Global Agricultural Land Loss due to Urban Expansion: Implications for the Sustainability of Global Food Security

Taher Radwan, Duncan Whyatt, Alan Blackburn and Peter Atkinson

Lancaster Environment Centre, Lancaster University

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Summary

Globally, agricultural land provides essential food for billions of people. Rapid global population growth and associated urban expansion have raised concerns over the sustainability of global food production due to the persistent loss of existing agricultural land to urban land. In this research, 24 land use/land cover (LULC) maps from 1992 to 2015 were used to monitor historic LULC changes at global, continental and national scales and quantify the rates and types of LULC transitions. The results show that globally, 24% of the agricultural land lost was converted to urban land. Furthermore, 68% of urban land gained was at the expense of agricultural land. The continent of Asia lost the largest amount of agricultural land to urban land over this period. The countries of China, USA and India experienced the largest losses of agricultural land to urban development.

KEYWORDS: Land Use/Land Cover Change, Agricultural Land Sustainability, Global Food Security

1. Introduction

The existence of humanity depends on agricultural land for food production. As the global population increases, so does demand for food and natural resources, with critical consequences for ecosystems (Foley et al., 2005). Global croplands cover approximately 15 million km^2 (12%) of the total land surface area of the planet, providing food to billions of people (Ramankutty et al., 2008; Monfreda et al., 2008). Rapid global population growth and urban expansion have raised concerns over the sustainability of global food production due to the persistent loss of global cropland (Avellan et al., 2012; Cai et al., 2013).

Urban areas comprise a relatively small proportion of the Earth's total land area, however, this proportion is rapidly increasing and with implications for global environmental sustainability. Most urban areas are located near areas of fertile agricultural land, hence, these land use/land cover (LULC) classes are in direct competition with each other for land (Bren D'Amour et al., 2016; van Vliet et al., 2017). Conversion of LULC to urban land is irreversible, leading to unfavourable impacts (Schneider et al., 2012). Urban expansion is occurring on existing cultivated land in many developing countries (Seto et al., 2011; van Vliet et al., 2017).

Remote sensing through satellite observations provides persistent monitoring of planet earth and its natural resources. These continual remote observations contribute substantially to the current understanding of global transitions, as reflected by patterns and changes in our planet's LULC (Song et al., 2018). The aim of this paper is therefore to evaluate the implications of global urban expansion on the loss of productive croplands at global, continental, and national scales to identify better LULC strategies for maintaining environmental sustainability and preserving the global food security. To meet this aim, the following objectives were set:

- Monitor global historic LULC changes from 1992 to 2015
- Quantify the rates and types of global LULC transitions that have occurred
- Assess the impacts of rapid urbanization on the loss of productive cropland

2. Materials and Methods

2.1. Data collection and processing

2.1.1. Global, continental and national LULC change analysis

Twenty-four LULC maps based on a multi-sensor dataset were acquired from the ESA-CCI Land Cover viewer (http://maps.elie.ucl.ac.be/CCI/viewer/). These maps provide access to consistent global LULC coverage at 300 m spatial resolution on an annual basis from 1992 to 2015 based on the processing of MERIS, SPOT-VEGETATION, PROBA-V and AVHRR images (ESA, 2018). The ESA-CCI dataset covers the longest period available to date and it is considered the first time-series of global LULC coverage at 300 m. At this relatively high resolution (compared to previous LULC products), global LULC change analysis is possible. The original dataset assigns the global LULC into 37 classes (22 global classes and 15 regional classes) based on the Land Cover Classification System developed by the Food and Agriculture Organization (FAO) with an overall accuracy of about 75% (ESA, 2018).

