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Potential denitrification and N2O efflux from riparian soils during short-time flooding

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Denitrification can contribute significantly to the filter function of soils because it leads to permanent removal of nitrate. Denitrification has been intensively studied in wetlands characterized by seasonal wet-dry cycles and in riparian buffer zones between agricultural land and rivers. Less attention has been paid to the effects of overbank flooding in river floodplains, in particular to short terms effect of flood pulses. We monitored denitrification potential, N2O efflux and related parameters in soils of a restored reach of the Alpine river Thur in northeastern Switzerland during and after flashy flood events. The study was part of the interdisciplinary project cluster RECORD, which was initiated to advance the mechanistic understanding of coupled hydrological and ecological processes in river corridors.

The studied river reach comprised the following three functional processing zones (FPZ) representing a lateral successional gradient with decreasing hydrological connectivity (i.e. decreasing flooding frequency and duration). (i) The grass zone developed naturally on a gravel bar after restoration of the channelized river section (mainly colonized by canary reed grass Phalaris arundinacae). The soil is composed of up to 80 cm thick fresh sediments trapped and stabilized by the grass roots. (ii) The bush zone is composed of young willow trees (Salix viminalis) planted during restoration to stabilize older overbank deposits. (iii) The mixed forest is a mature riparian hardwood forest developed on older overbank sediments with ash and maple as dominant trees.

The study period was between April and October 2009 including two flood events in June and July. The first flood inundated the grass zone and lower part of the willow bush while the second bigger flood swept through all the FPZs. Topsoil samples were taken from four spatial replicates in each FPZ mostly biweekly and with higher frequency following the floods. Potential denitrification was measured as denitrifier enzyme activity (DEA) and substrate limitation was assessed by the same assay but without addition of glucose and nitrate.

Over the entire observation period, soil moisture was the main controlling factor of DEA in all FPZ (correlation between DEA and gravimetric water content with R = 0.74, 0.61 and 0.47 for grass zone, willow bush and mixed forest, respectively, at $p<0.01$). Considering extractable nitrate and the results from the denitrification assay without nitrate and glucose we conclude that there was some substrate limitation but it was not severe. During the flooding events, DEA responded instantaneously to the changes in soil moisture. Particularly strong denitrification “pulses” were observed 1 to 2 days after peak floods in the grass zone, while the scale of change decreased with distance from the river. A severe substrate limitation in the grass zone was indicated 5 days after the peak of the second flood. N2O emissions did not correlate with DEA. High N2O emissions were measured in the grass zone during the entire period of relatively high soil moisture encompassing the two floods with maximum values shortly after water level fell below the overbank sediment. Smaller N2O emissions during complete or partial saturation of the sediments indicated a smaller proportion of denitrification related N2O vs. N2. In addition, a comparison with the composition of soil solution collected in-situ (in particular nitrate and DOC) will be presented for additional insight into controls and limitations of denitrification.