Design and evaluation of a multifunctional plate sediment trap suitable for subaqueous and floodplain environments

Reference:

Schoelynck Jonas, Oosterlee Lotte, Struyf Eric, Maris Tom, Meire Patrick, Temmerman Stijn.- Design and evaluation of a multifunctional plate sediment trap suitable for subaqueous and floodplain environments
Ecohydrology - ISSN 1936-0584 - 8:2(2015), p. 286-293
Full text (Publishers DOI): http://dx.doi.org/doi:10.1002/eco.1507
To cite this reference: http://hdl.handle.net/10067/1251780151162165141

Schoelynck[1], J., Oosterlee[1], L., De Groote[2], T., Maris[1], T., Struyf[1], E., Meire[1], P., Temmerman[1], S., 2015. Design and evaluation of a multifunctional plate sediment trap suitable for subaqueous and floodplain environments. Ecohydrology 8(2), 286-293.

[1]*University of Antwerp, Department of Biology, Ecosystem Management Research Group, Universiteitsplein 1C, B-2610 Wilrijk, Belgium.*

[2]*University of Antwerp, Department of Biology, Plant and Vegetation Ecology Research Group, Universiteitsplein 1C, B-2610 Wilrijk, Belgium.*

[3]*VITO, Unit Environmental Modelling, Boeretang 200, B-2400 Mol, Belgium.*

[*]**Corresponding author:**
Jonas Schoelynck
UA - Campus Drie Eiken
Ecosystem Management research group
Universiteitsplein 1
Building C, C1.20
B - 2610 Wilrijk, Belgium
jonas.schoelynck@ua.ac.be
Tel +32 3 265 22 52
Fax +32 3 265 22 71

Keywords: Biogeomorphology, lowland river, tidal flat, tidal marsh, macrophytes, plant-flow interaction, sediment

Abstract

In recent years it has become increasingly clear that two-way interactions between organisms and landscape-forming processes play a key role in the evolution of many aquatic ecosystems. To be able to compare sedimentation processes among different environments, a standardised method that is generally applicable is necessary. Current methods are usually designed for one environment only, or are unreliable in the presence of vegetation. This paper presents the functionality of a plate sediment trap with a lid in combination with a filter paper, which enables the measurement of sedimentation rates in both permanently subaqueous environments and periodically flooded wetlands. We first present the trap design and demonstrate its functionality. No significant differences were found between replicates, nor was there any indication of a trap size effect on the sedimentation rate. Secondly, we demonstrate its applicability in periodically flooded and permanently subaqueous environments, and in the presence or absence of vegetation. It is concluded that the use of a standardized method and equipment makes it possible to compare (bio)geomorphological changes in totally different environments.

Introduction

In recent years it has become increasingly clear that two-way interactions between organisms and landscape-forming processes, also called biogeomorphological feedbacks, play a key role in the evolution of many aquatic landscapes, such as floodplains and subaqueous environments ((Bouma *et al.*, 2013) and references therein). For example, (i) Larsen and Harvey (2010) explained the stability of different landscape patterns in the Everglades by coupling vegetation dynamics to both sediment transport and flow; (ii) a study by Temmerman et al. (2012) demonstrates that large-scale vegetation die-off on tidal floodplains does not only result in decreased platform sedimentation rates, but also in sediment infilling of the channels; and (iii) Schoelynck et al. (2012) showed that the patchy vegetation pattern of *Callitriche platycarpa* Kutz. in lowland rivers can be explained by scale-dependent feedbacks resulting patterns of sedimentation and erosion, which stimulates or restricts patch growth. The difficulty in studying the plant-flow-sediment interactions under natural conditions is compounded by the fact that plants often form patches together with non-colonised spaces or spaces colonised by different types of vegetation (Sukhodolov and Sukhodolova, 2010). This has led to insufficiently detailed data sets for rigorous examination of plant-flow interactions relevant for natural conditions (Sukhodolov and Sukhodolova, 2010). An important missing instrument in this context is a standardised method to measure and compare sedimentation processes among different environments and in different vegetation types (e.g. emergent vs. submerged). Most sediment traps are designed for one environment only, or are unreliable in the presence of vegetation (Banas and Masson, 2003).

Existing sediment traps

Sediment traps are relatively simple instruments which are commonly used for environmental monitoring of the quantity and quality of sediment depositions in permanently or periodically subaqueous environments. Sediment is collected over a limited period of time, measuring net sediment accumulation over short periods (order of hours to months) rather than long-term elevation change. A wide range of different designs of sediment traps have been used to quantify sedimentation rates or downward sediment fluxes (Thomas and Ridd, 2004). Plates or tiles are often applied in rivers (Gust and Kozerski, 2000; Kozerski, 2002), tidal wetlands (Keizer *et al.*, 1989; Pasternack and Brush, 1998; Temmerman *et al.*, 2003), riparian wetlands and floodplains (Steiger *et al.*, 2003). Differently shaped cylinders, funnels, or containers are often used to study settlement of sediment in a wide range of subaqueous environments (Bloesch and Burns, 1980). However, plate sediment traps are preferred over cylindrical traps in rivers and dynamic subaqueous environments in general (Kozerski and Leuschner, 1999).

Until the end of the 1970s, there was little consensus concerning the design requirements of this equipment and the validity of sediment trap data (Bloesch and Burns, 1980). Then, crucial laboratory and field investigations, primarily by Gardner (1980), later by Butman (1986) and critical reviews (among others (Bloesch and Burns, 1980)) significantly improved the understanding of sediment trap design and data collection. Cylindrical traps are known to perform well in still waters, but have a tendency to overestimate sedimentation rates in more hydrodynamic environments, because the reduction of turbulence and bottom shear stress within the traps causes higher rates of sedimentation (Gust *et al.*, 1996; Gust and Kozerski, 2000;

Kozerski, 1994). Shear stress in flowing waters is an important controlling factor on sedimentation, and should not be affected by the sediment trap design.

