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Influence of changes in developed land and precipitation on hydrology of a coastal Texas watershed

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ABSTRACT

Freshwater inflows, among the most important factors in the overall health of estuarine environments, can be altered both by regional climatic influences as well as changes in land use and land cover. We conduct a scenario analysis to study the individual and combined impacts of changes in land use and land cover and in precipitation patterns in a coastal Texas watershed. The watershed is one of the major sources of freshwater for the estuarine area within the Mission-Aransas National Estuarine Research Reserve (NERR). Our scenario analysis suggests that climatic changes are more influential than land changes at the watershed level. However, localized impacts of land change may still be significant on habitats within the NERR site. Results from our watershed-level analysis poorly agree with the recommended freshwater flows established for the region, which deserve further scrutiny. Our findings suggest that geomorphic characteristics of the streams in the watershed need to be taken into consideration in hydrological modeling. Further research on the interactions between land change and hydrological dynamics should also aim for tighter temporal integration of the two sets of processes.

Introduction

Freshwater inflows are among the most important factors in the overall health of estuarine environments (Estevez, 2002; Martin, 1987). They are important not only as sources of freshwater but also because they are major drivers of salinity gradients, sedimentation rates, and nutrient delivery (Chen, 2010). Several natural and anthropogenic factors, through their impact on the hydrologic cycle, can alter the volume and timing of freshwater delivery and its chemical and sediment loads to coastal ecosystems (Scavia et al., 2002). In particular, regional climate and land use interact in complex ways to modify hydrology and water quality (Nearing et al., 2005; Praskievicz & Chang, 2009).

Chang (2004) simulated hydrologic impacts from climate change and land-use change both individually and interactively; he found that the precipitation signal is the dominant driver of surface water flows and nutrient loadings. Franczyk and Chang (2009) and Praskievicz & Chang (2011) also noted similar sensitivities to the amount of precipitation within a set of watersheds in northwest Oregon. Changes to seasonal precipitation are inferred to be the principal factor of hydrologic impacts within predominantly rainfed basins (Lee & Chung, 2007; Nelson et al., 2009; Praskievicz & Chang, 2011; Tong, Sun, Ranatunga, He, & Yang, 2012). However, land change due to urbanization, in particular replacing vegetation with impervious surfaces, can also impact the hydrology. Expansion of impervious surfaces reduces infiltration and results in greater amounts of rainfall to be converted to surface runoff that washes out sediment and pollutants stored within watersheds to receiving water bodies (Haase, 2009; Peel, 2009).

Coastal areas can especially be vulnerable to issues associated with the transformation of land surfaces and climatic change (Klein & Nicholls, 1999; McGranahan, Balk, & Anderson, 2007). In Texas, estuaries, bays, and drainage basins upstream from these marine water bodies provide habitat for several fish and bird species of commercial and recreational value (Chen, 2010). The Mission-Aransas (M-A) region on the coastal bend of Texas, in particular, contains habitats in its bays and estuaries that are vital for fisheries and for several endangered species (Beyer, Rasser, & Morehead, 2007). These habitats are especially sensitive to changes in land use/land cover (LULC) within the drainage basins upstream (Evans, Madden, & Morehead, 2012, pp. 183).

To address questions and concerns associated with estuarine environments in the M-A Coastal Region, Mission-Aransas National Estuarine Research Reserve, the M-A NERR, was established in 2006 (Evans et al., 2012, pp. 183; NERRS, 2012). One of the objectives of the M-A NERR management plan is to understand how changes in

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LULC and climate could impact the quantity and quality of freshwater inflows to the M-A estuarine system (UTMSI, 2006). Regional freshwater inflow estimates and recommendations for the Mission-Aransas system have been established (Chen, 2010; Schoenbaechler & Guthrie, 2011), but there is a lack of knowledge on how land-use/land-cover change (LULCC) and precipitation trends in the drainage basins that drain into the M-A estuary, could impact freshwater inflows and their associated sediment constituents. This knowledge would provide useful information for adaptive management of the coastal and estuarine environment.

In this study, we investigate the relative influence of future changes in developed land and precipitation on freshwater inflows and their associated sediment loads to the M-A estuarine system. To this end, we focus on the Lower Aransas River Basin (LARB) that drains into Copano Bay, part of the M-A NERR. We ask two specific questions:

(1) How did freshwater inflows and their associated sediment loads from the LARB into the M-A estuary change from 1972 to 2010?

(2) How will freshwater inflows and their associated sediment loads from the LARB into the M-A estuary change from 2010 to 2040 under various scenarios of changes in developed land and precipitation patterns?

