An area-weighted index for measuring urban land expansion

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Abstract: Recent studies have reported that urban land expansion rates are higher than population growth rates in many parts of the world, thus raising concerns about a variety of resource and environmental issues. Urban land expansion is characterized by its intensity as well as its area extent. Previous studies of urban sprawl have focused on individual indices describing the spatial patterns of urban expansion. This study takes a different approach by combining urban expansion intensity and urban land ratio into a new index, area-weighted urban expansion rate.

Keywords: urban land expansion, urbanization, area-weighted urban expansion rate, East Asia

1. Introduction

Two recent studies of urban land expansion have reported that, in many parts of the world, urban land expansion rates are higher than population growth rates, suggesting that urban growth is becoming more expansive than compact (Angel et al., 2011; Seto et al., 2011). In a study of global urban land expansion of 67 countries from 1970 to 2000, China was ranked with the highest rates, from 13.3% for the coastal areas to 3.9% for the western regions annually (Seto et al., 2011). Although China accounts for less than 20% of the global urban population at present, close to one third of the global urban population growth between 2000 and 2010 was realized in China (http://data.worldbank.org/).

Many previous studies on urban land expansion have used satellite images and GIS to derive land cover data and employed landscape metrics (McGarigal et al., 2002) to analyze the patterns of urban land expansion (Yeh and Li, 1999; Schneider et al., 2005; Seto and Fragkias, 2005; Xiao et al., 2006; Seto et al., 2007; Ma and Xu 2010; Sun et al., 2013; Yue et al., 2013). These studies have also used individual indices to describe and analyse the dynamics of urban land changes.

2. Indices of urban expansion

Although the terminology is not standardized, indices of urban expansion are all based on the following variables: total land area of an administrative unit (A), total built area at the initial time period (U_a), total built area at the final time period (U_b), and the time period (T). Here is a summary of these indices expressed as average annual rates.

Average annual urban expansion rate (UE) is defined as (Xiao et al. 2006; Schneider and Woodcock 2008; Ma and Xu 2010; Seto et al. 2011; Xu and Min 2013):

$$UE = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

Average annual urban expansion intensity rate (UI) is defined as (Schneider and Woodcock 2008; Seto et al. 2011; Xu and Min 2013):

$$UI = \frac{U_b - U_a}{U_b} \times \frac{1}{T} \times 100\% \quad (2)$$

Average annual urban land expansion index (SI) is defined as (Tian et al. 2005; Xu and Min 2013):

$$SI = \frac{U_b - U_a}{A} \times \frac{1}{T} \times 100\% \quad (3)$$

3. Area-weighted urban expansion intensity

In contrast to the above indices, this study has developed the ratio of new urban land to the total area (AU) to quantify and compare urban expansion. The index is the multiplication of the two elements of urban expansion intensity (UI) and urban land ratio (UR):

$$UI = \frac{U_b - U_a}{U_b} \tag{4}$$

$$UR = \frac{U_b}{A} \tag{5}$$

$$AU = \frac{U_b - U_a}{U_b} \times \frac{U_b}{A} = \frac{U_b - U_a}{A} \tag{6}$$

Ranging in value from 0 to 1, AU can also be defined as the area-weighted urban expansion intensity.

The two elements of the index vary in time. Whereas UI indicates the intensity or dynamics of urban expansion, UR indicates the size or area extent of urban land. This also means that it is possible to split the ratio of new urban land into the intensity and extension components. In the early stage (I in Fig. 1) of urban expansion, UI is strong but UR is low, resulting in a low AU value. In the final stage (IV) of urban expansion, UR is high but UI is weak, resulting also in a low AU value. AU values are expected to be high in case of large urban areas and an intense urban expansion, i.e., in the middle stage of urban expansion. The middle stage can be further divided into the dynamic (II) and late stages (III). In the first part of the middle stage the intensity component is still dominant but is waning. In the late stage, the extension component becomes dominant. These different stages can be separated not only in time but also in space. Thus, from the core urban area to the periphery, we can see changes from the final to early stages. Suburban areas typically have the dynamic or the late stage. Areas of dezurbanization could have the early stage; however, this early stage does not lead automatically to the dynamic stage.

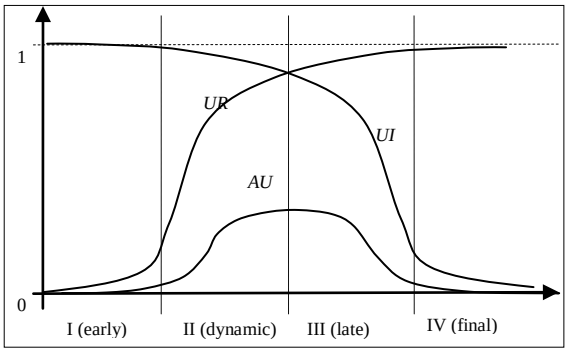

Fig. 1. Stages of urban sprawl defined by UR, UI, and AU

4. Conclusion

This study has proposed a new index, ratio of new urban land to the total area, for analyzing the process of urban sprawl. The index combines urban expansion intensity, a measure of the dynamics of expansion, and urban land ratio, a measure of the extent of urban land. By having these two elements, the index can trace the different stages of urban sprawl, with a strong intensity and a low ratio at the early stage and a weak intensity and a high ratio at the late stage. Additionally, the two elements of the index can be correlated with population growth data to separate older and more established urban areas from younger and more

dynamic urban areas. The index provides a new tool for studies of urban land expansion. Several projects are being planned for improving and testing the usefulness of the index. The index when used with a multi-temporal land use database can offer an opportunity to check the process of urban land expansion in more detail.

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