Effects of urbanization on Water Yield, Ecosystem Productivity, and Micro-Climate: Case studies in the United States and China

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Abstract

Land use and land cover changes (LULCC) associated with urbanization affect watershed functions and services through fundamental alteration of biogeochemical cycles. Quantifying the potential changes in water, carbon, and energy due to urbanization helps sustainable city planning and integrated watershed management. We hypothesize that 'impacts of urbanization do not create equal'. We conducted two case studies in the US and China at watershed to national scales to show how urbanization affect watershed hydrology, meteorology, and Gross Primary Productivity (GPP). We used both empirical data and ecohydrological models including WaSSI, SWAT, and MIKE SHE. We used stepwise regression and geographically weighted regression models to assess the variable impacts of urbanization on watershed water and carbon balances across a large disturbance and climatic gradient. We show that LULCC may overwhelm the impacts of climate warming on hydrology and urban microclimate (Urban Heat Island and Urban Dry Island) in the humid southern China. We found that the impacts of urbanization on both water yield and GPP are more pronounced in the area with high precipitation and forest covers. The magnitude of changes in ecosystem functions were influenced by many factors such as the background climate (high precipitation vs. low precipitation), previous land use and cover types and land use and cover changes, and the magnitude of urbanization (change in % impervious surface). We conclude that effective environmental management measures and strategies such as maintaining forest vegetation and wetlands to mitigate the negative effects must be designed to fit local watershed conditions.

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Effects of Urbanization on Water Yield, Ecosystem Productivity, and Micro-Climate: Case studies in the United States and Eastern China

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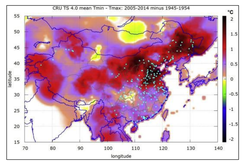
INTRODUCTION

- **World's urban population is projected to rise to 66% by 2050**
- **China's urban population passed 50% in 2011**
- **Global urban land uses increased by over 34% from 1980 to 2000; projected to double by 2030, mostly in developing counties**
- **Urbanization affects global water and energy cycles by removing vegetation covers**
- **Water, energy, and carbon cycles are coupled in watersheds**
- **Feedbacks between vegetation, land cover and climate exist *(Urban Heat Island, Dry Island, Wet Island, Rain Island, Dirty Island; flooding and heat waves)***

Urban Flooding

Urban Heat islands



OBJECTIVES

❖**Empirically examine how urbanization affects watershed hydrology and meteorology**

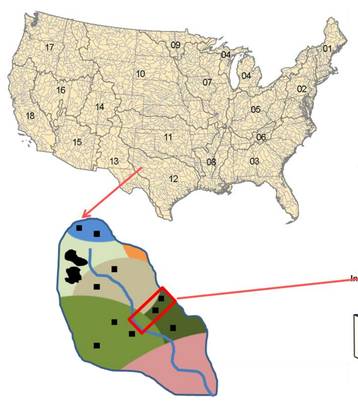
❖**Project effects of urbanization on water and carbon balances at the 12-digit Hydrologic Unit Code (HUC) watershed scale across the continental United States in the next 100 years**

❖**Compare environmental effects of urbanization between eastern China and the U.S. under a humid subtropical climate**

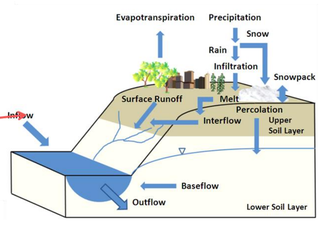
DATA & METHODS

- ❖ Hydrological gaging station flow data
- ❖ Eddyflux data used for model validation on evapotranspiration
- ❖ Water and carbon balance model, Water Supply Stress Model (WaSSI)
- ❖ MODIS-based estimate of leaf area index (LAI), GPP for model validation and application
- ❖ Solar-induced chlorophyll fluorescence (SIF) products for GPP validation
- ❖ SEBAL, SWAT, MIKE SHE energy balance and hydrological models for Qinhuai River Basin
- ❖ EPA Integrated Climate and Land Use Scenarios (ICLUS) data for future land use change projection for 2000, 2010, 2050, 2100

WaSSI Ecohydrology Model

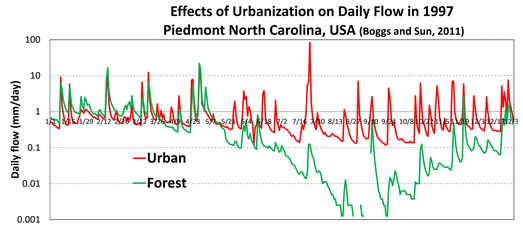


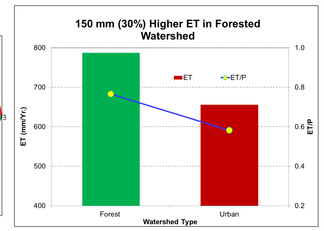
- Water balance and flow routing
- Monthly time-step
- HUC12 resolution
- Accounts for land cover effects on ET and water yield

