Heliyon 8 (2022) e10423

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Decoupling relationship analysis between urbanization and carbon emissions in 33 African countries

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ARTICLE INFO

Keywords:
Decoupling status
Urbanization
Carbon emissions
Sustainable development

ABSTRACT

Global warming is a serious environmental problem facing the world in the 21st century. Carbon dioxide, an important greenhouse gas, is the driver of global warming. Rapid urbanization has not only improved the quality of life, but has also led to radical increases in carbon emissions. In order to achieve a win-win situation between urbanization and carbon emissions reduction, research on the decoupling relationship between urbanization and carbon emissions has great significance, especially in Africa, where urbanization is advancing rapidly. This study explores the decoupling relationship between different types of urbanization (demographic urbanization, spatial urbanization, economic urbanization, social urbanization) and carbon emissions in Africa. The results show that the decoupling relationship between demographic urbanization and carbon emissions is similar to the decoupling relationship between spatial urbanization and carbon emissions. The decoupling relationship between economic urbanization and carbon emissions is similar to the decoupling relationship between social urbanization and carbon emissions. Only 4 of the 33 African countries studied have achieved the decoupling of four types of urbanization from carbon emissions in the long period (2000–2018). These findings can provide some guidance for the sustainable development of Africa.

1. Introduction

Climate change is a major challenge facing the world today (Rogelj et al., 2014). Global warming is happening at an unprecedented speed. In the 10 years from 2011 to 2020, the global average temperature increased by 1.09 °C over 1850–1900 (Arias et al., 2021; Yan et al., 2021). Greenhouse gas emissions caused by human life and social production, especially carbon dioxide, are the main culprits of global warming (Shakoor et al., 2020; Zhu et al., 2019). Global carbon emissions have continued to grow since 2013. In 2020, the average concentration of carbon dioxide in the atmosphere is about 415ppm, reaching a new high in human history (Chen, 2021). Regional droughts, high temperatures, heat waves and floods caused by climate change pose a huge threat to biodiversity, water resources security, food security and even human survival (Berchin et al., 2017; Williams, 2008), with developing countries bearing the brunt. Since 2008, an average of 21.8 million people in the world have had to migrate within the country due to weather disasters each year (Quiggin et al., 2021). If the current carbon emissions trends continue, global temperatures will continue to rise, which will bring more severe social and environmental impacts to the entire planet. Therefore, carbon emissions reduction is imperative, which requires the joint efforts of all countries around the world. At the United Nations Climate Change Conference in 2015, nearly 200 States parties pledged to hold global warming to well below 2 °C and to "pursue efforts" to limit it to 1.5 °C (Perkins-Kirkpatrick and Gibson, 2017; UNFCCC, 2015). At present, 137 countries have proposed the goal of achieving carbon neutrality by 2050, accounting for 73% of global carbon emissions. China, the world's largest emitter, also proposes to achieve carbon neutrality by 2060 (Mi et al., 2017; Shi et al., 2021).

Cities are the regions where human economic and social activities are concentrated and distributed. They account for about 2% of the global area, but contribute about 70% of GDP, consume more than 60% of energy and produce 75% of the global carbon dioxide (Xu et al., 2018). Urbanization is an inevitable trend of human development, which is manifested in the transfer of population from rural areas to urban areas (Wang et al., 2020b, 2022), including the comprehensive impact of demographic urbanization, spatial urbanization, economic urbanization, and social urbanization (Li et al., 2019a). It not only enables the continuous growth of urban population, expansion of urban space, rapid economic development, and steady improvement of social welfare, but also

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https://doi.org/10.1016/j.heliyon.2022.e10423
Received 13 February 2022; Received in revised form 27 May 2022; Accepted 18 August 2022

triggers many environmental problems (Liu et al., 2017). Among them, the prominent problem is the increase of energy consumption related to urbanization, which is widely considered to be the main source of carbon emissions (Waheed et al., 2019). Liu and Bae (2018) indicated that 1% augments of China's urbanization increase its carbon emissions by 1.0%. Anwar et al. (2020) found positive effect of urbanization on CO_2 emission in the research of nine Far East Asian countries. With the advancement of urbanization, global carbon emissions may continue to grow.

Africa is one of the fastest urbanizing regions in the world (Sulemana et al., 2019). It is estimated that by 2035, 810 million people will live in African cities (Saghir and Santoro, 2018). We assume that in a technologically backward region such as Africa, carbon emissions will increase with the advancement of urbanization. Although the carbon emissions of Africa account for only 3% of the world at present, due to poor geographic and economic conditions, this region has suffered more losses than other continents under the severe situation of global climate change (Nangombe et al., 2018). If no effective measures are taken, African countries, particularly in East Africa, are likely to spend more than 10 per cent of their gross domestic product dealing with rising sea levels caused by global warming (United Nations, 2015). Thus, it is urgent to reduce carbon emissions while promoting urbanization. Some scholars have examined the decoupling relationship between economic growth and carbon emissions in Africa. However, there are few researches on the decoupling relationship between urbanization and carbon emissions in Africa, especially the decoupling relationship between four types of urbanization and carbon emissions.

Therefore, this study analyzes the decoupling relationship between different types of urbanization (demographic urbanization, spatial urbanization, economic urbanization, social urbanization) and carbon emissions in different countries, with the main purpose of the following three aspects: (1) explore the similarities and differences in the relationship between different types of urbanization and carbon emissions; (2) understand the necessity of carbon emissions reduction in Africa; (3) propose policy recommendations based on the results and local conditions to achieve sustainable development.

