Changes in the Geographical Distributions of Global Human Settlements

Authors: Hongtao, Ye, and Ting, Ma

Source: Journal of Resources and Ecology, 12(6) : 829-839

Published By: Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences

URL: https://doi.org/10.5814/j.issn.1674-764x.2021.06.011

J. Resour. Ecol. 2021 12(6): 829-839
DOI: 10.5814/j.issn.1674-764x.2021.06.011
www.jorae.cn

Changes in the Geographical Distributions of Global Human Settlements

YE Hongtao[1,2], MA Ting[1,2,*]

1. State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China;
2. University of Chinese Academy of Sciences, Beijing 100049, China

Abstract: In recent decades, the continuous growth in the population has significantly changed the area of human settlements across the globe. The change of human settlements has brought great challenges to human development, environmental change, resource allocation, and disaster prediction and prevention. In the current paper, we integrate data products provided by the European Commission, Joint Research Centre with multi-source remote sensing data to analyze the changing trends of global human settlements under varying geographical distributions from 1990 to 2014. The results demonstrate that on the global scale, human settlements are generally distributed in Europe, East Asia, Southeast Asia, South Asia, the eastern United States, the Gulf Coast and the coast of Oceania, with most of them distributed in urban agglomerations and coastal areas. Global human settlements have continued to grow over the past 25 years, mainly in East Asia, Western Europe and the United States. The area of human settlements in eastern Europe has been slightly reduced. The distribution of human settlements is affected by climate, water and terrain conditions. Humans were more likely to have settled in temperate regions with wetter climates, and most of the human settlements are located within 500 km of the coastline and 30 km of land-based water sources. Our results can provide insights into further investigations of the spatio-temporal dynamics of human settlements and its connections to ecological and environmental issues in a changing world.

Key words: human settlements; protected area; temporal and spatial variation; GHSL

1 Introduction

The land surface of the Earth is a finite resource that is central to human welfare and the functioning of the Earth's system. Human activities are transforming the terrestrial environment at unprecedented rates and scales across the globe (Seto et al., 2011). For centuries, human settlement areas were compact, densely populated and the physical extent of the settlement areas grew at a gradual pace.

However, there has been a marked change in the growth trends over the past 30 years. In particular, the current rapid growth of the world's population, the replacement of transportation means and economic development have resulted in the rapid growth of the physical area of human settlements. Although human settlements make up a relatively small proportion of the Earth's total surface, their expansion has had a significant effect on the environment. Therefore, research on the distribution of human settlements and their relationships with the environment and social economy is particularly important. The majority of related studies generally focus on the spatiotemporal variation characteristics of human settlement areas (Cohen et al., 2004; Angel et al., 2011; Gong et al., 2019); the environmental problems caused by the expansion of human settlements (Mcdonald et al., 2008; Wittemyer et al., 2008; Seto et al., 2011; Hutyra et al.,

Received: 2021-02-14 **Accepted:** 2021-05-06
Foundation: The National Science and Technology Key Project (2016YFB0502301).
First author: YE Hongtao, E-mail: yeht.19s@igsnrr.ac.cn
***Corresponding author:** MA Ting, E-mail: mting@lreis.ac.cn

Citation: YE Hongtao, MA Ting. 2021. Changes in the Geographical Distributions of Global Human Settlements. *Journal of Resources and Ecology*, 12(6): 829–839.

2011; Seto et al., 2012; Haddad et al., 2015; Ibisch et al., 2017); natural disasters impacting human settlements near the sea (Nicholls et al., 1996; Small et al., 2003; Abel et al., 2011; Strauss et al., 2012; Addo et al., 2013; Haer et al., 2013; Hauer et al., 2016; Hauer et al., 2019; Antonioli et al., 2020; Baisero et al., 2020); the influence of climate on the distribution of human settlements (Gray et al., 2012; Hunter et al., 2013; Nawrotzki et al., 2015; Egan et al., 2016; Leyk et al., 2017; Fang et al., 2020); and the prediction and analysis of human settlement areas (Angel et al., 2011; Seto et al., 2012).

The rapid development of network and remote sensing technologies has allowed for the advancement of research on human settlements. Most of the previous human settlement-related studies are based on a single problem or region. For example, Wittemyer et al. (2008) found that average population growth rates in 306 protected area boundaries in 45 countries in Africa and Latin America were almost double the rural average, suggesting that protected areas attract rather than repel human settlements. However, the expansion of human settlements results in multiple effects. This study combines multi-source data with GIS-related technologies to investigate the distribution pattern of human residential areas with rich data sources. Based on the available data, we explore the multiple drivers of human settlement distributions and their effects. The aims of this study are to analyze the spatial and temporal distribution characteristics of human settlements, reveal their impacts on the ecological environment, and provide a scientific basis for human sustainable development.

2 Materials and methods

2.1 Materials

2.1.1 Global Human Settlement Layer (GHSL) data

The global human settlements data employed in this paper were provided by the European Commission, Joint Research Centre. The dataset was derived from Landsat imagery (MSS, TM, ETM+, OLI) collected during 1975, 1990, 2000, and 2014, and also from built-up presence as derived from Landsat image collections (GLS1975, GLS1990, GLS2000, and an ad-hoc Landsat 8 collection 2013/2014) (Pesaresi et al., 2015). As the data coverage was limited in 1975, we only used the data from 1990, 2000 and 2014. The GHSL data were corrected using Global Urban Footprint (GUF) data. The most recent global GUF binary settlement mask demonstrates an unprecedented spatial resolution of 12 m that provides – for the first time – a complete picture of the entirety of urban and rural settlements. This was followed by corrections using night-light remote sensing data (DMSP/OLS). The kilometer grid data obtained were then projected to the World Mollweide equal area projection at a 1 km spatial resolution. The final dataset represents the percentage of human settlements per square kilometer.

2.1.2 Protected area data

In this study, we used the World Database on Protected Areas (WDPA) for the protected area data. This database is developed by UNEP-WCMC and the IUCN World Commission on Protected Areas in collaboration with governments and NGOs. Following simple preprocessing, the WDPA data were subject to a 10 km buffer and a raster image with a 1 km spatial resolution was then obtained based on the World Mollweide equal area projection.

