Journal of Environmental Management 91 (2010) 2087–2095

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Review

Integrating objectives and scales for planning and implementing wetland restoration and creation in agricultural landscapes

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ARTICLE INFO

Article history:
Received 5 November 2009
Received in revised form
4 May 2010
Accepted 2 June 2010
Available online 26 June 2010

Keywords:
Creation/restoration strategy
Semi-arid
Mediterranean conditions
Creation/restoration scenarios
Environmental services

ABSTRACT

Traditionally, wetland management strategies have focused on single familiar objectives, such as improving water quality, strengthening biodiversity, and providing flood control. Despite the relevant amount of studies focused on wetland creation or restoration with these and other objectives, still little is known on how to integrate objectives of wetland creation or restoration at different landscape scales. We have reviewed the literature to this aim, and based on the existing current knowledge, we propose a four step approach to take decisions in wetland creation or restoration planning. First, based on local needs and limitations we should elucidate what the wetland is needed for. Second, the scale at which wetland should be created or restored must be defined. Third, conflicts and compatibilities between creation or restoration objectives must then be carefully studied. Fourth, a creation or restoration strategy must be defined. The strategy can be either creating different unipurpose wetlands or multipurpose wetlands, or combinations of them at different landscape scales. In any case, in unipurpose wetland projects we recommend to pursue additional secondary objectives. Following these guidelines, restored and created wetlands would have more ecological functions, similar to natural wetlands, especially if spatial distribution in the landscape is considered. Restored and created wetlands could then provide an array of integrated environmental services adapted to local ecological and social needs.

1. Introduction

Intensification of agriculture has dramatically altered the structure and function of agricultural ecosystems, and has been highlighted as the main reason for loss of farmland biodiversity (Krebs et al., 1999; Hendrickx et al., 2007; Billeter et al., 2008). Some of the most severe impacts of agricultural intensification are being the homogenization of the landscape, with the subsequent impact on the biodiversity(Benton et al., 2003; Haslem and Bennett, 2008), the degradation of the soil, usually associated to a depletion of the organic matter (Stoate et al., 2001; Lal, 2002), to salinization processes (Darwish et al., 2005) or to a general reduction of biodiversity (Gilroy et al., 2008), and the eutrophication and salinization of the water bodies (Goldman and Horne, 1983; Skaggs et al., 1994).

Loss or destruction of wetlands has resulted in the loss of valuable raw materials and services worldwide, disrupting water supplies and food resources (Mitsch and Gosselink, 2000a; Millenium Ecosystems Assessment, 2005). Recently, wetland restoration or creation has received increased attention because of the multiple, valuable environmental services provided by wetlands worldwide (Zedler and Kercher, 2005). As environmental services provided by wetlands have become more highly valued (Costanza et al., 1997), the number of restoration and creation projects undertaken worldwide has continued to increase annually. This is of especial relevance in intensified agricultural landscapes where the severe impacts have leaded to the loss of services and ecological functions of natural ecosystems. In this context, the creation and restoration of wetland with multiple functions can return some of the lost functions or provide other of special service of especial relevance for the local conditions. In the traditional view, the primary goals of wetland restoration are water quality, biodiversity, flood control and recreation (Knight, 1992; Zedler, 2000). Although these remain the most prominent goals, new objectives are emerging, including fisheries preservation, carbon sequestration and maintenance of landscape heterogeneity (Comín et al., 2001; Richardson and Hussain, 2006; Gary and Whiting, 2001).

Interactions and conflicts between individual restoration objectives are still poorly understood. Several relevant studies have demonstrated that one objective, such as removing nitrogen or strengthening biodiversity, may create outcomes that are bad for another, like phosphorous removal (Hansson et al., 2005).

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doi:10.1016/j.jenvman.2010.06.002

Similarly, a strategy that is beneficial for one animal group (e.g., birds) may not be good for another (e.g., fishes); thus, one restored site cannot maximally serve all potential functions (Findlay et al., 2002). And conversely, wetlands removing nutrients from agricultural runoff have been proved to have similar diversity of aquatic macroinvertebrates to that of natural lentic waters in the same region (Thiere et al., 2009). To implement restoration objectives, an array of guidelines have been proposed, mainly based on ecological knowledge (Zedler, 2000, 2005), hydrological science (Acreman et al., 2007) or landscape limitations (Arheimer et al., 2004; Newbold, 2005; Lesta et al., 2007; Verhoeven et al., 2008). Although studies have provided some general indications about the optimal scale of restoration (Kershner, 1997; Zedler, 2003; Thiere et al., 2009) and the effectiveness of certain restoration strategies (Thom et al., 2005), the field lacks an integrative approach for restoring and creating wetlands under local limitations at a specific scale.

The aim of this study is to provide a general strategy for wetland creation or restoration based on two fundamental questions: first, what are the functions do we want to retrieve from the wetland? and second, at what scale do we want to retrieve them? Although the approach is applicable to most of environmental conditions, we will mainly study the restoration or creation of wetlands in catchments degraded by intensive agricultural use.