2. Study area and data

2.1. Study area

As the second largest continent in the world, Africa straddles the equator and has a rapid urbanization wave (Sulemana et al., 2019). In 2000, the urbanization rate in Africa was 30.8%, and this figure reached 38.8% in 2017 (Nathaniel and Adeleye, 2021), which put tremendous pressure on local sustainable development. Although the carbon emissions of Africa account for only 3% of the world at present, due to poor geographic and economic conditions, this region has suffered more losses than other continents under the severe situation of global climate change (Nangombe et al., 2018). Therefore, exploring the decoupling relationship between urbanization and carbon emissions in Africa is essential for scientifically guiding African urbanization and reasonably controlling carbon emissions. Due to the limitation of data acquisition, this study selects 33 countries in Africa for exploration, including Nigeria, DR Congo, Tanzania, Uganda, Sudan, Morocco, Mozambique, Ghana, Madagascar, Cameroon, Ivory Coast, Niger, Burkina Faso, Mali, Senegal, Chad, Guinea, Rwanda, Benin, Burundi, Tunisia, Togo, Sierra Leone,

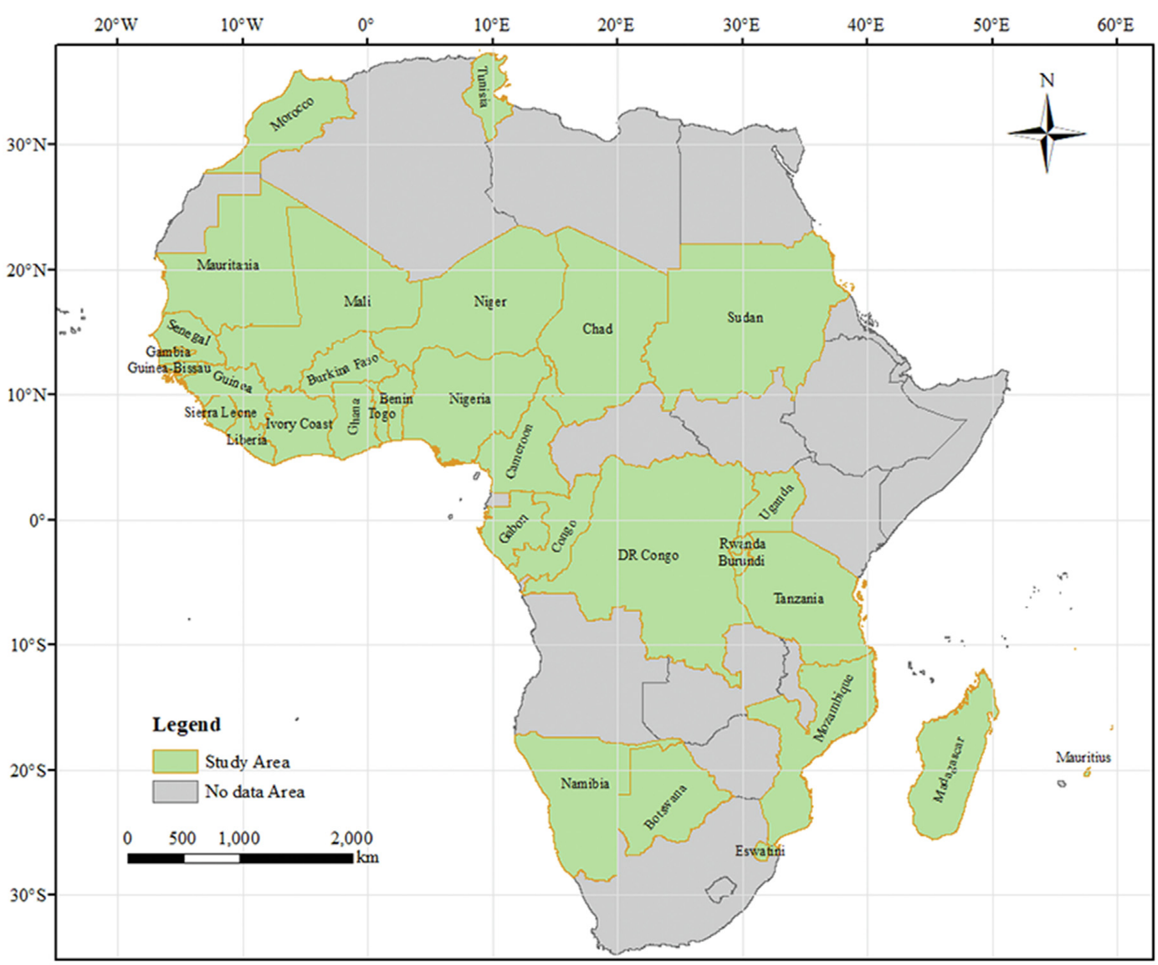

Figure 1. Spatial distribution of 33 countries in Africa.

Congo, Liberia, Mauritania, Namibia, Gambia, Botswana, Gabon, Guinea-Bissau, Mauritius and Eswatini (Figure 1).

2.2. Data sources

Most of the data in this paper are from the World Development Indicators (https://databank.worldbank.org/source/world-development-indicators) of the world bank. The land use data is from the European Space Agency (http://maps.elie.ucl.ac.be/CCI/viewer/download.php). This study calculates the values of demographic urbanization, spatial urbanization, economic urbanization and social urbanization according to the weight of each index in the urbanization index system. The total nighttime light in each country (Figure 2) is calculated by using the global NPP-VIIRS-like nighttime light data, which is accessible at https://doi.org/10.7910/DVN/YGIVCD (Chen et al., 2020b).

3. Methods

3.1. Construction of urbanization index system

The evaluation of urbanization usually needs to be carried out from four dimensions: demographic, spatial, economic, and social ones (Guo et al., 2015; You, 2016). Considering the diversity of urbanization processes, this study draws on previous research results and uses this four-dimensional framework to measure the level of urbanization (Liao et al., 2020; Wang et al., 2020b). Among them, comprehensive urbanization level is the average of four types of urbanization level, and each type of urbanization contains two indicators, as shown in Figure 3. The criterion for selecting indicators are as follows: (1) the most cited indicators; (2) the data corresponding to the indicators can be obtained. The entropy method is used to quantify the importance of each basic indicator (Eqs. (1), (2), (3), (4), and (5)), which can overcome the shortcomings of the subjective weighting method.

(i) Data standardization: This is the first step of calculation, which can remove the unit limit of data and convert it into dimensionless values. Since all indicators are positive indicators, the processing methods are the same.

$$y_{ij} = (x_{ij} - \min\{x_{1j}, x_{2j}, \ldots, x_{nj}\}) / (\max\{x_{1j}, x_{2j}, \ldots, x_{nj}\} - \min\{x_{1j}, x_{2j}, \ldots, x_{nj}\}) \tag{1}$$

where y_{ij} is the value after normalization , x_{ij} is the value of the j-th indicator of the i-th sample. The data of different years in the same country are different samples.

