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Impacts of Land Change on Ecosystem Services in the San Antonio River Basin, Texas, from 1984 to 2010

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ABSTRACT

The San Antonio River Basin (SARB) is an ecologically diverse region in South Texas. The city of San Antonio is located within the basin and is the hub of the North American Free Trade Agreement (NAFTA). San Antonio, together with other major metropolitan centers in Texas, has experienced rapid population and economic growth over the last thirty years, which accelerated after the implementation of NAFTA in 1994. To assess the environmental implications of this growth in the SARB, we first conducted a land-change analysis using Landsat images from 1984, 1995, and 2010. Then, we analyzed spatiotemporal changes in ecosystem services across the SARB and within three watersheds in Bexar County where the city of San Antonio is located. To estimate changes in ecosystem service values (ESV) during this period, we combined the results of the land-change analysis with a benefit transfer approach using two sets of widely cited ecosystem-service valuation coefficients published in 1997 and 2014 but we modified the urban coefficient from the 2014 publication for low-density and high-density urban areas. When 1997 coefficients were applied, the ESV in the SARB decreased, on average, by $1.2 million/year during 1984–1995 and by $1.8 million/year during 1995–2010. The ESV in Bexar County decreased, on average, by $0.5 million/year and $0.7 million/year during the first and second periods, respectively. When the 2014 coefficients and modified urban value coefficients were applied, the ESV in the SARB decreased, on average, by a 27% more during the first period than when the 1997 coefficients were applied, while, ESV increased during the second period by an average of $2.2 million/year. This temporally opposite trend in ESV change did not occur in Bexar County, however. Using the 2014 coefficients, ESV in Bexar County decreased 5 times more during the first period and decreased 2.5 times more during the second period than when 1997 coefficients were applied. The differences in ESV trends resulting from the two sets of coefficients can be explained primarily by the different coefficients assigned to urban spaces ($0/ha/year in the 1997 study and $7005/ha/year in the 2014 study). Our results suggest that the value placed on urban areas in the 2014 publication, taken from a single case study and intended primarily for large urban parks, substantially overestimates the ESV of urban space. In our study areas, applying this value, even only to urban green space, led to the improbable conclusion that urbanization had a positive overall effect on the delivery of ecosystem services. While open spaces in urban areas do provide valuable ecosystem services, it is highly unlikely that their value exceeds those provided by less modified ecosystems. The ability to confidently use value coefficients when applying benefit transfer methods to estimate ESVs demands rigorous assessments of their broad applicability.

1. Introduction

A recent global assessment highlighted how massive urbanization is negatively impacting biodiversity and ecosystems around the world (Elmqvist et al., 2013). In particular, urban land expansion is one of the primary factors that affect the services humans derive from ecosystems (Millennium Ecosystem Assessment, MEA, 2005; Intergovernmental Panel on Climate Change, IPCC, 2007; Grimm et al., 2008). In the US where more than 80% of the population resides in urban areas, high rates of urban growth in the last several decades have led to various impacts on ecosystem services (Alberti, 2005; U.S. Census Bureau, 2010). Texas is one of the few states in the country where rapid urban growth is still prevalent. Over the past few decades, the state has experienced the largest increase in impervious surface cover in the US (Xian et al., 2011) concentrated around its three largest cities (Houston, San Antonio, and Dallas), which are among the ten

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largest US cities by population. Beyond these aggregate estimates, however, there is little understanding of how the growth of urban areas in the state impacted biodiversity and ecosystems.

A major challenge in reducing the detrimental effects of economic development and urbanization on functional ecosystems is that many of the services these ecosystems provide are non-market public goods and, thus, economic values are poorly understood (Costanza et al., 2014; McDonald et al., 2014). The rationale for establishing ecosystem service values (ESVs) is to assess the contribution of these services to the sustainable, equitable and efficient use of ecosystems (Costanza and Folke, 1997). Additionally, establishing ESVs provides a useful approach for comprehensively evaluating tradeoffs among alternative land uses (Ingraham and Foster, 2008; de Groot et al., 2012).

The San Antonio River Basin (SARB) in south central Texas contains the rapidly urbanizing San Antonio Metropolitan Statistical Area. The city of San Antonio is the seventh most populous city in the US (U.S. Census Bureau, 2015) and a trade center of the North American Free Trade Agreement (NAFTA) (Brookings Institution, 2013). Since NAFTA was enacted in 1994, trade between the United States, Mexico, and Canada has grown significantly and reached $2.3 trillion in 2012. Bilateral trade between the United States and Mexico comprised 70% of this amount and increased 5-fold between 1993 and 2012 (U.S. Diplomatic Mission to Mexico, 2013). Currently, Mexico is the top country of origin for Texas imports (U.S. Census Bureau, 2016).

