Geomorphology xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Geomorphology

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

Anthropogenically accelerated sediment accumulation within playa wetlands as a result of land cover change on the High Plains of the central United States

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ARTICLE INFO

Article history:
Received 23 November 2016
Received in revised form 20 February 2017
Accepted 20 February 2017
Available online xxxx

Keywords:
Accelerated sedimentation
GIS
Grass buffers
Kansas High Plains

ABSTRACT

Playa wetlands are ubiquitous features of the central and southern Great Plains, and in Kansas alone, there are > 22,000 playas. Consequently, playas are critical wetland resources for the region, providing a range of ecosystem functions, such as groundwater recharge, surface water storage, and wetland habitat. Anthropogenically accelerated sediment accumulation is the primary impact reducing playa ecosystem functions. Objectives of this study were to estimate the amount of recent sediment accumulated within playas, determine how watershed and playa morphometry and land cover influenced sediment accumulation, and assess the role of grass buffers in reducing sediment accumulation. Land surveys and sediment thickness measurements were conducted throughout 64 Kansas playas with watershed cropland ranging from 0 to 100% and grass buffers ranging from nonexistent to continuous to a width of ≥30 m. Results indicate watershed and playa morphometry have minimal influence on recent sediment accumulation within playas, and land-cover change is the primary driver. Playas without grass buffers within cropland watersheds on average accumulated 8.5 cm of recent sediment and lost 30% volume of storage capacity, while those with grass buffers in mixed cropland watersheds accumulated an average of 1.8 cm of recent sediment and lost 7% volume. Playas within grassland watersheds on average accumulated 2.3 cm of recent sediment and lost 13% volume. Grass buffers, while rarely utilized, could be highly effective at reducing the impacts of anthropogenically accelerated sediment accumulation and protecting playa ecosystem functions. Without grass buffers, anthropogenically accelerated sediment deliveries will continue to accumulate within playas, greatly reducing ecosystem functions, and, ultimately, many playas will disappear from the landscape.

1. Introduction

Playa wetlands are typically relatively small, quasi-circular, ephemeral, depressional wetlands found within semi-arid and arid watersheds around the world (Fig. 1) (Goudie and Wells, 1995; Sabin and Holliday, 1995). They are ubiquitous features of the central and western Great Plains, particularly the High Plains regions of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, and Texas. Nearly 90,000 playas are included in the Playa Lakes Joint Venture "Maps of Probable Playas" geodatabase (http://pljv.org/for-habitat-partners/maps-and-data/maps-of-probable-playas/). In the State of Kansas alone, there are > 22,000 playas, with the majority distributed throughout the High Plains of western Kansas (Fig. 2) (Bowen et al., 2010). Consequently, playas are critical wetland resources for the region, providing a range of essential ecosystem services including groundwater recharge, surface water storage, wetland habitat, biodiversity, flood mitigation, sediment and pollutant filtering, and nutrient cycling (Smith et al., 2011).

Playas occupy the lowest elevation within internally drained watersheds and accumulate sediment eroded from the surrounding watershed as well as regional dust. Transport in overland flow is the primary mechanism delivering recent sediment to playas (Luo et al., 1999), and sediment is removed from playas only by aeolian deflation. Prior to cultivation, playas existed on the landscape for thousands of years (Holliday et al., 1996, 2008; Bowen and Johnson, 2012, 2015), maintaining a quasi-equilibrium between sediment accumulation, soil formation, and deflation. Over the past century, however, conversion of significant portions of the landscape from short-grass prairie to cultivated cropland has accelerated the rates of sediment accumulation within playas (Luo et al., 1997). Accumulated sediment can reduce wetland biodiversity, habitat value, and surface-water availability, increase nutrient and pesticide delivery to playas and evaporation of water from playas (Tsai et al., 2010; Smith et al., 2011), and can potentially result in the total disappearance of the playa from the landscape (Luo et al., 1997; Johnson et al., 2012). Anthropogenically accelerated sediment accumulation is the greatest threat to playas (Smith, 2003). Linking recent sediment accumulation in playas to site- and landscape-scale variables, such as watershed and playa morphometry, watershed land cover, and