(ii) The proportion of the indicator j for sample i

$$p_{ij} = y_{ij} \Big/ \sum_{i=1}^{n} y_{ij} \tag{2}$$

(iii) The information entropy of the indicator j

$$e_j = -\frac{1}{In(n)} \sum_{i=1}^{n} p_{ij} In(p_{ij}) \ (0 \le e_j \le 1) \tag{3}$$

(iv) The entropy redundancy

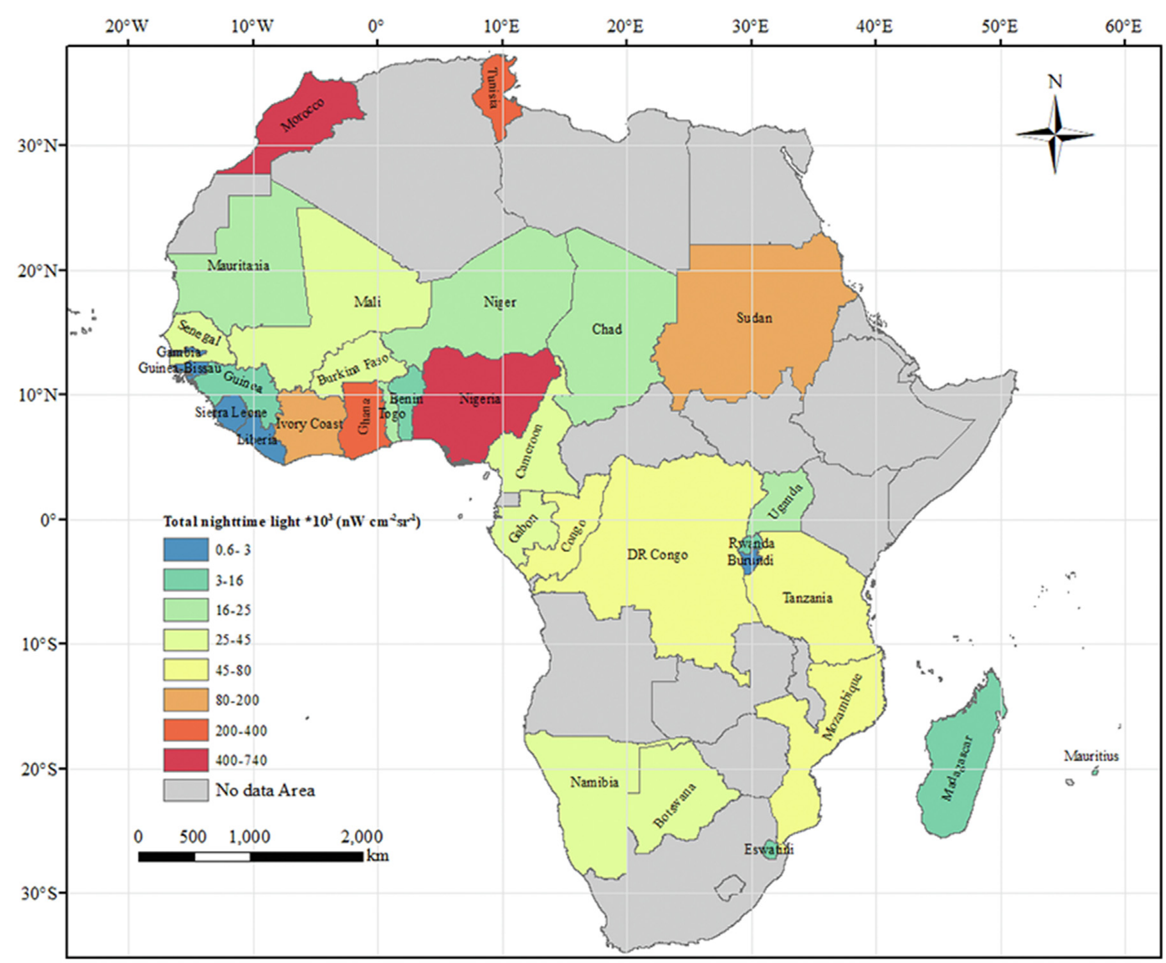

Figure 2. Total nighttime light in each country.

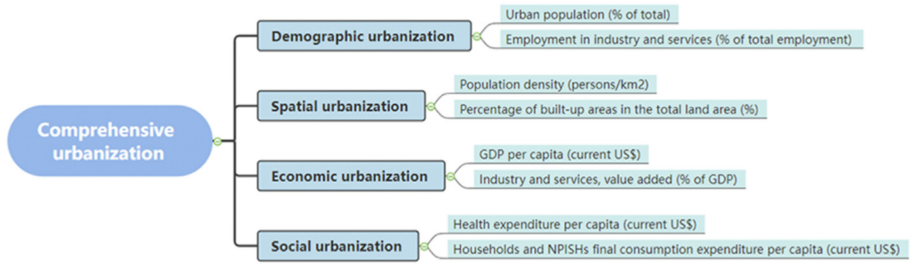

Figure 3. Index system for urbanization.

$$d_j = 1 - e_j \tag{4}$$

(v) The weight of the indicator j

$$w_j = d_j \Big/ \sum_{j=1}^{m} d_j \tag{5}$$

In the above formula, n is the number of samples and m is the number of indicators.

Figure 4 shows the relationship between comprehensive urbanization level and carbon emissions. Among them, Nigeria and Mauritius are the most prominent countries. Nigeria's comprehensive urbanization level is low, but the carbon dioxide emissions are large, while Mauritius's comprehensive urbanization level is high, but the carbon dioxide emissions are low. Nigeria is the largest oil and gas producer in Africa. The combustion of natural gas will release a large amount of methane, carbon dioxide and other greenhouse gases. After 1960, it began to develop industries, manufacturing and other industries on a large scale. These sectors need to rely heavily on fossil fuels to meet their energy needs. The increased demand for fossil fuel power generation has also increased the country's carbon dioxide emissions. As an island country in eastern Africa, Mauritius is known as "Switzerland in Africa" because of its rapid urbanization, relatively affluent life and developed economy. In 2019, the primary, secondary and tertiary industries in Mauritius accounted for 2.7%, 23.3% and 74% of GDP respectively. The low proportion of the secondary industry may be one of the reasons for its low carbon emission level.

3.2. Tapio decoupling method

The concept of decoupling was first proposed by Von in 1989, and then it was used to describe the decoupling between economic growth and environmental quality by the Organization for Economic Cooperation and Development (OECD) (Gong et al., 2021). However, the OECD decoupling method is too sensitive to the selection of base period, and the model has only two states: decoupling state and coupling state, which makes the decoupling analysis impossible to be carried out accurately. Furthermore, decoupling elasticity is introduced by Tapio to improve the model (Tapio, 2005) and many scholars use this method for decoupling research. The Tapio decoupling model can present decoupling states in more refined detail and its accuracy is not limited by the research interest period (Wu et al., 2018). There are researches on the decoupling of carbon emissions from economic growth (Wang and Zhang, 2021), carbon emissions from construction land (Li et al., 2019b), carbon sequestration from urbanization (Li et al., 2022) and so on.

