

Ecological consequences of rapid urban expansion: Shanghai, China

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Since China's economic reform in the late 1970s, Shanghai, the country's largest and most modern city, has experienced rapid expansion and urbanization. Here, we explore its land-use and land-cover changes, focusing on the impacts of the urbanization process on air and water quality, local climate, and biodiversity. Over the past 30 years, Shanghai's urban area and green land (eg urban parks, street trees, lawns) have increased dramatically, at the expense of cropland. Concentrations of major air pollutants (eg SO₂, NO_x, and total suspended particles) were higher in urban areas than in suburban and rural areas. Overall, however, concentrations have decreased (with the exception of NO_x), due primarily to a decline in coal consumption by industry and in private households. Increased NO_x pollution was mainly attributed to the huge increase in the number of vehicles on the roads. Water quality changes showed a pattern similar to that of air quality, with the most severe pollution occurring in urban areas. Differences in mean air temperatures between urban and rural areas also increased, in line with the rapid pace of urban expansion, indicating an accelerating "urban heat island" effect. Urban expansion also led to a decrease in native plant species. Despite its severe environmental problems, Shanghai has also seen major economic development. Managing the tradeoffs between urbanization and environmental protection will be a major challenge for Chinese policy makers.

摘要: 自 1970 年代末改革开放以来, 中国经历了快速的城市化。作为中国最大和最现代化的城市, 上海市在过去 30 年里经历了极其快速的城市化。本文利用遥感数据分析了 1975—2005 年上海市土地利用/覆盖的变化, 探讨了上海的城市化过程以及对上海及周边地区大气和水质、区域小气候以及生物多样性的影响。在过去 30 年里, 上海市的城镇用地和城市绿地迅速增加, 农业用地急剧减少。城区大气中的主要污染物含量高于郊区和乡村, 但总体上主要大气污染物的含量(氮氧化物除外)呈下降趋势, 这主要源于工业和生活用煤的减少。大气中氮氧化物含量增加的原因主要源于机动车辆的迅速增加。水质的变化趋势与大气质量类似, 水质退化主要发生在城区。过去 30 年, 城区与郊区的气温差异明显增加, 表明上海的城市热岛效应在增加。城市化导致本地的植物物种减少, 同时引进了许多外来物种。尽管上海快速城市化带来了严重的生态负面影响, 但它确实促进了上海经济的繁荣发展。如何协调城市化和环境保护的关系是中国的决策者们所面临的巨大挑战。

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China has been undergoing a period of economic reform and expansion since the late 1970s, accompanied by rapid and widespread urbanization. During the early 1980s, 18% of China's population lived in cities, but this rose to 39% by 2003, while the number of cities increased from 190 to 660 (including about 170 cities with a population greater than 1 million) over the same time period. From 1980 to 2003, the contribution of Chinese cities to gross national product (GNP) increased from 69.9% to 85.9% (Chinese Statistical Bureau 2004). However, urbanization has also led to serious environmental and ecological problems, both in urban and surrounding areas, including increased air and water pollution (Briant and Guo 2000; Liu and Diamond

2005; Shao *et al.* 2006), local climate alteration (Zhou *et al.* 2004), and a major reduction in natural vegetation cover and production (Fang *et al.* 2003). Urban residents have experienced an increase in levels of cholesterol-related diseases (Lee 2004) and an overall decline in quality of life.

As the largest and most modern city, Shanghai has experienced extensive urban expansion over the past three decades (Figure 1a). Between 1975 and 2003, the city's population increased from 10.8 million to 13.4 million (Shanghai Statistic Bureau 2004). The resulting ecological consequences of urban sprawl have caused considerable concern among scientists and policy makers. Several studies have documented some environmental impacts of Shanghai's increasing urbanization; for example, an analysis of meteorological data from both the city's

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