

Different stages of urbanization lead to cropland loss: Geospatial data analysis in a global rural-urban continuum perspective

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Abstract—Rapid urbanization has resulted in widespread loss of cropland, but the spatial-temporal patterns and key stages of this transformation have not been clearly understood. In this study, we mapped cropland loss caused by urban expansion in rural-urban continuum since 2000 based on multiple global land maps. Results show a total 3.35×10^6 ha cropland loss resulting from urban expansion and about 70 % of this land use change occurred in Asia. However, there is a trend of reducing cropland loss area caused by urbanization over the years. In a detailed view of urbanization stages, most cropland losses occurred in the stage of further urbanization of towns. Such land use change patterns are relatively rare in urban centers with a high degree of urbanization or in rural areas that have not yet begun urbanization. Especially in Asia, where nearly 60% of cropland loss occurs in densely clustered towns. These findings identify the global spatial-temporal patterns and key regions in which cropland loss caused by urban expansion occurs, and further highlight the implicit link between urbanization stages and land-use change patterns, which could provide data and analytical support for more sustainable land use in the future.

Keywords—urbanization, cropland loss, rural-urban continuum, sustainability, geospatial data analysis

I. INTRODUCTION

Urban expansion, one of the fundamental aspects of urbanization, has occurred rapidly and widely around the world over the past few decades. Urban areas are forecast to triple between 2000 and 2030 with urban populations expected to increase from 2.6 billion to 5 billion during this period [1, 2]. Urban expansion brings inevitable land use conversion, it is recognized that there is potential competition for land between agriculture and urban use [3]. Rapid urban expansion comes at the expense of cropland loss, for more than 60% of irrigated cropland is located near urban areas [4].

This dramatic shift in land use has raised concerns about food security [5]. By 2030, urban expansion will lead to a loss of 1.8-2.4% of global cropland, which would cause 3-4% reduction in worldwide crop production. In addition, about 80%

of the global loss of cropland due to urban expansion will occur in Asia and Africa. Most cropland loss will occur on more productive land [3].

Urban expansion can be simply regarded as the transformation from unbuilt-up area to built-up area, but a more multifaceted process is involved in urbanization that is the development and transformation of urban and rural areas [6, 7]. This concept, which emphasizes the continuous transitional landscapes between urban and rural areas, is called the rural-urban continuum. This perspective of rural-urban continuum provides new insights into the conflicts between urban expansion and the maintenance of existing cropland. Some regional studies also recognize that rural-urban fringe areas where competition for land use frequently occurs should get extra attention [8, 9].

However, the relationship between urbanization process and cropland loss has not been clearly understood globally. In order to better achieve the United Nations Sustainable Goals (SDGs) of zero hunger and sustainable cities and communities, we mapped cropland loss caused by urban expansion in rural-urban continuum since 2000 based on multiple global land maps, identify the global spatial-temporal patterns and key regions in which cropland loss caused by urban expansion occurs, and further highlight the implicit link between urbanization stages and land-use change patterns.

II. DATA AND METHOD

A. Global maps of cropland extent and change

This dataset represents a globally consistent cropland extent time-series at 30-m spatial resolution in four-year intervals (2000-2003, 2004-2007, 2008-2011, 2012-2015, and 2016-2019) [10]. Cropland is defined as land used for annual and perennial herbaceous crops for human consumption, forage (including hay), and biofuel which doesn't include perennial woody crops, permanent pastures, and shifting cultivation.

B. Global artificial impervious surface area (GISA) dataset

GISA 2.0 is a new 30-m global ISA dataset produced in a framework considering the consistency degree of the existing products [11]. Results showed that GISA 2.0 achieved an F1-score of 0.935, better than other similar products such as GISA 1.0 (0.893), GAIA (0.721) and GAUD (0.809).

C. Global rural-urban continuum maps

Furthermore, to explore the differences in cropland loss caused by urban expansion under various urbanization stages, we adopted global rural-urban continuum maps at 1000m resolution in a five-year interval from 2000 to 2020, which was produced by our previous study using a decision tree based on land cover data and population data [12, 13]. In the rural-urban continuum, urban and rural areas are not distinct entities but two poles of a gradient with various transitional landscapes in between. In this product, rural-urban landscapes are further classified as urban centers, urban landscapes, densely clustered towns, sparsely clustered towns, dense villages, sparse villages, and isolated villages [13].

D. Mapping cropland loss caused by urban expansion in rural-urban continuum

In order to obtain the time series of global cropland loss maps, we overlaid the five global cropland maps since 2000 and extracted the change area of cropland to non-cropland between the two adjacent periods' maps respectively. In addition, we adopted the GISA 2.0 product and masked the area of cropland loss with its urban expansion area after 2000, which proves that cropland loss is caused by urban expansion. Finally, we used the rural-urban continuum maps to calculate the loss area of cropland on various landscapes in different periods (2000,2005,2010,2015).

III. RESULT

Results show a total 3.35×10^6 ha cropland loss resulting from urban expansion globally since 2020 and this phenomenon varies greatly in geography. China and the United States are the regions with the largest area of loss of cultivated land encroached by urban expansion. This land use change pattern also widely occurs in other countries in Asia, Europe and North America, such as Germany, Spain, Russia, Canada and Mexico (Fig 1).

According to the data, 70% of the cropland area loss from urban expansion occurred in Asia, 16 % in North America, 8% in Europe and 6 % in Africa (Fig 1).