Based on the above discussion, Tapio's decoupling method is adopted in this paper. The decoupling elasticity index r can be expressed as Eq. (6):

$$r = \frac{\Delta C / C^0}{\Delta U / U^0} = \frac{(C^t - C^0)/C^0}{(U^t - U^0)/U^0} \tag{6}$$

where ΔC is the change in carbon emissions from the base year to the target year , ΔU is the change in urbanization level from the base year to the target year. C^0 is the carbon emissions in the base year , C^t is the carbon emissions in the target year. U^0 is the urbanization level in the base year , U^t is the urbanization level in the target year. If the change is 0, the data is adjusted according to the change of the previous and subsequent years.

According to the criterion from Tapio, the eight scenarios of decoupling statuses can be shown in Figure 5. For example, if $\Delta C < 0$, $\Delta U > 0$, $r < 0$, then the status is Strong Decoupling (SD).

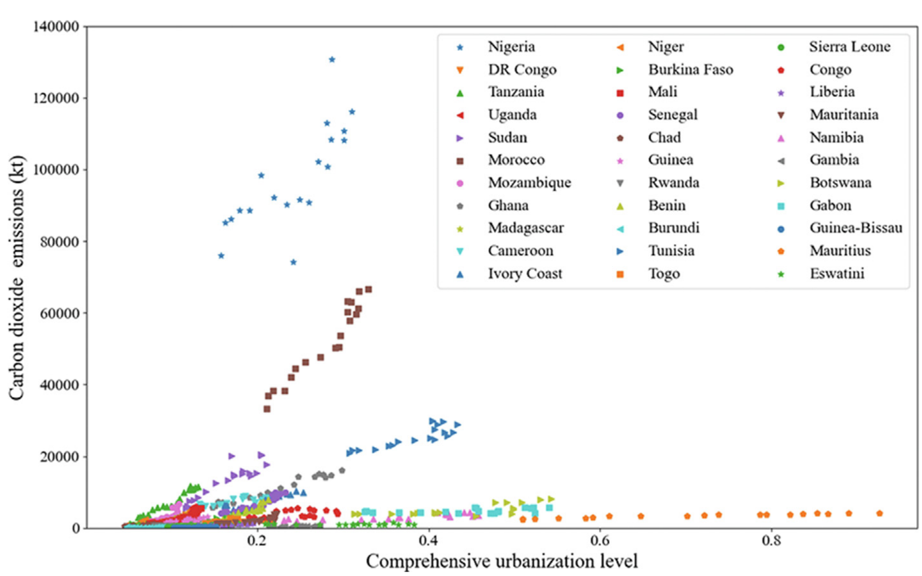

Figure 4. The relationship between comprehensive urbanization level and carbon emissions.

4. Results

4.1. Decoupling statuses of comprehensive urbanization from carbon emissions

Figure 6 shows the decoupling statuses of comprehensive urbanization from carbon emissions of the 33 countries (decoupling elasticities are shown in Appendix Table S1). The vertical axis shows the number of countries in different decoupling statuses. The horizontal axis represents the time period. In the eight decoupling statuses, END has always occupied a large proportion, indicating that urbanization is highly dependent on carbon emissions. The proportion of WD showed an upward trend before 2008, indicating that the decoupling performance in Africa has an improving trend. But after 2008, the number of countries in WD declined significantly. The development of urbanization on 08-09, 11-12 and 14-15 was hit, resulting in a sudden increase in the proportion of SND.

4.2. Decoupling statuses of four types of urbanization from carbon emissions

Figure 7 shows the decoupling statuses of 33 countries. Gabon and Eswatini show SD status of four types of urbanization from carbon emissions. This indicates that in the process of urbanization, its carbon dioxide emissions have decreased, which is the ideal state pursued by many countries. Cameroon and Congo show WD status of four types of urbanization from carbon emissions. This shows that in the process of urbanization, its carbon dioxide emissions have increased, but its growth rate is slower than that of urbanization. Three of the four countries (Gabon, Cameroon and Congo) are beneficiaries of funds from the Central African Forests Initiative, and Gabon is the first African country to receive financial compensation for protecting its rainforests to reduce CO_2 emissions. It is thus clear that policy incentives play a certain role in promoting national low-carbon development.

Figure 8 shows the decoupling statuses of four types of urbanization from carbon emissions (decoupling elasticities are shown in Appendix Table S2, S3, S4, S5). We can see that Figure 8a) and Figure 8b) are very similar. When the status of demographic urbanization from carbon emissions is SD, the status of spatial urbanization from carbon emissions is also SD. This shows that when demographic urbanization is promoted,

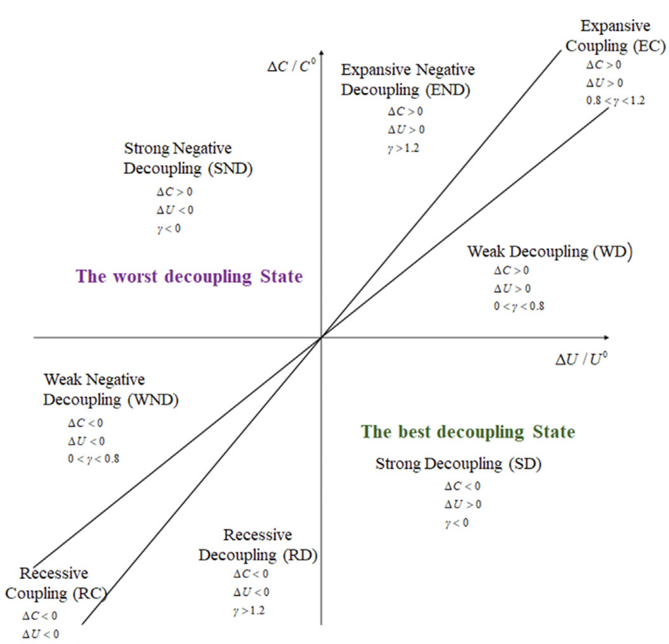

Figure 5. The decoupling statuses of Tapio model.

