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Assessment of nitrogen reduction by constructed wetland based on InVEST: A case study of the Jiulong River Watershed, China

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ABSTRACT

The Jiulong River watershed (JRW) in southeast China includes livestock breeding and agriculture, leading to large amounts of non-point source pollution. Nitrogen (N) reductions were simulated and mapped using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) under scenarios that were built considered both constructed wetlands (CWs) and climate change, which are not common in the literature on ecosystem services assessments. The results showed that the amount of N exported from non-point sources within the JRW was 12,569 $t \cdot yr^{-1}$. The areal N load was relatively higher in the north, while more N exported in the southeast. Constructed riparian wetlands can intercept and reduce the N loads that enter water bodies, but climate change may be a factor driving the deterioration of water quality. The methodology can be generalized to reduce other contaminants, and provides a tool for decision-makers to weigh the costs and benefits of urbanization and conservation.

1. Introduction

Ecosystems provide a variety of essential ecological functions to support life and supply benefits to humanity, and these functions are also called as ecosystem services (ES) (Groot et al., 2010; MA, 2005). Water purification is a significant ecosystem function that is directly related to the aquatic environment and life, as well as those of human beings (Keeler et al., 2012). In addition, the ocean is also affected by terrestrial nutrients. As the channels connecting land and oceans, rivers play vital roles in the transport of terrigenous material to the marine environment. Approximately 2.25×10^{10} $t \cdot yr^{-1}$ of terrestrial materials enter the ocean on a global scale (Wu et al., 2017). In recent years, there has been a significant increase in social-economic development. To increase crop production and meet the increasing demands of the growing population, fertilizer application and poultry/livestock culture have also increased (Cao et al., 2014; Strokal et al., 2014). In regard to environmental and water quality management on land, non-point source pollution is an important problem, which occurs when precipitation, snowmelt, or irrigation water runs over or below the ground. Surface and subsurface flow can pick up pollutants and introduce them into rivers, groundwater, and eventually coastal waters (Liu et al., 2008). Due to the characteristics of randomness, intermittence, latency, lag and sophistication (Hong et al., 2008), it is of great importance to study non-point source pollution.

One way to reduce non-point source pollution is to reduce the number of anthropogenic inputs, such as those from fertilizer application. Another way is to utilize the natural purification services provided by ecosystems, which include retaining or degrading pollutants before they enter water bodies. For example, vegetation can absorb or transform some pollutants; soils can filter flows and trap some soluble pollutants (Sharp et al., 2016); riparian vegetation plays an especially important role, which often serves as the last barrier before pollutants enter a stream (Mayer et al., 2007a; X. Zhang et al., 2009).

Land use and land cover (LULC) and climate change should be the primary factors used to assess ES, especially water-related ES (Bateman et al., 2013). LULC varies with time and space, leading to changes in the amounts and locations of ES (Bennett et al., 2009; Lautenbach et al., 2011) and resulting in the heterogeneity of ES. Green infrastructure has become a prominent concept in recent years (Ahern, 2007; Mell, 2008; Spanò et al., 2017), which is considered to consist of natural, semi-natural and artificial networks of multifunctional ecological systems within, around and between urban areas at all spatial scales (Tzoulas et al., 2007). Green space has significance in a wide variety of ES, from environmental quality improvement to climate change adaptation and

