Applied Geography 67 (2016) 129–139

Contents lists available at ScienceDirect

Applied Geography

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

Urban stream deserts: Mapping a legacy of urbanization in the United States

Jacob A. Napieralski*, Thomaz Carvalhaes

University of Michigan-Dearborn, Department of Natural Sciences, 4901 Evergreen Road, Dearborn, MI 48128, USA

ARTICLE INFO

Article history:
Received 30 September 2015
Received in revised form
14 December 2015
Accepted 16 December 2015
Available online 6 January 2016

Keywords:
Urban areas
Workflow
Geographic information systems (GIS)
Urban stream desert
Buried streams
Urbanization
Urban stream syndrome
Fluvial geomorphology
Urban geography
United States
Megaregions
Channel change
Population density
Impervious surface coverage
Land use change

ABSTRACT

Protecting, as well as restoring, natural resources within the urban landscape has environmental and economic importance, especially as the global population continues to shift towards urban areas. One extreme legacy of rapid development and urbanization is stream burial. Here, riverless urban areas are mapped in 11 Megaregions within the United States, with additional focus on the Great Lakes, using a semi-automated, geoprocessing workflow completed within ArcMap10.2. Combining U.S. Census Bureau Urban Areas (UAs), Impervious Surface Coverage (ISC) from the 2011 National Land Cover Dataset (NLCD), and National Hydrography Dataset (NHD) flowlines, allowed the delineation of urban stream deserts (UrbSDs), or watershed areas where stream channels have likely been buried or removed. Approximately 6.2% of the area of UAs (or 11,490 km^2) within the 11 Megaregions are UrbSD, and they are most prevalent in major cities in the North California and Great Lakes Megaregions. More specifically, 537 UrbSD exist within the Great Lakes Megaregion, with Detroit (MI) and Chicago (IL) comprising some of the largest UrbSDs in the United States. Regardless of Megaregion, UrbSDs represent the most intensely urbanized components of the urban environment, as UrbSDs have higher population densities, impervious surface coverage and developed land uses than adjacent urban areas. UrbSD are unique, but poorly understood, components of the urban ecosystem that highlights the consequences of sacrificing long-term environmental sustainability (e.g., ecosystem services) for short-term economic growth (rapid development).

1. Introduction

Global population shifted rapidly from rural to mostly urban during the last century, with urban population increasing from 14% of the world's population (224 million) in 1900 to more than 50% in 2015 (3.9 billion). Due to the growth of megacities and conglomerates of urban settlements, especially within developing countries, this number is expected to reach 6.3 billion by 2050 (UN PD, 2011). Although the land footprint of urban areas covers only 0.5% of Earth's total land area (Schneider, Friedl, McIver, & Woodcock, 2003), the impact urban areas have on climate, biogeochemistry, and hydrology is substantial (Grimm et al., 2008). Urban environments are responsible for more than 75% of global, anthropogenic, greenhouse gas emissions (Hoornweg, Sugar, & Gomez, 2011; Bellucci, Bogner, & Sturchio, 2012) and contribute substantial amounts of trace gases and organic acids (Grimm et al., 2008), but they also have an intensive and extensive impact on surface waters. Large cities (>750,000 people) procure a majority (~75%) of water from upstream contributing areas that may actually exceed 40% of Earth's terrestrial surface (McDonald et al., 2014). Urbanization also decreases the spatial heterogeneity of surface waters, including streams and rivers, such that the distribution of surface water within cities is more similar to each other than to adjacent, natural landscapes, leading some to suggest urbanization is a “stronger predictor of the abundance of surface water features than climate and topography” (Steele et al., 2014, p. 695). As a consequence, urban areas rely on distant water sources because water sources within urban boundaries are often polluted by wastewater leakage and stormwater runoff, and because many urban water bodies have been buried, rerouted or filled.

One detrimental legacy of rapid urbanization is stream burial. Urban stream burial is the deliberate diversion of a stream or river

* Corresponding author.
E-mail address: jnapiera@umich.edu (J.A. Napieralski).

http://dx.doi.org/10.1016/j.apgeog.2015.12.008
0143-6228/

into underground pipes and ditches, or the removal of a stream channel from the stream network, which is then developed (Meyer & Wallace, 2001; Leopold, Huppman, & Miller, 2005; Veliz & Richards, 2005; Elmore & Kaushal, 2008). Stream burial became a common urban management practice in the 19th and 20th centuries because urban riverscapes offered valuable space for development (e.g., Du, Ottens, & Sliuzas, 2010) and were therefore engineered and maintained to be unchanging in shape, dimension, and pattern (Schumm, 1977). But when channelization was not possible, the end product was excessive burial of the urban stream network. As a result, many European and North American cities are manifestations of an urban stream management practice to "bury them, turn them into canals, line them with concrete and build upon the floodplain" (Eden & Tunstall, 2006; pg. 662). The United Kingdom has numerous subterranean rivers, including a highly modified stream network in London that has a substantial percentage of the River Thames network buried (more than 20 major, subterranean rivers) (Fig. 1A, B). Other European countries, such as Denmark and Switzerland, estimated 15% and 20% of streams had been buried, respectively (Wild, Bernet, Westling, & Lerner, 2011). Furthermore, in the United States, the City of Detroit (Michigan, USA) has buried over 500 km of stream channels since 1906 (Fig. 1C, D), while substantial stream loss due to urbanization has also been described in Baltimore (Maryland, USA) (Elmore & Kaushal, 2008), Greater Oklahoma City (OK, USA) (Julian, Wilgruber, de Beurs, Mayer, & Jawarneh, 2015), and Cincinnati (Ohio, USA) (Roy, Dybas, Fritz, & Lubbers, 2009).