Flat devices have been used for sediment trapping in riparian or tidal wetlands (for an overview, see (Steiger *et al.*, 2003)). Examples include plain plywood boards (Braskerud, 2001; Mansikkaniemi, 1985) or plain hardboard (Gretener and Stromquist, 1987), quasi-flat fire clay roof tiles (Brunet *et al.*, 1994), roughened plastic (Kleiss, 1996) or ceramic tiles (Pasternack and Brush, 1998) anchored with a steel rod, sheets of plastic (Dezzeo *et al.*, 2000), petri dishes (Meeker, 1996), nylon carpet squares stitched to aluminium frames (Walker, 1995), or artificial turf (Jeffiries *et al.*, 2003) . Still, one of the major technical problems of plate sediment traps is the loss of material during retrieval (Gardner, 1980). In intertidal flats, marshes, or fluvial floodplains the traps can be removed after inundation, but in permanently subaqueous environments the trap should be covered with a lid before retrieval.

The first plate sediment trap described in literature that makes use of a lid is the bottom sediment trap of Hakanson (1976), used in deep lakes. The trap consists of a big roughened Plexiglas bottom plate with a raised edge of 0.05 m, and in the centre a brass tube, to which a lid is attached. The lid prevents material loss during the retrieval of the trap, yet also vertical settling of suspended sediment is restrained by the lid. The same problem was still present with Kozerski and Leuschner (1999), who proposed a plate sediment trap to determine sedimentation rates in flowing waters. In collecting position, the cover still forms a roof above the collecting area and vertically-settling particles are not collected. This may cause an underestimation of total sedimentation rates, and the trap can definitely not be used in lentic systems (Banas and Masson, 2003). A solution for lentic systems came from Banas & Masson (2003), who designed a plate sediment trap with a bag system. During sediment collecting configuration, the polyethylene bag is folded under the collecting area. The bag is unfolded during trap retrieval by pulling threads, preventing settled sediment to escape from the trap.

Filter paper method

Sediment deposition in floodplain environments is mostly measured by using the filter paper method of Reed (1989): sampling the deposited sediment on pre-weighed filter paper, which is secured to plastic discs and laid down on the marsh surface. After collection, the filter paper is dried and reweighed to determine the weight of the deposited sediment. This is a very accurate method, also in case of very slow sedimentation rates (Reed, 1989). Slight changes were introduced to this method: (i) the type of filter paper: glass fibre (Culberson *et al.*, 2004; Davidson-Arnott *et al.*, 2002; French *et al.*, 1995), ashless filter paper (French and Spencer, 1993); (ii) the disc itself: petri dish lid with slot (Davidson-Arnott *et al.*, 2002), petri dish varying from rim up- or downwards (Culberson *et al.*, 2004; French and Spencer, 1993; French *et al.*, 1995), aluminium plate (Temmerman *et al.*, 2005), plastic plate (Temmerman *et al.*, 2003), metal plate (Allen and Duffy, 1998); (iii) fixation of the trap to the soil: metal pins (French and Spencer, 1993; French *et al.*, 1995), steel claws (Temmerman *et al.*, 2003); and (iv) fixation of filter to the trap: plastic coated pins (Davidson-Arnott *et al.*, 2002), wire staples (Culberson *et al.*, 2004).

All traps described so far are either specifically designed for floodplain environments or tidal marshes (i.e. periodically subaqueous) or for permanent subaqueous environments. The first category often uses filter paper and the use of a lid is not necessary (because of the periodically dry periods). In the second category, the use of filter paper is not common, and the use of a lid is inevitable for retrieving the trap with the sediment. To be able to compare sedimentation processes among different environments, a standardised method that is applicable everywhere is necessary. Based on the proven and established features of previously described traps, we designed and tested a plate sediment trap with a lid in combination with the filter paper method. This method enables the measurement of sedimentation rates on vegetated and non-vegetated soils in both permanently subaqueous environments and periodically flooded wetlands. We first present the trap design and demonstrate its functionality by evaluating the reproducibility and the effect of different trap sizes. Secondly, we demonstrate its applicability in three different ecosystems: (i) two tidal flats, (ii) a tidal marsh, and (iii) a lowland river, all three characterised by different hydrodynamic conditions and diverse vegetation cover. Due to the use of a special lid system, no loss of material occurs during retrieval.

Materials and methods

Construction

The sediment trap (figure 1; movie 1) is a circular PVC plate of any size with a groove of 1-2 mm deep, which is carved at the edge of the bottom of the plate. A small hole (Ø = 5 mm) is drilled through the middle of the plate and three more screw thread holes are drilled on the outside. On the top of the trap, a circle is carved out leaving a rim of 1-2 mm high and 1-2 cm wide. The inside of the rim has a bevelled edge. In this inner circle, a cellulose filter is attached by pressing it between the plate and a PVC ring that fits the inner circle exactly. In this way water is prevented from flowing under the filter. The ring, which is a little bit larger in diameter (1 mm) than the inner circle, has a conversely bevelled edge and from this ring 1 cm is removed, making it incomplete so that its diameter can be slightly adjusted by the flexibility of the PVC. This construction allows the ring to slot into the rim of the trap. The cellulose filter has a pore size of 2.7 µm (supporting its strength when it is wet) and is circular, with a diameter equal to that of the inner circle of the trap. The filter is capable of withstanding wetting and drying without loss of weight (e.g.: Whatman 50 Cellulose Filters, hardened low ash, Whatman International Ltd., Maidstone, England). The circular part of the filter enclosed by the PVC ring is the actual area on which sedimentation will be measured. The lid is constructed from part of a PVC tube and a circular PVC plate, both of equal diameter to that of the trap itself. A small hole (Ø = 5 mm) is drilled into the centre of the lid. The upright edge is covered with a flexible rubber ribbon making the lid water- and airtight when attached to the trap. On the outside of the lid, three clamps are attached that can hook into the carved groove on the bottom of the trap.

