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Changes in land use, climate and the environment during a period of rapid economic development in Jiangsu Province, China

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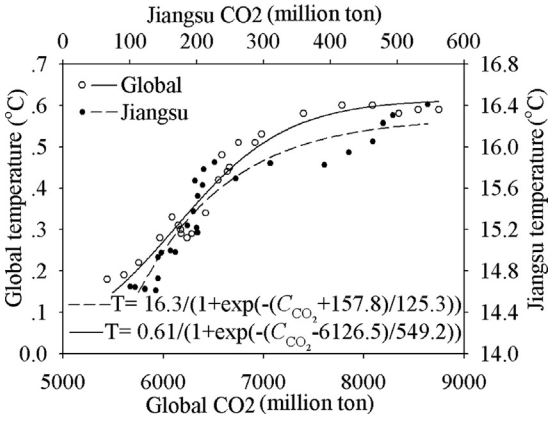
HIGHLIGHTS

- Reconstructed LUCC in Jiangsu Province from 1980 to 2010 by Landsat image data.
- Revealed the interaction of Land use cover, environment and climate changes.
- Revealed Influence of human and economic activities on the climate changes.

GRAPHICAL ABSTRACT

The increase of temperature with CO_2 in Jiangsu Province is much more moderate than that in the global scale, but the increased magnitudes of temperature in Jiangsu Province is bigger than that in the global scale. The temperature in regional scale (Jiangsu Province) is much more sensitive to other influencing factors than to CO_2.



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ABSTRACT

Understanding changes in climate and environment on a regional scale can provide useful guidance for regional socio-economic development. The present study characterizes changes in the environment, climate, land use and cover types via in situ observed, statistical data and remote sensing images for Jiangsu Province, China, during the period 1980–2012. Statistical and spatial analyses indicate that the pace of urbanization in southern Jiangsu is more rapid than that in northern Jiangsu. Urbanization (92.7%) results primarily from the loss of farmland. While emissions of pollutants from industrial sources were well controlled, and wastewater, which more frequently derives from urban domestic sources, was found to be increasing. The rates of wastewater to population

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increased from 0.17 ± 0.017 to 0.32 ± 0.090 (billion ton/million persons) during the two periods of 1980–2000 and 2000–2012. However, the rates of wastewater to Gross Domestic Product (GDP) decreased from 0.26 ± 0.20 to 0.014 ± 0.009 (billion ton/billion Yuan), respectively. The significant increase in scattering radiance and Earth's albedo caused by the urbanization and its process (Pearson correlation coefficient (r) between urban land and scattering radiance = 0.86, $p < 0.0001$; r between farmland and scattering radiance = −0.92, $p < 0.0001$) aggravates the warming in the regional scale. This correlation analysis indicates that temperature will decrease with the increase of woodland, grassland and farmland, and will increase with the increase of urbanized and unexploited lands. Added to warming caused by an increase in CO_2, land use/cover change and human activities may be the primary reason for the rising temperatures in Jiangsu Province. The change in regional thermal conditions reduces both local humidity and land atmosphere flux exchange. The low atmosphere flux exhange contributes to the spread of atmospheric pollutants and the deposition of atmospheric particles.

1. Introduction

Land use/cover change (LUCC) is a reflection of human activities and of the driving forces behind changes in the environment and climate (Bu et al., 2014; De Vries et al., 2013; Migliaccio et al., 2007; Park et al., 2014). Generally, intense human activity results in an increase in construction and farmland and loss of forest (Lambin et al., 2001; Lambin and Geist, 2003; Lawrence et al., 2012). Farmland affects the input of nutrients to the water (such as nitrogen and phosphorus) within a watershed, and particularly affects nitrogen (Woli et al., 2004; Robson, 2014). Construction land (including urban and rural residential lands) is associated with atmospheric, (such as emission of SO_2, NOx and dust) water and soil pollutions (such as organic pollution, heavy metals and nutrients) (Zhao and Pitman, 2005; IPCC, 2007; Lohila et al., 2010; Li et al., 2009; Kang et al., 2010). Research on the relationship between land use cover and environmental parameters has defined the drivers and variations for environmental change caused by LUCC (Kang et al., 2010; Huang et al., 2014). Remote sensing and geographical information systems have provided added convenience to these studies (Xian et al., 2009; Matthews et al., 2012; Olofsson et al., 2013; Huang et al., 2014).

