



# Ecological consequences and restoration potential of abandoned wet grasslands



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## ABSTRACT

Wet grasslands of nature conservation importance have been maintained for centuries by agricultural management such as grazing and mowing for hay, but are now threatened by abandonment despite recent restoration initiatives. This paper is the first to synthesise published information to elucidate the main patterns, timescales, and consequences of wet grassland abandonment with an international perspective, and to evaluate restoration success. Results showed that abandonment is a particular concern in Europe, especially in central European and Baltic countries, but is also a factor in the deterioration of North American wet grasslands. In Europe, abandonment peaked in the second half of the 20th century, driven by inter-related political and socio-economic changes. Nearly all ecological studies of wet grassland abandonment (94%) focus upon vegetation and they reveal that community changes have been measured within three years, including species elimination as competitors expand and woody plants encroach. However, some wet grasslands show resilience as dominant herbaceous species can persist for up to 50 years, restricting woody invasion. Herbaceous species dominating abandoned grasslands are typically native, tall, productive and competitive grasses or sedges, while small, stress-tolerant, rare species characteristically decrease. Few studies have measured soil properties (11%) or animals (6%) during abandonment, although it seems that invertebrates may increase (for up to 20 years) and then decline in unmanaged wet grasslands. Evidence suggests that wet grasslands that have been abandoned for <40 years can be rehabilitated within 10 years by reinstating vegetation management, but fully successful restoration to a previous condition is elusive. Long-abandoned grasslands may need more interventionist restoration efforts to create regeneration niches and introduce species. Although managers should assess specific site characteristics and potential constraints before restoring abandoned wet grasslands, it is recommended that restoration initiatives should generally prioritise treeless wet grasslands with low soil nutrients that have been abandoned for <20 years.

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## 1. Introduction

Wet grasslands are biologically diverse components of agricultural landscapes that have been managed, often for centuries, by farming but are now threatened by the abandonment of traditional practices. They provide multiple ecosystem services, including flood attenuation, groundwater recharge, sediment storage, nutrient removal, erosion protection, and aesthetic value (Joyce and Wade, 1998). Wet grasslands are mostly semi-natural, formed by drainage of other wetland types (e.g. fens or marshes) or forest clearance on floodplains, and are maintained by human intervention, often cutting for hay (called meadows) or extensive grazing by livestock (pastures). They have an abundance of grasses (or sedges),

periodic flooding with fresh or brackish water, or a high water table for at least some of the year, sufficient to influence the vegetation and associated biological diversity. Wet grassland types in Europe include wet meadows and pastures, floodplain or alluvial grasslands, polders, fen meadows, and sea-shore meadows. In North America, sedge-dominated meadows, fen grasslands, floodplain, alluvial or riparian grasslands, and wet prairies are comparable, albeit with different evolutionary and management histories. The extent and status of wet grasslands is not well known beyond the regional or occasionally national level, partly due to inconsistencies with defining the various types, but it is likely that the wet grassland resource experienced losses of at least 80% during the 20th century, mostly due to drainage and agricultural changes. In some countries or regions, such as Finland, eastern England, and mid/western USA, it is thought that less than 1% of the former area of wet grassland remains (e.g. Clark and Wilson, 2001; Luoto et al., 2003).

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Agricultural management has been practised at wet grasslands in Europe for hundreds or thousands of years as a vital part of the farm economy, coincidentally producing highly-valued and protected cultural landscapes with few if any trees but a characteristic biodiversity (Joyce and Wade, 1998). Regular management is perceived as beneficial or even essential for nature conservation because cutting and grazing remove aboveground biomass to allow a diversity of less robust plants to coexist, and to maintain an open landscape suitable for large numbers of wading birds and wildfowl. For example, it has been estimated that over half of all wading birds in the European Union breed on wet grasslands (Hötter, 1991). Outside Europe, perspectives on grassland management are often less positive or at least ambiguous, not least because grazing can be considered an intensive or unnatural disturbance that facilitates alien or weedy species (Green and Kauffman, 1995; Middleton et al., 2006). Examples include the riparian wetlands of the western USA, despite their evolution with extensive grazing communities (Kauffman et al., 2004), and the flooding Pampean grasslands of South America, which developed under low densities of herbivores but are now mostly subject to cattle grazing (Facelli et al., 1989). There is growing recognition in North America, however, that wet grasslands there have been subjected to burning, hay mowing or grazing management, in some cases for centuries, and could therefore be analogous with European systems (Middleton et al., 2006; Scanga and Leopold, 2012). Furthermore, there is increasing concern in both North and South America over the expansion of woody species, loss of rare species, and invasion of non-native or aggressive plant species, following the suppression of disturbance such as fire, cutting and grazing (e.g. Middleton, 2002a; Cabral et al., 2003; Middleton et al., 2006; Scanga and Leopold, 2012). Climate change could exacerbate such problems, as increasing carbon dioxide, long-term drying, and climate oscillations may facilitate woody species expansion into wet grasslands (Quinlan et al., 2003; Sundberg, 2012).