Operation

Filters are pre-weighed in the lab after drying at 105 °C to constant mass. The filters are then pinched into the traps. The traps are fixed to the soil surface at a measuring site by screwing three metal pins into the screw thread holes underneath the trap and pushing them all the way into the sediment. On floodplains, this is best done during low water, when the wetlands are not flooded. When the water level rises, the sediment traps become flooded and the sediment particles can settle out of suspension. The filters with sediment are collected during subsequent low water, dried and weighed in the laboratory to determine the amount of sediment deposited during one inundation event. In subaqueous environments where the bottom can be reached by hand, the traps can easily be placed under water manually. In deeper parts the operator has to dive, which can be a limiting factor, yet not different from other devices applied in deep water ((Bloesch and Burns, 1980) and references therein). Sedimentation occurs immediately after installation and particles settle partially from bed transport as well as from suspension. The duration of time for which the traps collect sediments is used for calculating the sedimentation rate.

Trap retrieval is easy in periodically flooded environments as these sites are dry during periods of low water. Using the lid is not necessary, yet is recommended to prevent contamination or loss of material during transport. For retrieving the traps in subaqueous environments the traps are best approached from downstream, preventing extra sedimentation or erosion from the operators' movements. The hole in the lid needs to be covered with waterproof tape and the lid should be moved gently in the water towards the trap. Under the water the clamps are attached into the groove and the trap can be removed safely. The tape will prevent water leaking out of the trap by creating a vacuum under the lid. Once transported to the lab removing the tape allows the water to leak out slowly through the filter and through the hole at the bottom side of the trap. Once it stops leaking, the lid can be removed and the filter with the sediment becomes accessible.

Filters are removed by removing the PVC ring. Filter and sediment are dried together at a 105 °C until a constant mass is reached. Sedimentation rates are calculated with equation (1):

$$\frac{mass_{filter+\mathrm{sediment}} - mass_{filter}}{surface_{trap} * time} \qquad \left(in \ \frac{g}{m^2 s} \right) (1)$$

Afterwards, dry sandy sediment can easily be wiped from the filter using a small brush, yet fractions with a small grain size (clay) may stick to the filter pores. Note that if chemical analyses on the sediment are required, it may be necessary to dry it at different temperatures.

Evaluating the functionality of the trap

The functionality of the trap was tested for two parameters: reproducibility and trap size influence. This was done in three different ecosystems (figure 2): (i) two tidal flats with different tidal regimes (i.e. a non-vegetated periodically flooded environment), (ii) a tidal marsh adjacent to one of the studied flats (with vegetation), and (iii) a lowland river (i.e. permanently subaqueous environment) dominated by patchy submerged vegetation, interspersed with non-vegetated zones.

The first tidal flat-tidal marsh system is part of an experimental area ("Lippenbroek"; 8.2 ha) in the freshwater zone of the Scheldt estuary, Belgium. In this area a controlled reduced tide system (CRT) was created (Beauchard *et al.*, 2011; Maris *et al.*, 2007; Vandenbruwaene *et al.*, 2011). Managed realignment would have resulted in complete flooding due to the initially low elevation of the area; an adapted sluice system now regulates the tide in a way that the area is exposed to almost natural tidal flooding, including the spring-neap cycle of approximately 3 m, which allows the development a range of estuarine habitats from mudflat to tidal marsh. The major difference compared to a natural system is a prolonged flooding duration of app. three hours. Vegetation consists of pioneer freshwater marsh species, such as water pepper (*Persicaria hydropiper*), purple loosestrife (*Lythrum salicaria*), several helophytes, such as common reed (*Phragmites australis*), common bulrush (*Typha latifolia*), saltmarsh bulrush (*Bolboschoenus maritimus*) and willow forest (Salix sp.). Vegetation cover differs with season and elevation between 0 and 100%. In highly productive areas, reed densities differ between 1500 – 3000 g m^{-2}, reed canary grass (*Phalaris arundinacea*) between 100 – 1000 g m^{-2}. The second tidal flat is part of another nature restoration area for intertidal habitats ("Burchtse Weel"; 14.4 ha) located in the brackish water zone of the Scheldt estuary. This area is exposed to the complete estuarine tidal cycle of app. 5 m and has currently no vegetation cover. Sediments in both tidal areas are silty (D50 = 14 µm) and current velocities at both sites are typically not more than a few cm s^{-1} (e.g. (Temmerman *et al.*, 2012)). The Zwarte Nete is a typical lowland river in the NE of Belgium dominated by submerged patchy vegetation (40% coverage and biomass may reach 0.5 kg DM m^{-2}) . The river has an average width of 4.5 m (max. 6.2 m). The river bed consists of sandy sediments (D50 = 167 µm) and water flows with an average stream velocity around 0.1 m s^{-1} and an average discharge of 0.2 m^3 s^{-1} in summer. Water depth rarely exceeds 1 m and water surface slope is on average 0.0012 m m^{-1} (for more details on the study area see e.g. Schoelynck et al. 2012).

In the first test for reproducibility, twelve pairs of identical sediment traps were positioned in the Zwarte Nete river (six pairs in non-vegetated zones and six pairs in patches of different submerged and emergent species) and in Lippenbroek (six pairs on the tidal flat (bare sediment), and six pairs in the vegetation of different emergent species). Each member of a pair was treated as a replicate, and a few meters distance was kept between each pair to minimise possible interference. Diameters of the traps were 0.10 m in the river and 0.20 m on the tidal flats/marsh. The bathymetry of the Zwarte Nete was more variable than those of the tidal flats/marsh. We therefore used smaller trap sizes in the river so that each pair of traps could be placed horizontally next to each other. Secondly, to test possible trap size effects, five pairs of a large (Ø = 0.20 m) and a small (Ø = 0.10 m) sediment trap were placed two-by-two randomly on non-vegetated soil in each of the three test sites (only four pairs in Lippenbroek). This test was repeated on vegetated soils with six pairs in the river and six pairs in Lippenbroek. All experiments lasted for five days (Zwarte Nete) or for app. twelve hours (one tidal cycle). After retrieval the samples were dried for 48 h at 105 °C. Statistical analyses were performed with SAS 9.2 (SAS Institute inc., Cary, USA). We used a paired t-test to compare results from identical traps in each pair and a Pearson correlation test to test the relationship between results obtained by traps of different sizes.