During the urban burial process, streams are either *culverted* or *buried* (surface channels replaced with subsurface conveyance structures), *captured* (buried channels merged with combined sewer systems) (Elmore & Kaushal, 2008; Broadhead, Horn, & Lerner, 2013), or *graded* (channels simply paved over and removed from the network). When rapid urbanization occurs near the confluence of major rivers or a watershed outlet, the stream burial process follows the suburbanization growth pattern (outward, from the urban center toward watershed boundaries), and is concentrated in large areas of an urban watershed. If multiple stream channels are buried, then the efficiency and effectiveness of the natural stream network is reduced, decreasing stream density and overburdening the remaining channels and requiring an increased dependence on engineered, subsurface structures (i.e., an overall decrease in ecosystem services). During the urbanization of

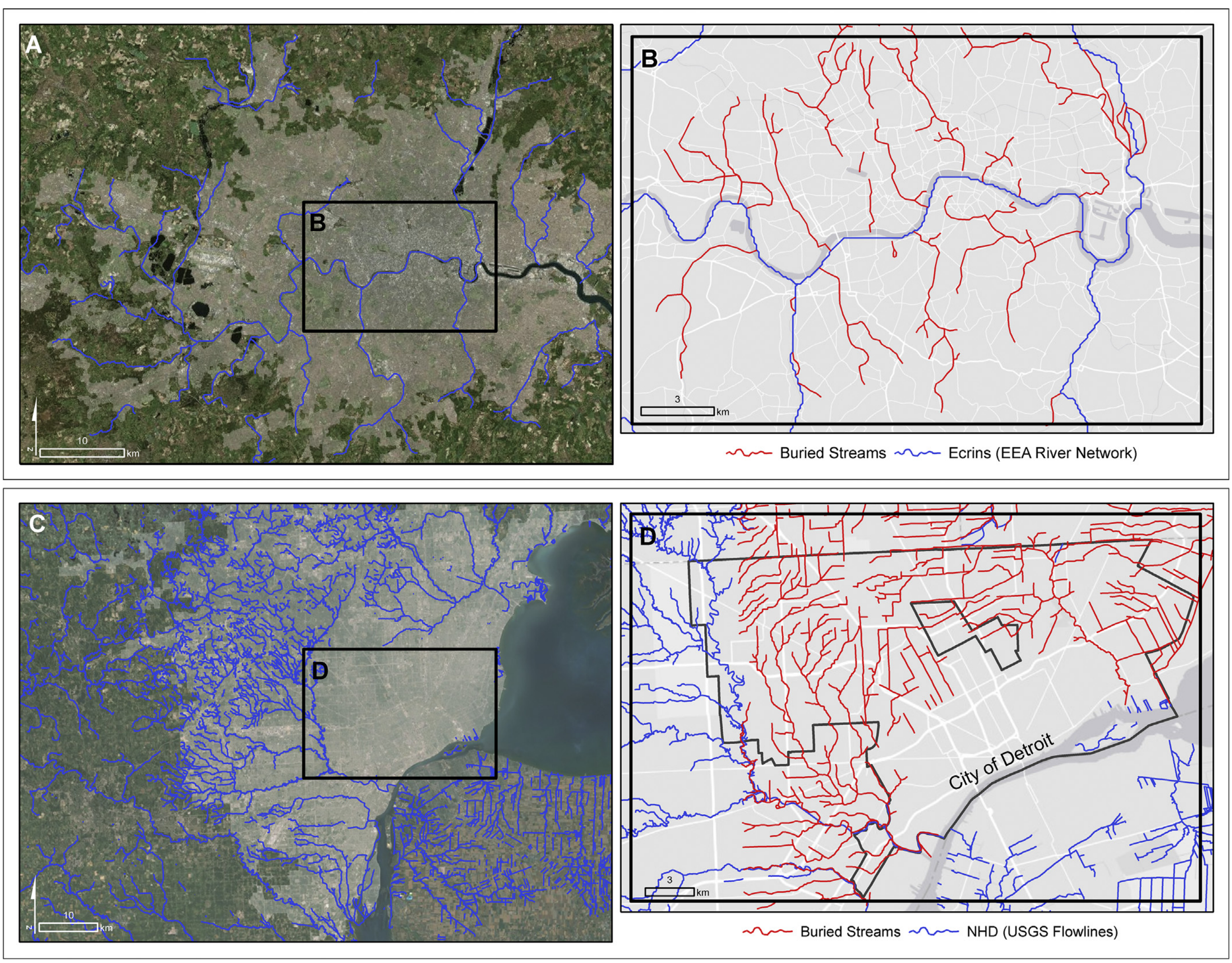

Fig. 1. (A) The Greater London (UK) urban morphological zone with the European catchments and rivers network system (Ecrins) data showing stream locations. (B) Overlay of Ecrins flowlines and buried stream channels. (C) The Detroit, Michigan (US) Urban Area (UA) with the National Hydrography Dataset (NHD) flowlines showing current stream network. (D) Overlay of NHD flowlines and buried stream channels. Note substantial reduction in stream density in both urban environments.