2.1.3 Coastline data

The coastline dataset compromised GSHHG data provided by Paul Wessel (Wessel et al., 1996). The dataset contains a global grid with distances to the nearest GSHHG shoreline in km (negative distances for oceans) on a 1 × 1 arc minute grid based on GSHHS version 2.3.7 (released 15 June, 2017). The coastline data were projected to the World Mollweide equal area projection at a 1 km spatial resolution.

2.1.4 Land water data

The land water dataset contains data on lakes, reservoirs and river widths. The lake and reservoir boundary data include 3721 polygons obtained from the Global Lakes and Wetlands Database GLWD–level 1, developed through a partnership between WWF (World Wide Fund for Nature), the Center for Environmental Systems Research, and the University of Kassel, Germany (Lehner et al., 2004). River width data were extracted from the Global River Widths from Landsat (GRWL) Database, which is derived from Landsat images (Allen et al, 2018). The GLWD data were subject to a 1 km buffer, while the GRWL data were converted into an equidistance projection with a 1 km buffer. The two buffered datasets were combined into a single set, and a 2–50 km land and water buffer zone was established. We combined all buffer data into a 1–50 km land water buffer dataset and finally converted its projection into that of World Mollweide.

2.1.5 DEM and slope data

For the DEM data, we employed elevation data from the Shuttle Radar Topography Mission (SRTM) obtained at a near-global scale with a radar system. This data generally represents a dramatic improvement in the availability of high-quality and high-resolution elevation data (Hijmans et al., 2004). We used the GTOPO30 database for the areas where SRTM data were unavailable (e.g., north of 60°N) (Hijmans et al., 2005). Following the processing of the two datasets, the projection was transformed into the World Mollweide projection with a 1 km spatial resolution. The slope was calculated based on the DEM data in ArcGIS (v.10.6, Esri) and the projection and spatial resolution were maintained.

2.1.6 Climate data

Köppen-Geiger climate classification data were used to analyze the distribution of human settlement areas. The Köppen-Geiger system classifies climate into five key classes and 30 sub-types. The classification is based on threshold values and the seasonality of monthly air temperature and precipitation (Beck et al., 2018). The data were transformed into a World Mollweide projection and resampled to a 1 km spatial resolution.

2.1.7 Population and economic data

The population dataset was obtained from the United Nations Department of Economic and Social Affairs, Population Division (Revision of World Population Prospects, 2017). The original population dataset contains 1950–2015 assessment data for 245 countries and regions, as well as median, low and high scenarios for 2015–2100. GDP per capita data were taken from the National Accounts Main Aggregates Database, provided by the Economic Statistics Branch of the United Nations Statistics Division.

2.2 Methods

Data processing and analysis were performed in ArcGIS and Python (v.3.8). Based on the above description, GHSL data were calibrated using Global Urban Footprint (GUF) data and night-light remote sensing data (DMSP/OLS) to obtain raster data with a spatial resolution of 1 km based on Mollweide projection. At the same time, other data were also converted to Mollweide projection and preprocessed accordingly. Based on the preprocessing results, we calculated the temporal and spatial variation of human residential areas across different geographical distributions (e.g., protected areas and climatic zones).

3 Results and discussion

3.1 Spatiotemporal changes in human settlement areas

The global data of human settlements in 1990, 2000 and 2014, reveal a gradual increase in the global area of human settlements over the past 25 years (Fig. 1) from 310707.37 km² in 1990 to 460421.38 km² in 2014. Human settlements have grown in different areas across different continents. The largest growth of human settlements is Asia, followed by North America, again for Europe. Oceania is the least growth in human settlements. Figure 2 maps the global distribution of human settlements. Human settlements are evidently concentrated in the United States, China, India and Western Europe. The human settlements located in the United States are generally distributed in the eastern plains and coastal areas, along the Great Lakes and the western coast of the United States. In Europe, the human settlements are concentrated in central Europe and the coastal areas. Convenient transportation facilitates the movement of the population and affects the distribution of human settlements to some extent. In contrast, countries such as Russia and Ukraine exhibit relatively dispersed human settlements with small-scale clustering. This is attributed to the influence of geographical location and land area, among other factors. In Asia, human settlements are principally distributed in the eastern coastal areas of China, South Korea, Japan, near the Strait of Malacca and the coastal areas of India. Compared with other regions, the distribution of human settlements in Africa is relatively scattered, and mainly around the River Nile, along the coast of the Guinea Sea and in South Africa. In Oceania, human settlements are generally distributed in Indonesia, southern Australia and New Zealand.

Figure 3 depicts the human settlement distributions in terms of longitude and latitude. In addition to the trend of increasing overall area of human settlements for more than 30 years, the principal distribution of human settlements is observed to be within the ranges of 75 to 125 degrees west; 10 degrees west to 50 degrees east; and 100 to 150 degrees east. In terms of latitude, human settlements are generally distributed is in the northern hemisphere, from approximately 25 to 55 degrees north.

Figure 4 ranks the top 20 countries in terms of the human settlement area. Human residential areas are observed to increase on a yearly basis for all countries, with the United States ranking first and Turkey last. In the inset of Fig. 4,

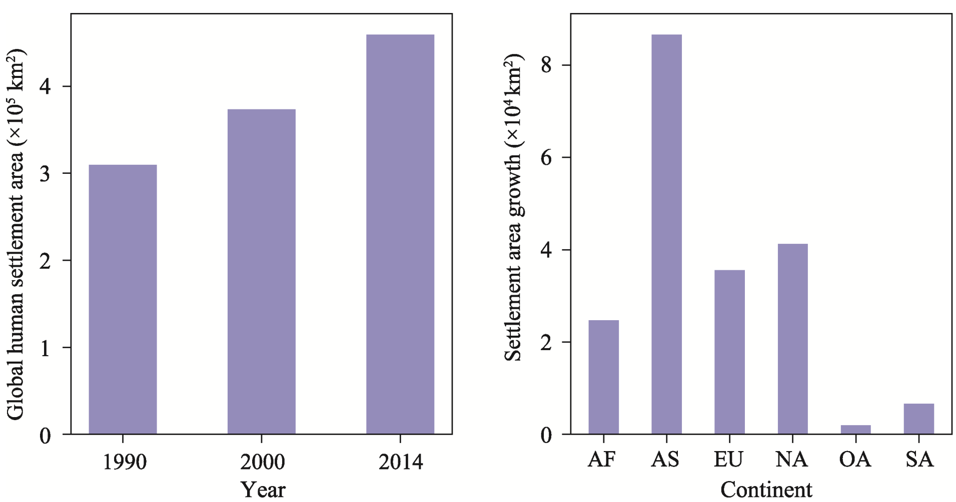

Fig. 1 Global area of human settlements over the past 30 years

Note: AF-Africa; AS-Asia; EU-Europe; NA-North America; OA-Oceania; SA-South America.