Results

No significant difference in reproducibility between traps of the same pair in both habitats was found (paired t-test, $p=0.65$ for non-vegetated soil, $p=0.35$ for vegetated soil; table 1). To evaluate the effect of trap size, sedimentation rates measured on the small traps were plotted against the sedimentation rates measured in the large traps (in g m^{-2} day^{-1}, figures 3a,b). We found that sedimentation rates on non-vegetated soils are one order of magnitude higher than those inside vegetation. The results obtained for non-vegetated soil with a large trap and with a small trap are significantly correlated (Pearson correlation test, $p<0.0001$, $R^2=0.94$). The slope of the regression line (0.97) is close to 1, and the intercept is 0. The results obtained on a vegetated soil with a large trap and with a small trap are also significantly correlated (Pearson correlation test, $p<0.0001$, $R^2=0.93$). Similarly, the slope of the regression line (1.05) is close to 1, and the intercept 0. There are no significant differences between sedimentation rates measured in the small and large traps of the same pair in all three study areas (paired t-test, $p=0.94$ for non-vegetated soil, $p=0.80$ for vegetated soil).

Discussion

Classic plate sediment traps are known to accurately measure sedimentation in dynamic systems, because they limit the reduction of turbulence and bottom shear stress in comparison to cylindrical traps with a high rim (Gust and Kozerski, 2000; Kozerski, 2002). However in most studies the design of the trap was (slightly) different to suit the variety of environments the trap was deployed in. This made it difficult to compare results from different ecosystems. This paper showed that the same plate sediment traps in combination with filter paper and a lid can be used in various ecosystems. It renders robust reproducible estimations of sedimentation rates that can be compared among the different aquatic habitats. The design of the trap has many advantages: (i) it is robust and can therefore withstand repeated flooding and laboratory processing; (ii) it can be securely attached to the soil surface with metal pins thereby resisting relatively high stream velocities and associated shear stresses (tested up to 0.4 m s^{-1}, personal experience); (iii) it is light and easily manipulated in the field; (iv) a lid can be placed on the trap before retrieval, avoiding the loss of material during or after retrieval; and (v) the use of the filter paper allows for full recovery of all deposited sediment, which is especially important for measuring small amounts of sediment and it allows sampling of the trapped material for chemical or physical analyses. Trap construction is relatively easy and inexpensive. The average time for our university technicians to construct one trap is about 30 minutes. The material cost per trap is app. 50 Euros, although actual costs will vary per country. Only commercially available materials and techniques were used.

The trap was shown to work effectively in lowland rivers, as an example of a permanently subaqueous environment, as well as on tidal flats and tidal marshes, as an example of periodically flooded environments. Moreover these traps have been successfully used in different vegetation types: submerged, emergent, and shrubs and trees (Figure 4). The application in different habitats and environments gives an unmistakable advantage. Geomorphological changes can now be compared between different ecosystems in a reliable way. In fact, in periodically flooded environments the use of cylindrical traps with a rim is not possible: traps must be able to drain during low water while retaining sediment deposited on them. Our experiments showed that there is no influence of trap size, indicating minimal 'edge' effects. This is in accordance with French and Spencer (1993), who performed experiments with 3 different trap diameters (Ø = 0.05, 0.09 and 0.11 m), revealing no significant variation in sedimentation per trap. Small traps may be used when areas have irregular surfaces. Microtopography of the surface may influence sedimentation, and this effect is absent on flat filter paper. Nevertheless, the small trap size allows it to be placed on horizontal parts of the surface where such influences are negligible. Small traps are also better to use in vegetation stands (in permanently subaqueous environments, as well as periodically flooded areas). They fit better in between individual stems whereas larger traps may crush and cover part of the vegetation which can influence sedimentation. The fact that the same small plate traps can now be used in vegetation of different environments makes it possible to measure the effect of vegetation on geomorphological processes, or to compare the effects of vegetation on geomorphology in different ecosystems, or of plants with different traits and growth forms. Trap size can be adjusted to field characteristics: e.g.: larger traps may be more suitable in non-vegetated, flat areas with very few transported particles.

Practical tips and shortcomings

The robustness and easy handling of the trap makes it suitable in many situations, as was discussed previously. However based on our personal experience, there are circumstances under which special attention is needed. In tidal habitats the investigated period of time may comprise several tides and the weather during low tides may influence the result. On sunny days, sediment can dry out on the filter paper more than on the flat/marsh itself. Obtained sedimentation rates are always net results of sedimentation and resuspension, but it is likely that dried sediment will adhere to the paper surface (Reed, 1989) and may not resuspend during the next flooding. This may result in an overestimation for tidal flats, although resuspension of deposited sediments on marshes is very rare because of the typically low flow velocities and bed shear stress values within marsh vegetation (Christiansen *et al.*, 2000). Rain events during low tide or before collection may cause sediment erosion which can result in an underestimation. This can be prevented with a floatable cover to protect the deposited sediment from splashing by raindrops during low tides (Temmerman *et al.*, 2003), but this is technically more challenging. In subaqueous environments too much aquatic vegetation can make it complicated to find traps. Attaching small floaters with nylon wire to the iron rods of the trap can help without influencing the current and the resulting sedimentation. It is also important to acknowledge the potential additive effect of suspended material caught underneath the lid when moving it towards the trap in subaqueous environments. This effect could cause an overestimation when the actual sedimentation is very small. It can be corrected by subtracting this amount (i.e. suspended solids concentration of the environment (g per volume) times the volume of the lid) from the total amount on the filter. Finally in general, the use of sticks close to the trap as a marker is not recommended in any situation as it may influence the result, traps cannot be used on slopes and their use is seriously restricted in deep or fast flowing water.