2. Wetlands restoration objectives

One of the two fundamental questions proposed in this study in considering restoring or creating wetlands is: what are the functions do we want to retrieve by making a new wetland or restore an existing one? The answer to this question, which can be approached stepwise as shown schematically in Fig. 1, defines the overall objectives of the wetland restoration or creation project. Thus, objectives could be considered as functions we expect to retrieve from a restored or created wetland and are closely relying on the characteristics that we can manipulate to increase the succeed (Table 1).

A brief literature review will identify trends in how different wetland restoration and creation objectives have been viewed historically and how they are viewed now and summarize the current state of our knowledge. This overview includes all studies conducted over the last 30 years and reported in journals included in the Science Citation Index Expanded (ISI Web of Science, Thompson Corp. 2009) that address one or more of three relevant wetland restoration objectives.

The first priority objective was water quality improvement, to include a consideration of nutrients, solids, salts, heavy metals and organic pollutants. All articles where water quality was studied in restored or created wetlands were accounted (Table 2). The second priority objective was the strengthening of biodiversity in restored or created wetlands. Articles dealing with any aspect related to the effects of wetland restoration or creation on biodiversity and wildlife were counted. The third priority objective was soil improvement. Articles that studied processes happening in soils of restored or created wetlands were included. All articles selected under these three restoration and creation objectives studied wetlands at a site scale. In order to understand how landscape scales broader than the site scale have been considered in creation or restoration studies, studies dealing with wetland restoration or creation at any landscape scale (catchment or territory) with any restoration or creation objective were also accounted. The restoration or creation of wetlands at the landscape scale is usually carried out to attain some of the previous objectives, especially, the improvement of the water quality.

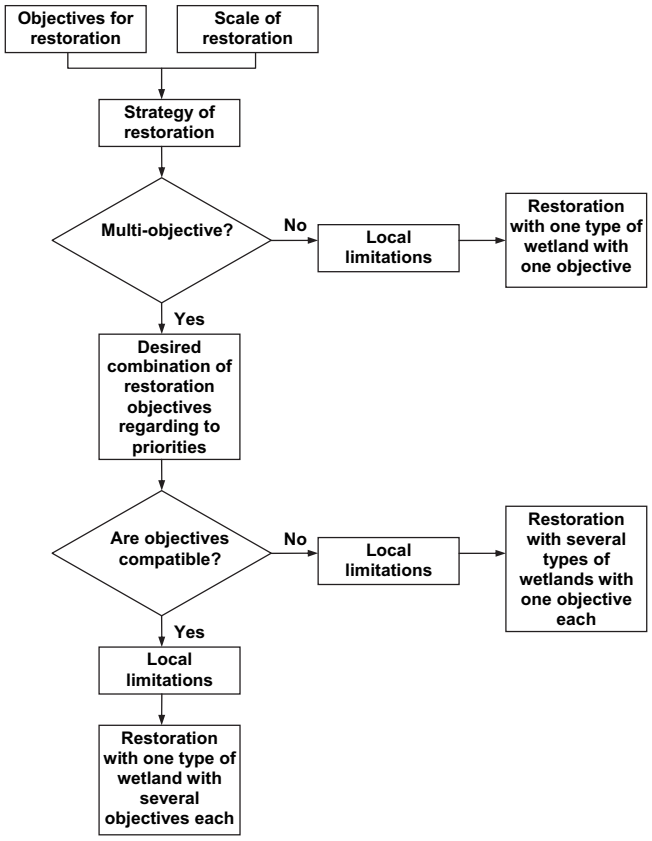

Fig. 1. Proposed protocol for planning wetland creation and restoration projects with uni or multiobjective perspectives.

2.1. Improving the water quality

Table 2 shows that the most studied objective for wetland restoration was the improvement of the water quality (542 selected articles in the last 30 years). In the first time-span considered in the reference search only three articles appeared. In that moment appeared the first complete studies on wetland creation to treat water pollution, although some of them were not yet included in the SCI (e.g., Jones and Lee, 1980; Hammer, 1989). The first study found in SCI journals that satisfied the search criteria was published in 1989 (Wieder, 1989). Since that time, the volume of studies has increased dramatically each year. This increase is mainly due to the strong interest in nutrient retention (nitrogen and phosphorous), especially for treating agricultural runoff or sewage in agricultural catchments (Kuusemets and Mander, 1999; Mander et al., 2000; Zedler, 2003; Novotny, 2005; Mustafa et al., 2009). Wetlands have been shown to retain widely variable amounts of nitrogen (30–99%) and phosphorous (0–99%), and the use of wetlands for this purpose has generally proven suitable for most conditions, including arid, boreal, temperate and tropical environments (e.g., Romero et al., 1999; Woltemade, 2000; Koskiaho et al., 2003; Kantawanichkul and Somprasert, 2005; Moreno et al., 2007). The creation of surface flow wetlands on natural soils is an interesting case because of their low cost of creation and maintenance, which has favored their rapid proliferation worldwide (Hammer, 1992; Mitsch and Gosselink, 2000b; Kovacic et al., 2006). Recent studies have highlighted the role of wetlands in the emission of greenhouse gases (Mitsch et al., 2001; Verhoeven et al., 2006), a consideration that must be taken into account before initiating new wetland creation or restoration projects.