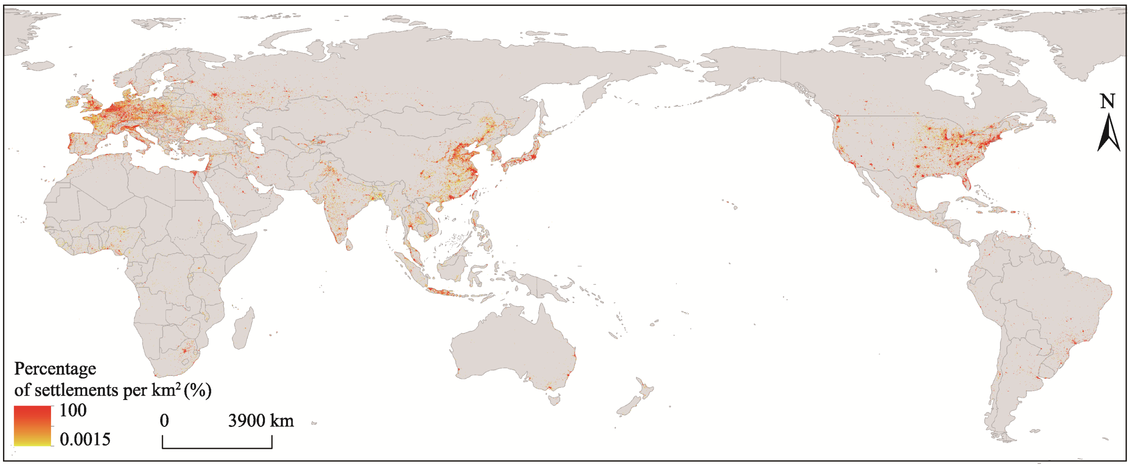

Fig. 2 Distribution of human settlements in 2014

we performed a rank-size rule analysis for 233 countries and territories as follows:

$$P_i = P_1 \times I^{-q} \tag{1}$$

$$\ln P_i = \ln P_1 - q \ln I \tag{2}$$

where P_i is the size of the ith city; P_1 is the human residential area of the largest city; I is the order of city i; and q is the Zipf index, which reflects the spatial pattern of human settlements. When q =1, the distribution of human settlements is relatively balanced and the human settlement areas in high- and low-order countries are also balanced; when $q >1$, high-order countries have a strong monopoly; and when $q <1$, the spatial distribution is relatively scattered.

We performed a rank-size analysis of the human settlement areas in each country and their corresponding ranks to obtain q_{1990}=1.723, q_{2000}=1.696, and q_{2014}=1.674. All of them are greater than 1. This indicates the countries with the highest ranking of human settlement area tend to have a strong monopoly on settlement area.

We then analyzed the correlations between the human settlement area, per capita GDP and population for each country in the corresponding years. In order to account for the interaction between population and per capita GDP, we employed partial correlation analysis.

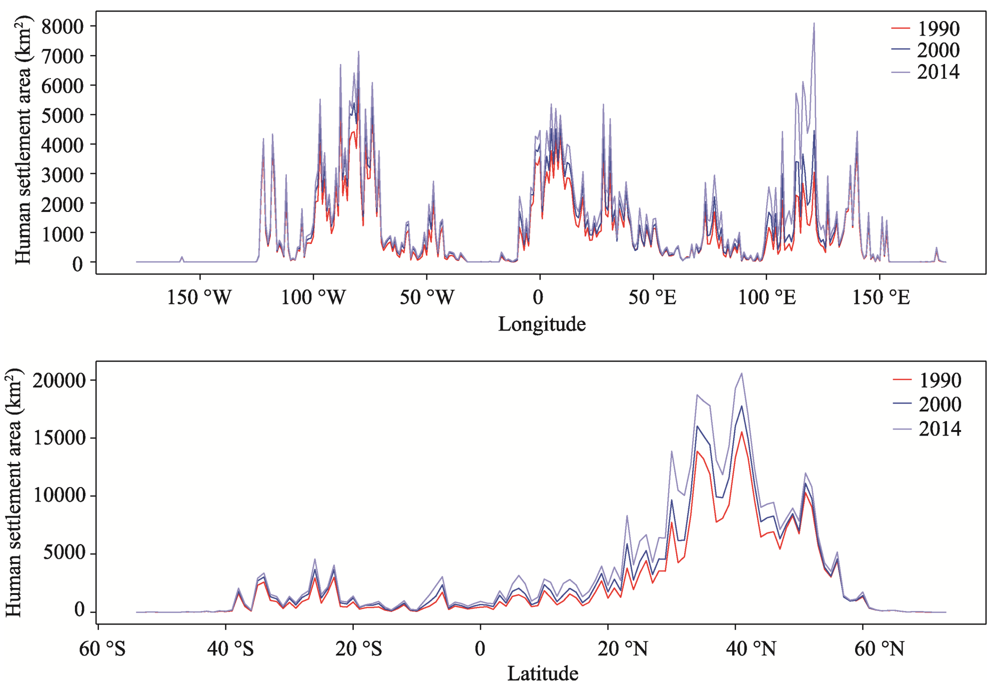

Fig. 3 Distribution of human settlements by longitude and latitude

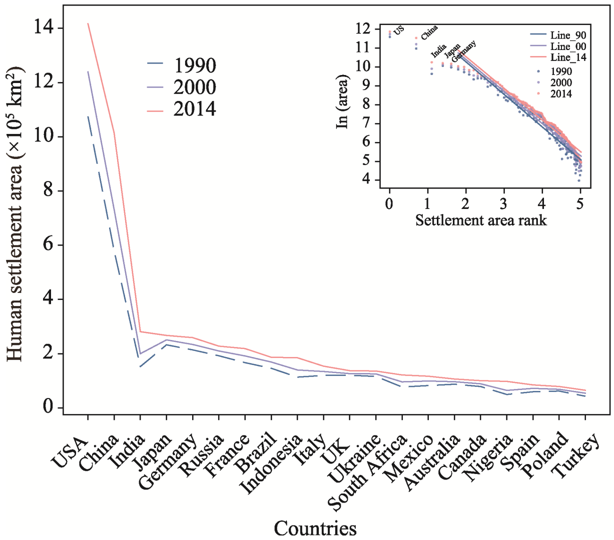

Fig. 4 Top 20 countries in terms of human settlements and rank-size rule analysis

In the third period of the data, by controlling the influence of population factors, we determined the partial correlation coefficient e between human residential area and per capita GDP in each country as approximately 0.3 (e_{1990}=0.301, e_{2000}=0.292, e_{2014}=0.294), with P values less than 0.05. The analysis results demonstrate the significant positive correlation between human residential area and per capita GDP. By controlling the influence of per capita GDP, the partial correlation coefficient between the human settlement area and population was determined as approximately 0.95 (e_{1990}=0.946, e_{2000}=0.946, e_{2014}=0.934), with P values less than 0.05. This indicates that there is also an obvious positive correlation between the human settlement area and population.