In conclusion, we presented an integrated version of a classical plate sediment trap in combination with a lid and a filter paper. Several tests showed that the trap gives good reproducible estimations of sedimentation rates in various ecosystems. There is no size effect of the trap which makes it possible to fit any desired space or location, vegetated or not. The use of a standardized method and equipment makes a comparison of (bio)geomorphological changes in different environments and in various vegetation types possible.

Acknowledgements

The authors like to thank the technical staff of the Antwerp University for building the traps. We also thank Waterways and Sea Canal (W&Z) for financing the monitoring projects along the Scheldt and BELSPO for funding project SOGLO. T.D.G. is a Ph.D. fellow of the Research Foundation – Flanders (FWO) and the Flemish Institute for Technological Research (VITO). The authors acknowledge Amon Kimeli for the mangroves picture, Johnny Teuchies for the tidal marsh picture, Jens Verschaeren for help in the field, Kurt Kerkhofs for editing the movie and Alanna Rebelo for proofreading this manuscript and being the narrator of the movie. The authors have no conflict of interest to declare.

References

Allen, J.R.L., Duffy, M.J., 1998. Temporal and spatial depositional patterns in the Severn Estuary, southwestern Britain: intertidal studies at spring-reap and seasonal scales, 1991-1993. *Marine Geology* **146**, 147-171.

Banas, D., Masson, G., 2003. New plate sediment traps for lentic systems. *Archiv Fur Hydrobiologie* **158**, 283-288.

Beauchard, O., Jacobs, S., Cox, T.J.S., Maris, T., Vrebos, D., Van Braeckel, A., Meire, P., 2011. A new technique for tidal habitat restoration: Evaluation of its hydrological potentials. *Ecological Engineering* **37**, 1849-1858.

Bloesch, J., Burns, N.M., 1980. A Critical-Review of Sedimentation Trap Technique. *Schweizerische Zeitschrift Fur Hydrologie-Swiss Journal of Hydrology* **42**, 15-55.

Bouma, T.J., Temmerman, S., van Duren, L.A., Martini, E., Vandenbruwaene, W., Callaghan, D.P., Balke, T., Bierman, G., Klaassen, P.C., van Steeg, P., Dekker, F., van de Koppel, J., de Vries, M.B., Herman, P.M.J., 2013. Organism traits determine the strength of scale-dependent bio-geomorphic feedbacks: A flume study on three intertidal plant species. *Geomorphology* **180-181**, 57-65.

Braskerud, B.C., 2001. The influence of vegetation on sedimentation and resuspension of soil particles in small constructed wetlands. *Journal of Environmental Quality* **30**, 1447-1457.

Brunet, R.C., Pinay, G., Gazelle, F., Roques, L., 1994. Role of the floodplain and riparian zon ein suspended matter and nutrogen-retention in the Adour river, south-west France. *Regulated Rivers-Research & Management* **9**, 55-63.

Butman, C.A., 1986. Sediment Trap Biases in Turbulent Flows - Results from a Laboratory Flume Study. *Journal of Marine Research* **44**, 645-693.

Christiansen, T., Wiberg, P.L., Milligan, T.G., 2000. Flow and sediment transport on a tidal salt marsh surface. *Estuarine Coastal and Shelf Science* **50**, 315-331.

Culberson, S.D., Foin, T.C., Collins, J.N., 2004. The role of sedimentation in estuarine marsh development within the San Francisco Estuary, California, USA. *Journal of Coastal Research* **20**, 970-979.

Davidson-Arnott, R.G.D., van Proosdij, D., Ollerhead, J., Schostak, L., 2002. Hydrodynamics and sedimentation in salt marshes: examples from a macrotidal marsh, Bay of Fundy. *Geomorphology* **48**, 209-231.

Dezzeo, N., Herrera, R., Escalante, G., Chacon, N., 2000. Deposition of sediments during a flood event on seasonally flooded forests of the lower Orinoco River and two of its black-water tributaries, Venezuela. *Biogeochemistry* **49**, 241-257.

French, J.R., Spencer, T., 1993. Dynamics of Sedimentation in a Tide-Dominated Backbarrier Salt-Marsh, Norfolk, Uk. *Marine Geology* **110**, 315-331.

French, J.R., Spencer, T., Murray, A.L., Arnold, N.S., 1995. Geostatistical Analysis of Sediment Deposition in 2 Small Tidal Wetlands, Norfolk, Uk. *Journal of Coastal Research* **11**, 308-321.

Gardner, W.D., 1980. Sediment trap dynamics and calibration - a laboratory evaluation. *Journal of Marine Research* **38**, 17-39.

Gretener, B., Stromquist, L., 1987. Overbank sedimentation-rates of fine-grained sediments - a study of the recent deposition in the lower river Fyrisan. *Geografiska Annaler Series a-Physical Geography* **69**, 139-146.

Gust, G., Bowles, W., Giordano, S., Huttel, M., 1996. Particle accumulation in a cylindrical sediment trap under laminar and turbulent steady flow: An experimental approach. *Aquatic Sciences* **58**, 297-326.

Gust, G., Kozerski, H.P., 2000. In situ sinking-particle flux from collection rates of cylindrical traps. *Marine Ecology-Progress Series* **208**, 93-106.

Hakanson, L., 1976. Bottom sediment trap for recent sedimentary deposits. *Limnology and Oceanography* **21**, 170-174.

Jeffiries, R., Darby, S.E., Sear, D.A., 2003. The influence of vegetation and organic debris on flood-plain sediment dynamics: case study of a low-order stream in the New Forest, England. *Geomorphology* **51**, 61-80.

