Analysis on Temporal and Spatial Evolution of UNESCO Global Geoparks and Impact Factors

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Abstract
Since 2015, the new label of UNESCO Global Geoparks (UGGps) has been ratified by UNESCO, attracting more public attention. By 2021, there are 169 UNESCO Global Geoparks in 44 countries. Different from the Biosphere Reserves and World Heritage Sites, UNESCO Global Geoparks are nascent projects that face various challenges. How to continuously enhance its impact in future and realize sustainable development attracted the attention of researchers. In this study, we analyzed the spatial structure of UGGp in the world and the factors affecting it. Afterwards, we made some suggestions for sustainable development of UGGp. In this research, we obtained information on the geographical location of UNESCO Global Geoparks. The spatial structure was analyzed using quantitative geography models, such as nearest neighbor index, Ripley’s K function, Gini coefficient and uniformity of distribution, kernel density analysis, taking into account the influence of economy, local policies, and geological structure. The results of econometric geographical analysis demonstrate that the distribution of UGGp is obviously non-uniform, with a calculated nearest neighbor index value $R$ of 0.553 and a Gini coefficient of 0.804. This implies that further balancing of regional differences and sustainable development should be considered in future development. This study also found that the distribution is influenced by the level of economic development and geological structure of Geopark territories. The distribution of UGGp is denser in economically developed regions, except for the USA, which is not part of the program. In contrast, the number of UGGp increased in areas with complex geological structures due to various types of geological relics. In order to promote sustainable economic development of local communities, more consideration should be given to construction of more UGGps in less economically developed areas in the future.

Keywords UNESCO Global Geopark · Temporal evolution · Spatial evolution

Introduction
The Global Geopark was recognized by UNESCO in 2015, officially became one of UNESCO’s the three major protected area brands. A UNESCO Global Geopark is a “single and unified” geographic area that manages global geological sites and landscapes with a holistic concept of conservation, education, and sustainable development (UNESCO, 2015). The establishment of the UNESCO Global Geopark (UGGp) represents UNESCO’s philosophy of communication.
through education, science, and culture to build a global partnership for peace and promote regional sustainable development (Rosado-González et al. 2020). At the same time, Geopark have played an important role in promoting science education, employment, as well as local tourism benefits, and devotes great contribution to local economy (Chen 1996, 2016; Zhang, 2020a).

As early as 2004, with the support of UNESCO and International Union of Geological Sciences (IUGS), 17 European Geoparks and eight Chinese National Geoparks formed Global Geoparks Network (GGN) on basis of the European Geoparks Network and Chinese National Geoparks Network (Martini and Zouros 2001; Zouros and Martini 2003; Eder 2004; Jones 2008). Until 2015, the GGN was responsible for to accepting and evaluating new member applications of Global Geoparks Network. After UNESCO launched the “International Geoscience and Geoparks Programme (IGGP)” in November 2015, the GGN became one of the two pillars of the UNESCO IGGP plan, and the “UNESCO Global Geopark” (UGGp) logo was officially born. As a laboratory of “global sustainable development,” the UGGp is an important tool for UNESCO to achieve the goals of poverty eradication and educational equity, and it is also the main carrier to implement management and protection of resources and earth heritages (UNESCO 2015).

By end of 2021, 169 UNESCO Global Geoparks are distributed in 44 countries. Before 2015, number of new Geoparks in Europe remained largely stable between 5 and 7 per year. After 2015, it started to decline due to revision of application rules. By 2020, there are 81 Global Geoparks in Europe, accounting for half of the total number of UNESCO Global Geoparks. Spain (15) occupies the first place, Italy has 9 designations in the second place, and the UK (7) and France (7) are tied for third.