The effect of LUCC on regional and global climate change has been well documented (IPCC, 2007; Hasler et al., 2009; Davin and de Noblet-Ducoudré, 2010; Hua and Chen, 2013). A large share of greenhouse gas derives from LUCC. Approximately 35% of CO_2 at a global scale, for example, is from LUCC (Zhao and Pitman, 2005; IPCC, 2007). The expansion of farmland (primarily rice farming), urbanization and forest degradation are the primary sources of CH_4 (Keith and Dowlatabadi, 1992; Kalnay and Cai, 2003; Lohila et al., 2010; Wang et al., 2014; Herrero et al., 2014). Meanwhile, LUCC modifies the reflected radiation and latent heat ratio by altering Earth's albedo (e.g., by replacing forest with cropland, construction land and pasture, it has led to an increase in albedo) (Foley et al., 2005; Hua and Chen, 2013). Increased levels of greenhouse gas and heat emission from urbanization significantly increase global temperatures. Moreover, temperature and radiance changes have affected humidity and precipitation, which in turn reduces the regeneration ability of forests (Shukla et al., 1990; Bonan et al., 1992; Snyder et al., 2004; Hasler et al., 2009; Davin and de Noblet-Ducoudré, 2010).

These patterns at the global scale provide a context for understanding global climate. Understanding changes in climate and environment on a regional scale can provide useful guidance for regional socio-economic development. Jiangsu Province is in particular need of such guidance. The climate and environment in the province are not only are affected by rapid regional economic development and intense human activity, but they are also strongly influenced by the East Asian monsoon climate. In the present study, we evaluated LUCC to the environment and climate change in Jiangsu Province over the past three decades. Specifically, we attempt to reveal the interactions of land use cover, environment and climate change, and to clarify the relative influence of human activity and East Asian monsoon that constrain these changes.

2. Material and methods

2.1. Study area

Jiangsu Province is an important economic zone in the Yangtze River delta. It borders the city of Shanghai and Zhejiang Province in the south, the Shangdong Province in the north, Anhui Province in the west, and the ocean in the east (Fig. 1). The province has a population of 79.2 million with a population density of 770/km^2. It is located in the East Asian monsoon region and has a coastline of over 1000 km along the Yellow Sea. It has the highest Gross Domestic Product (GDP) per capita of all 31 provinces in China. With rapid economic development, the environment and climate of the region have significantly changed.

2.2. Datas

Landsat (MSS/TM/ETM$^+$) images downloaded from USUG (http://glovis.usgs.gov/) with a spatial resolution of 30 m were used to obtain land use cover data from 1980 to 2010. The Landsat TM images of Jiangsu Province cover paths 127–130 and rows 36–39, and the ETM$^+$ images cover paths 118–121 and rows 36–38. The time phases of land use cover data for the province include 1980, 1995, 2000, 2005, 2008 and 2010. All the images for each time phase were spliced according to their match-up geographic coordinates (geometric correction). All mosaicking images for each time phase were corrected by a quick atmospheric correction module (embedded in the ENVI software, ITT Visual Information Solutions, USA) before classification. The quick atmospheric correction is a method for multispectral and hyperspectral

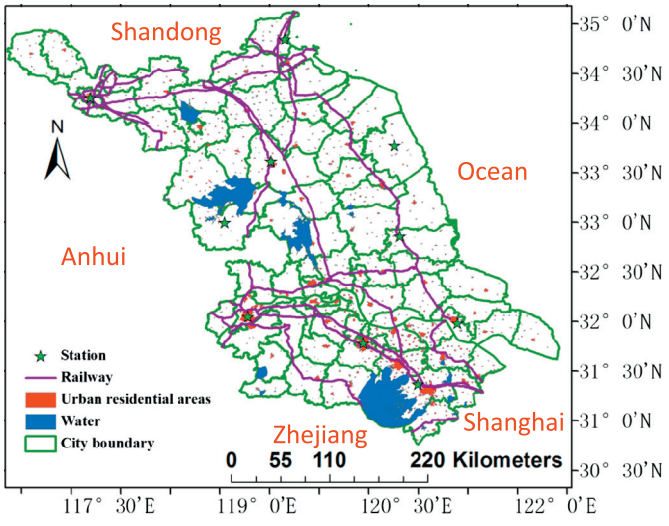

Fig. 1. Study area. Chart is administrative division of Jiangsu province with information of traffic route, urban residential areas and water.