Keizer, P.D., Hargrave, B.T., Gordon, D.C., 1989. Sediment-Water Exchange of Dissolved Nutrients at an Intertidal Site in the Upper Reaches of the Bay of Fundy. *Estuaries* **12**, 1-12.

Kimeli, A.K., 2013. Sedimentation in response to sea level rise in the mangroves of Mwache Creek, Mombasa-Kenya: a field and modeling study. Interuniversity master thesis in Marine and Lacustrine Science and Management, Antwerp.

Kleiss, B.A., 1996. Sediment retention in a bottomland hardwood wetland in Eastern Arkansas. *Wetlands* **16**, 321-333.

Kozerski, H.P., 1994. Possibilities and limitations of sediment traps to measure sedimentation and resuspension. *Hydrobiologia* **284**, 93-100.

Kozerski, H.P., 2002. Determination of areal sedimentation rates in rivers by using plate sediment trap measurements and flow velocity - settling flux relationship. *Water Research* **36**, 2983-2990.

Kozerski, H.P., Leuschner, K., 1999. Plate sediment traps for slowly moving waters. *Water Research* **33**, 2913-2922.

Larsen, L.G., Harvey, J.W., 2010. How Vegetation and Sediment Transport Feedbacks Drive Landscape Change in the Everglades and Wetlands Worldwide. *American Naturalist* **176**, E66-E79.

Mansikkaniemi, H., 1985. Sedimentation and water quality in the flood basin of the river Kyrönjoki in Finland. *Fennia* **163**, 155-194.

Maris, T., Cox, T., Temmerman, S., De Vleeschauwer, P., Van Damme, S., De Mulder, T., Van den Bergh, E., Meire, P., 2007. Tuning the tide: creating ecological conditions for tidal marsh development in a flood control area. *Hydrobiologia* **588**, 31-34.

Meeker, J.E., 1996. Wild-rice and sedimentation processes in a Lake Superior coastal wetland. *Wetlands* **16**, 219-231.

Pasternack, G.B., Brush, G.S., 1998. Sedimentation cycles in a river-mouth tidal freshwater marsh. *Estuaries* **21**, 407-415.

Reed, D.J., 1989. Patterns of sediment deposition in subsiding coastal salt marshes, Terrebonne Bay, Louisiana - The role of winter storms. *Estuaries* **12**, 222-227.

Schoelynck, J., De Groote, T., Bal, K., Vandenbruwaene, W., Meire, P., Temmerman, S., 2012. Self-organised patchiness and scale-dependent bio-geomorphic feedbacks in aquatic river vegetation. *Ecography* **35**, 760-768.

Steiger, J., Gurnell, A.M., Goodson, J.M., 2003. Quantifying and characterizing contemporary riparian sedimentation. *River Research and Applications* **19**, 335-352.

Sukhodolov, A.N., Sukhodolova, T.A., 2010. Case Study: Effect of Submerged Aquatic Plants on Turbulence Structure in a Lowland River. *Journal of Hydraulic Engineering-Asce* **136**, 434-446.

Temmerman, S., Bouma, T.J., Govers, G., Wang, Z.B., De Vries, M.B., Herman, P.M.J., 2005. Impact of vegetation on flow routing and sedimentation patterns: Three-dimensional modeling for a tidal marsh. *Journal of Geophysical Research-Earth Surface* **110**, 18.

Temmerman, S., Govers, G., Wartel, S., Meire, P., 2003. Spatial and temporal factors controlling short-term sedimentation in a salt and freshwater tidal marsh, Scheldt estuary, Belgium, SW Netherlands. *Earth Surface Processes and Landforms* **28**, 739-755.

Temmerman, S., Moonen, P., Schoelynck, J., Govers, G., Bouma, T.J., 2012. Impact of vegetation die-off on spatial flow patterns over a tidal marsh. *Geophysical Research Letters* **39**.

Thomas, S., Ridd, P.V., 2004. Review of methods to measure short time scale sediment accumulation. *Marine Geology* **207**, 95-114.

Vandenbruwaene, W., Maris, T., Cox, T.J.S., Cahoon, D.R., Meire, P., Temmerman, S., 2011. Sedimentation and response to sea-level rise of a restored marsh with reduced tidal exchange: Comparison with a natural tidal marsh. *Geomorphology* **130**, 115-126.

Walker, I., 1995. Sedimentation in the inundation forest flanking the Central Amazonian blackwater stream Rio Taruma Mirim (Manaus, Amazonas State). *Amazoniana-Limnologia Et Oecologia Regionalis Systemae Fluminis Amazonas* **13**, 237-243.

Table 1 Sedimentation rates of 12 pairs of replicate traps in two different environments: a lowland river (Zwarte Nete) and a tidal flat/marsh (Lippenbroek). Both sites have non-vegetated locations, as well as locations with various vegetation types: (e) = emergent, (s) = submerged, (t) = tree/shrub.

	Zwarte Nete ($g\ m^{-2}\ day^{-1}$)			**Lippenbroek ($g\ m^{-2}\ day^{-1}$)**		
Non vegetated soil	*Plate 1*	*Plate 2*		*Plate 1*	*Plate 2*	
	606	531		244	317	
	256	155		246	154	
	420	640		147	114	
	480	527		323	302	
	376	222		279	257	
	143	127		90	119	
Vegetated soil	102	79	*Sparganium emersum* (s)	15	40	*Phalaris arundinaceae* (e)
	178	138	*Ranunculus fluitans* (s)	25	30	*Salix sp.* (t)
	87	222	*Typha latifolia* (e)	20	18	*Phragmites australis* (e)
	13	25	*Potamogeton natans* (s)	9	6	*Phragmites australis* (e)
	25	74	*Potamogeton natans*	8	6	*Phragmites australis* (e)
	69	59	*Potamogeton natans* (s)	31	35	*Phragmites australis* (e)