We subtracted the 1990 processed global human settlements data from the corresponding 2014 dataset in order to obtain the changes in global human settlements over the past 30 years (Fig. 5). The human settlements are observed to increase sharply at the global scale and the greatest changes are located principally in the United States, China, Japan and Europe. The Middle East, Western Europe and Central Asia exhibit a general decline in human settlement area.

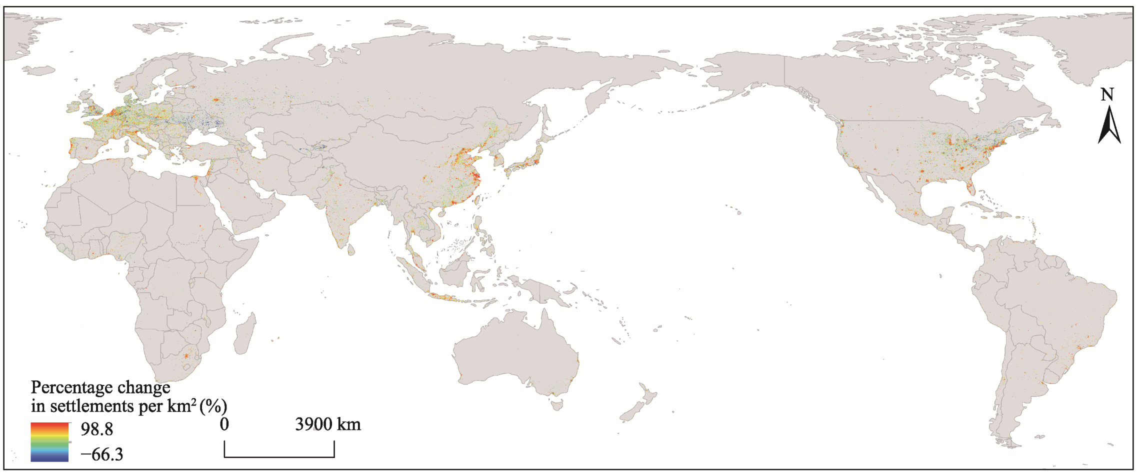

Fig. 5 Changes in human settlements (1990–2014)

In Asia (Fig. 6), the growth of human settlements is mainly distributed in China's Beijing-Tianjin-Hebei urban agglomeration, the Yangtze River Delta urban agglomeration, Guangdong-Hong Kong-Macao Greater Bay Area, the Chengdu-Chongqing urban agglomeration, Seoul in South Korea, and along the coasts of Japan and India. The declines in human settlements are concentrated in Uzbekistan, northern Pakistan and Japan.

The growth of human settlements in North America is generally observed in the Great Lakes region, Boston, New York, Washington, the Gulf Coast, the Pacific Coast, and Mexico City (Fig. 7). A noticeable increase in human settlements is also revealed in several smaller countries such as Guatemala, Puerto Rico, Dominica and Haiti. The majority of the growth in human settlements in these countries is concentrated around their capitals. Decreases in human settlements are mainly distributed in the Boston-Washington and Chicago-Pittsburgh metropolitan areas in the United States.

In Europe, growing human settlements are concentrated in Manchester, UK, the Netherlands, Belgium, Switzerland, Austria, Moscow, Warsaw, Poland, Prague, the Czech Republic, the Mediterranean coast and Portugal (Fig. 8). In the Nile valley of Africa, the growth of human settlements has also been remarkable. The loss of human settlements is observed in southern England, central Germany and in Ukraine. Western Russia has also exhibited a decrease in human settlements scattered throughout the country. In Africa, the main areas of growing human settlements are distributed along the Gulf of Guinea and in South Africa.

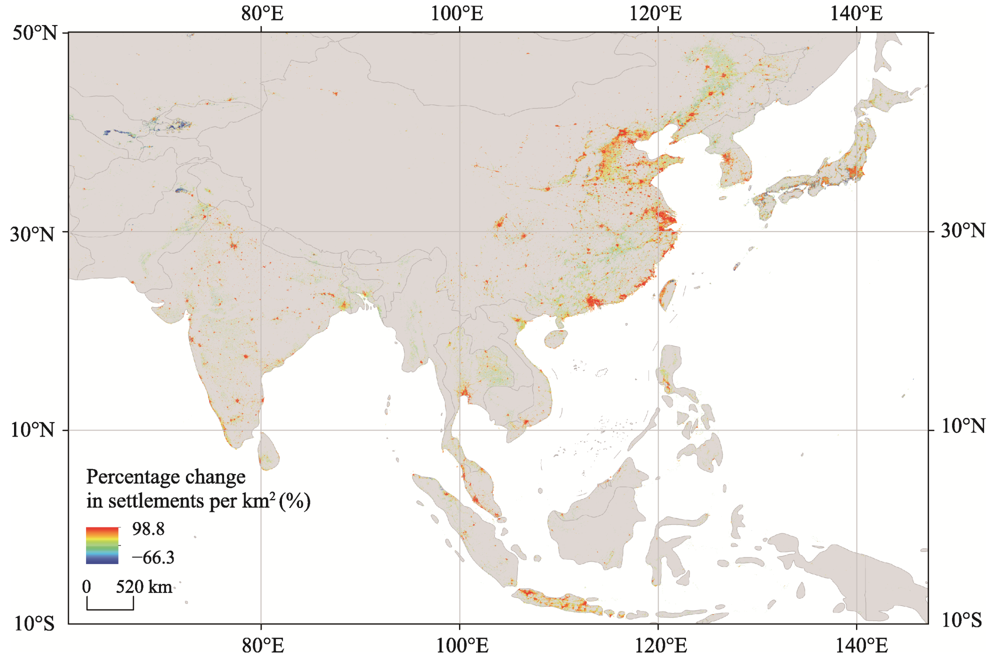

Fig. 6 Changes in human settlements in Asia (1990–2014)