Turning to China, the country with the largest number of UNESCO Global Geoparks in the world, it grew at an annual rate of 4–8 until 2006. After 2007, it basically soared marginally at a rate of 2 per year, accounting for a quarter of the total to date. Other regions in Asia (mainly Japan, South Korea, and Indonesia) also joined Global Geoparks Network after 2008, and are gradually becoming an important part of the GGN. By 2020, there are 24 Geoparks in Asian area (except China). The number of new members in America has remained at 1–3 per year since 2016. There are currently 13 UGGps in the Americas, including five in North America, all of which are located in Canada and eight in Latin America. Africa hosts only two UNESCO Global Geoparks, located in Morocco and Tanzania (Chart 1).

As the distribution of Geoparks continues to expand, their influence is becoming more wide-spread and attracting more scholars’ attention. The predecessors mainly focus on Geopark management and operation (Zhao and Zhao, 2003a, 2005; 2009; Sun et al. 2010; Du and Girault 2018; Orús and Urquí 2020; Zhang 2020b, 2021), classification and protection of geoheritage (Grube 1994; Chen 2003; Zouros 2004, 2007; McKeever and Zouros 2005; Gray, 2004; Ding et al. 2012; Brilha 2016), and earth heritage education and scientific popularization (Farsani et al. 2014; Bujdósz et al. 2015; Liang et al. 2015; Catana and Brilha 2020; Wu et al. 2020; Wang and Zouros 2021). However, with update and
iteration of GIS technology and database technology, digital informatization of UNESCO Global Geoparks has lagged far behind the rapid development of UNESCO Global Geoparks, and the lag of informatization has become a bottleneck restricting further development of UNESCO Global Geoparks (Xu 2012). Some scholars have sorted out and discussed the development history and geographic distribution characteristics of Global Geoparks in China and Europe (Huang 2005; Du and Girault 2018; Wu et al. 2019; Orús and Urquí 2020); however, they lack an overall and quantitative research on the geospatial structure and evolutionary process of the designation on a global scale. As an example, less attention has been paid to underdeveloped regions such as Africa and Latin America (Gorfinkiel 2010, 2015; Rosado-González 2016, 2020). Until 2011, Uruguay raised the issue of unequal distribution of Global Geoparks. Since then, more concerns are given to underdeveloped regions such as Africa and Latin America.

The main purpose of this article is to quantitatively describe and analyze the development and distribution trends of UNESCO’s Global Geoparks on a global scale, using geographic information system and zoning models with spatial and temporal parameters and considering economic conditions and policy orientations. From the researcher’s perspective, every 5 years from 2004 to 2020 was chosen as a time point, corresponding to the three phases of the development of Global Geopark in 2004, 2010, and 2015 (Du and Girault 2018), which clearly reflects the development and changes in a linear time period; spatially, the world was chosen as the research area. Through the spatial distribution analysis and spatial point pattern analysis methods, the evolution trend of UNESCO Global Geoparks’ geographic spatial pattern is simulated scientifically and intuitively. Thus, it provides a scientific basis and some reference suggestions for future development of UNESCO Global Geoparks and Global Geoparks Network.

Methodology

Spatial Distribution Analysis

Spatial Mean Center (Spatial Mean)

The mean center is an important indicator to describe the geographic spatial distribution, which represents the average geometric center of spatial point features. In order to analyze the transfer of the mean center in the development of Global Geopark, this paper uses the spatial mean center to measure the mean center of Global Geoparks, and the definition formula is:

\[
(x, y) = \left( \frac{1}{n} \sum_{i=1}^{n} x_i, \frac{1}{n} \sum_{i=1}^{n} y_i \right)
\]

Directional Distribution (Standard Deviation Ellipse)

Standard deviation ellipse, as a spatial statistical technique to measure the distribution characteristics of geographic elements, has been widely used in economics, geography, environmental science, and other fields. This paper uses the standard deviation ellipse technique to analyze the directional characteristics of the spatial agglomeration of Global Geoparks. The standard deviation ellipse analysis includes distribution center of gravity, long axis standard deviation, short axis standard deviation and azimuth angle, etc. The calculation formula is:

\[
(x_0, y_0) = \left( \frac{1}{n} \sum_{i=1}^{n} (x_i - \overline{x}), \frac{1}{n} \sum_{i=1}^{n} (y_i - \overline{y}) \right)
\]