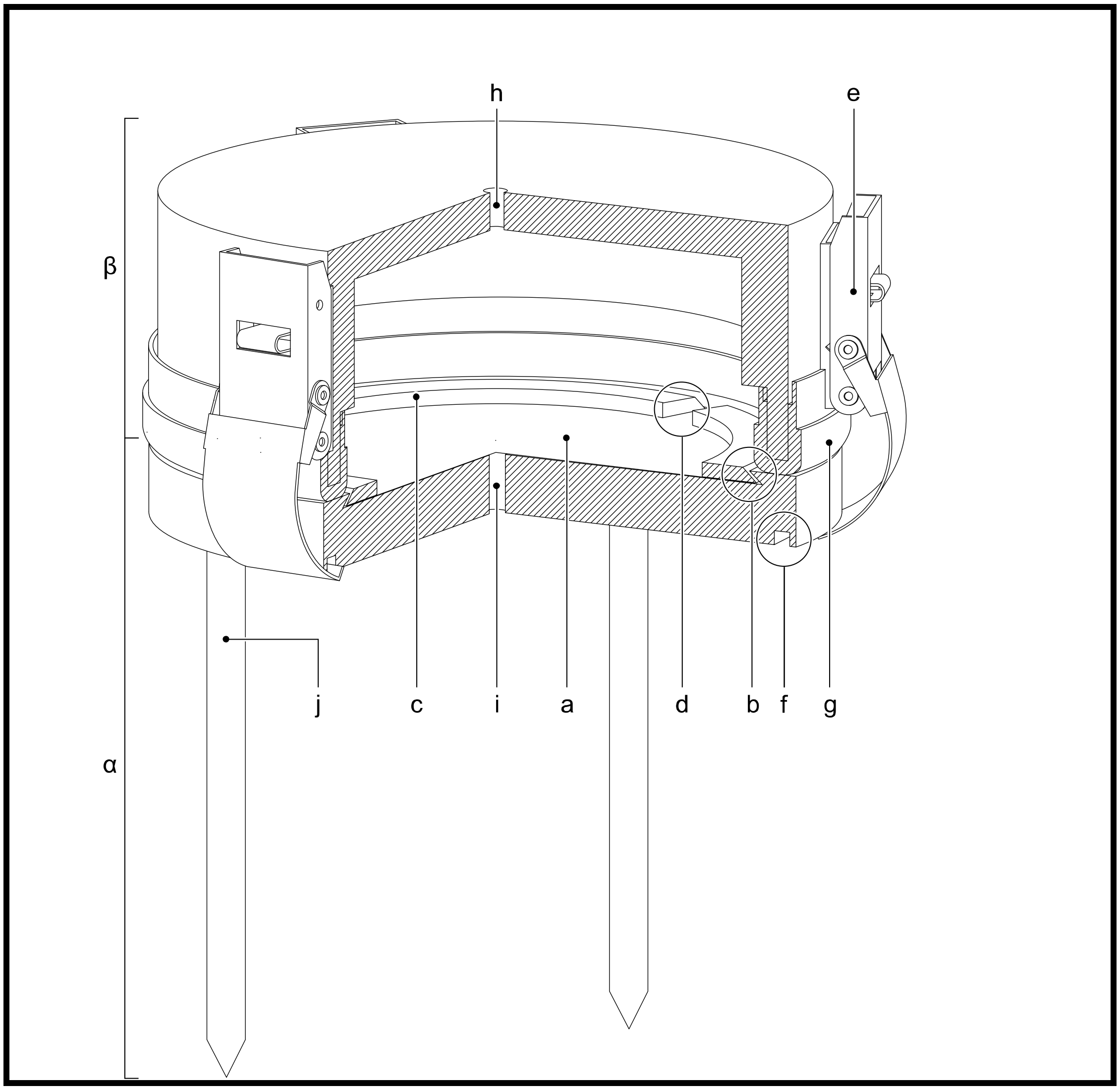

Figure 1

Schematic design of the plate sediment trap (α) and lid (β) with the cellulose filter (a), carried by the base plate of the trap and locked into place (b) by a PVC ring (c) with a small interruption (d). The clamps (e) of the lid fit into the groove in the bottom of the trap (f), securing the lid to the sediment trap. A flexible rubber ribbon on the rim of the lid (g) controls the pressure (vacuum) inside the trap when the small hole in the lid (h) is covered with tape. The water inside the trap is empties through a second small hole in the trap (i). The sediment trap is anchored onto the soil surface with three metal pins (j).

