Ecological Engineering xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Ecological Engineering

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

Changes and trajectories of wetlands in the lowland landscape of the Czech Republic

Jan Skaloš*, Pavel Richter, Zdeněk Keken

Czech University of Life Sciences Prague, Faculty of Environmental Sciences, Kamýcká 1176, 165 21 Praha 6–Suchdol, Czech Republic

ARTICLE INFO

Article history:
Received 23 April 2017
Received in revised form 28 June 2017
Accepted 28 June 2017
Available online xxx

Keywords:
Wetlands
Change trajectories
Habitat continuity
Land use/cover history

ABSTRACT

Wetland biotopes play many roles in the landscape. The primary objective of this study was to analyse historical long-term changes of wetlands in the lowland areas of the Czech Republic, with emphasis on their spatio-temporal changes in the landscape and with stress on the use of different types of information sources. The following research questions were asked: (1) What are the wetland spatio-temporal changes (expressed through the number and size of continuously existing, extinct, and recent wetlands) and wetland change trajectories (expressed by quantifying and localising LULC categories that replaced extinct wetlands as well as categories of LULC at the expense of which wetlands occur) in the lowland landscape of the Czech Republic? (2) What methodological conclusions and recommendations for the investigation of wetland changes in a landscape can be derived from the study? The sources used for the study included historical maps from the Stable Land Registry 1841, a current orthophoto map (2015), the DIBAVOD database, LPIS [Land-Parcel Identification System] database verification, the Czech Land Registry, and field mapping (2015). Three wetland biotope types were examined: swamps and marshes, waterlogged meadows, and waterlogged woody vegetation. Spatial analysis using GIS tools (intersection, symmetrical difference) was performed to analyse the spatio-temporal wetland changes. The total wetland area has decreased dramatically from 5762 ha (over 9.5% of the territory included in the study) in 1825–1843 to 54 ha (0.9%) in 2014. Extinct wetlands predominate (99.1%) in the area, whilst recent and continuous wetlands are nearly identical (0.5% and 0.4%, respectively). A selected sample of 10 cadastral districts was used to examine the error against the DIBAVOD method and find that the error is relatively low (0.13%). The results of this study document fundamental spatio-temporal changes (expressed through change trajectories) of wetland biotopes at the landscape level in the lowland and hilly areas of the Czech Republic. The most frequent change type is wetland loss in favour of arable land (nearly one-half of all wetlands) due to extensive agricultural management. The use of the DIBAVOD method is effective, taking the relatively low error into account. The results of the study substantially contribute to the development of methods for the investigation of spatio-temporal changes in wetlands and other selected biotopes in the context of the landscape.

1. Introduction

Wetlands play a number of roles in a landscape, mainly non-production ones, such as hydrological and ecological roles, e.g., they help to retain water in the landscape, play a role in the flood protection system and retain sediments, nutrients and pollutants on their way to the river system (Mitsch and Gosselink, 2015; Hattermann et al., 2008; Vymazal, 2001). "Wetlands are also among the most efficient elements in the renewal of the short water cycle in the landscape (Pokorný and Eiseltová, 1998) and often represent the main reduction ecosystem in the landscape owing to their large potential in the conversion of nutrients and other materials (Richardson, 1989; Faulkner and Richardson, 1989).

The location, extent and structure of wetlands in a landscape change over time to a large extent follow changes in the landscape due to natural and, in particular, anthropogenic factors (Forman and Godron, 1986). In the past, the population in the area of today's Czech Republic used wetland biotopes to its advantage without endangering the wetlands or inappropriately affecting their functioning (regular wetland meadow mowing and reed cutting), and also maintained the optimum moisture of the natural wetlands by means of amelioration ditches. This type of management is rare

* Corresponding author.
E-mail address: skalos@fzp.czu.cz (J. Skaloš).

http://dx.doi.org/10.1016/j.ecoleng.2017.06.064
0925-8574/

today, and as a result, wetlands have nearly disappeared from the Czech landscape (except for fishponds and some sites in specifically protected areas) (WPM, 2015).

The favourable role of wetlands (thought to cover from 6 to 10% of the world's land area (Mayer and Turner, 1992)) used to be underestimated and wetland areas were mainly drained for agricultural uses on a worldwide scale, particularly during the 20th century. An estimated 85–95% of wetlands have been lost due to this draining, resulting in a number of adverse environmental impacts (Mayer and Turner, 1992). This trend was present to a lower extent before the 19th century and the first half of the 20th century, when large-extent amelioration projects were implemented. One example refers to the Everglades (Florida, US) subtropical freshwater wetland system, whose historical area was 11,000 km^2. Some 65% of the initial area was drained by the amelioration during the early 20th century, and is primarily currently used for growing sugar cane. The current wetland system assumes 5,000 km^2 (Vymazal, 1999). Today, the adverse impacts are recognised and wetlands are restored and protected (Hattermann et al., 2008). Europe has a long history of changing landscape and its use by the population. A large proportion of wetland area in Central Europe has been converted to agricultural land over the past centuries (Brandt et al., 1999).