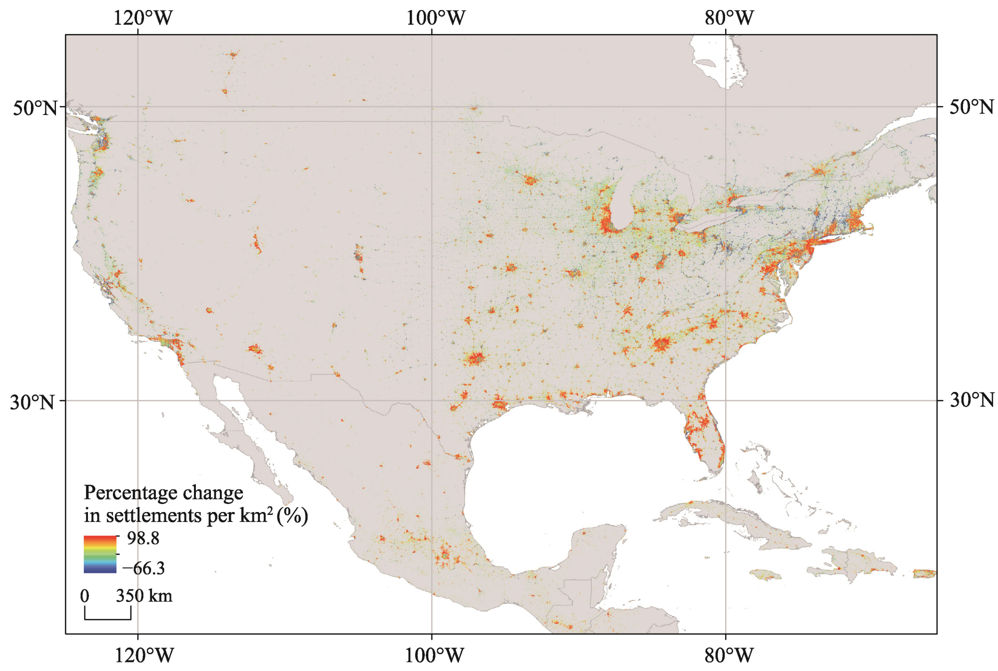

Fig. 7 Changes in human settlements in regions of North America (1990–2014)

3.2 Distribution of human settlement areas near protected areas

Protected areas are vital to the preservation of biodiversity, particularly as protected species have suffered habitat loss as a result of land use changes. However, the continuous increase of the global population has enhanced human settlement areas, and human encroachment on protected areashas consequently become more serious. Therefore, it is important to maintain a distance between protected areas and human settlements. Figure 9 presents the cumulative distribution of human settlement distances to protection zones. The cumulative distributions exhibit similar trends for the years 1990, 2000, and 2014. The largest area of human habitation is located approximately 15 km from the protected areas. The human settlement area is observed to gradually decrease with an increasing distance from the protected areas. Note that the increase in human settlement

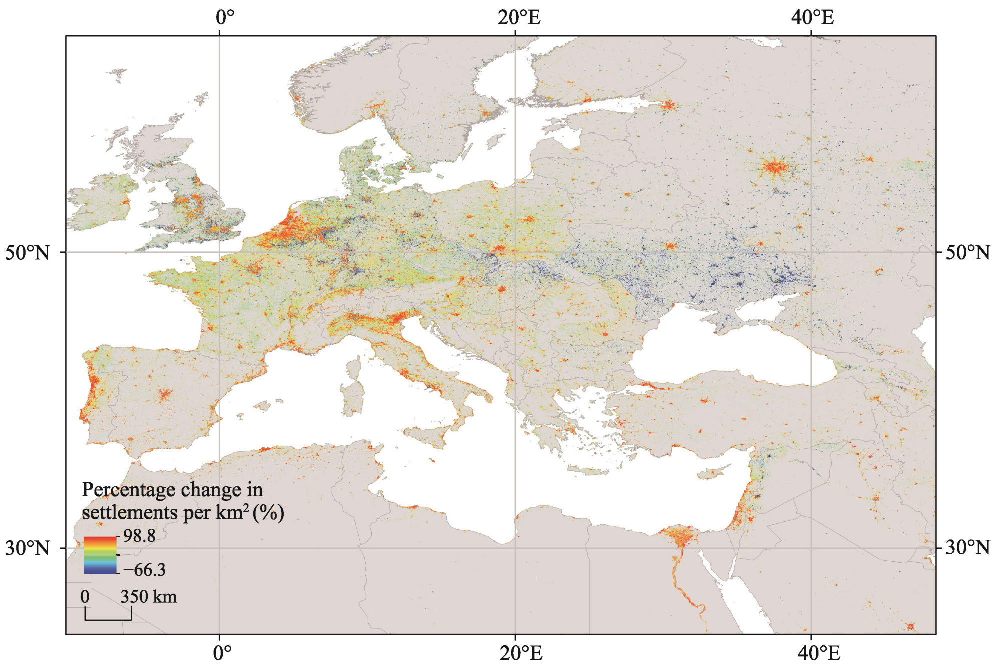

Fig. 8 Variations in human settlements in Europe, Western Asia and the northern parts of Africa (1990–2014).

area on the edge of the protected areas is relatively high. We also calculated the human settlement area within 10 km of a protected area (Table 1), which represents a reasonable distance for an individual to walk each day (George et al., 2008). The areas of global human settlements within 10 km of a protected area were determined as 21475 km², 25655 km² and 30010 km² for 1990, 2000 and 2014, respectively, indicating a rapid increase in human settlement area in the vicinity of protected areas. This overabundance of human settlements highlights the threats nature reserves face and the limitations of biodiversity conservation. Determining how to scientifically and effectively solve the problems caused by growing human settlement areas should be a focus of future research.

