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Applying geospatial tools to assess the agricultural value of Lower Illinois River floodplain levee districts

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ABSTRACT

During the 1920's, Illinois River levees became increasingly difficult for private landowners and the state to maintain as commodity prices fell and flood levels increased. However, the 1928 U.S. Flood Control act shifted a substantial portion of the burden of flood mitigation from local landowners to the federal government, preventing the dissolution of levee districts. While these levee systems have facilitated floodplain agricultural production and development for the last century, disconnecting the river from its floodplain has led to concerns about the negative impacts of levees on the physical and biological systems of the Illinois River Valley. Recent studies have emphasized approaches that would result in setting back or removing levees in order to naturalize portions of large river-floodplain systems, including the Illinois. The costs and benefits of such projects along the Illinois have shown potential restoration benefits may outweigh potential costs, but these studies have not demonstrated the specific levee districts which have the highest reconnection potential from an economic standpoint. This study uses geospatial methods to fill this gap by assessing the National Commodity Crops Productivity Index (NCCPI) soil values and agricultural production and profit values for corn and soybeans in 32 individual levee districts along a 235-km segment of the Lower Illinois River. In general, soil productivity index values were lower for Illinois River levee districts compared to the county averages in which the districts are located. Over the five-year study period from 2010 to 2014, the total agricultural profits in the levee districts ranged from $18–61 million. Several levee districts have relatively low per hectare agricultural values when compared to the value of wetland benefits, indicating these protected floodplain areas may be more suitable for reconnection.

1. Introduction

Recent research has focused on the rehabilitation of river-floodplain systems in order to improve the respective systems' hydrology and hydraulics, which consequently reduces flood risk, while also improving river-floodplain ecosystem health and increasing environmental benefits (Dierauer, Pinter, & Remo, 2012; Guida, Swanson, Remo, & Kiss, 2015; Jacobson, Lindner, & Bitner, 2015; Opperman et al. 2009; Remo, Carlson, & Pinter, 2012). However, such broad projects that prioritize environmental benefits often overlook the true costs beyond those to urbanized or built environments and structures. As such, there is a need to assess the tradeoffs that may accompany the potential benefits of floodplain reconnection. This study aims to quantify the agricultural benefits that would be lost by reconnecting levee districts to the Lower Illinois River (LIR), a river segment that has been recommended for potential levees setbacks and removals in order to naturalize river-floodplain function (Akanbi, Lian, & Soon, 1999; Sparks et al. 2005). This naturalization would restore the hydrologic function between the river and floodplain.

Natural floodplains have high biodiversity and ecosystem service values due to the complex aquatic and terrestrial relationships that species have adapted to over time (Costanza et al. 2014; Tockner, Lorang, & Stanford, 2010). Worldwide, many rivers have been disconnected from their floodplains, permanently altering their hydrologic, hydraulic, and ecological systems and the services they provide. Specifically, the installation of levees and/or floodwalls along many of these systems have disrupted or even eliminated lateral connectivity from rivers to their floodplains. This

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disconnection prevents the exchange of water, nutrients, and biota access during seasonal pulses of high flows (Junk, Bayley, & Sparks, 1989; Poff et al. 1997; Richter, Mathews, Harrison, & Wigington, 2003). Strategic reconnection of rivers to their floodplains offers a set of tradeoffs (e.g., agricultural production vs. improved water quality and reduced flood risk) while potentially increasing long-term floodplain ecosystem service benefits and decreasing long-term flood mitigation costs (Guida et al. 2015; Opperman et al. 2009).

Reconnection of floodplains through levee setbacks and/or removal has been shown to restore ecosystem services and was also ranked highly as a floodplain rehabilitation option by large river managers (Gilvear, Spray, & Casas-Mulet, 2013; Schindler et al. 2014). Further, as floodplain development continues behind levees, the benefits of levees increase, but so too do the potential damages (Remo et al. 2012). Along the Illinois River, several floodplain reconnection scenarios have been modeled and demonstrated that selectively allowing some levee districts to flood may reduce flood levels along the whole reach, thereby reducing risk to others that may be prioritized for protection (Akanbi et al. 1999). However, more research is needed to address the potential costs and risks associated with reconnection proposals along the Illinois (Akanbi et al. 1999; Sparks et al. 2005). Such research would lead to more realistic assessments of floodplain restoration costs and benefits which are necessary to make more informed management and policy decisions on the tradeoffs between the value of levees for flood-loss mitigation and the other services (e.g., wetland benefits) that reconnected floodplains may provide (Brouwer & van Ek, 2004; Guida et al. 2015; Jacobson et al. 2015; Jonkman, Bočkarjova, Kok, & Bernardini, 2008; Prato & Hey, 2006).

