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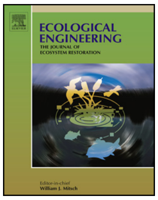

How to stop nitrogen leaking from a Cross compliant buffer strip?

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ABSTRACT

A lowland stream was subject to an ecological restoration with the creation of a 11 m wide buffer strip reconnected to the river channel. Monitoring results revealed the efficiency of this buffer system in removing nitrogen. This site was compared with other buffer strips designed according to the technical specifications of Italian Standard 5.2 in Italy (M.D. 27417, December 22, 2011). While some of the systems resulted very effective in inorganic nitrogen removal, reaching values of 62 and 75%, two of the monitored sites resulted completely ineffective even if realized according to the required technical specifications. Our results indicate that this was due to a lack of hydraulic connectivity with C_{org}-rich active soil layers in contact with the rhizosphere. A comparison of the main factors limiting nitrogen retention is proposed, highlighting the key role played by hydrology and in particular by groundwater depth and soil carbon availability. One of the most common objections to the prescriptions of Cross-compliance standard 5.2, concerning the excessive narrowness of buffer strips (5 m), did not seem to be particularly relevant. Starting from the comparison of monitoring results obtained at different experimental sites, this contribution provides practical indications about the correct planning and management of buffer strips for nitrogen retention.

1. Introduction

During the last 40 years, riparian buffer strips have been the subject of research worldwide in order to better understand processes involved in nitrogen retention (Gilliam et al., 1974; Lowrance et al., 1984; Haycock and Pinay, 1993; Mander et al., 2005; Stutter et al., 2012). Different conclusions were reached relative to key parameters such as buffer strip width (Borin and Bigon, 2002; Hickey and Doran 2004,b; Gumiero et al., 2011a,b), and vegetation type (Hefting et al., 2005; McGill et al., 2010). On the other hand, several other factors revealed to be crucial; for example: water table depth, groundwater slope and water residence time, (Balestrini et al., 2016), organic matter content (Dhondt et al., 2004). Soil texture was considered as an indirect factor because it affects hydraulic conductivity (Ks) and the capacity to retain organic matter (Mayer et al., 2007).

While this was happening on the scientific frontline, during the last decade, European agriculture changed development strategy moving through a cultural and economic "revolution". This change was driven by the Common Agricultural Policy (CAP, revisions 2008–2013 and 2014–2020) and by the Water Framework Directive (WFD, Dir 2000/60/EC) – including the Nitrates Directive of 1991 (Directive 91/676/EEC)- that played a key role in defining agricultural and environmental goals.

The Good Ecological Status of surface water bodies (GES) embodies a complex set of objectives defined by the WFD; their implementation requires pursuing the sustainable land management through the adoption of an integrated management strategy addressing multiple human activities (Werner and Collins, 2012). Given that the WFD does not provide funds for its implementation, European Member States support it through other policy sectors such as CAP, which provides direct incentives to farmers. Agriculture is called upon to play a crucial role in the sustainable development of our environment and our water resources, both quality and quantity, and to generate substantial benefits for nature conservation and human health.

The CAP's cross compliance," *a mechanism that links direct payments to compliance by farmers with basic standards concerning the requirement of maintaining land in good agricultural and environmental condition*", standards (CAP 2008–13 and 2014–20 version) include obligations that directly affect water quality. Standard 5.2 "Good Agronomic Environmental Conditions" requires provisions for vegetated "*buffer strips*" between rivers and agricultural crops, in order to protect surface and ground water from diffuse pollution (Gumiero et al., 2015). Introduced in 2009, it was implemented in Italy from the 1st of January 2012 (http://ec.europa.eu/agriculture/

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envir/cross-compliance/index_en.htm). Standard 5.2 "*Establishment of buffer strips along water courses*" (M.D. 27417, December 22, 2011) establishes that any strip of land, minimum 5 m wide, adjacent to all water courses (with some exceptions), where no farming is carried out, can be considered a buffer strip. This without making any distinction between the presence of trees or simple herbaceous vegetation, and with a lack of attention to subsurface hydrology and hydraulic connectivity. To what extent does this policy support the creation of buffer strips effective in slowing the delivery of nutrients to water bodies from the surrounding basin? This legitimate question raises a number of scientific issues that need to be clarified.

As a contribution to the interface between scientific research and policy, the present study evaluates buffer efficiency in terms of nitrogen removal through an assessment of buffer strips designed in adherence to the Cross compliance standard. Starting from a simple river restoration plan, we demonstrate how it is possible to transform an ineffective but apparently well designed buffer strip into one characterized by a high nutrient retention capacity. In addition, we contrast these results with two other experimental sites (see Gumiero et al., 2015) located in different Italian Regions, that were set according to the technical specifications reported in standard 5.2.