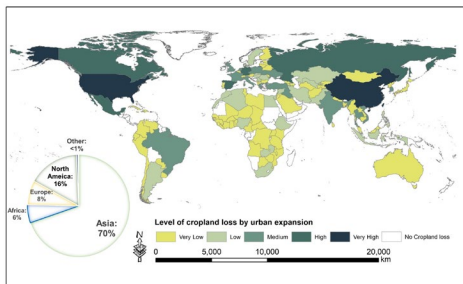


Fig. 1. Global distribution of cropland loss caused by urban expansion.

In a global view, this pattern of unsustainable land-use change is occurring less frequently than it used to, with urban expansion in the early 2000s leading to the loss of more than 1×10^6 ha cropland, this figure has recently fallen by almost 50%, largely due to Asian contributions (Fig 2a). In order to better understand the time trend of this land use change pattern, we calculated and fitted the slope of cropland loss area over years on 2-degree \times 2-degree grids. Most regions are in a reducing trend, while some are still in an increasing trend, with more than 20% of Asia and Africa in the stage of accelerating the sacrifice of cropland for urban expansion, almost none of North America, and about 10% of the remaining continents (Fig 2b,2c).

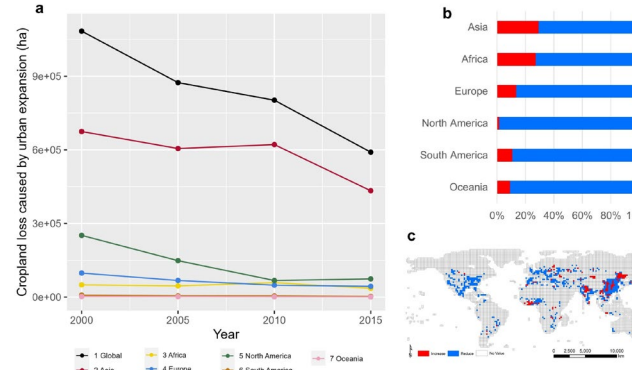


Fig. 2. Time series and its trends of cropland loss caused by urban expansion in each continent. Fig 2a. Time series of cropland loss area caused by urban expansion in each continent. Fig 2b. Proportion of units with an increasing or decreasing trend of cropland loss caused by urban expansion in each continent. Fig 2c. Global distribution of units with an increasing or decreasing trend of cropland loss caused by urban expansion.

Such spatial-temporal patterns may be related to the urbanization stage of different areas. In the various types of rural-urban continuum, most cropland losses occurred in the stage of further urbanization of towns, and such land use change patterns are relatively rare in urban centers with a high degree of urbanization or in rural areas that have not yet begun their urbanization (Fig 3a). Evidence for such a rule can be found in land change of all continents (Fig 3b). About 40%-60% of cropland loss is related to land use in towns' urbanization, especially in Asia, where nearly 60% of cropland loss occurs in densely clustered towns (Fig 3b). In North America, urbanization process of towns also consumes a high proportion of cropland, but the proportion of densely clustered towns and sparsely clustered towns is relatively close. In recent years, sparsely clustered towns even consumed more cropland than densely clustered towns, which is also found in Oceania (Fig 3b,3c). While in Europe, cropland encroachment by dense clustered towns' urbanization has fallen to the level of rural urbanization (Fig 3c).

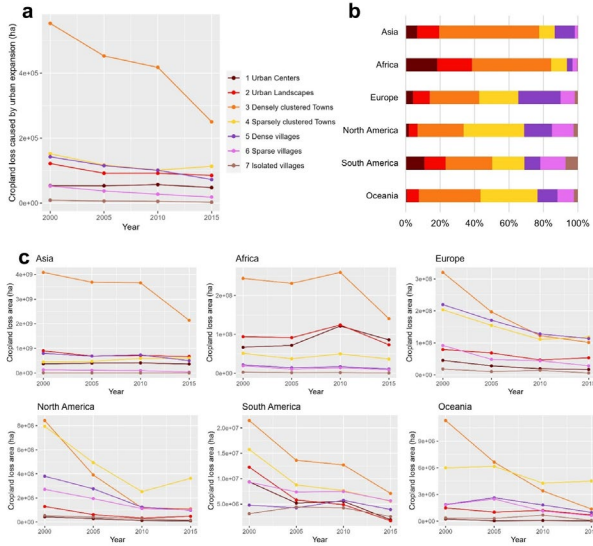


Fig. 3. Time series and proportions of cropland loss caused by urban expansion in each continent's rural-urban continuum. Fig 3a. Time series of cropland loss area caused by urban expansion in a global rural-urban continuum. Fig 3b. Proportion of cropland loss in each continent's rural-urban continuum. Fig 3c. Time series and proportions of cropland loss caused by urban expansion in each continent's rural-urban continuum.

IV. CONCLUSION

In this study, we mapped cropland loss caused by urban expansion in rural-urban continuum since 2000 based on multiple global land maps. Results show a total 3.35×10^6 ha cropland loss resulting from urban expansion and about 70% of this land use change occurred in Asia. However, compared with the early period of 21st century, there is a trend of reducing cropland loss area encroached by urbanization. In a detailed view of urbanization stages, most cropland losses occurred in the stage of further urbanization of towns. Such land use change patterns are relatively rare in urban centers with a high degree of urbanization or in rural areas that have not yet begun urbanization. Especially in Asia, where nearly 60% of cropland loss occurs in densely clustered towns. These findings identify

the global spatial-temporal patterns and key regions in which cropland loss caused by urban expansion occurs, and further highlight the implicit link between urbanization stages and land-use change patterns, which could provide data and analytical support for more sustainable land use in the future.

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