The original 37 LULC classes were reclassified into seven major LULC classes for clarity and simplicity of analysis, namely: agricultural land, forest land, shrub/grassland (GSH), urban land, bare land, water bodies and snow/ice as shown in Figure. 1. LULC changes were then analysed at global, continental and national scales by selecting countries from different regions worldwide with the highest rates of agricultural land loss due to urban expansion.
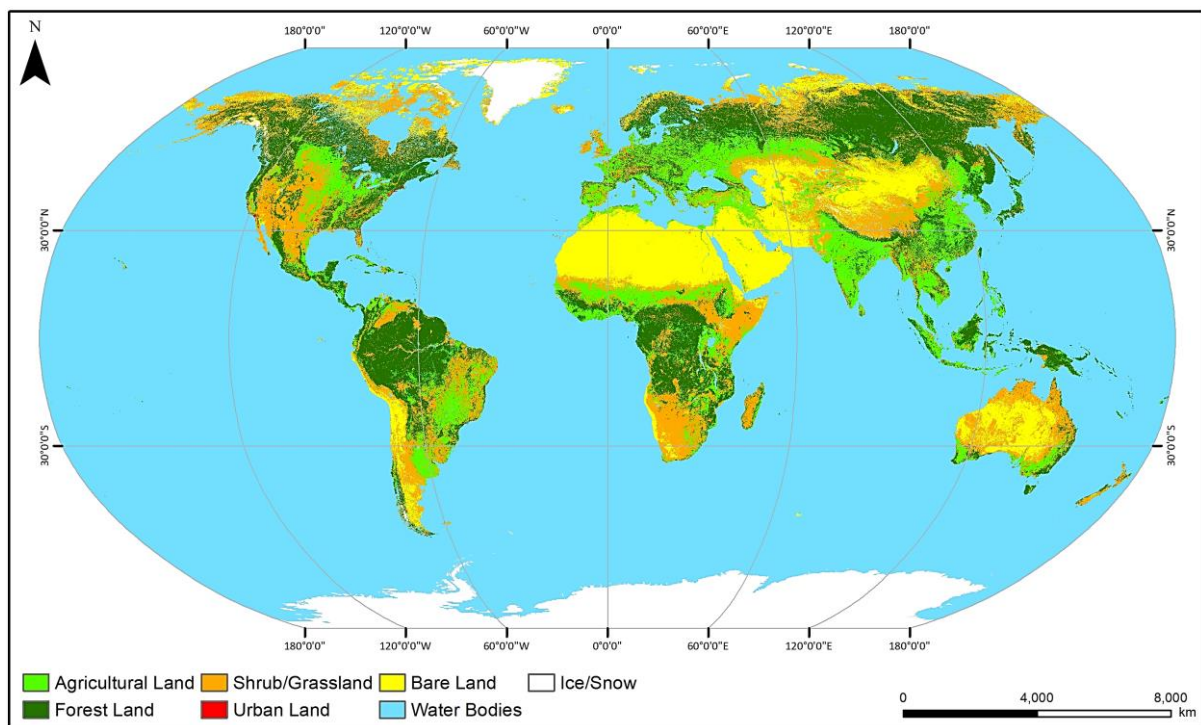

Figure 1: The global LULC map of 2015 after simplification

3. Results and Discussion

3.1. Global and continental LULC change analysis

Globally, agricultural land has increased by 0.82 million km^2 and urban land by 0.39 million km^2 over the 1992-2015 period. Forest has decreased by 0.58 million km^2 over the same period (Figure 2). At the continental level, the amount of agricultural land had a net increase by 0.28 million km^2 in Asia, accounting for 34% of the global increase. Furthermore, urban land has also increased by 0.17 million

km^2 over this period, accounting for 44% of total global urban expansion with 52% of this occurring in China (Figure 2). In Africa, agricultural land has increased by 0.22 million km^2, accounting for about 27% of the global rate of increase. Urban areas have also increased by 25,000 km^2, with 24% of this occurring in Nigeria and Egypt.