spatial urbanization will also be promoted, that is, the advancement of demographic urbanization may promote spatial urbanization. Figure 8c) and Figure 8d) show the decoupling statuses of economic urbanization from carbon emissions and social urbanization from carbon emissions. It is also worthy to note that countries at SND status during 2008–2009 and 2014–2015 are of large amount. This shows that economic urbanization and social urbanization in most countries are regressing during this period, while carbon emissions are increasing. This is related to the outbreak of the global financial crisis in 2008 and the impact that Africa suffered in 2014. Since the outbreak of the financial crisis in the second half of 2008, its impact on the African economy has undergone an evolution from minor to severe, from financial first to entity. The major industrial sectors of African countries such as finance, oil extraction, mining, tourism, manufacturing, and agriculture have all been impacted. This has largely affected the process of economic urbanization and social urbanization. In 2014, there were also many negative factors in Africa, which impacted the economic and social urbanization of the region. One is the spread of terrorist forces, which has led to political turmoil in some regions and countries. The second is the impact of the Ebola virus. Although it broke out in West Africa and most countries in Africa were not affected by the Ebola virus, the panic caused by Ebola spread to the entire African continent. Not only did this scare off world investors, some countries also began imposing trade and travel bans on West Africa and other African countries, leading to the cancellation of international investments and disruption of travel and supply chains. Third, the world economy is sluggish, and the economic growth rate of new economies has fallen, which has reduced the demand for African goods and reduced investment in Africa. These factors have caused the economic urbanization and social urbanization of most countries in Africa to regress, showing a state of SND.

4.3. Decoupling statuses in typical countries

In this study, 6 out of 33 countries were selected as typical countries. Among them, Nigeria has the largest carbon emissions, Mauritius has the highest comprehensive urbanization level. Congo, Eswatini, Cameroon and Congo have achieved the decoupling of four types of urbanization from carbon emissions in the long term (2000–2018). Figure 9 shows the decoupling statuses of four types of urbanization from carbon emissions in 6 typical countries. Congo showed a SD trend in demographic urbanization from carbon emissions and spatial urbanization from carbon emissions after 2009, and Gabon showed a SD trend after 2012. The decoupling status of other countries fluctuates during the study period. Regarding the decoupling between economic urbanization and carbon emissions, and the decoupling relationship between social urbanization and carbon emissions, most countries were in SD and WD states before 2008, and then fluctuated in varying degrees.

Figure 10 shows the decoupling trend of four types of urbanization from carbon emissions after 2014. From Fig.10 a) and Fig.10 b), it can be found that most of the points locate in the first and fourth quadrants, which shows that after 2014, the demographic urbanization and spatial urbanization of these countries have been steadily advancing. Among them, the change rate of demographic urbanization level and spatial urbanization level of Mauritius is particularly small, close to the Y-axis, indicating that its demographic and spatial development is limited, which is related to its small land area. It can be found in Fig.10 c) and Fig.10 d) that the urbanization change rate of most countries during 2014–2015 and 2015–2016 is less than 0, that is, it locates in the negative half axis of the horizontal axis, which indicates that economic urbanization and social urbanization suffer a lot due to the external situation changes. In addition, the change rate of economic urbanization level and social urbanization level of Mauritius and Cameron was less than 0 from 2014 to 2015, and then recovered quickly, maintaining the steady development of economic urbanization and social urbanization. It shows that the two countries can respond quickly to external shocks and adjust the national urbanization process in time. This is obviously

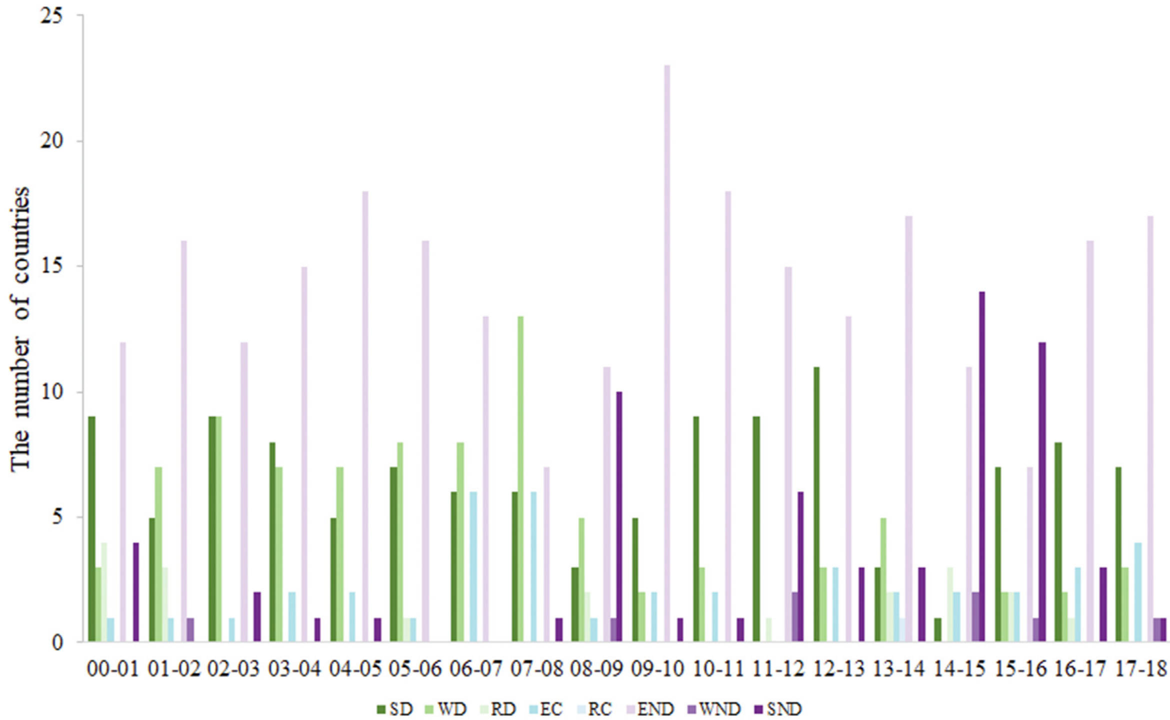

Figure 6. The decoupling statuses of comprehensive urbanization from carbon emissions of the 33 countries (every year from 2000 to 2018).

