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Review

Reconciling agriculture and stream restoration in Europe: A review relating to the EU Water Framework Directive

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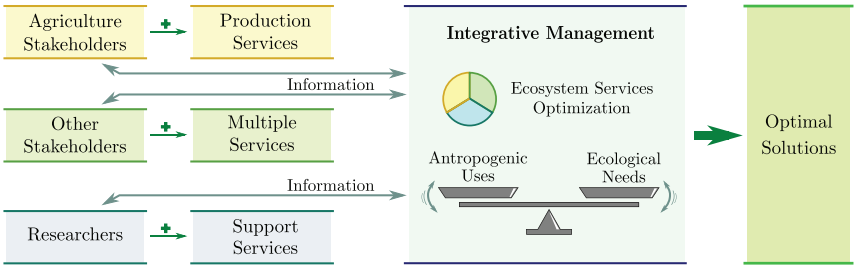
HIGHLIGHTS

- Agriculture is the main contributor to freshwater ecosystem degradation in Europe.
- The WFD deadline to reach good ecological state on European streams closed in 2015.
- Recent research on reconciling agriculture and stream restoration was integrated.
- Involving and acknowledging stakeholders is likely to improve restoration outcomes.
- Increasing peer-reviewed restoration reports is crucial for integrative management.

GRAPHICAL ABSTRACT



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ABSTRACT

Agriculture is widespread across the EU and has caused considerable impacts on freshwater ecosystems. To revert the degradation caused to streams and rivers, research and restoration efforts have been developed to recover ecosystem functions and services, with the European Water Framework Directive (WFD) playing a significant role in strengthening the progress.

Analysing recent peer-reviewed European literature (2009–2016), this review explores 1) the conflicts and difficulties faced when restoring agriculturally impacted streams, 2) the aspects relevant to effectively reconcile agricultural land uses and healthy riverine ecosystems and 3) the effects and potential shortcomings of the first WFD management cycle.

Our analysis reveals significant progress in restoration efforts, but it also demonstrates an urgent need for a higher number and detail of restoration projects reported in the peer-reviewed literature. The first WFD cycle ended in 2015 without reaching the goal of good ecological status in many European waterbodies. Addressing limitations reported in recent papers, including difficulties in stakeholder integration and importance of small headwater streams, is crucial. Analysing recent developments on stakeholder engagement through structured participatory processes will likely reduce perception discrepancies and increase stakeholder interest during the next WFD planning cycle.

Despite an overall dominance of nutrient-related research, studies are spreading across many important topics (e.g. stakeholder management, land use conflicts, climate change effects), which may play an important role in guiding future policy. Our recommendations are important for the second WFD cycle because they 1) help secure the development and dissemination of science-based restoration strategies and 2) provide guidance for future research needs.

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1. Introduction

1.1. Background

1.1.1. Connections between agriculture and freshwater ecosystems

A large part of Europe's land is dedicated to agricultural uses, which are driven by a variety of macro elements (e.g. socioeconomic and cultural drivers), as well as local factors (e.g. climate, topography, farmer motivation; Kristensen, 2016; Lima et al., 2015; van Vliet et al., 2015). These factors have an important influence on land suitability for agricultural use (i.e. natural and anthropogenic factors covary; Allan, 2004; Hughes et al., 2010) and often lead to an overuse of lands directly connected to stream networks (Conroy et al., 2016; Holden et al., 2004).

Agricultural activities often have large impacts on riverine ecosystems (Allan, 2004; Grizzetti et al., 2012; Ormerod et al., 2010; Windolf et al., 2012), which may range from physical impacts such as riparian clearance, erosion or water regulation for irrigation, to chemical impacts, such as increased nutrient runoff or pesticide contamination. Degradation is further aggravated by high degrees of hydromorphological change, which leads to the breakdown of the longitudinal and lateral continuity that is characteristic of riverine ecosystems (Bolpagni and Piotti, 2015).

Throughout Europe, agriculture is the type of land use with the most significant impacts on freshwater ecosystems (e.g. Davies et al., 2009; Poole et al., 2013) and, with an increasing recognition of the services provided by these ecosystems, there is growing public support for their restoration. Nowadays, it is a political priority to provide the necessary conditions for freshwater ecosystems to recover from anthropogenic impacts.

1.1.2. The importance of restoring streams and rivers

Freshwater ecosystems are highly diverse and complex (e.g. small headwaters, large rivers, estuaries; Allan, 2004; Culp and Baird, 2006; Yeakley et al., 2016) , providing a wide variety of ecosystem services including water abstraction (for human consumption or irrigation), flood protection or biodiversity maintenance. Streams and rivers are directly related to the surrounding terrains, and are affected by stressors (e.g. pollution) that may extend beyond on-site processes (Jansson et al., 2007; Naiman et al., 2002). Furthermore,

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