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Research paper

Impact of maintenance operations on the seasonal evolution of ditch properties and functions

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ABSTRACT

Ditch networks were traditionally designed to protect fields from soil erosion or control waterlogging. They are still frequently managed by either mowing, chemical weeding, dredging or burning to ensure their optimal hydraulic capacity. Ditches were recently reported also to improve water quality and sustain biodiversity. These ditch functions are related to specific ditch properties. By contrastingly modifying ditch properties, maintenance operations were supposed to regulate these functions. There is, therefore, a need to re-examine the design and maintenance strategies of ditches to optimize the whole range of ecosystem services that they provide. In this study, we address the innovator question of how maintenance operations affect the yearly evolution of ditch properties, and in turn, the panel of functions that ditches support. During one year, we monitored the vegetation, litter, soil properties, and ash cover of five ditches that were being unmanaged, dredged, mowed, burned, and chemically weeded, respectively, with timing and frequency as generally operated by farmers in the study area. We then used indicators to evaluate the effect that the evolution of these properties has on the ditch water conveyance, herbicide retention and biodiversity conservation functions. We found that the evolution of these properties significantly contrasted among the 5 maintenance strategies. All the maintenance operations cleared the vegetation, which improves the hydraulic capacity by up to 3 times. The optimal hydraulic capacity is maintained longer after chemical weeding and dredging, but these operations have negative impacts on the herbicide retention and biodiversity conservation functions. The litter and ash layers generated by mowing and burning, respectively, improve the herbicide retention by up to 45%. Our results confirm that maintenance can be an efficient tool for optimizing ditch functions. The choice of maintenance operation and timing are key to successfully optimizing most of the functions that ditches can support.

1. Introduction

Farm ditches are infrastructures that have been used for centuries by farmers to regulate excess water fluxes in cropped areas, which, depending on the pedoclimatic context, were used either to protect crop fields from soil erosion or to control waterlogging (Dollinger et al., 2015; Levavasseur, 2012; Levavasseur et al., 2014). The design of these human-made channels, which are arranged as networks in cropped catchments, was optimized over time to efficiently collect runoff and drainage fluxes and rapidly evacuate them towards receiving water bodies (Levavasseur et al., 2014, 2016). Additionally, these infrastructures have also recently been reported to sustain biodiversity, buffer agricultural non-point source pollutions or participate in groundwater recharge and flood regulation, depending on their properties (e.g., Dollinger et al., 2015; Herzon and Helenius, 2008; Needelman et al., 2007).

As part of a more global strategy that aims to limit the adverse effects of intensive agriculture on the environment, the interest in promoting those ditch functions that are not directly involved in protecting crops from waterlogging and soil losses is growing (Dollinger et al., 2015; Herzon and Helenius, 2008; Needelman et al., 2007). This interest is particularly the case for non-point source pollution buffering and biodiversity conservation ditch functions. For instance, pesticides sprayed in intensive crop systems to protect crops from pests and weeds may be partly dissolved by runoff and drainage fluxes and then transferred towards surface water bodies or groundwater via ditch networks (Louchart et al., 2001; Tang et al., 2012). This non-point source pollution threatens the quality and ecological health of these water bodies, thereby restricting specific usages, such as drinking water supply,

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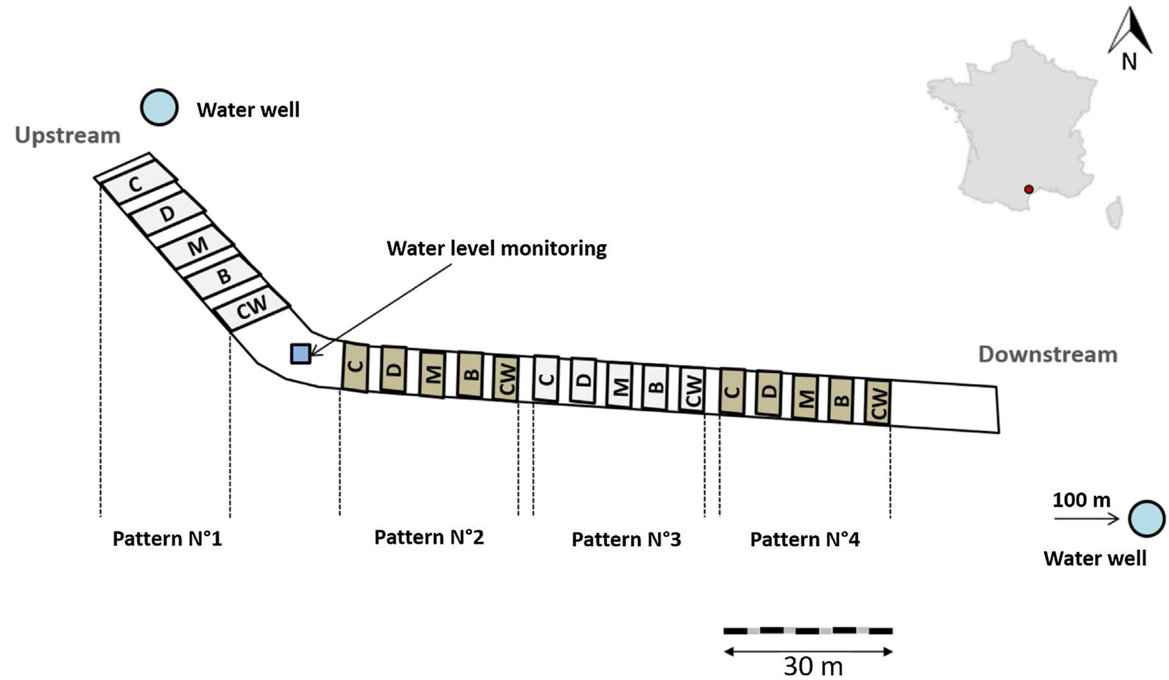