In Europe, agricultural land has decreased by 86,000 km^2 from 1992 to 2015. This is the only continent in which the amount of agricultural land declined over time. Conversely, urban land expanded by 92,000 km^2, with 18% of this occurring in Italy, Spain and Romania. In South America, agricultural land increased mainly at the expense of forest by 0.37 million km^2. Urban land increased by 21,000 km^2, with more than 35% of this occurring in Brazil. In North America, the amount of agricultural land increased by more than 10,000 km^2. Urban land, however, increased by 72,000 km^2 with 81% of this occurring in the USA over the 1992-2015 period (Figure 2).
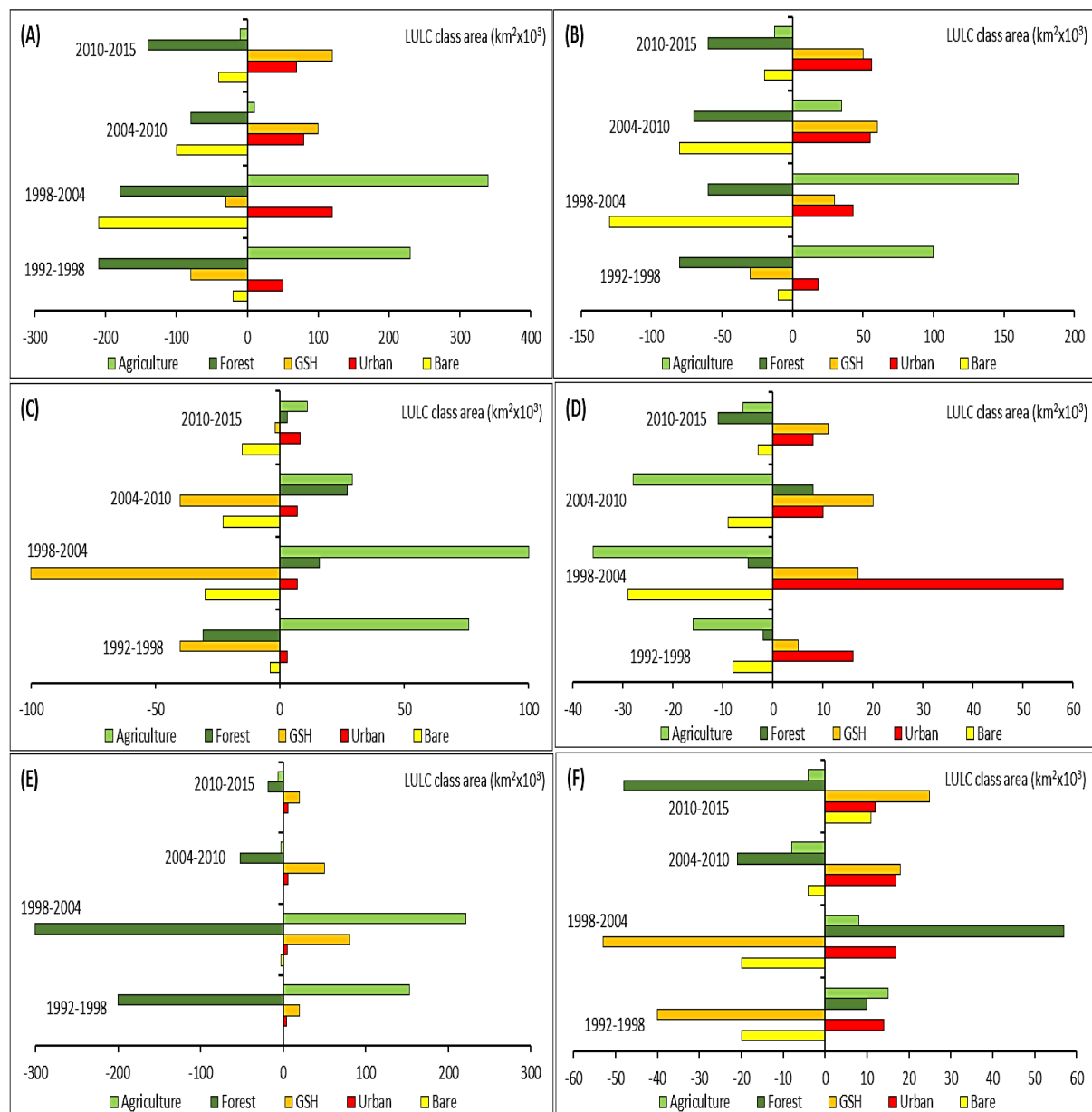