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http://dx.doi.org/10.1016/j.geomorph.2017.02.017
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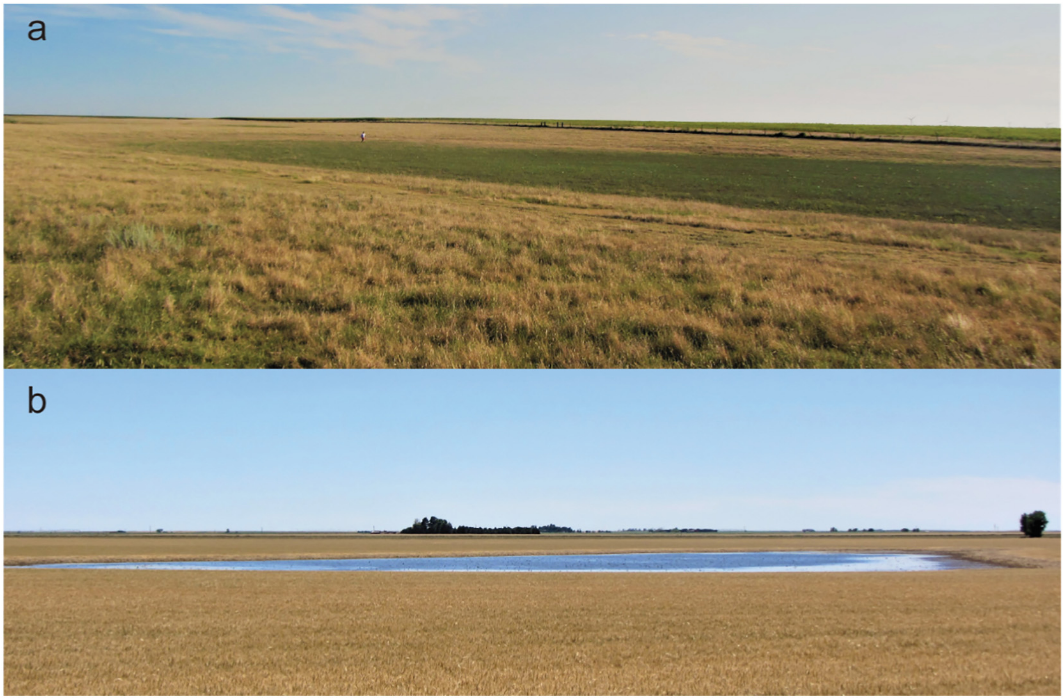

Fig. 1. (a) Ground-view of the northern two-thirds of an approximately 150 m long and 70 m wide grassland playa with distinct vegetation composition visible; (b) ground-view of an approximately 80 m wide cropland playa storing water and completely surrounded by wheat.

playa grass buffer conditions is essential to provide a robust model to assess impacts to playa ecosystem functions.

A growing body of research addresses the role of land cover as it relates to anthropogenically accelerated sediment accumulation within playas (Luo et al., 1997, 1999; Tsai et al., 2007, 2010; Johnson et al., 2012; O'Connell et al., 2013; Daniel et al., 2014; Gitz et al., 2015; Tang et al., 2015), but to date, only one playa-sedimentation study has been completed in Kansas (O'Connell et al., 2013). Additionally, the impacts of long-term land-cover change (i.e., change that persists for decades) on playa sedimentation rates and processes has been largely overlooked.

Planting and maintenance of grass buffers can be used as a management technique to reduce the amount of sediment delivered to a playa as a result of increased erosion due to cultivation within the watershed. Little research has been done, however, assessing the effectiveness of grass buffers as a playa management technique (Skagen et al., 2008), and grass buffers are rarely used to protect playas (Johnson et al., 2012). The most effective width of grass buffers needed to control playa sedimentation is not well understood, with recommendations ranging from <1 m to 300 m, depending upon site conditions (Melcher and Skagen, 2005). On the southern High Plains, playa-focused biologists have recommended buffer widths of 30–90 m, but that range of widths is based on "best judgement" (Smith, 2003). Haukos et al. (2016) recently determined that buffers with at least 80% vegetation cover and a width of 30–60 m were effective at removing >80% of the sediment load in runoff, while still allowing runoff to reach the playa. As such, grass buffers could be an effective and economical management technique targeted at a small portion of a cultivated watershed to protect playas from the effects of anthropogenically accelerated sediment erosion. The Conservation Reserve Program (CRP) has likely had the greatest influence on enhancing playa grass buffers by converting cropland areas susceptible to erosion to grassland (Smith et al., 2011). The CRP is a U.S. Department of Agriculture voluntary land conservation program in which farmers receive a payment for removing environmentally sensitive land from agricultural production. The Non-Floodplain Wetlands Initiative (CP-23A) is a practice within the CRP with a specific emphasis on reducing cropland within and surrounding playas for at least 10–15 yr periods (USDA Farm Service Agency, 2011).

The objectives of this study were to: (1) estimate amount of recent sediment accumulated within playas, (2) determine how watershed and playa morphometry and land cover influenced recent sediment accumulation, and (3) assess the role of grass buffers in reducing sediment accumulation. Accordingly, the project consisted of: (1) calculating watershed morphometric variables; (2) calculating playa morphometric variables; (3) determining recent sediment thickness and volume in playas and percent playa volume currently occupied by stored sediment; and (4) measuring the amount of grassland and cropland within associated watersheds, within a 30 m buffer surrounding playas, and within playas.

2. Regional setting and methods

2.1. Regional setting

The Kansas section of the High Plains physiographic region encompasses portions of at least 30 counties in the western third of the state and contain >21,000 playas (Bowen et al., 2010) (Fig. 2). Playas occupy a region characterized by a climate that is semi-arid in the west and dry sub-humid to the east (Veregin, 2005). Native plant communities were composed of dense stands of short-grasses such as blue grama (*Bouteloua gracilis*) and buffalo grass (*Bouteloua dactyloides*) (Küchler, 1974). Kansas is currently one of the leading agricultural states in the nation, and the state's most agriculturally productive counties are located on the High Plains (Kansas Department of Agriculture, 2015). As a result, little native vegetation remains.

2.2. Study area

This research focused on 64 playas and their watersheds distributed throughout ten counties on the High Plains of Kansas (Fig. 2). These sites were selected from the Kansas Playa Wetlands geospatial database (Johnson et al., 2009) available from the Kansas Data Access and Support Center (DASC; www.kansasgis.org). Specifically, the sites were