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The impact of manipulating surface topography on the hydrologic restoration of a forested coastal wetland☆

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ABSTRACT

A wetland, converted to agriculture in the mid-1970s, was restored to re-establish a non-riverine wet hardwood forest community in eastern North Carolina. Three surface techniques were implemented during construction to determine their effect on successfully restoring target wetland hydrology. The surface treatments, replicated within a randomized complete block design, were: plugging field ditches without altering the land surface (PLUG), plugging the field ditches and roughening the surface (ROUGH), and plugging the field ditches and removing the field crown (CR). Hydrologic conditions for the restoration and a nearby reference site were evaluated based on three years of monitoring data. Daily water table depths between the restoration and reference were within 11 cm on average. An initial evaluation found inconsistencies of treatment effect between blocks, and an as-built survey later confirmed surface elevations within Block 3 deviated from the intended design and was excluded from further analysis. Water table and outflow conditions for the remaining treatment plots and the reference were evaluated using several hydrologic criteria. The CR treatment was found to produce the wettest surface conditions and exported the lowest volume of outflow. For the majority of criterion considered, CR also produced significantly wetter conditions than the reference. The PLUG and ROUGH treatments produced similar hydrologic conditions and tracked closely with the median hydrologic conditions in the reference. Based on the results of this study and several others in low lying coastal areas, plugging pre-existing field ditches may be adequate to restore jurisdictional wetland hydrology and match reference hydrologic conditions. However, surface roughening is low cost method to increase surface storage and introduce microtopographic diversity. For many areas, the removal of existing field crown may be cost-prohibitive and produce wetter than desired conditions. Crown removal should be reserved for sites which have borderline historic wetland hydrologic characteristics.

1. Introduction

The magnitude of wetland loss and alteration in the U.S. has resulted in measurable negative impacts on habitat and water quality. Therefore, efforts to strategically restore some of these lands back to their natural condition are vital to reclaim damaged or lost ecosystem functions. Approximately 50% of the land in eastern NC originally contained hydric soils, and over 50% of these native wetlands were altered to accommodate other land uses (Cashin et al., 1992). The majority of these wetland alterations occurred to enhance agricultural production, and were achieved through land clearing, installation of subsurface drainage systems (comprised of open ditches or subsurface drains), and smoothing and crowning of soil surfaces to improve surface drainage (Lilly, 1981). This type of artificial drainage, while necessary for agricultural production in many parts of the country, has also resulted in environmental consequences. Studies have found that drainage from agriculture drainage increases peak runoff rates as much as 300–400% (Skaggs et al., 1980) and can lead to a 10-fold increase in nitrate (NO_3–N) losses (Skaggs et al., 2005). In addition to NO_3–N, agricultural drainage is also linked to increased exports of phosphorus and suspended solids (Skaggs et al., 1980).

The goal of wetland restoration/creation is to successfully establish a system that exhibits the same structure and beneficial functions as a targeted wetland community in the most efficient manner possible. Inappropriate designs or inefficient implementation can result in restorations that are too expensive and fall short of achieving target ecosystem services. In a survey of practitioners,

☆ *Disclaimer*: The views presented in this paper are those of the authors and do not necessarily represent the views of the US Army Corps of Engineers.

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Holman and Childres (1995) estimated that 40–50% of wetland restoration problems were simply due to poor site selection.

Achieving appropriate hydroperiod is a major component in successful wetland restoration. A wetter site is not always better, since many natural wetlands alternate seasonally between dry and wet conditions. This is a major reason that at least one and preferably multiple reference wetlands should be identified prior to restoration to determine the target hydroperiod.

To restore wetland hydrology on lands drained for agricultural practices, ditches that were installed must be plugged to reduce drainage from the site. However, Tweedy and Evans (2001) showed that simply plugging ditches may produce conditions that are drier than the targeted wetland community. This is especially true on sites that, prior to artificial drainage, may have only marginally satisfied the U.S. Army Corps of Engineers (USACE) jurisdictional hydrologic criterion (i.e. the water table within 30 cm of the surface continuously for more than 5% of growing season (USACE, 1987)). Removing the field crown and adding microtopography (defined here as slight ridges and depressions along the soil surface) in addition to ditch plugging may improve the chances of meeting wetland hydrology requirements, but it does increase costs. Currently, the U.S. Department of Agriculture – Natural Resources Conservation Service recommends implementing varying levels of microtopography to promote not only hydrologic but habitat diversity (NRCS, 2003). Several studies support this restoration technique because it can increase stormwater storage, prolong surface moisture during dry periods, provide more diverse habitat and vegetation, improve microbially mediated nutrient cycling and removal, and promote more overall ecosystem heterogeneity common in natural wetlands (Smith et al., 2012; Ahn and Dee, 2011; Courtwright and Findley, 2011; Simmons et al., 2007, 2011; Wolf et al., 2011; Alsfeld et al., 2009; Moser et al., 2009). Despite these existing studies, there is a lack of data that strongly supports a particular treatment practice for maximizing appropriate wetland hydrologic characteristics across entire restoration sites.