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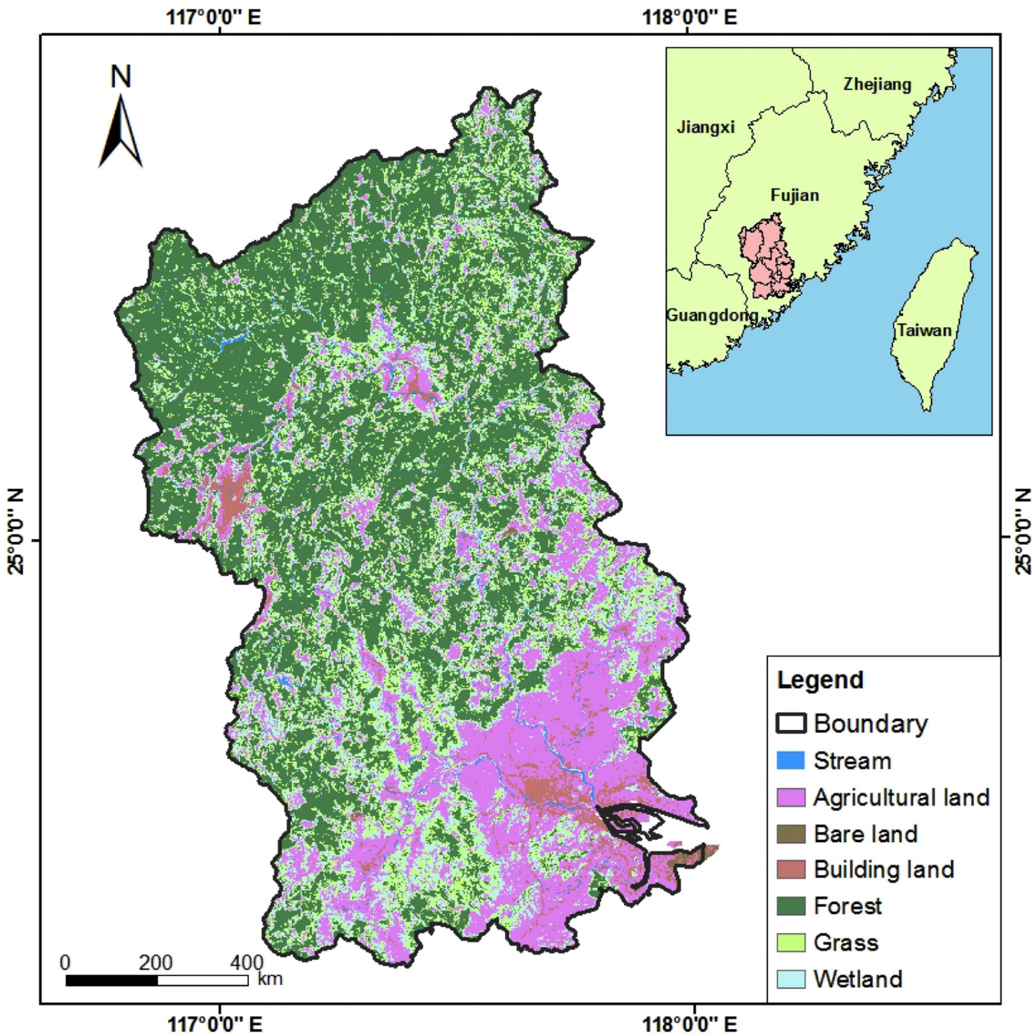

Fig. 1. Study area.

Table 1
The sources of data used in this study.

Data	Descriptions	Sources
LULC (land use/land cover)	A spatially continuous GIS raster dataset for 2002 with a resolution of 30 m. The LULC code for each pixel is an integer.	Produced by the interpretation of 30-m Landsat thematic mapper (TM) data.
DEM (digital elevation model)	A 30 m-resolution GIS raster dataset with an elevation value for each cell.	Geospatial Data Cloud, Chinese Academy of Sciences, http://www.gscloud.cn/
Pre (precipitation)	A 30 m-resolution GIS raster dataset for the current (1970–2000) and future (2041–2060) periods with an annual average precipitation for each pixel.	Worldclim-Global Climate Date, http://worldclim.org/
Biophysical table	A .csv table of LULC classes, containing the data on water quality coefficients used in this tool, including N loading, retention efficiency, and proportion of dissolved N.	(Berg et al., 2016; Han et al., 2016; Huang et al., 2004; Pan, 2016; Sharp et al., 2016; Ying et al., 2016)

mitigation (Ely and Pitman, 2012; Pakzad and Osmond, 2016), and provides social and economic benefits for human-beings, such as improving psychological health levels and mental well-being, promoting local economic activities and increasing property values (ARUP, 2014; UEPA, 2014). As an important branch of green infrastructure, constructed wetlands (CWs) are systems that are designed and constructed to utilize the natural processes to assist in treating wastewater, including wetland vegetation, soils and associated microbial assemblages (Vymazal, 2007). In addition, the purified water produced in constructed wetlands is also suitable for reuse (Lee et al., 2009). Compared to conventional treatment systems, CWs are low cost, easy to operate and maintain (Kivaisi, 2001) and have relatively high nitrogen (N) removal efficiencies (Lee et al., 2009; Vymazal, 2007, 2010). Based on the type of macrophytic growth and water flow regime, CWs can be classified into many types (Vymazal and Kröpfelová, 2008), but generally speaking, free water surface (FWS) systems, horizontal subsurface flow (HSSF) and vertical subsurface flow (VSSF) systems are the most commonly designed and used types in China (D. Zhang et al., 2009). With regard to climate change, scientists and policy-makers have reached a consensus that some human-induced climate change is unavoidable (Whitehead et al., 2009). The quantity and movement of water through the landscape can shift with climate change, which will also lead to the alteration of nutrient transport dynamics.

The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) was developed by the Natural Capital Project (NatCap, www.naturalcapitalproject.org) and is a spatially explicit ES modeling tool