Table 1 Areas of human settlements within 10 and 50 km of protected areas

Distance (km)	Area (km²)		
	1990	2000	2014
⩽ 10	21475	25655	30010
⩽ 50	86930	102020	117270

3.3 Distribution of human settlement areas near coastlines and land water

Life cannot develop without water. The growing global population has resulted in a large number of people flooding into coastal areas, placing great pressure on the ecosystem and its resources. We calculated the distribution of human settlements along the coastline and near terrestrial water bodies. Figure 10 shows the distribution of human settlements close to the coastline. The distribution of human settlements near the coastline is similar across the 30 years. The largest distribution of human settlements is located approximately 10 km from the coastline. As the distance from the coastline increases, the area of human settlements gradually decreases. This indicates a relationship between the distribution of human settlement areas and their distance from the ocean, namely, the closer an area is to the coastline, the greater the distribution of the human settlement area.

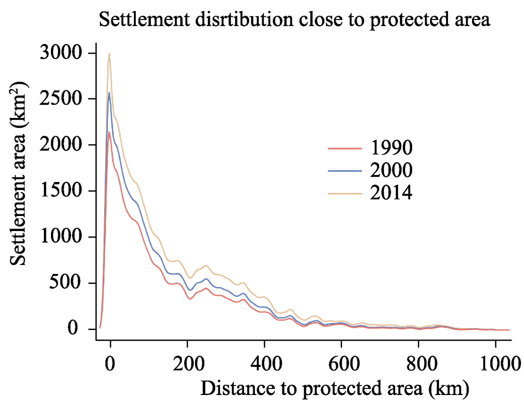

Fig. 9 Distribution of human settlement areas close to protected areas

Figure 11 depicts the distribution of human settlement areas close to land-based water sources, indicating that approximately 30% of the world's human settlement area is located within 5 km of these water bodies, while approximately 80% of human settlement areas are located within 30 km of

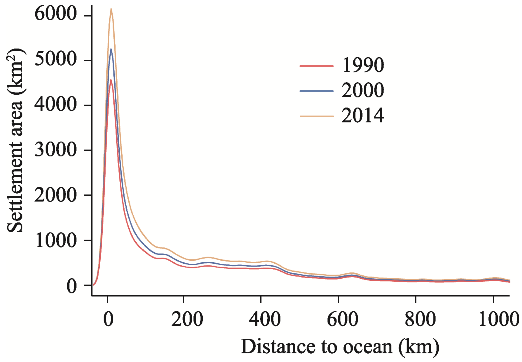

Fig. 10 Distribution of human settlement area close to ocean

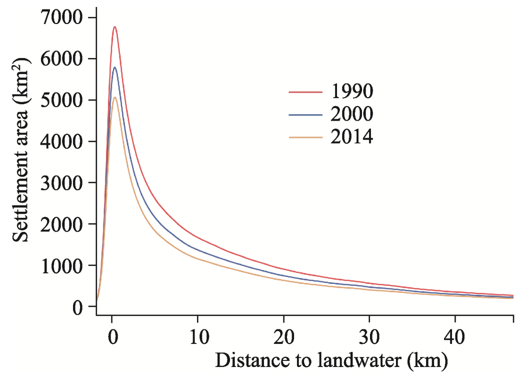

Fig. 11 Distribution of human settlement area close to land water

land-based water. Only approximately 15% of human settlements are located at farther than 50 km from land water.

3.4 Distribution of human settlement areas under varying climate classifications

The Köppen-Geiger system classifies climate into five principal classes and 30 sub-types (Beck et al., 2018), which are listed in Table 2. This classification is based on threshold values and the seasonality of monthly air temperature and precipitation. We calculated the variations in the areas occupied by human settlements across different climatic zones (Fig. 12). The human inhabited area is maximized in the Cfb sub-type (temperate, no dry season, warm summer), followed by Dfb (cold, no dry season, warm summer) and Dfc (cold, no dry season, cold summer). The human settlements are generally distributed in humid and temperate regions. Cfb also exhibits the largest increase in human settlements within the 25-year period.

Table 2 Köppen-Geiger climate classification

Name	Representative characteristics
Af	Tropical, rainforest
Am	Tropical, monsoon
Aw	Tropical, savannah
BWh	Arid, desert, hot
BWk	Arid, desert, cold
BSh	Arid, steppe, hot
BSk	Arid, steppe, cold
Csa	Temperate, dry summer, hot summer
Csb	Temperate, dry summer, warm summer
Csc	Temperate, dry summer, cold summer
Cwa	Temperate, dry winter, hot summer
Cwb	Temperate, dry winter, warm summer
Cwc	Temperate, dry winter, cold summer
Cfa	Temperate, no dry season, hot summer
Cfb	Temperate, no dry season, warm summer
Cfc	Temperate, no dry season, cold summer
Dsa	Cold, dry summer, hot summer
Dsb	Cold, dry summer, warm summer
Dsc	Cold, dry summer, cold summer
Dsd	Cold, dry summer, very cold winter
Dwa	Cold, dry winter, hot summer
Dwb	Cold, dry winter, warm summer
Dwc	Cold, dry winter, cold summer
Dwd	Cold, dry winter, very cold winter
Dfa	Cold, no dry season, hot summer
Dfb	Cold, no dry season, warm summer
Dfc	Cold, no dry season, cold summer
Dfd	Cold, no dry season, very cold winter
ET	Polar, tundra
EF	Polar, frost

3.5 Distribution of human settlement areas by slope and elevation

We further investigated the distribution of human settlement area by determining its relationship with elevation and slope. Figure 13 presents the distribution of human settlements according to elevation, revealing that the majority of the human settlement areas are located at low elevations. Furthermore, the human settlement areas are greatest at 20 m asl. The area of human settlements is observed to gradually decrease with increasing altitude and stabilizes at the altitude of 500 m. Figure 14 shows the distribution of human settlements at varying slopes. The human settlements are essentially distributed in areas with a slope of less than 5°, and the smaller the slope, the larger the human settlement area. At slopes greater than 5°, the human settlement area stabilizes.

