Spatiotemporal Changes in Ecosystem Services Values in Dongguan, China: Implications for Urban Sustainability

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Abstract

Land use/cover change is a proxy for quantifying ecosystem service values. This study examined ecosystem service values based on land use/cover changes and exemplified the implications for sustainability in the rapidly urbanizing city of Dongguan, China. This city has experienced rapid urban expansion for more than twenty years, and it had a compound annual urban growth rate of 9.57% and 2.51% during the periods 1994–2005 and 2005–2015, respectively. The urban land increased from 11.77% in 1994 to 32.16% in 2005 and 41.20% in 2015.

In the study area, agricultural land was in a decreasing trend; it decreased from 48.05% in 1994 to 35.47% in 2005 and 29.50% in 2015. More interestingly, the bare land changed from 14.51% in 1994 to 5.84% in 2005 and 1.20% in 2015. It should be noted that agricultural land and bare land were the major contributors to urban expansion from 1994 to 2015. Specifically, agricultural land contributed more land conversion to urban expansion than bare land during the period 1994–2005. During the period 2005–2015, both agricultural land and bare land contributed equally to urban expansion. Forest land increased from 12.50% in 1994 to 14.05% in 2005 and 17.69% in 2015, meaning that the forest land was in an increasing trend in Dongguan.

Urban land will increase to more than 50% of the total area in two scenarios in 2030. Agricultural land will be the main contributor to urban expansion. Agricultural land will decrease from 29.50% in 2015 to 18.27% in 2030 according to the Spontaneous Scenario and to 18.85% according to the Ecological Protection Scenario. However, the forest is in an increasing trend due to ecological protections. It will grow from 17.69% in 2015 to 19.31% in 2030 based on the Ecological Protection Scenario.

The total ecosystem service values decreased from 4148.24 × 10^6 Yuan in 1994 to 3749.86 × 10^6 Yuan in 2005 and 3529.26 × 10^6 Yuan in 2015. The decline of ecosystem service values in the city for all years is due to urban expansion. From 1994 to 2015, ecosystem service functions, mainly waste treatment, water supply, soil formation, and food production, also declined. The regulating services were heavily affected by urban expansion. During the period 2015–2030, the ecosystem service functions of soil formation, waste treatment, and food production will seriously decline. Notably, these environmental issues needs to gain much attention for landscape conservation. The scenarios of land use/cover changes also reflect the future decline of total ecosystem service values. Strict ecological protection can help save the total ecosystem service values. In the context of rapid urbanization, agricultural land needs to gain more attention for achieving sustainable development.

Spatially, the high ecosystem service values areas were located on the west coastal areas, the south and east high elevated mountain areas. The ecosystem service values per unit area for forest and water were higher than that other land use/cover categories. However, north, southwest, and southeast regions had low ecosystem service values.

Hotspot areas of ecosystem service values were located especially in forest and water areas where the relatively high ecosystem service values have accumulated over the past 20 years. Furthermore, the hotspots of ecosystem service values increased especially during the period of 1994–2005. In addition, the contributions to urban expansion were mainly from agricultural land and bare land and because the increase of forest land contributed to the total ecosystem service value although the total ecosystem service value was decreasing. Hotspot and coldspot mapping is an effective method for ecosystem management. The hotspots of ecosystem service values closely matched the distribution of water and forest.

From 1994 to 2015, the decline of the total ecosystem service values was 618.98 × 10^6 Yuan. In 1994, the human to ecosystem service value (H-ESV) ratio was about 1:1404 (Yuan/Year), but it decreased to around 1:572 in 2005 and 1:428 in 2015. Additionally, the ecosystem service values will decline to about 506.66 × 10^6 Yuan in 2030 under the Spontaneous Scenario and will have an H-ESV ratio of 1:401. Under the Ecological Protection Scenario, the ecosystem service values will decline to about 306.25 × 10^6 Yuan in 2030 and will have an H-ESV ratio of 1:403. The rapidly increasing city population influences the H-ESV ratio.

The urban to ESV (U-ESV) ratio changed from 1.60 in the 1994–2005 period to 2.20 in the 2005–2015 period. This indicates that the decline in ecosystem service values was affected mainly by urban expansion during the period 1994–2005. The U-ESV ratio will be 1.59 during the period 2015–Spontaneous Scenario 2030 and 1.71 during the period 2015–Ecological Protection Scenario 2030. However, during the period 2015–Spontaneous Scenario 2030, the decline of total ecosystem service values will be affected by urban expansion as well as by other non-urban landscape changes.

Keywords: Land Use/Cover Changes; Ecosystem Service Values; Scenario Analysis; Spatial Pattern; Dongguan

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Acronyms/Abbreviations

CNY	Chinese Yuan
CS	Coefficient of Sensitivity
DEM	Digital Elevation Model
ESV	Ecosystem Service Value
FoM	Figure of Merit
FP	Food Production
GDP	Gross Domestic Product
GIS	Geographical Information Science
H-ESV ratio	Human-to-Ecosystem Service Value ratio
LUC	Land Use/Cover
MEA	Millennium Ecosystem Assessment
MLP	Multi-Layer Perceptron
MLP	Multi-Layer Perceptron
NDBI	Normalied Difference of Built-up Index
NDVI	Normalized Difference of Vegetation Index
puESV	Ecosystem Service Value per unit area
SVM	Support Vector Machine
U-ESV ratio	Urban-to-Ecosystem Service Value ratio
UN	United Nations
USD	U.S. Dollar

GR	Gas Regulation
CR	Climate Regulation
WS	Water Supply
SFR	Soil Formation and Retention
WT	Waste Treatment
BP	Biodiversity Protection
FP	Biodiversity Production
RM	Raw Material
RC	Recreation and Culture