Fig. 1. Experimental design. For each pattern, the quadrats C, D, M, B, CW were respectively unmanaged (control), dredged, mowed, burned and chemically weeded with frequencies and timing that apply to farmers in the study area. Each pattern is 30 m long, quadrats are 4 m long each and are separated by 2 m long buffer sections.

and engendering significant depollution costs around the world (Reichenberger et al., 2007; Schultz et al., 1995). Therefore, there is a need to re-examine the design and maintenance strategies of ditches to optimize the whole range of ecosystem services that they provide. In this paper, we address the specific issue of the impact of maintenance practices on the ditch functions. Ditches are distinguished here from irrigation channels, as, even though they might share design and maintenance similarities, their flooding regime is greatly contrasted.

Ditch maintenance strategies originally aimed to preserve an optimal hydraulic capacity thanks to frequent vegetation clearance (Dollinger et al., 2015; Levavasseur et al., 2014, 2016). Ditch maintenance primarily consists of the succession in time and location of some of the 4 basic operations, which are ditch mowing, dredging, chemical weeding and burning (Dollinger et al., 2015; Levavasseur, 2012). The frequency and timing of these maintenance operations differ. Ditch dredging is usually performed once every 5–10 years but can be more frequent in the case of small in-field ditches that are designed to protect sloping croplands from erosion (Bailly et al., 2015a; Levavasseur, 2012; Smith and Pappas, 2007). Mowing, chemical weeding and burning are usually performed at least once a year (Bailly et al., 2015a; Levavasseur, 2012; Levavasseur et al., 2014; Smith and Pappas, 2007). Moreover, a given ditch is very likely to undergo a combination of maintenance operations every year. While chemical weeding, mowing and dredging are usually performed from spring to late summer, burning is performed in winter when the vegetation dries out. This operation is thereby restricted to the highland or semi-arid areas where there is no base-flow in the ditches during winter (e.g., Bailly et al., 2015a).

The maintenance of ditches, by modifying their properties, also modulates the occurrence and intensity of the biogeochemical processes involved in the multiple functions supported by ditches (Dollinger et al., 2015). The change in ditch properties after maintenance may favour certain functions over others as an intensity shift of a given biogeochemical process may favour a function or a group of functions and be disadvantageous to others (Dollinger et al., 2015). Designing ditch maintenance strategies for sustaining a panel of functions, including those for which the ditches were created, requires a good knowledge of how each maintenance operation modifies the ditch properties, not only immediately but also after their mid-term evolution. Few studies have attempted to describe the spatial and temporal variability of ditch properties along networks and link them to maintenance strategies (Bailly et al., 2015a; Lecce et al., 2006; Levavasseur et al., 2014). However, to our knowledge, the effect of the maintenance operations on the mid- evolution of ditch properties and how this evolution affects a panel of functions has never been described in the literature.

In accordance with these gaps of knowledge, the objectives of this study are to i) experimentally assess the mid-term evolution of ditch properties after each maintenance operation, ii) evaluate with semi-quantitative indicators the influence of these ditch property evolutions on the hydraulic capacity, herbicide retention and biodiversity of the ditches, and iii) try to identify maintenance operations or strategies that could jointly sustain a panel of functions. The study was conducted during one year in South of France in a vineyard area that is subjected to rare but highly intensive rainfall events and where ditch networks were originally designed to prevent soil erosion.

2. Materials and methods

2.1. Experimental design

2.1.1. Study site

The study site is located in the downstream part of the Bourdic catchment in South of France (43°5′ Nord, 3°3′ East). This 6.4 km^2 catchment, primarily covered by vineyards, is subject to a Mediterranean climate, which is characterized by rare but high-intensity rainfall events that occur mostly in spring and fall (Levavasseur et al., 2012). The dense ditch network is managed in the catchment with the principal aim of preventing soil loss by erosion (Levavasseur et al., 2016).

The study site is a ditch receiving both drainage (groundwater exfiltration flux) and runoff (overland flow) water from the surrounding vineyards. The ditch length is approximately 120 m, its bottom width 64 cm, its top width 160 cm, its depth 54 cm and its