Figure 2: Global and continental LULC change: (A) World, (B) Asia, (C) Africa, (D) Europe, (E) South America, (F) North America (km^{2}x10^3). Note that each plot has been scaled separately on the x-axis (loss or gain of LULC in km^{2}x10^3)

3.2. Global and continental LULC transitions analysis

Four-time periods have been used (6-year equal interval) to explore and analyse the transitions within LULC classes focussing specifically on the agricultural and urban land classes. We calculated the percentage loss of agricultural land to other LULC classes (Figure 3) and percentage loss of other LULC classes to urban land (Figure 4). Globally, from 1992 to 1998, 17% of agricultural land that was converted to urban areas. This increased to 43% between 2010 and 2015. Similar patterns occurred at the continental level. The proportion of existing agricultural land in Asia lost to urbanization increased from 15% between 1992 and 1998 to 57% between 2010 and 2015 with the highest rates of agricultural land loss due to urban expansion worldwide.
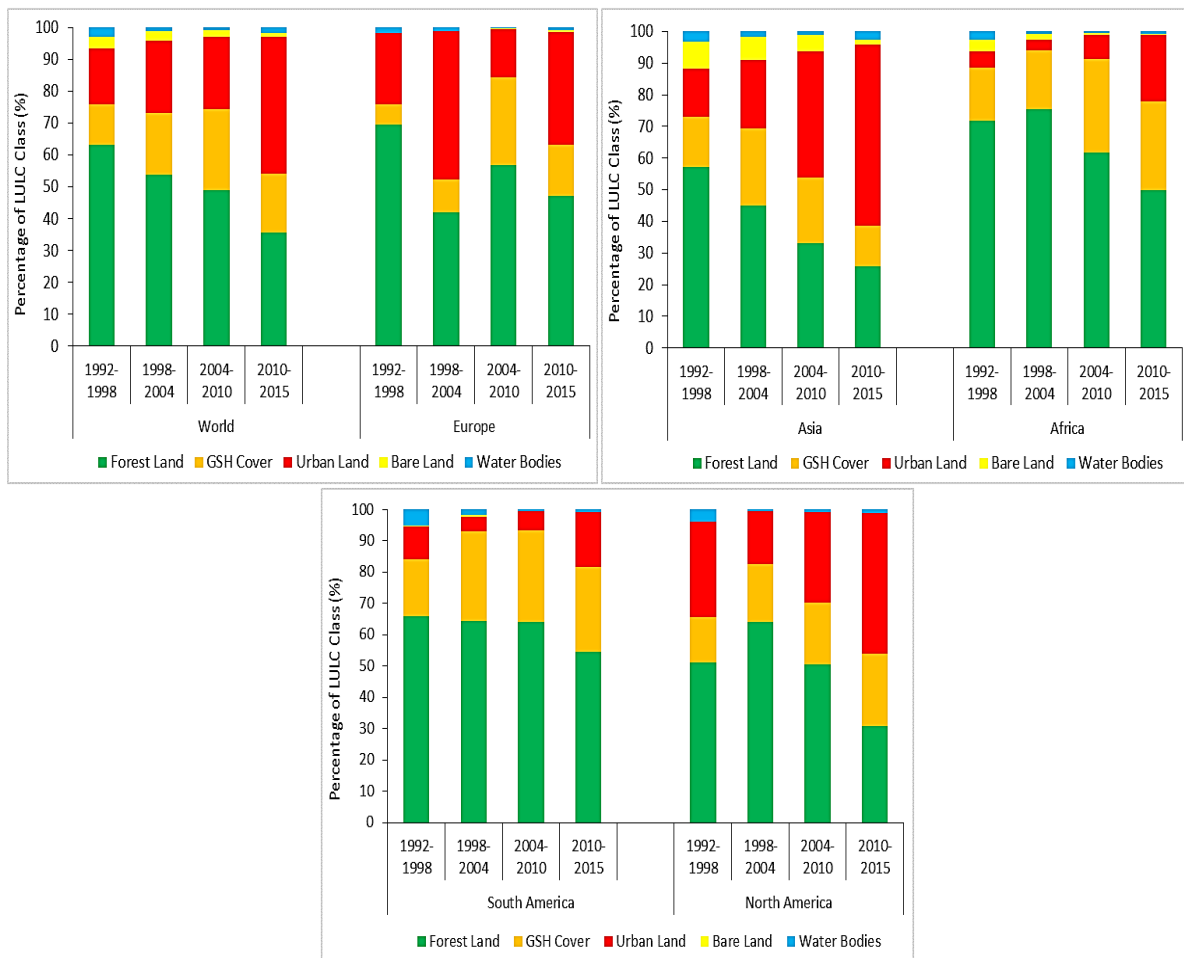