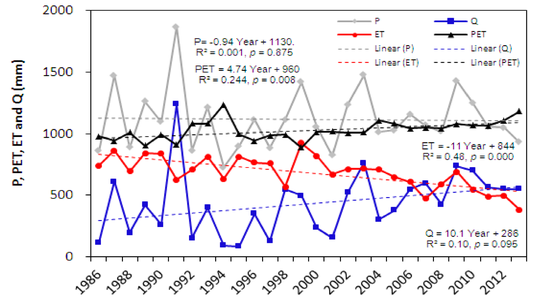


Sun et al. JGR, 2011; Caldwell et al. 2014 SRS-GTR-197

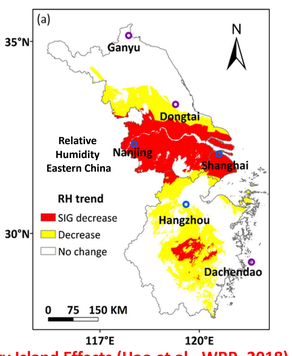
RESULTS





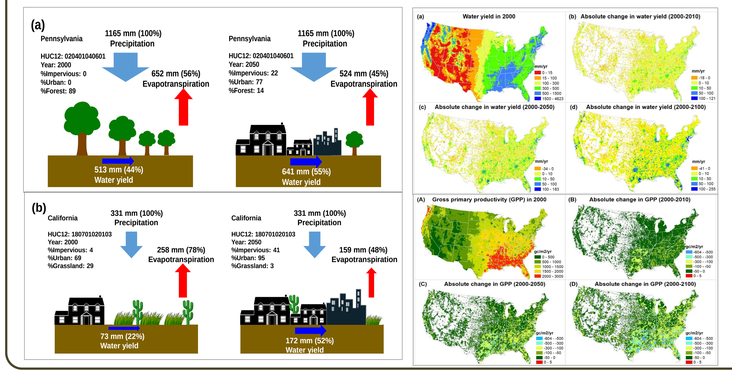


Urbanization increased flow, decreased ET in the rice paddy dominated Qinhuai River Basin, Nanjing, southern China (Hao et al., HESS, 2015)



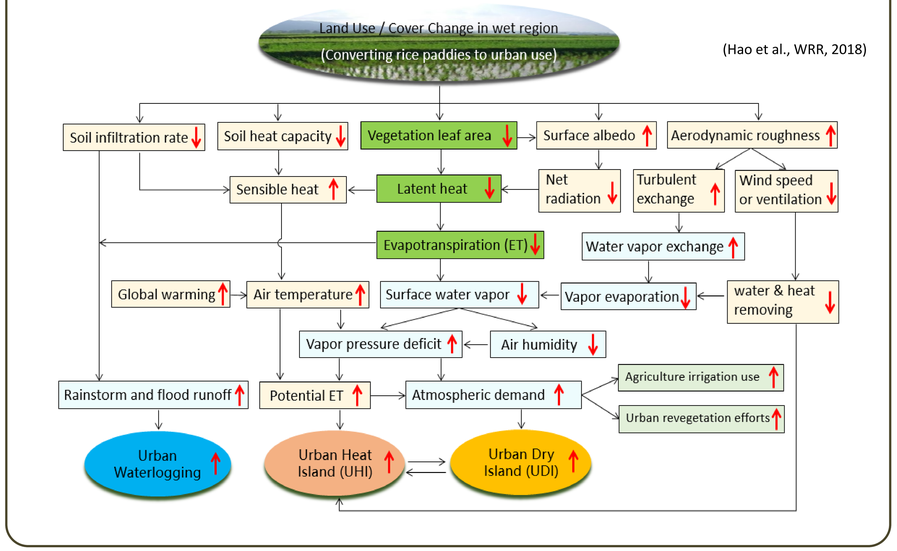
Urban Dry Island Effects (Hao et al., WRR, 2018)

Simulated U.S. Watershed Water and Carbon Balances *(Li et al., WRR ; J hydrology in review)*



Water Yield

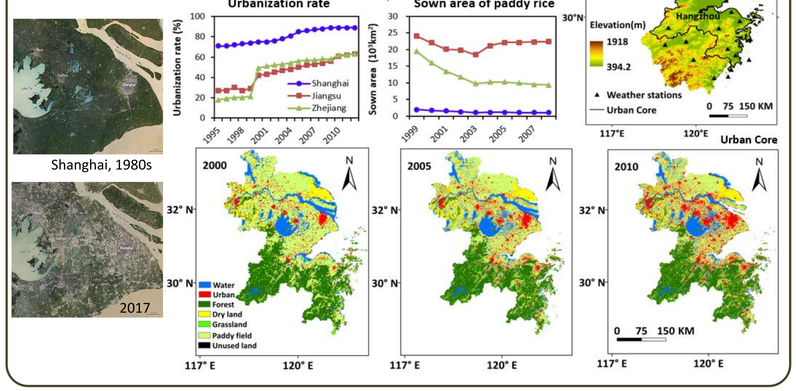
Gross Primary Productivity



(Hao et al., WRR, 2018)

Urbanization in the Yangtze River Delta, China

(Hao et al., WRR, 2018)



KEY FINDINGS

- ✓ **Wetland or forest dominated watersheds show pronounced change in flow (>50%) and "Urban Dry Island" effect.**
- ✓ **Impacts of U.S. urbanization on water yield and GPP were influenced by background climate, previous land cover. characteristics, and the magnitudes of land-use change (e.g., impervious surface) .**
- ✓ **"Impacts of urbanization on water yield and GPP are not created equal".**
- ✓ **The role of vegetation in moderating impacts of urbanization on water and carbon might have been under-estimated (i.e., EPA guidelines on storm water management).**