Materials and methods

Study area

The Lower Aransas River Basin (LARB) lies on the M-A Coastal Region of Texas just north of Corpus Christi that makes up the lower portions of the Aransas River Basin (Fig. 1). The LARB has an area of 1384 km^2 and it occupies ∼62% of the total Aransas River Basin area. The lower Aransas River (∼73 km), one of the two major rivers that deliver freshwater into the M-A NERR, is the principle river in the drainage basin and one of the few rivers in Texas that is not obstructed by dams (Schoenbaechler & Guthrie, 2011). The Aransas River has a highly meandering course within the coastal plain. Major tributaries to the

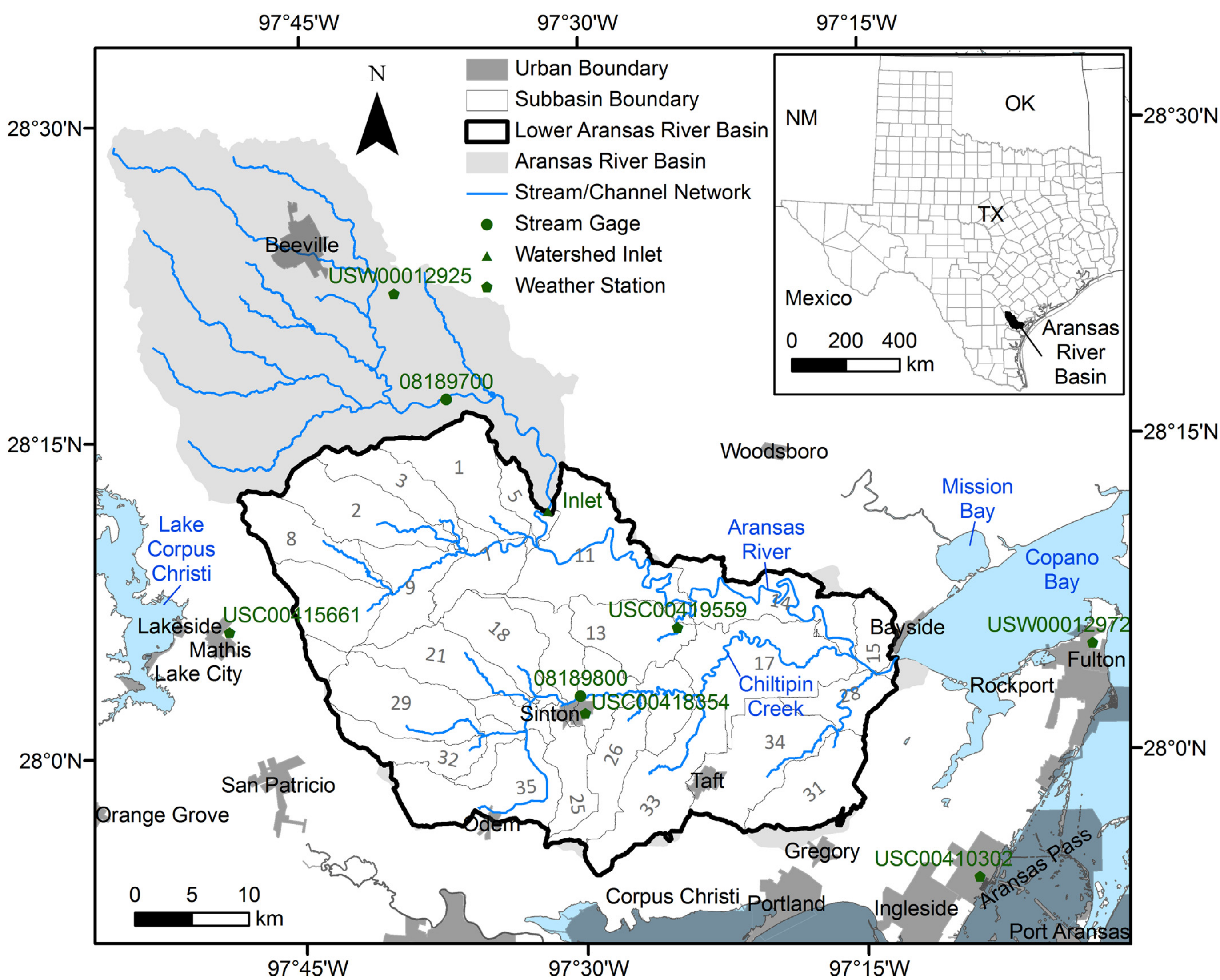

Fig. 1. Location map of the Lower Aransas River Basin (LARB) (delineated with ArcSWAT); Aransas River Basin (ARB) (HUC: 12100407); stream/channel network (National Hydrography Dataset and ArcSWAT delineation); stream gaging stations (U.S. Geological Survey); weather stations (National Climatic Data Center); and urban boundaries (Texas Natural Resources Information System: StratMap).