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Design of riparian buffer strips affects soil quality parameters

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ABSTRACT

Vegetated buffer strips alongside watercourses are commonly used to counteract diffuse pollution from agricultural activities. If properly designed, they can provide multiple environmental benefits by increasing wildlife habitats and biodiversity. Little attention has been paid to the effects of buffer strips on soil quality. This study was conducted to determine the impact of different buffer designs on soil biochemical parameters and to define relevant quality parameters for soil monitoring. We compared four buffer arrangements: 3 m wide grass buffer; 3 m grass with one tree row; 6 m grass with one tree row; 6 m grass with two tree rows; plus two controls: an adjacent maize crop field and a plot without buffer. Buffers were established 13 years ago at the Padua University Experimental Farm in the Po Valley, north-east Italy. Studied parameters included soil organic matter composition and soil microbial and enzymatic assays. As expected, control plots showed the lowest values for all the studied parameters. Among buffer designs, 3 m grass and 3 m grass with 1 tree row buffers gave the highest values. Multivariate analysis demonstrated that the increase of soil organic carbon content distinguished buffers from controls, whereas soil humic carbon quality parameters such as humic compounds apparent molecular weight, together with acetyl esterase (fluorescein test) enzyme activity, were discriminatory in separating buffer designs. These results are an important contribution to the knowledge base and can help to improve the management of these systems.

1. Introduction

Vegetated buffer strips (BS) form a border physically separating the agricultural activities within the field from nearby watercourses, thus protecting water resources from non-point source agricultural pollution, with minimal impact on farm income (Popov et al., 2006). These areas have long been a feature of agricultural landscapes and the European Union's agricultural policy still promotes their establishment (Mathews, 2011; Stutter et al., 2012). In addition to their primary role of intercepting and treating the waters leaving cropland, buffers have a very positive impact on the ecological health of rural landscapes, leading to an increase in biodiversity (McCracken et al., 2012), expansion of wildlife habitats (Lovell and Sullivan, 2006) and improved soil quality (Udawatta et al., 2009). Riparian buffer strips have the potential to be multifunctional, integrating both agronomic and environmental objectives in intensely managed agricultural areas (Borin et al., 2010). In order to fully exploit the multiple benefits provided by buffer strips, a deeper understanding of their effects on the environment is required. In particular, the outcome of buffer establishment in terms of soil properties is a key subject as this is known to influence biogeochemical cycles of N, C and P (Stutter and Richards, 2012), vegetation type and productivity (Stockan et al., 2012) and invertebrate species richness (McCracken et al., 2012). Although differences in soil biochemical properties are to be expected comparing areas cropped annually and those covered by perennial vegetation (Paudel et al., 2012; Stutter and Richards, 2012), there have been few studies on the relationship between buffer design and soil quality parameters.

BS designs can differ in size and vegetation cover, with or without woody species (Paudel et al., 2012). Plant cover is an important soil quality factor, mainly due to its shield effect against raindrop impact (Folorunso et al., 1992), retaining suspended solids by plant culms and soil particles by plant roots, maintaining and increasing soil organic matter (SOM; Vance, 2000), and supporting the soil biological population by supplying carbon and energy sources from root exudates and plant debris (Garcia et al., 2005). Moreover, the presence of a permanent woody vegetation in the BS leads to the formation of a litter layer absent in the cultivated field or in grass covered BS. The balance between humification and

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decomposition of this layer strongly influences the SOM quality and quantity (Prescott, 2010).

SOM is the star indicator for evaluating the overall soil health in agricultural soils and one of the few parameters accepted as a measure for assessing soil quality (Bastida et al., 2008). It is a key component of terrestrial ecosystems and is functionally and structurally integrated into basic ecosystem processes.

Dissolved organic matter (DOM) is defined as the organic matter fraction in solution that passes through a 0.45 mm filter (Zsolnay, 2003). DOM is often quantified by its carbon content and referred to as DOC. DOC comprises only a small part of soil organic matter (Kalbitz and Kaiser, 2003) but can be envisioned both as a link and bottle-neck among various environmental compartments and can serve as a sensitive indicator of shifts in ecological processes such as those impacted by land use and management practices (e.g. conversion of forest to arable land; Bolan et al., 2011).

Humic substances (HS), the largest constituents of SOM, can be considered to be on the top rung in its stabilization and a key intermediate in the mineralization to CO_2 (Nardi et al., 2009). These molecules participate in many agronomic, environmental, and geochemical processes (Hayes and Swift, 1978; Stevenson, 1994). Their relative abundance and breakdown rate affect (a) the soil structure and porosity (Piccolo, 2002), (b) the water infiltration rate and moisture holding capacity of soils (Russo and Berlyn, 1990), (c) the diversity and biological activity of soil organisms (Nardi et al., 2009) and (d) pesticide degradation (Staddon et al., 2001).

