Landscape features

Impact: Nutrient leaching and run-off

Reference 6

Carstensen, MV; Hashemi, F; Hoffmann, CC; Zak, D; Audet, J; Kronvang, B 2020 Efficiency of mitigation measures targeting nutrient losses from agricultural drainage systems: A review AMBIO, 49, 1820-1837. 10.1007/s13280-020-01345-5

Background and objective

Wet landscapes have been systematically drained to enable anthropogenic activities such as food production. However, in addition to water, drainage systems also transport nutrients rapidly to surface waters. Diffusive losses of nitrogen and phosphorus from agricultural areas have detrimental effects on freshwater and marine ecosystems. Mitigation measures treating drainage water before it enters streams hold a high potential for reducing nitrogen and phosphorus losses from agricultural areas. To review the nitrate and total phosphorus removal efficiency of 1) free water surface constructed wetlands, 2) denitrifying bioreactors, 3) controlled drainage, 4) saturated buffer zones and 5) integrated buffer zones. Here, the results for nitrogen and phosforous removal are reported for objectives 1 and 2.

Search strategy and selection criteria

A search of published studies was conducted via ISI Web of Science for 1900–2019 employing different search strings. 1) For free water surface constructed wetland and subsurface flow constructed wetland (FWS+SFF): ((bed OR bio*reactor OR bio*filter OR layer OR wetland) AND (nitrogen OR phosph* OR TP OR TN OR nitrate OR NO3* OR PO4* OR TKN OR sediment*) AND (retention OR trap* OR reduc* OR denitrification OR uptake OR sedimentation OR remov* OR settling OR accretion OR precipitat* OR *sorption OR loss OR performance*) AND (agricultur* OR drain*)). 2) For controlled drainage (CD): ("controlled drain*" OR "controlled tile drain*" OR "groundwater management" OR "drain* water management") AND (nitrogen OR phosph* OR TP OR TN OR nitrate OR NO3* OR PO4* OR TKN) AND (remov* OR retention OR loss OR reduc* OR denitrification OR performance*) AND (agricultur* OR drain*). 1) The inlet water had to originate from drainage systems transporting water from agricultural fields, and must not be mixed with water from other sources such as streams; 2) based on the Köppen-Geiger climate classification system, the sites had to be located in oceanic (Cfb, Cfc) or continental (Dfa, Dfb, Dfc, Dfd, Dsc) climates, where the conditions for denitrification are often suboptimal. Thus, climate zones with dry winters were excluded; 3) the study had to be a field study with sites exposed to ambient temperature and with a surface area larger than 10 m2; 4) the study had to include a mass balance for either nitrate—N, total phosphorus (TP) or total suspended solids (TSS) for at least one drainage season, whose length depended on the climate region.

Data and analysis

Prior to the analysis, the assumption of normality was tested visually (Q–Q plot, histogram) and by the Shapiro–Wilk test. Meta-analysis was only conducted for a mitigation measure if sufficient data were available, i.e. data from more than two sites originating from different studies. The meta-analysis was performed in R software 3.6.1 using the R package ‘meta’. Each effect size was weighted. The summary effect was calculated based on the effect sizes and their weight, using a random effect model which allow the true mean to vary between studies. To account for this variability, the DerSimonian and Laird method was applied to estimate the between-study variance, and the Hartung-Knapp method was used to adjust the 95% confidence intervals (CI). The consistency of the effect sizes was assessed using forest plot, funnel plot and multiple statistical measures. The observed variation (Q) was tested to investigate if the true effect varied between studies and if application of the random effect model was appropriate.

Number of papers	Population	Intervention	Comparator	Outcome	Quality score
42	Pilot and full-scale field studies on drainage mitigation measures in croplands	Outflow from 1) Free water surface constructed wetlands; 2) denitrifying bioreactors	Inflow from 1) Free water surface constructed wetlands; 2) denitrifying bioreactors	Metric: 1) Nitrogen removal efficiency; 2) Total phosforous removal efficiency; Effect size: Percentage of the considered metrics in the intervention that represents the difference of the considered metrics between intervention and control	94%

Results

- The weighted average obtained by meta-analysis showed that free water surface constructed wetlands (FWS) significantly reduced nitrate loading by 41% within a range from - 8 to 63%. The CI varied from 29 to 51%.
- The weighted average calculated by meta-analysis showed a significant reduction of the annual nitrate loading by denitrifying bioreactors (DBR) of 40% within a range from 6 to 79% (CI: 24 to 55%).
- The meta-analysis showed that controlled drainage (CD) significantly reduced the annual nitrate loading by, on average, 50% within a range from 19 to 82% (CI: 41 to 59%).
- According to the meta-analysis, the average total phosforous (TP) removal efficiency of free water surface constructed wetlands (FWS) was 33%, ranging from - 103 to 68% (CI: 19 to 47%).
- The average loss of TP via drainage water was reduced by 34% (CI: 10 to 58%).

Factors influencing effect sizes

- NA : NA
- NA : NA
- NA : NA

Conclusion

Data analysis showed that the load of nitrate was substantially reduced by drainage mitigation measures. As well, mitigation measures mainly acted as sinks of total phosphorus, but occasionally, also as sources.