



Urban land-use change effects on nitrogen biogeochemical cycle in the São

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Urban land area and the global urban population have expanded dramatically over the past decades, with a concurrent expansion in urban ecological research to understand both the environment in which most people live and the feedbacks among urbanization and ecosystem structure and function. Most of the global human population lives in urban areas where biogeochemical cycles are controlled by complex interactions between society and the environment. Disturbances in the global carbon cycle, and other biogeochemical cycles, in particular the nitrogen (N) cycle, induced by urban human activities, lead to global, regional and local environmental problems, such as photochemical smog, stratospheric ozone depletion, soil acidification, and nitrate pollution of water. Urban areas are expected to continue their rapid growth in the 21st century, are increasingly coupled with the Earth System (ES), and are major drivers of global environmental change through their influence on the major biogeochemical cycles. Moreover, a high density of people makes them focal points of vulnerability to global environmental change. An initial step towards understanding urbanization interactions with the ES is to characterize contemporary cities and their biogeochemical interactions. With 19 million inhabitants, the Metropolitan Area of São Paulo (MASP) is the 3th largest metropolis in the world, the largest and most populous region in the Southern Hemisphere. The land of 39 municipalities of the whole MASP is spread over 8,000 km² being an example of the fastest long-term rate of urban growth; it contains 10% of the total country population and the degree of urbanization in the region is predicted to reach 80% by the year 2020. The city is located in the southeastern Brazil, on a plateau of 760 m above sea level which original vegetation was the At-

lantic Rain Forest. The climate is humid subtropical with mean annual temperature of 18.5°C and 1350 mm/yr of rainfall. Less than one third of the total wastewater is treated, which results in large volumes of wastewater draining directly into the Tietê watershed. In the case of solid waste, there are landfill sites in the area, still many of them are operating without any license and control, resulting in potential leakage of dangerous substances into the ground water. It has been recognized that an industrialized city expends 10–100 times more energy compared with most unmanaged ecosystems and that urban metabolism depends upon external energy and matter. To characterize this dependence upon external inputs at the whole-ecosystem scale we used the mass-balance approach. Mass balances quantify inputs and outputs of elements, and yield information about whether a city is a source (input>output) or sink (input<output) for the element and how it is transformed by urban activities. In terms of N, humans alter N sources by changing atmospheric deposition rates and by importing fertilizer and food. In São Paulo, food imports were 8 Gg N y⁻¹ and 33 Gg N y⁻¹ of atmospheric N were generated by combustion; collectively, these human-mediated fluxes account for over 90% of N input. Imported human food is entrained into the engineered infrastructure, with waste products transported from the site of consumption via sewage and garbage. Bio-nitrogen fixation rates in the green areas and dry deposition were also accounted as N input to the urban system, but fixation by wet deposition, and surface water input were not computed. Total fixed N output was 78 Gg N y⁻¹, where more than half of N leaves the system mainly via the atmosphere, but considered N output leaves via riverine exports, since most of wastewater is not treated. The N mass balance for São Paulo showed that single-element studies can be balanced to reveal specific points of element accumulation and loss. The N mass balance showed MASP to be a net source of N, suggesting that urban air and water N pollution are the main drivers of the urban biogeochemistry. In the case of N cycle, this land-use conversion would be adding N from the original biome with higher density of biomass as well as productivity (rainforests) to the atmosphere but mainly to the waters. Although human control is complex, all the drivers we examined appear to be linked to three classes of human activity: engineering, urban demographic trends and household-scale actions. Ultimately, the challenge is to integrate human choices and ecosystem dynamics into a seamless, multidisciplinary model of biogeochemical cycling in urban ecosystems, that should include mass-balance studies to understand how human-dominated fluxes couple or decouple elemental cycles in cities, focusing as a first step on the evaluating quantitatively the mutual relationship between urban land-use changes and natural ecosystem from the standpoint of global N Balance.