Figure 3: Percentage of existing agricultural land lost to other LULC classes

The proportion of urban land gained globally from agricultural land from 1992 to 1998 was 57%, this increased to 71% between 2010 and 2015. Similar patterns occurred at the continental level. The proportion of global urban areas gained from agricultural land in Asia, was the largest of all continents, from 62% to 85%. Conversely, in North America, this proportion decreased from 42% to 36% between the two time periods (Figure 4).

Amounts of continental agricultural land converted to urban land over the 1992-2015 time-period were as follows: Europe (73,165 km^2), Asia (133,379 km^2), Africa (12,711 km^2), South America (11,087 km^2), North America (30,133 km^2). The continent of Asia experienced the largest percentage loss of agricultural land to urban land globally (51%) over this period.
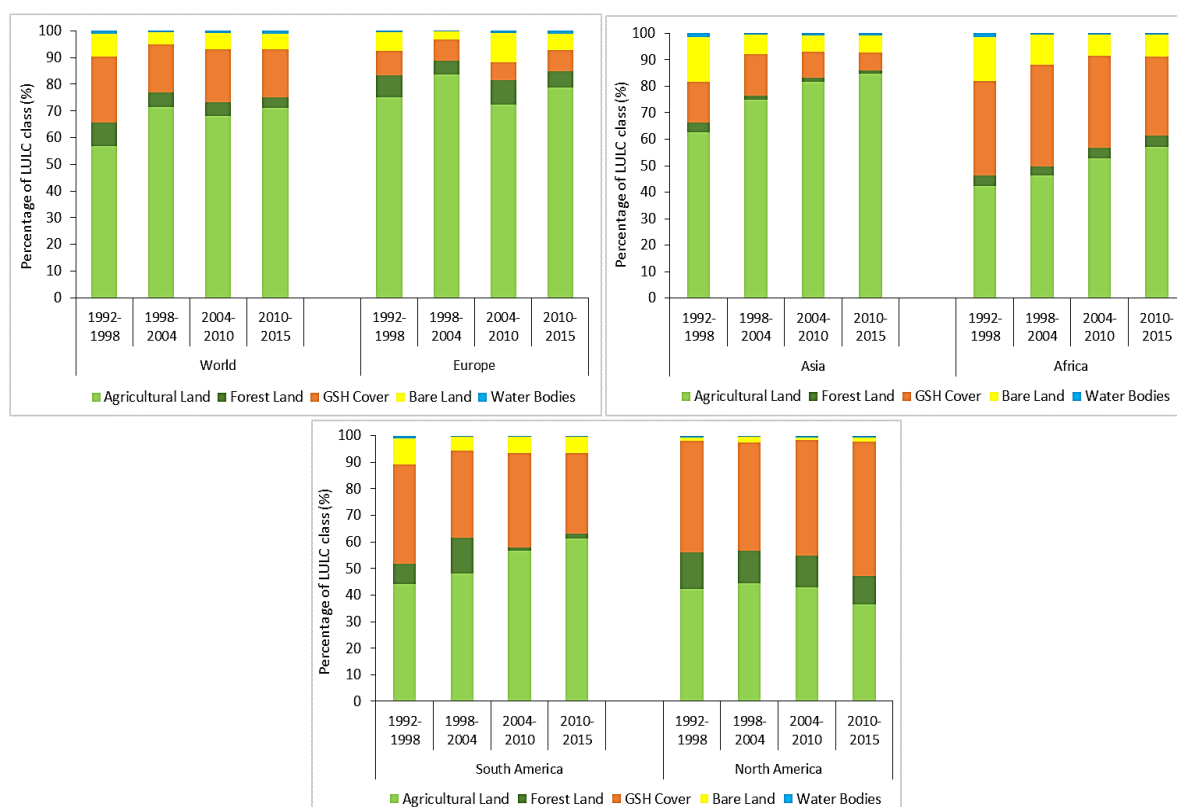
Figure 4: Percentage of other LULC classes converting to urban land