2. Materials and methods

2.1. The experimental sites

The study area is located in the Venetian Plain (lower Po floodplain in the North-East of Italy) where the coarser deposits of the Piedmont terrace grade into the finer sediments of the lower floodplain and the phreatic water table rises closer to the surface (Fontana et al., 2008). Soils are well drained sandy-loams, sub-alkaline and moderately calcareous. The climate is subcontinental with temperatures ranging from a daytime average of 1 °C in January to 23 °C in July and August. Average rainfall is 900 mm per year, peaking in autumn and spring and with lower values in winter and summer. The surrounding farmland includes maize rotating with an Italian chicory (*Radicchio 'Rossa di Treviso'*) typical of this area.

The Scandolara site (Fig. 1) is located in an area where deep groundwater, recharged in the upper part of the basin, tends to move towards the surface(Pasini et al., 2012). As a consequence, groundwater is directly connected to the adjacent water course.

An 11 m wide buffer strip (Fig. 1) was realized along the left bank of the Piovega di Scandolara stream (45°36′51″N; 12°05′5″E) in 2007. This project was part of a wider river restoration project aiming to reduce nutrient loading into the Venice Lagoon and to control flood risk. The trapezoidal section of this lowland stream was reshaped for a length of 1.1 km along the left bank in order to create a 6 m wide riparian strip that would become flooded during moderate water level rise. Two rows of trees were planted −one tree every 2 m- within the higher portion of the bank with a combination of different trees and shrubs (see Fig. 1), such as: white willow *Salix alba* L., almond willow *Salix triandra*, black alder *Alnus glutinosa* (L.) *Gaertner*, pedunculate oak *Quercus robur* L., field maple *Acer campestre* L., common hazel *Corylus avellana* L., common hawthorn *Crataegus monogyna Jacq*., manna ash *Fraxinus ornus* L. and black dogwood *Frangula alnus* L. A 4 m wide strip, between farmland and the restored river section, was sown with a mixture of herbaceous species, to restore the grass strip close to the channel as was before the project. The inner part of the buffer strip, interposed between the river and the tree rows, was covered by spontaneous and unmanaged helophytic vegetation.

A surface of 110 m^2 was set out as experimental site for the monitoring of hydrological dynamics and nitrogen retention, which started four years after restoration (from the 28th of March 2011 to the 5th of September 2012, two crop seasons/years). Sixteen samplings campaigns took place during this period, mainly during the growing season and often following rainfall, approximately at 15–20 days interval.

The upslope portion of the buffer zone, simulating the original condition preceding restoration, different significantly from the portion with reshaped section (Fig. 1). The two portions were considered separately: (1) Scandolara-upslope is a 4 m wide herbaceous strip that maintained the original ground level; (2) Scandolara-downslope, 7 m wide, had a reshaped bank and a newly created vegetated strip lying close to the surface water level.

2.2. Hydrological monitoring

A grid of 3 × 5 piezometers, ranging from 1 to 2 m long, 5 cm in diameter, were installed (see Fig. 2) perpendicularly to the supposed direction of groundwater flow; they enabled the determination of water table depth and the collection of water samples. Three additional piezometers were equipped with a pressure transducer (Druck – PT-B1, GE Measurement & Control Solutions) connected to a data logger (SmartReader 7 Plus, ACR Systems Inc.,

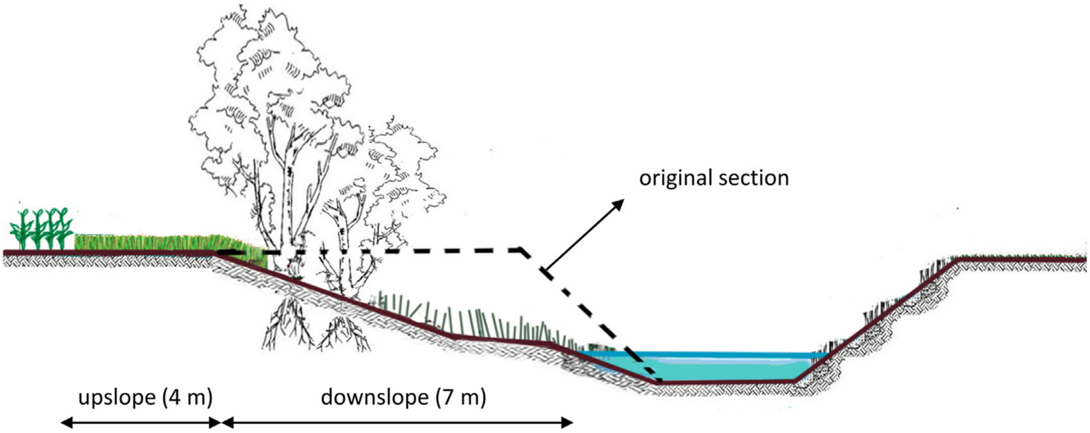

Fig. 1. Section representing enlargement of the stream bank during restoration.