These wetland benefits and ecosystem services have been evaluated in several studies. Woodward and Wui (2001) determined that the mean benefit value of wetlands across 39 studies was between $915/ha and $986/ha (in 1990 US$). Brander, Florax, and Vermaat (2006) analyzed 191 wetland valuation studies, resulting in a mean value of wetland services of $2800/ha (1995 US$). Perhaps most relevant to the Illinois River since it is a tributary to the Mississippi River, Jenkins, Murray, Kramer, and Faulkner (2010) placed the market value of three ecosystem services for forested wetlands in the Mississippi River Alluvial Valley at $1035/ha (2008 US$). However, the potential costs of restoring floodplains to produce these environmental benefits have not been well quantified.

Thus, despite the recent interest in the tradeoffs in services provided by leveed versus non-leveed floodplains (e.g., Dierauer et al. 2012; Prato & Hey, 2006; Remo et al. 2012; Sparks et al. 2005), to the best of our knowledge, no existing study quantifies the full agricultural production value of individual levee districts along a specific river reach or segment. These finer-scale cost estimates are necessary and valuable in providing a more robust picture of floodplain areas which, if reconnected and taken out of production, may yield higher benefits with minimized buyout costs. This study fills this need by: (1) providing a robust methodology to assess the full agricultural production value of levee districts along the Lower Illinois River; (2) using soil productivity values, reported corn and soybean yields, crop prices, and total non-land use costs to calculate revenue and profits for 32 LIR levee districts over the last five years (2010–2014); and (3) comparing the five-year average per hectare agricultural value of the levee districts to previous wetland benefit valuation studies. The methods for assessing the agricultural value of floodplains in this study are likely to be broadly applicable to other agricultural restoration projects.

2. Study area

The single-thread, meandering Illinois River forms at the confluence of the Des Plaines and Kankakee Rivers and flows 440 km to its outlet at the Mississippi River at Grafton, IL (Fig. 1). Draining over 75,000 km^2, 85% of the Illinois River Basin (IRB) is located within the state of Illinois with portions of the basin extending into southeast Wisconsin and northwest Indiana. Referred to as the Lower Illinois River (LIR) throughout, the study reach extends 235 km from just downstream of Peoria, IL (River mile 156) to 25 km above the Mississippi River confluence (Fig. 1). Both the LaGrange Pool and the Alton Pool, named for the dams that create the upstream pools, are within the study reach, which contains 37 total levee districts that protect 98,000 ha of land from flood events up to the 100-year flood recurrence interval (Fig. 1; see SAST, 1995 for levee flood-protection levels).

2.1. Historical alterations

Like many rivers in developed countries, human alteration of the Illinois River began in the 19th century. The first substantial human alteration to the hydrology of the Illinois River was the construction of the Michigan Canal in 1836, which linked the River to Lake Michigan and permanently increased its natural flow by 14 m^3/s (Lian, You, Sparks, & Demissie, 2012). Construction of levees and drainage of the floodplain started in the late 19th century in order to facilitate agricultural production in the Illinois River Valley. However, extensive hydrologic alteration was not documented until the Chicago River's flow was reversed, allowing it to empty into the Illinois River in 1900 (Lian et al. 2012). By 1915, the majority of floodplain wetlands had been drained with nearly 80% of the present-day levee and drainage districts already in place along the Lower Illinois (Thompson, 2002). No new districts were built post-1922, and many of the existing drainage and levee districts were overtopped and inundated by floods in 1922 and 1926–27. Coupled with falling commodity prices, state and local investors struggled to maintain the Illinois River levee districts. With the passage of the U.S. Flood Control Act in 1928, large-scale non-federal levee construction along the Illinois River came to an end (Thompson, 2002).

In the following decades, other federal projects continued to alter the hydrology, hydraulics, and morphology of the Illinois River. The most substantial of these federally-backed alterations was the construction of seven locks and dams between 1933 and 1939. The purpose of these locks and dams was to maintain a federally-mandated 2.7-m navigational depth (Lian et al. 2012). However, unlike many of the locks and dams elsewhere on the Mississippi River System, the navigation dams on the Lower Illinois are wicket dams, which are only raised during low flows to maintain the 2.7-m navigation channel (Sparks et al. 2005). The operation of the wickets controls water levels, and consequently, the riparian vegetation regime and ecological function. Though the operation of these dams generally only changes the water levels by ~3 m at a given dam, on the low-gradient Illinois River that can translate into tens of kilometers of additional floodplain inundation upstream of these structures (Sparks et al. 2005).

Post-1938, flood heights have continued to increase as a result of levee and dam construction and sedimentation on the confined floodplain (Bhowmik & Demissie, 1989; Lian et al. 2012), prompting calls for a change to the status quo of continuing to raise levees to provide flood protection along the Illinois (Prato & Hey, 2006; Sparks et al., 1998, 2005; Sparks & Braden, 2007). Additionally, the U.S. Army Corps of Engineers (USACE) identified multiple priority ecosystem restoration areas along the Illinois River as part of its *Upper Mississippi River System Ecosystem Restoration* plan