, topography etc.) and management goals.

## 4.5 | Conclusion

We found that species richness increased sedimentation underneath the vegetation. However, identity effects had a stronger influence on sedimentation when included. For our experiment, 14 species were selected based on their abundance in the River Mulde floodplains. All of these species have the potential to dominate or be highly abundant in floodplain meadows. Their structural characteristics drive the overall sedimentation per patch in contrasting ways. For floodplain management that aims to improve sediment retention, we suggest (1) promoting species or species mixtures that increase biomass, (2) reducing mowing to increase the standing biomass, for example, by omitting low sites in the lower floodplain from mowing, and (3) promoting species with a canopy stature (crown-building-species), similar to *U. dioica*. In conclusion, floodplain vegetation can significantly improve sediment retention and thereby increase water purification. Though our study is a specific case study along an east-central German river, we think that our results are transferable to other rivers and regions, especially due to our mechanistic- and trait-based approach and because these key species are common in many European floodplain areas.

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## DATA AVAILABILITY STATEMENT

Data are deposited in the iData repository (<https://idata.idiv.de/>).

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