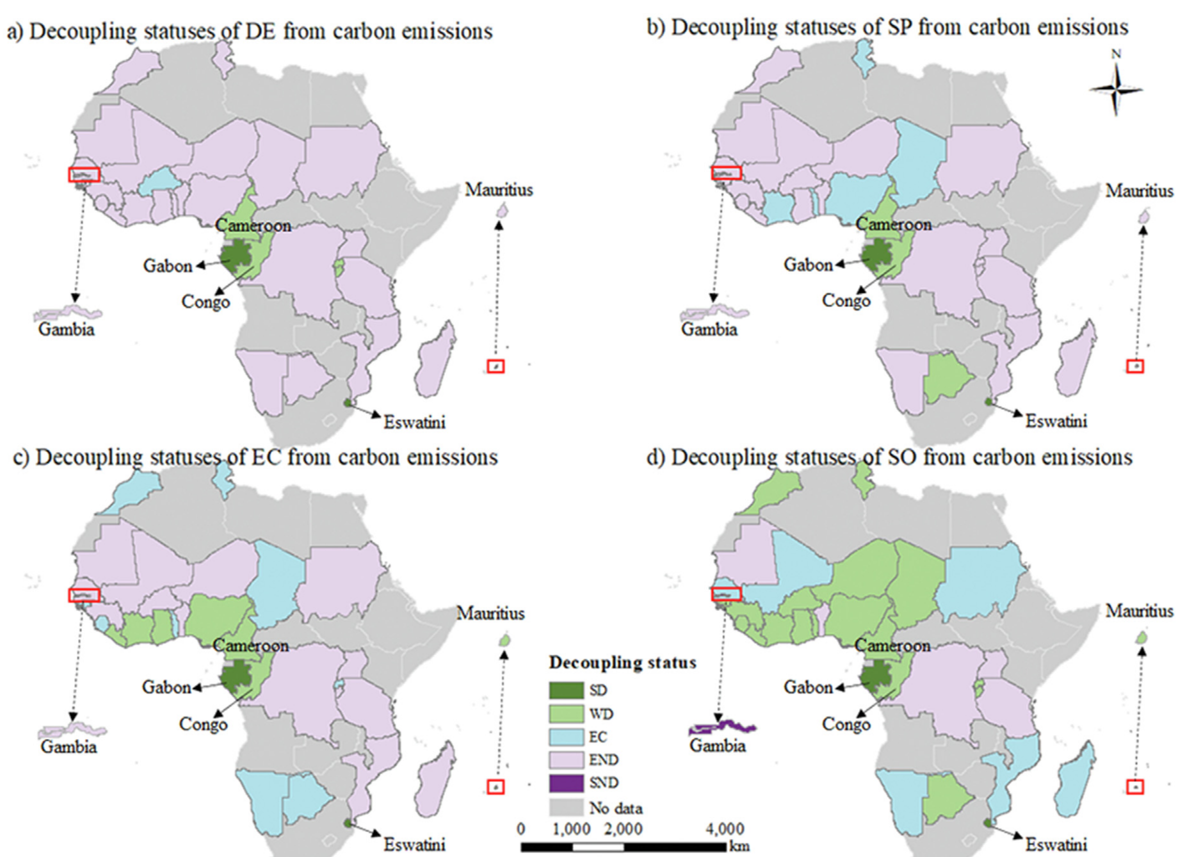

Figure 7. The long-term analysis (from 2000 to 2018) of decoupling statuses in 33 countries (DE: Demographic urbanization SP: Spatial urbanization EC: Economic urbanization SO: Social urbanization).

Figure 8. The decoupling statuses of four types of urbanization from carbon emissions (DE: Demographic urbanization SP: Spatial urbanization EC: Economic urbanization SO: Social urbanization).

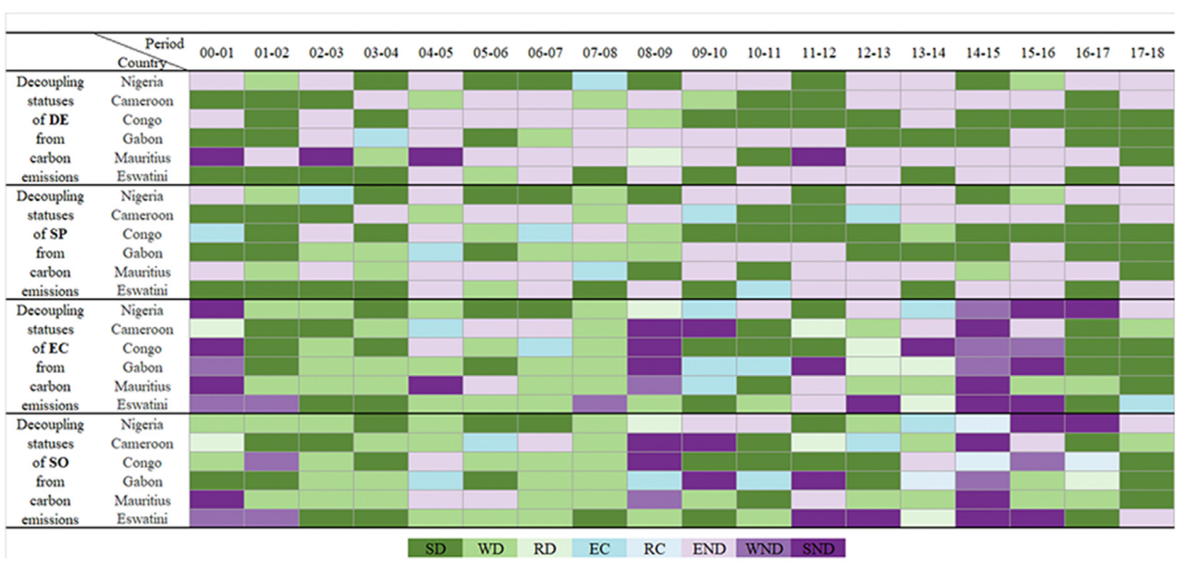

Figure 9. The decoupling statuses of four types of urbanization from carbon emissions in 6 typical countries (DE: Demographic urbanization SP: Spatial urbanization EC: Economic urbanization SO: Social urbanization).

different from Nigeria, which did not recover until 2017–2018 after the change rate of economic urbanization and social urbanization was less than 0 in 2014–2015.