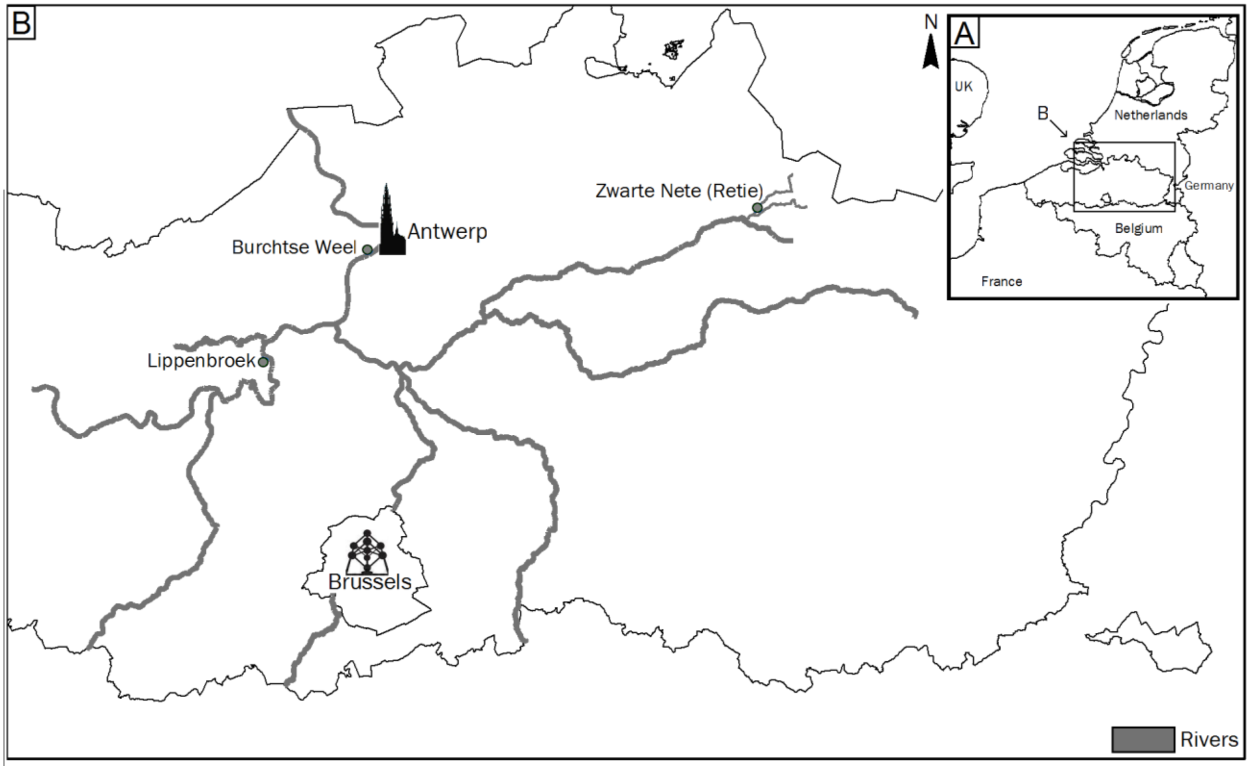

Figure 2

Map of the Northern part of Belgium with its main rivers draining towards the Belgian part of the Scheldt estuary. Sample station Lippenbroek is a tidal flat/marsh system, station Burchtse Weel is a tidal flat, and station Zwarte Nete is a lowland river.

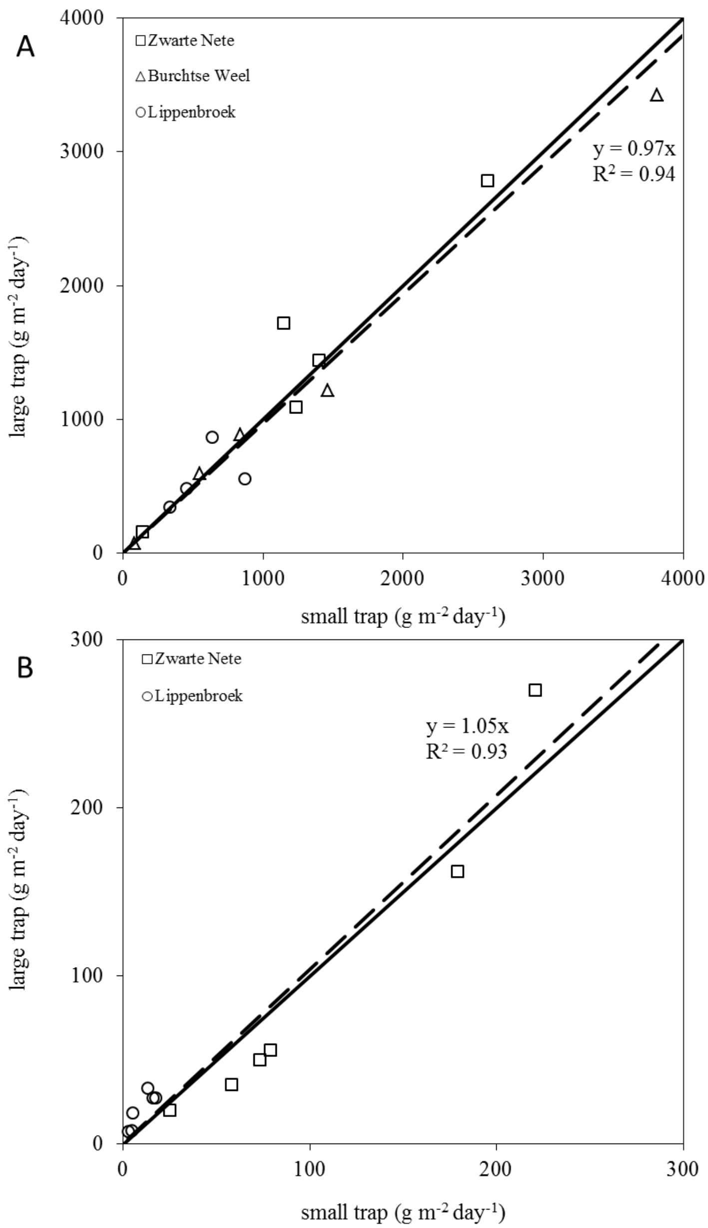

Figure 3

Linear relations between sedimentation rates derived from small trap data and large trap data over three different ecosystems with bare soil (A), and over two different ecosystems with vegetation (B). Data are significantly correlated (Pearson correlation test, $p<0.0001$ in both panels) and the linear regressions are represented by a dashed line. A 1:1 relation is represented by a solid line.

Figure 4

These sediment traps may be used in many aquatic ecosystems: (A) in a river with submerged macrophytesas well as in adjacent non-vegetated areas (Zwarte Nete, Belgium); (B) in emergent vegetation on tidal marshes (Lippenbroek polder, Belgium); (C) on non-vegetated mudflats (Lippenbroek polder, Belgium), and (D) between the roots of mangrove trees (Mwache Creek, Kenya). The examples in pictures A to C are taken from the previous described field sites. Picture D is an example from a study on sedimentation in response to sea level rise in mangroves (Kimeli, 2013). The position of the traps is indicated with white arrows.