This paper describes how various types of soil surface alterations affected wetland hydrology at a 100 ha forested wetland restoration in eastern North Carolina. In an effort to build on earlier results from research conducted by Wright et al. (2006), field monitoring at the restoration site was intensified to ultimately develop improved recommendations and guidance for future coastal wetland restorations. Goals of this study were to determine (1) differences in hydrologic response of various soil–surface manipulation techniques, (2) how much surface manipulation was required to produce hydrologic conditions within a range of reference hydrologic conditions, and (3) what degree of surface manipulation would be considered optimum for producing acceptable hydrologic conditions at minimal restoration costs. It was hypothesized that roughening the surface and creating microtopographic features similar to those found in natural wetlands would be ideal for achieving hydrologic conditions found in a reference wetland. It was further hypothesized that simply plugging the ditches would produce the driest conditions because the intact field crown and smooth soil surface would result in more rapid surface drainage, while field crown removal would produce the wettest conditions due to the decreased surface flow gradient. Several hydrologic indicators and metrics were used to provide an extensive evaluation of the hydrology at the restoration site because of annual and seasonal climactic variations. A secondary goal was to demonstrate how these metrics might be applied to hydrologic assessments for future wetland restorations.

2. Materials and methods

Field-scale studies were conducted at a coastal wetland restoration site located in Carteret County, North Carolina (Fig. 1). The 2400 ha site was artificially drained for agricultural row crop production in the 1970s before being acquired by the NC Coastal Federation for the purpose of restoration in 2002. Ditches were typically spaced at 100 m intervals and dug to 1 m depth, while fields were crowned by about 20 cm. Drainage water from the site discharged south into the North River estuary, an area important to the local shellfishing industry. The overall goals of the project were to restore hydrologic function, increase wetland habitat, and improve downstream water quality.

The first of multiple phases of the project included hydrologic restoration of 100 ha of cropland to a non-riverine wet hardwood wetland ecosystem. This ecosystem is described as hardwood forest located on broad inter-stream flats with poorly drained mineral soils, and are common in the lower coastal plain of NC (Schafale and Weakley, 1990). Completed in 2003, Phase I included placement of earthen plugs in field ditches and installation flashboard risers to control water table levels and outflow. Wetland features such as 0.1 ha open water areas and simulated tree falls (about

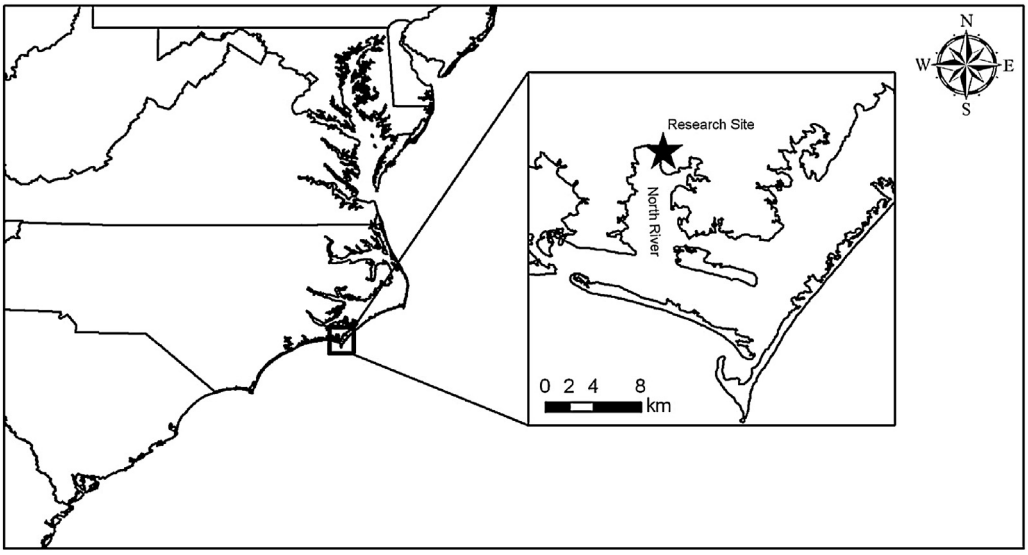

Fig. 1. Vicinity map of the restoration site in Carteret County, NC.