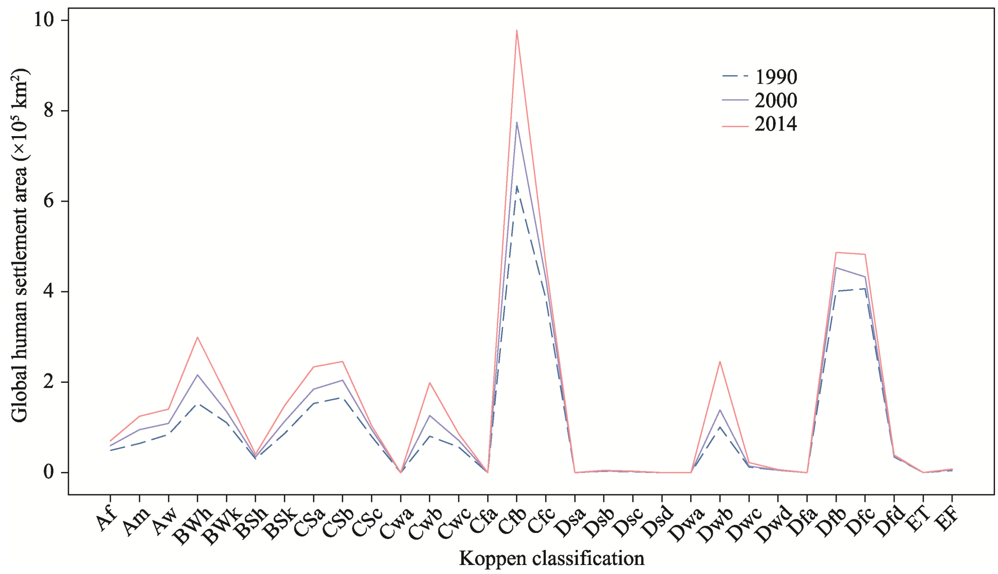

Fig. 12 Distribution of human settlements among the different Köppen-Geiger climatic classifications

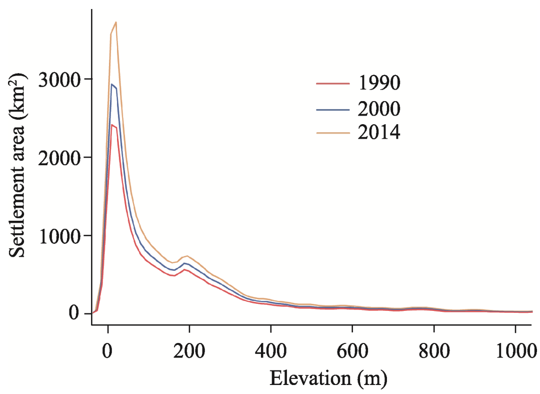

Fig. 13 Human settlement area distribution relative to elevation

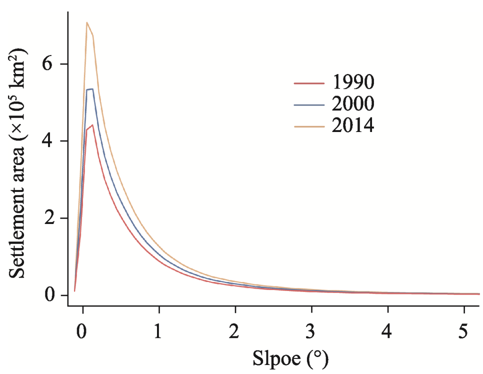

Fig. 14 Human settlement area distribution relative to slope

4 Conclusions

In the current study, we integrated GHSL and multi-source remote sensing data to analyze the temporal and spatial variations of global human settlements from 1990 to 2014 and under different geographical distributions. The key conclusions are described in the following five items.

(1) At the global scale, human settlements are generally distributed in Europe, East Asia, Southeast Asia, South Asia, the eastern United States, the Gulf coast and the coast of Oceania, the majority of which are distributed around urban agglomerations and coastal areas. The area of human settlements exhibited a continuous increase globally from 1990 to 2014, particularly in the United States, China, India, Japan and Western Europe. Human settlement areas exhibited a marked decreased in Eastern Europe.

(2) By controlling the influence of population, we found a significant positive correlation between human residential area and per capita GDP. Moreover, controlling the influence of per capita GDP resulted in an obvious positive correlation between human residential area and population.

(3) Although the proportion of human settlements near protected areas decreased from 1990 to 2014, the total area of human settlements near protected areas increased. This indicates a growing threat to the ecological environment and results in problems such as biodiversity change, habitat fragmentation, and environmental pollution.

(4) The distribution of human settlements is observed to be related to proximity to water, namely human settlements tend to be located closer to water. In particular, the majority of human settlements are within 500 km from the coastline and 30 km from land-based water bodies.

(5) The distribution of human settlements is also affected by climate. The results show that humans are more likely to settle in temperate regions where the climate is wetter. Elevation and slope also have impacts on the distribution of human settlements. The majority of human settlements are located in areas with elevations and slopes of less than 500 m and 3°, respectively.

In conclusion, the area of human settlements is increasing throughout the whole world. Climate, elevation, slope, and the location of people relative to water all affect the distribution of human settlements. Meanwhile, we should also pay greater attention to the impacts of the expansion of human settlements on the ecological environment.

References

Abel N, Gorddard R, Harman B, et al. 2011. Sea level rise, coastal development and planned retreat: Analytical framework, governance principles and an Australian case study. *Environmental Science & Policy*, 14: 279–288.

Addo K A. 2013. Shoreline morphological changes and the human factor: Case study of Accra Ghana. *Journal of Coastal Conservation*, 17(1): 85–91.

Allen G H, Pavelsky T M. 2018. Global extent of rivers and streams. *Science*, 361(6402): 585–588.

Angel S, Parent J, Civco D L, et al. 2011. The dimensions of global urban expansion: Estimates and projections for all countries, 2000–2050. *Progress in Planning*, 75(2): 53–107.

Antonioli F, de Falco G, Lo Presti V, et al. 2020. Relative sea-level rise and potential submersion risk for 2100 on 16 coastal plains of the Mediterranean Sea. *Water*, 12(8): 2173. DOI: 10.339/w12082173.

Baisero D, Visconti P, Pacifici M, et al. 2020. Projected global loss of mammal habitat due to land-use and climate change. *One Earth*, 2(6): 578–585.

Beck H E, Zimmermann N E, McVicar T R, et al. 2018. Present and future Koppen-Geiger climate classification maps at 1-km resolution. *Scientific Data*, 5: 180214. DOI: 10.1038/sdata.2018.214.

Cohen B. 2004. Urban growth in developing countries: A review of current trends and a caution regarding existing forecasts. *World Development*, 32: 23–51.

Egan P J, Mullin M. 2016. Recent improvement and projected worsening of weather in the United States. *Nature*, 532(7599): 357–360.