The general process of grassland secondary succession is well described (e.g. Persson, 1984; Omacini et al., 1995; Battaglia et al., 2002; Rosenthal, 2010; Prévosto et al., 2011). Initially in the absence of management, grasses increase in leaf area, biomass accumulates as standing dead matter and litter, and productive, tall, robust and competitive grasses or forbs prevail because they out-compete smaller plants for resources, especially light. Consequently, species diversity tends to decline as relatively few species dominate. Typically, succession proceeds with the invasion and establishment of woody species (shrubs and trees), although the timescale for this is variable (Persson, 1984; Rosenthal, 2010). However, much of this generic successional template relates to vegetation structure and is derived from mesic or dry grassland sites (e.g. Prévosto et al., 2011); detailed descriptors for the wet grassland successional range following abandonment are lacking.

Agricultural intensification to increase production is a well-known and widespread impact upon grasslands, especially in the second half of the 20th century. For wet grasslands, it often includes flood defence and land drainage, and the use of inorganic fertilizers, herbicides and pesticides, with destruction by ploughing frequently the ultimate fate. Compared to intensification, the cessation of management has received much less attention, yet abandonment or neglect may be a critical threat given that wet grasslands depend upon regular vegetation management to maintain their ecological attributes and biodiversity. Abandonment normally refers to the cessation of traditional farming practices, such as grazing or hay meadow management, and at its most extreme involves land desertion. Williams (2006) reported that a greater proportion of protected fens and marshes in the UK were

adversely affected by abandonment (17%) and under-grazing (14%) than intensification (5%), indicating that the relatively few wet grasslands that have escaped intensification are now threatened by neglect. While abandonment may represent an opportunity for more naturally functioning wetlands and some wildlife may eventually benefit, such as woodland or reed bed species, the implications of wet grassland abandonment for nature conservation are often likely to be strongly negative. For example, it has been estimated that almost 10% of the regional fen flora would be lost if fen meadows in north west Germany were abandoned (Jensen and Schrautzer, 1999), while abandonment of coastal grasslands threatens endangered animals including the Natterjack toad (Rannap et al., 2007) and wading birds such as the Baltic Dunlin and Ruff (Hötter, 1991; Kuresoo and Mägi, 2004). In the USA, the globally rare herb *Trollius laxus* is threatened by abandonment of grazing and haying in Madison county fens (Scanga and Leopold, 2012). Consequently, initiatives to restore abandoned wet grasslands have begun, especially in Europe, and a comparison of the effectiveness of these initiatives would be timely.

Abandonment of wet grasslands therefore appears to be an important phenomenon. There have been a number of studies of specific grassland types, individual sites or sub-regions that have described abandonment and, generally more recently, initiatives to restore abandoned sites. However, there has been no published attempt to synthesise these studies into an evaluation of the key patterns, timescales and consequences of wet grassland abandonment with an international perspective, and to compare restoration attempts in order to assess their success. The objectives of this paper are therefore to: (i) identify the spatial and temporal context of the abandonment issue for wet grasslands (e.g. scale, history and factors driving the process); (ii) assess the ecological effects of abandonment over time (e.g. on species, traits and ecosystem properties); and (iii) evaluate the restoration potential for abandoned wet grasslands.

Primary literature searches with the combinations of title keywords 'wet grassland/meadow/pasture/oldfield/prairie', and 'prairie pothole/depressional wetland/sedge meadow/fen meadow' with 'abandon/succession/neglect' were conducted using ISI Web of Science. The use of terms commonly used in Europe, the Americas and elsewhere aimed to capture as many studies as possible. This search gave a global review base of 645 publications, of which 76 were considered most important and selected for comparison as they contained (a) information about hydrology, vegetation and/or species composition sufficient to meet the wet grassland definition, and (b) original data from abandoned wet grassland sites or experimental plots. The majority of suitable data-rich publications (71) were based upon European sites, possibly because of the long history of grassland management and research on the continent, so this synthesis focusses upon European wet grasslands, with the remaining comparable studies from North and South America. The database mostly comprised observations from abandonment and restoration field studies, but some data were also used from field experiments incorporating experimental abandonment as a treatment, i.e. where plots were excluded from management or control plots were left unmanaged. The rather broad definition of wet grasslands bounded by the search terms therefore incorporated peat or mineral substrates with basic, neutral or acidic properties, and sub humid or moist grasslands, but data from mesic grasslands were excluded unless species indicated a high water table at least partially. The altitude of most wet grasslands studied was <900 m but some more elevated montane and Swiss fen meadow grasslands, exceptionally up to 1950 m, were included where the vegetation composition showed similarities with lowland counterparts.

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