The population in the SARB has increased nearly 70% in the last 30 years due primarily to the economic growth in Bexar County, in which San Antonio is located. It is expected that the population will reach about 2.8 million by 2060, which would represent a 94% increase since 2000 (Texas Water Development Board, TWDB, 2011). Compared to a 1.63% annual population growth rate in Bexar County during the 10-year period leading up to the inception of NAFTA, the growth rate between 1994 and 2010 increased to approximately 1.90% per annum (Texas State Library and Archives Commission, TSLAC, 2015). Land change in this region has been associated to a large degree with the development of public transportation network and the NAFTA corridor including Interstate Highway (IH) 10, IH 35, IH 37, US Highway 281, and State Highway loop 1604. Among these highways, IH 35 represents the major freight road connecting San Antonio to Laredo and other southern border areas (Texas Department of Transportation, TxDOT, 2013).

Kreuter et al. (2001) investigated the impact on ESVs of urban expansion between 1976 and 1991 in Bexar County by combining land-change analysis with ecosystem services value coefficients provided by Costanza et al. (1997). They identified a 65% decrease in rangeland, 29% growth in urban areas and $6.24 million loss in ecosystem services within the county over the 15-year study period. In another study, American Forests (2002) estimated changes in forests and associated ESVs in the San Antonio region between 1985 and 2001. This study identified a 39% decrease in the woodlands with more than half canopy cover, which negatively affected storm water management and air quality, and boosted energy consumption. Beyond these two studies in Bexar County, no studies have been conducted in the SARB to evaluate the effects of population and economic growth on land and associated ecosystem services. This represents a critical knowledge gap for evaluating economic growth of the region in a larger context that incorporates potential effects on the provision of ecosystem services.

This study focuses on the SARB and Bexar County because of their central location in the corridor that has been the most affected by the implementation of NAFTA, with the City of San Antonio being a key trade center for this multinational agreement. In our study, we specifically examined the effect of land change on the ESVs in the SARB between 1984 and 2010. We repeated this analysis on the three watersheds that cover most of Bexar County, which was the focus of the

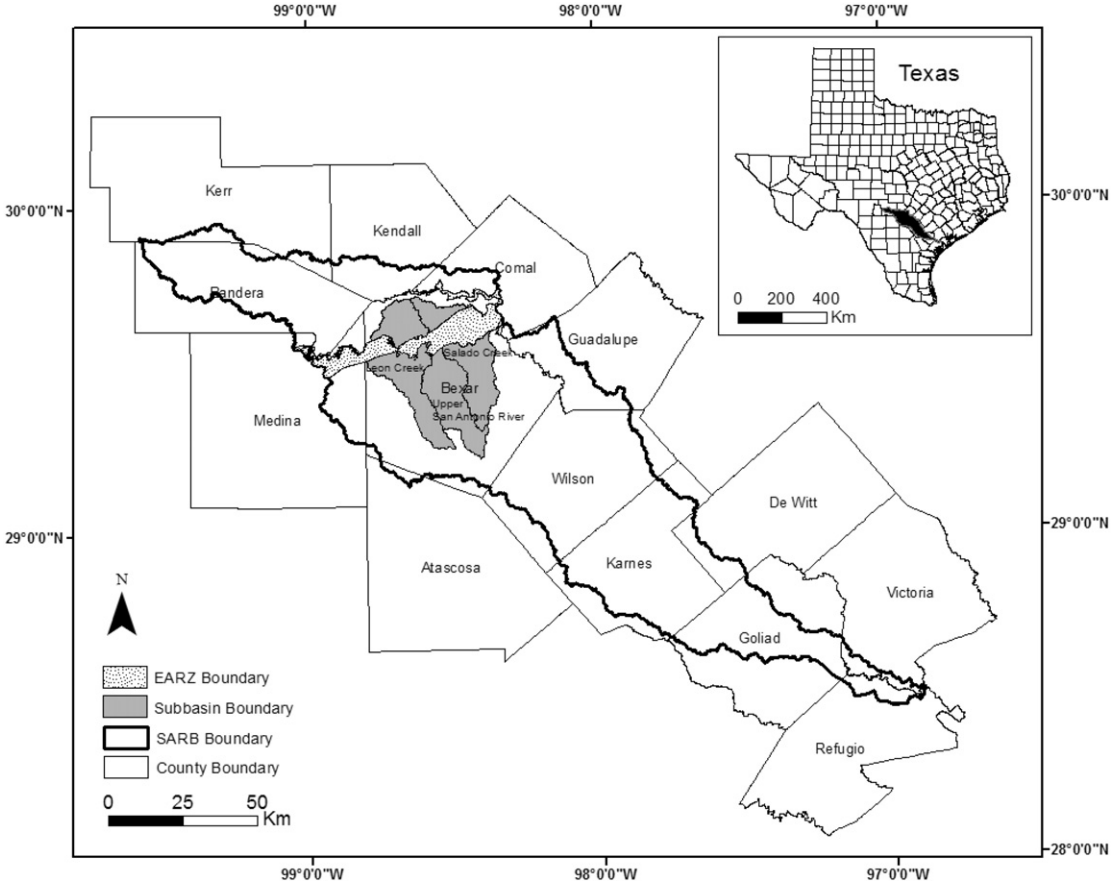

Fig. 1. San Antonio River Basin (SARB) and three watersheds containing Bexar County.