Esch T, Marconcini M, Felbier A, et al. 2013. Urban footprint processor—Fully automated processing chain generating settlement masks from global data of the TanDEM-X Mission. *IEEE Geoscience and Remote Sensing Letters*, 10(6): 1617–1621.

Esch T, Taubenböck H, Roth A, et al. 2012. TanDEM-X mission—New perspectives for the inventory and monitoring of global settlement patterns. *Journal of Applied Remote Sensing*, 6(1): 061702-1. DOI: 10.1117/1.Jrs.6.061702.

Fang Z H, Liu Z F, He C Y, et al. 2020. Will climate change make Chinese people more comfortable? A scenario analysis based on the weather preference index. *Environmental Research Letters*, 15(8): 084028. DOI: 10.1088/1748-9326/ab9965.

Gong P, Li X C, Zhang W. 2019. 40-Year (1978–2017) human settlement changes in China reflected by impervious surfaces from satellite remote sensing. *Science Bulletin*, 64(11): 756–763.

Gray C, Mueller V. 2012. Drought and population mobility in rural Ethiopia. *World Development*, 40(1): 134–145.

Haddad N M, Brudvig L A, Clobert J, et al. 2015. Habitat fragmentation and its lasting impact on Earth's ecosystems. *Science Advances*, 1(2): e1500052. DOI: 10.1126/sciadv.1500052.

Haer T, Kalnay E, Kearney M, et al. 2013. Relative sea-level rise and the conterminous United States: Consequences of potential land inundation in terms of population at risk and GDP loss. *Global Environmental Change*, 23: 1627–1636.

Hauer M E, Evans J M, Mishra D R. 2016. Millions projected to be at risk from sea-level rise in the continental United States. *Nature Climate Change*, 6(7): 691–695.

Hauer M E, Hardy R D, Mishra D R, et al. 2019. No landward movement: Examining 80 years of population migration and shoreline change in Louisiana. *Population and Environment*, 40(4): 369–387.

Hijmans R J, Cameron S E, Parra J L, et al. 2005. Very high resolution interpolated climate surfaces for global land areas. *International Journal of Climatology*, 25(15): 1965–1978.

Hunter L M, Murray S, Riosmena F. 2013. Rainfall patterns and US migration from rural Mexico. *International Migration Review*, 47(4): 874–909.

Hutyra L R, Yoon B, Hepinstall-Cymerman J, et al. 2011. Carbon consequences of land cover change and expansion of urban lands: A case study in the Seattle metropolitan region. *Landscape and Urban Planning*, 103(1): 83–93.

Ibisch P L, Hoffmann M T, Kreft S, et al. 2016. A global map of roadless areas and their conservation status. *Science*, 354(6318): 1423–1427.

Lehner B, Döll P. 2004. Development and validation of a global database of lakes, reservoirs and wetlands. *Journal of Hydrology*, 296(1–4): 1–22.

Leyk S, Runfola D, Nawrotzki R J, et al. 2017. Internal and international mobility as adaptation to climatic variability in contemporary Mexico: Evidence from the integration of census and satellite data. *Population, Space and Place*, 23(6): e2407. DOI: 10.1002/psp.2047.

McDonald R I, Kareiva P, Forman R T T. 2008. The implications of current and future urbanization for global protected areas and biodiversity conservation. *Biological Conservation*, 141(6): 1695–1703.

Nawrotzki R J, Hunter L M, Runfola D M, et al. 2015. Climate change as migration driver from rural and urban Mexico. *Environment Research Letters*, 10(11): 114023. DOI: 10.1088/1748-9326/10/11/114023.

Nicholls R J, Leatherman S P. 1996. Adapting to sea-level rise: Relative sea-level trends to 2100 for the United States. *Coastal Management*, 24(4): 301–324.

Pesaresi Martino, Ehrilch Daniele, Florczyk Aneta J, et al. 2015. GHS built-up grid, derived from Landsat, multitemporal (1975, 1990, 2000, 2014). European Commission, Joint Research Centre (JRC).

Seto K C, Fragkias M, Guneralp B, et al. 2011. A meta-analysis of global urban land expansion. *Plos One*, 6(8): e23777. DOI: 10.1371/journal.pone.0023777.

Seto K C, Guneralp B, Hutyra L R. 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Science of USA*, 109: 16083–16088.

Small C, Nicholls R J. 2003. A global analysis of human settlement in coastal zones. *Journal of Coastal Research*, 19: 584–599.

Strauss B H, Ziemlinski R, Weiss J L, et al. 2012. Tidally adjusted estimates of topographic vulnerability to sea level rise and flooding for the contiguous United States. *Environment Research Letters*, 7(1): 014033. DOI: 10.1088/1748-9326/7/1/014033.

Wessel P, Smith W H F. 1996. A global, self-consistent, hierarchical, high-resolution shoreline database. *Journal of Geophysical Research: Solid Earth*, 101: 8741–8743.

Wittemyer G, Elsen P, Bean W T, et al. 2008. Accelerated human population growth at protected area edges. *Science*, 321(5885): 123–126.

全球人类居住区在不同地理分布下的变化

冶宏涛 [1,2]，马　廷 [1,2]

1. 中国科学院地理科学与资源研究所 资源与环境信息系统国家重点实验室，北京 100101；
2. 中国科学院大学，北京 100049

摘　要：近几十年来，人口的持续增长显著改变了全球的人居环境。人类居住区的变化，对人类发展、环境变化、资源配置、灾害预测与防治等方面带来了巨大的挑战。本文结合欧洲委员会、联合研究中心提供的数据产品和多源遥感数据，分析了 1990–2014 年不同地理分布全球人居环境的变化趋势。结果表明：在全球尺度上，人类住区总体分布在欧洲、东亚、东南亚、南亚、美国东部、墨西哥湾沿岸和大洋洲沿岸，且大多分布在城市群和沿海地区。在过去的 24 年里，全球人类住区持续增长，主要分布在东亚、西欧和美国。欧洲东部的人类居住区面积略有减少。人类居住区的分布受气候、水和地形条件的影响。人类更有可能定居在气候湿润的温带地区，大多数人类定居点位于海岸线 500 km 以内和陆地水域 30 km 以内。本文的研究结果可为进一步研究变化世界中人类住区的时空动态及其与生态环境问题的关系提供参考。

关键词：人类居住区；保护区；时空变化；全球人类居住层 (GHSL)