4.4. The applicability of night time light data in decoupling analysis

As an important branch of remote sensing, luminous remote sensing has attracted more and more attention in the fields of natural science and social science research in recent decades (Zhou et al., 2021). It plays an important role in population density estimation (Kumar et al., 2019), economic development assessment (Keola et al., 2015) and power consumption estimation (Tripathy et al., 2018). Therefore, the night time light data can be used as one of the quantitative basis to measure the level of urban development. We can see that the decoupling statuses of total night time light from carbon emissions are diversified (Figure 11), which is similar to the decoupling between economic urbanization and carbon emissions and the decoupling between social urbanization and carbon emissions. However, from the perspective of decoupling trend, the

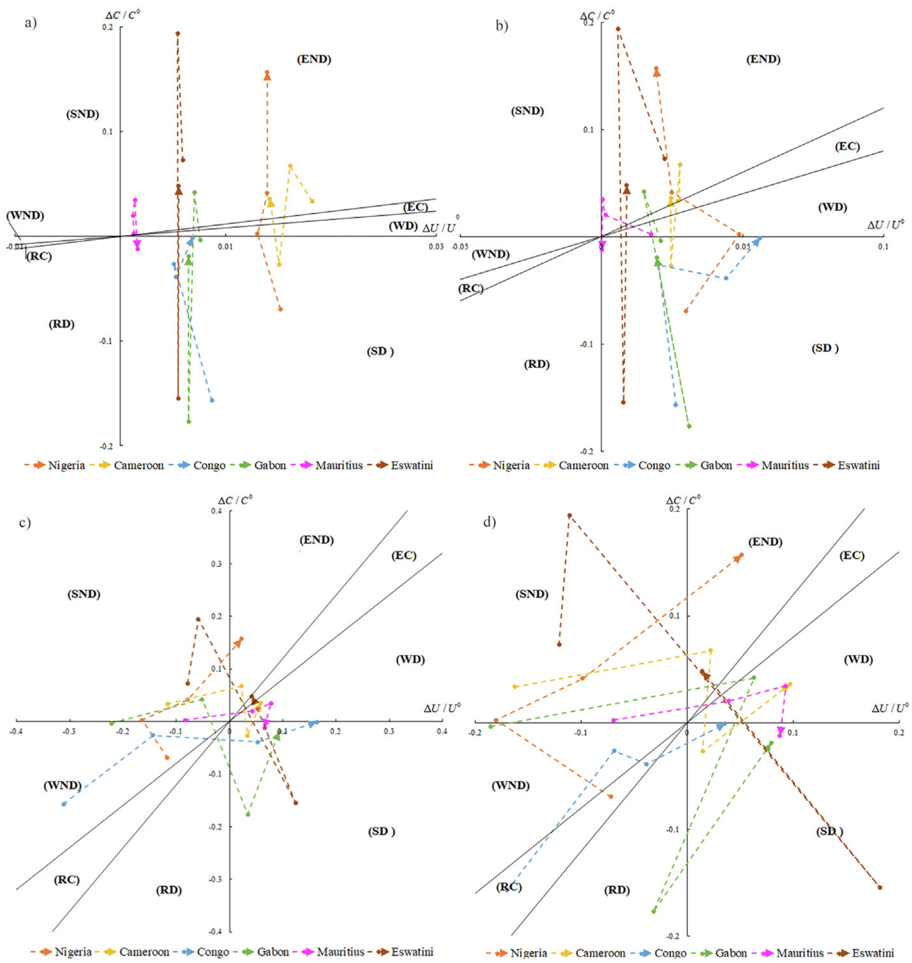

Figure 10. Decoupling trend of four types of urbanization from carbon emissions in 6 typical countries after 2014 (a: Demographic urbanization b: Spatial urbanization c: Economic urbanization d: Social urbanization).

decoupling status of total night time light from carbon emissions in Africa is not consistent with the decoupling status of any type of urbanization from carbon emissions. It generally shows the status of negative decoupling (END, SND, WND) first, and gradually becomes the status of decoupling. This may be that the night time light data in Africa can not well reflect the urbanization process of the region. Studies have shown that in low-density areas, DMSP or NPP/VIIRS can not detect up to 70% of the population even when more than half of the households in these areas use electric lights (Gibson et al., 2020). Therefore, the application of night time light data in low-density areas has certain flaws (Gibson et al., 2021). This leads to its unique decoupling relationship with carbon emissions.

5. Discussion

5.1. Similarities and differences of decoupling statuses

In this study, the decoupling relationship of demographic urbanization from carbon emissions and spatial urbanization from carbon emissions are similar, and the decoupling relationship of economic urbanization from carbon emission and social urbanization from carbon emission are also similar. This shows that demographic urbanization and spatial urbanization have similar trends, while economic urbanization and social urbanization show similar patterns, which is similar to the development of Nanjing, China (Ma et al., 2021). However, the decoupling statuses of urbanization from carbon emissions in different African countries is obviously different. Gabon, Eswatini, Cameroon and Congo show SD or WD status of four types of urbanization from carbon emissions, while DR Congo, Tanzania, Uganda, Sudan, Mauritania, Benin and Gambia show END or even SND status. And we found that countries with SD or WD status between four types of urbanization and carbon emissions are mostly distributed around the equator. This reflects regional differences in Africa. In other studies, regional differences have also been reflected. For example, Central Asia performs well in research on the decoupling of gross output value of transportation industry and carbon dioxide, while West Asia and North Africa are mostly in the decoupling status RC or END (Wang et al., 2020a). In the research of decoupling relationship between economic growth and carbon emission in China, the decoupling performance of cities in Western China is not as good as that in eastern China (Du et al., 2021).

5.2. Low carbon development in Africa

The World Bank recently released a report that Africa is experiencing a rapid process of urbanization. By 2050, the urban population of Africa will triple that of 2010, reaching 1.23 billion, accounting for about 60% of its total population (Bremner, 2012; Ogwu, 2019). The rapid urbanization process, especially in developing countries, is bringing great challenges to sustainable development. Although Africa's carbon emissions are much lower than other regions (Kifle, 2008; Ritchie and Roser, 2020), the emission rate of the region is soaring. In 1973, the continent accounted for 1.9% of global emissions, and it has now exceeded 3% (Shahbaz et al., 2015). Coupled with the increasing risk of global catastrophic climate change, Africa has to work together with the world to tackle climate change.