In contrast to monitoring changes in land use/cover (LULC), studies devoted to changes in wetlands are not common. The status of European wetlands and their development due to climatic change were examined by Čížková et al., 2013. The decrease in the occurrence of wetlands in the Czech landscape was documented by, e.g., Trpáková (2013) or by Hamáčková and Vačkář (2015). The 'collapse' in the network of wetlands was analysed by Gimmi et al. (2011) over the past 150 years in the Zürich canton, Switzerland, using old and current topographic maps. Wetland loss due to dramatic agricultural development was one of the major environmental issues in the lowland of Sanjiang, China. A decreasing wetland area and its ecological quality since 1950 in the Sanjiang Plain (north-eastern China) as a result of more extensive agriculture has been demonstrated by Huang et al. (2010).

Zhao et al. (2010) studied wetland landscape changes in the Pearl River mouth from 1979 to 2009 and investigated the spatio-temporal changes of different categories of wetlands. Wetland degradation maps have been set up based on the analysis, which was performed periodically every 5 years. The results show that the total wetland area in the region decreased by one-quarter (4598 km^2), with over 50% of built-up areas being on former wetland. Zhang et al. (2011) analysed dynamic characteristics of the wetland landscape arrangement and examined the development patterns and control factors of wetland landscape arrangement. An overall wetland area increase was observed from 1984 to 1996, followed by a decrease from 1996 to 2006. Zhao et al. (2015) quantitatively investigated wetland landscape fragmentation at the middle reach of the Heihe River. The total wetland area has decreased there by 23.2% over the past 35 years and their fragmentation increased markedly. Sun et al. (2015) assessed 8 wetland areas with respect to their potential for use in the basin region of the Taihu lake; for this, the authors used as a combination of ecology indices (water quality, vegetation cover, aquatic vegetation biodiversity, plant community integrity, stabilisation role, protection and improvement of natural sites, and intensiveness of disturbing anthropogenic activities), economy indices (importance of wetland product extraction, importance of wetland tourism, residential real estate price increase near wetlands), and sociology indices (management operation system integrity, public awareness of wetland protection (Sklenička et al., 2015), public satisfaction, scientific education services and new job creation). Four of these eight studied wetland areas passed this ecological-economic-social interpretation well, whereas the remaining 4 wetland areas emerged as unsatisfactory or very unsatisfactory from the ecological-economic-social interpretation point of view. McCauley and Jenkins (2005) examined the wetlands of Illinois, USA. It is estimated that whilst a 23% area of the state of Illinois (3.2 million out of the 14 million hectares) was covered by wetlands before the arrival of Europeans, an estimated 90% of the wetland area was dried during the period of landscape transformation for agricultural use and for settlement. GIS was employed to estimate the occurrence, density and size of former and existing wetlands. The results say that some 1077 to 4090 former wetlands in that region, i.e. 78.6% to 91.6%, have been drained. Spatial arrangement within the wetlands has changed as well. While a species that had adapted to the landscape formerly had a > 50% chance to reach a different wetland within a 260 m proximity, today the probability of reaching that distance is a mere 7.8% for the same species. Ward et al. (2010) used aerial photographs and the GIS to quantify the wetland biotope structure (i.e. the extent of vegetation emerged) and changes in the use of surrounding soil in the north-eastern region of Illinois (Chicago and suburbs). Subsequently the authors examined the impact of land use changes on the wetland structure and ultimately on the wetland bird population. For the 12 bird populations analysed (e.g. American Coot, Least Bittern, Sandhill crane, etc.), 7 exhibited an appreciable drop, 3 exhibited an insignificant decrease, and 2 exhibited a significant increase. The population decrease could not be explained by wetland loss: in fact, none of the wetlands monitored was destroyed. The rather vigorous construction activities within a radius of 2 km from the wetlands, however, brought about extreme changes in the wetland structure. The wetlands had a tendency to either lose most of their vegetation or become open water basins, or they ranged among dense vegetation stands. Both types of change were unfavourable to many wetland bird species. While current legislation is able to protect wetlands from draining, building activity near wetlands brings about change in their hydrology, resulting in degradation of the sites and the population reduction of some wetland-dependent bird species. Thus far, society has failed to respond to this fact with legislation updates. Minckley et al. (2013) studied desert wetlands (Cienegas) in the Apache Highland Ecoregion at the boundary between Arizona, USA, and Sonora, Mexico. The wetlands host an estimated 19% of endangered bird species within 2% of the regional area. Cienegas is not only a very important sanctuary for native fish, amphibians and plants, but it is also a highly significant site for migratory bird species. The distribution, preservation status and reclamation potential of the Cienegas in this region was investigated. Ninety-seven wetlands were identified but only 46 of them were considered as functioning. The remaining sites were either dry or altered to the extent that their initial environmental role had been lost.

Information on the historical development of wetlands at the landscape level is not only important from the theoretical aspect in order to gain insight into the forces and pressures acting on the changes of the wetland biotopes, but also as inspiration for wetland restoration in the landscape: in fact, historical understanding of wetland formation and dynamics is a basic precondition for implementation of effective wetland management, protection and renewal measures. In addition, the past landscape structure was often better able to play its environmental as well as economic roles than the present landscape structure (Meyer et al., 2015; Trpáková, 2013). At present, the number of activities aim at the rehabilitation of wetlands respecting the increasing awareness of wetland hydrological as well ecological values in multifunctional landscapes. To a large extend, the success of wetland restoration depends on the site selection. Here, the relevant knowledge of historical locations of wetlands based on the precise modelling of former wetland sites in the GIS can play an important role. For example, Trepel and Palmeri (2002) developed an appropriate GIS tool to identify the most suitable areas for a wetland restoration. This system com-