Microbial biomass C (C_{mic}) is one of the most commonly used properties in the literature for estimation of soil quality (Gil-Sotres et al., 2005). Although microbial biomass usually makes up less than 5% of SOM, it has many critical functions in the soil ecosystem. It is both a source and sink for nutrients, it participates in C, N, P and S transformation, plays an active role in the degradation of xenobiotic organic compounds and immobilization of heavy metals, and in the formation of soil structure (Nannipieri et al., 2002).

Finally, among biological parameters, enzyme activities have been shown to be good indicators of microbial activity and very sensitive detectors of both short-term (Lagomarsino et al., 2009) and long-term (Ge et al., 2010) soil responses. Enzymes integrate information from the microbial status and soil physicochemical conditions (Aon et al., 2001). Fluorescein diacetate (FDA) hydrolase, protease, urease and dehydrogenase provide a broad spectrum of enzymatic activities in soils. These enzymes are involved in the decomposition of complex organic compounds and nitrogen mineralization, and are correlated with fungal and microbial biomass (Garcia et al., 1997a; Gaspar et al., 2001; Gil-Sotres et al., 2005; Bastida et al., 2008). The activities of these enzymes have been widely used as response indicators of soil microbial communities to several environmental pressures (Costa et al., 2013).

In this work we hypothesize that different BS designs have uneven impacts on soil organic matter, soil microbial functional diversity and soil enzyme activities. These differences in soil parameters should be considered in the decision-making process of installing buffers to implement more effective multipurpose riparian strips.

To test our hypothesis we compared management and seasonal effects on physicochemical and biological parameters in four different long-established BS, regardless of their performance on pesticide retention. The aim was to: i) confirm the differences in soil fertility parameters between cultivated and vegetated areas; ii) evaluate the effects of BS design on soil biochemical properties; and iii) define the most relevant parameters for soil quality monitoring in these environmental conditions.

2. Materials and methods

2.1. Experimental site description

The study was conducted at the Padua University Experimental Farm in the Po Valley, north-east Italy. The soil is classified as Fulvi-Calcaric Cambisol (FAO-UNESCO, 1990). It is silty-loam textured (11.8% clay, 44.9% silt, 43.3% sand), rich in limestone, with sub-basic pH (pH 8.11) and medium-low hydraulic conductivity (4.7×10^{-4} cm s^{-1}).

The experimental site is a rectangular field of 200 × 35 m with a 1.82% slope downwards to a ditch until 2007 and then with a 0.8% slope. Between cropland and ditch, four types of buffer strips (BS) were established in 1997. Each BS is 20 m long and has two replicates. The BS differ in width and composition: (a) 3 m wide buffer with grass cover only (3G), (b) 3 m wide buffer with grass cover and a shrub and tree row (3G1R), (c) 6 m wide buffer with a shrub and tree row (6G1R) and (d) 6 m wide buffer with two rows of trees and shrubs (6G2R). The rows are 1.5 and 4.5 m from the ditch. The herbaceous cover, at the start of the trials, was *Festuca arundinacea* Schreber and the rows were of regularly alternating *Viburnum opulus* L. shrubs and *Platanus hybrida* Brot. trees. Two control plots were considered: a maize crop (MC) plot and a plot without buffer (WB) cultivated to the edge of the ditch, also with two replicates (Fig. 1).

2.2. Management of field and buffer strips

The field was cropped with winter wheat during 1997–1998 and 2000–2001 and soybean sod seeded on the winter wheat stubble in 2001, in the following years the crop was maize.

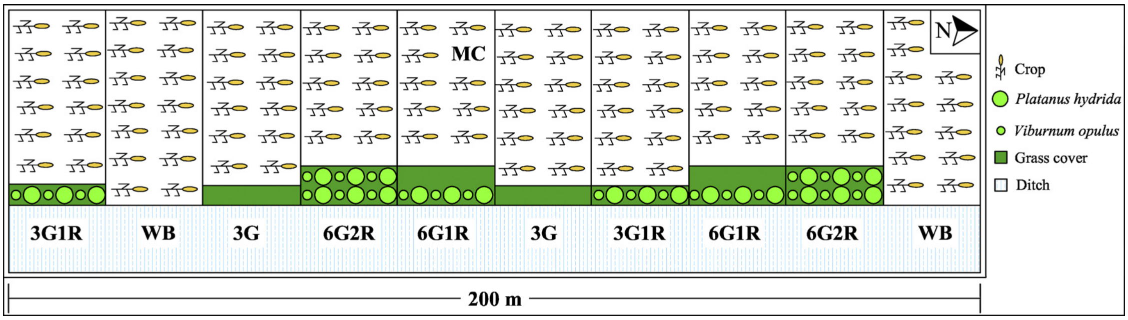

Fig. 1. Layout of the experimental field with the maize crop (MC), four types of buffer strips (BS) and plot without buffer (WB). 3G: 3 m wide buffer with grass cover only; 3G1R: 3 m wide buffer with grass cover and a shrub and tree row; 6G1R: 6 m wide buffer with a shrub and tree row; 6G2R: 6 m wide buffer with two rows of trees and shrubs.