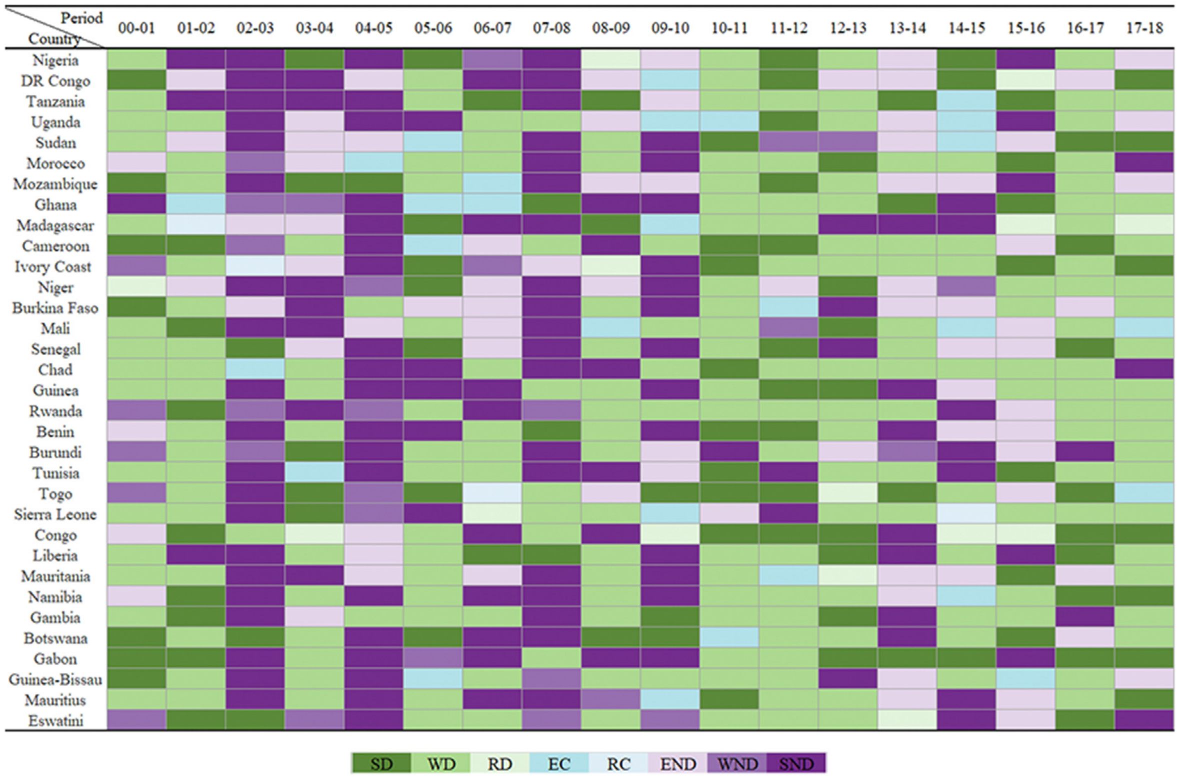

Figure 11. The decoupling statuses of total night time light from carbon emissions.

Under the global low-carbon emission reduction target requirements, African countries should formulate effective and targeted policies based on the decoupling statuses of urbanization from carbon emissions. From the perspective of the long-term, countries with SD status should maintain their current status and extend their good experience to other countries. For countries with END or EC status, since their urbanization development largely depends on high energy consuming industries, they should increase investment in energy conservation and emission reduction technologies, develop new and renewable energy, improve energy structure, and encourage innovation to reduce R & D costs for developing low-carbon economy (Chen et al., 2020a; Du et al., 2021; Wang and Su, 2019).

5.3. Implications and limitations

Due to the vast territory of Africa, there are differences in the distribution of natural and human resources among countries, resulting in differences in economic development, urbanization levels and carbon emissions. In the actual implementation of low-carbon development policies, countries should suit measures to the local conditions and ultimately achieve sustainable development. Take typical countries as examples. Congo, Cameroon, Gabon and other countries with large areas of virgin forests should separate urbanization from forest loss and sustainably develop forests and other resources (Abbasi et al., 2021; Poulsen et al., 2020; Tegegne et al., 2016). Countries like Mauritius, which are short of mineral resources but rich in marine resources, should make use of their coastal advantages to vigorously develop marine fisheries and port services, and combine their own advantages to promote the development of low-carbon tourism (Lee and Brahmasrene, 2016). Countries like Nigeria, which are rich in oil and gas resources, must strive to develop new technologies to use associated natural gas for power generation, processing and production of petrochemical products, or for gas injection in oil fields to increase oil recovery and reduce the combustion of vented natural gas (Anomohanran, 2012). At the same time, it is necessary to promote industrial upgrading, improve the level of green manufacturing, and achieve high-quality development.

There are two limitations in this study. Firstly, the decoupling relationship between urbanization and carbon emissions is explored in only 33 countries due to lack of data. Secondly, the driving factors of carbon dioxide emission are not studied, which will be further explored in the follow-up research.

6. Conclusions

Africa is one of the continents worst affected by climate change impacts. It suffers more losses than other continents, due to the geographic location and lack of provision to satisfy basic human needs. With the rapid development of urbanization, carbon dioxide emissions in African countries are attracting more and more attention. This study explored the decoupling statuses of four types of urbanization from carbon emissions in 33 countries of African. The main conclusions are as follows:

(1) The decoupling relationship of demographic urbanization from carbon emissions and spatial urbanization from carbon emission are similar, and the decoupling relationship of economic urbanization from carbon emission and social urbanization from carbon emission are also similar.
(2) Only 4 of the 33 African countries have achieved the decoupling of demographic urbanization, spatial urbanization, economic urbanization and social urbanization from carbon emissions in the long period (2000–2018).
(3) The decoupling relationship between night time light data and carbon emissions in Africa is not consistent with the decoupling relationship between the four types of urbanization and carbon emission. This may result from that the night time light data in Africa can not well reflect the urbanization process of the region.

Declarations

Author contribution statement

Xuelin Duan: Conceived and designed the experiments; Performed the experiments and Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Xi Li: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data.

Wenfang Tan: Performed the experiments and Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Rui Xiao: Conceived and designed the experiments; Performed the experiments and Analyzed and interpreted the data; Wrote the paper.

Funding statement

This research was supported by the National Key R&D Program of China (2019YFE0126800), Natural Science Foundation of Hubei Province (No.2021CFB402) and Key Laboratory of National Geographic Census and Monitoring, Ministry of Natural Resources (No.2022NGCM03).

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

Supplementary content related to this article has been published online at https://doi.org/10.1016/j.heliyon.2022.e10423.

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