3.3. National LULC transitions analysis

Eleven countries from different continents were selected to monitor and analyse LULC transitions at the national scale. These countries have experienced the highest rates of loss of existing agricultural land to urban expansion (Table 1). The results show that China lost the largest amount of agricultural land to urban development (71,000 km^2) then the USA and India (23,000 km^2 and 17,000 km^2 respectively). Egypt has experienced the largest percentage reduction (86%), particularly in the Nile Delta region.

Table 1: Amount of agricultural land converted to urban areas in the selected countries and its proportion relative to the total loss of agricultural land

Agricultural land area lost to urban land from 1992 to 2015 (km^2)					
Country	1992-1998	1998-2004	2004-2010	2010-2015	Total Loss 1992-2015	% relative to total Agric. loss
USA	5,813	6,854	6,626	3,653	22,946	39.7%
Brazil	1,137	2,080	2,043	2,175	7,435	8.5%
China	4,297	17,571	25,835	23,519	71,222	53.3%
India	856	5,378	5,090	5,900	17,224	54.0%
Pakistan	58	1,253	836	877	3,024	54.7%
Vietnam	146	301	620	1,157	2,224	56.4%
Nigeria	199	651	1,101	1,042	2,993	28.3%
Egypt	68	327	439	413	1,247	85.8%
Italy	463	1,025	881	772	3,141	41.6%
Spain	378	823	967	938	3,106	26.2%
Romania	678	2,818	492	982	4,970	48.0%

4. Conclusions

In this extended abstract, consistent historical data (1992-2015) were used to determine the magnitude and dynamics of LULC changes at global, continental and national scales and quantify the loss of agricultural land to urban development. The results show that globally, 24% of the agricultural land lost was converted to urban areas. Moreover, 68% of urban land was generated at the expense of productive agricultural land between 1992 and 2015. These rapid large-scale transitions between agriculture and urban LULC represent a significant threat to environmental sustainability and global food security. Further research is being conducted to better understand these trajectories of change and their associated drivers.

5. Acknowledgements

6. References

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7. Biographies

Taher Radwan is an early career researcher and a 2nd year PhD student at Lancaster University with a research interest in geospatial data science applications to monitor, detect and identify the changes in land use/land cover, particularly agricultural related changes and how this could affect the sustainability of the food production/security.

Alan Blackburn is a Professor in Remote Sensing at Lancaster University with research interests in developing remote sensing and GIS techniques for environmental applications.

Duncan Whyatt is a Senior Lecturer in GIS at Lancaster University with research interests in both natural and social sciences.

Peter Atkinson is a Professor of Spatial Data Science at Lancaster University with research interests in the development and application of spatial statistics to earth observation and other data to answer a wide range of science and social science questions.