Spatial distribution center of gravity:

\[
\tan \theta = \frac{\sum_{i=1}^{n} x_i y_i}{\sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i^2}; \quad A = \sqrt{\left( \sum_{i=1}^{n} x_i^2 - \sum_{i=1}^{n} y_i^2 \right)^2 + 4 \left( \sum_{i=1}^{n} y_i \right)^2}
\]

\[
\sigma_x = \sqrt{\frac{\sum_{i=1}^{n} (x_i \cos \theta - y_i \sin \theta)^2}{n}}; \quad \sigma_y = \sqrt{\frac{\sum_{i=1}^{n} (x_i \sin \theta + y_i \cos \theta)^2}{n}}
\]

Spatial Point Pattern Analysis

PPA (point pattern analysis): The method of studying the distribution pattern of an entity or event based on its spatial location is called PPA. PPA is a crucial type of spatial analysis method. The distribution of points in space is highly variable, and point patterns are generally classified into three basic types: aggregated distribution, random distribution, and uniform distribution. Therefore, the basic problem of the point set object or event distribution pattern is to determine whether the point pattern is random, uniform, or aggregated. Studying the distribution pattern is of great importance to explore the causes leading to the formation of such distribution patterns.

Nearest Neighbor Analysis

The average nearest neighbor refers to the mean value of the nearest distance between points. This analysis method compares and calculates average distance between the nearest point pair and average distance between the nearest neighbor point pair in the random distribution model to conclude its spatial pattern. When the average nearest neighbor considers the dot pattern to be randomly distributed, the above two distances are equal; when the dot pattern is concentrated, the former will be smaller than the latter; when the dot pattern diverges, the former will be greater than the latter. Therefore, the experiment first uses the average nearest
neighbor analysis to determine its spatial pattern. According to the principle of average nearest neighbor analysis, $z$-score is used to test statistical significance of spatial auto-correlation analysis, i.e., to help users test or decide whether to reject null hypothesis or accept null hypothesis; $p$ value is a probability value, very highly positive. $T$-score or very small negative $z$-score corresponds to a very small $p$ value, which usually appears at the tail of standard normal distribution curve. This situation can indicate that spatial element does not have characteristics of random distribution, and the null hypothesis can be rejected.

**Multi-distance Spatial Cluster Analysis**

As the spatial scale changes, the distribution pattern of point features may change. On small scales, aggregated distributions may occur, while on large scales, random or divergent distributions may occur. Multi-distance spatial cluster analysis is a common method to analyze the spatial pattern of point-like features at various scales. It calculates spatial clustering pattern based on a range of search circles of a certain radius. Through the average nearest neighbor analysis, the spatial distribution of tourists on the square can be obtained with clustering. Furthermore, multi-cluster spatial clustering can be used to analyze the causes of clustering.

**Kernel Density Estimation**

The previous analysis can only be derived from the value of individuals in a concentrated state on the square, and cannot directly see the location, shape, and size of the crowd. These can be revealed by the density maps. Density maps can be used to represent clusters of points, which can be done using the kernel density estimation method. The idea of kernel density estimation is to use spatial density analysis of event to express spatial point patterns. The probability of occurrence of events in densely dotted areas is high, and probability of occurrence in sparsely dotted areas is low.

**Results**

**The Distribution and Space–Time Evolution of UNESCO Global Geoparks in Continents, Latitudes, and Longitudes**

**Space Distribution Characteristics**

The distribution of UNESCO Global Geoparks varies greatly in continents, latitudes, and longitudes. More than 90% of UGGPs are in Eurasia, the majority of them are in the Easter and Northern Hemispheres. More than 70% of them are located in mid-latitude regions.

**Continental Distribution Characteristics** By 2021, 169 UGGPs are distributed in 44 countries and regions, most of which are in Europe and Asia, except Oceania and Antarctica, Europe hosts 50.3%, Asia hosts 40.4%. North America, South America, and Africa host 4.3%, 3.7%, and 1.3% of the total number, respectively (Table 1). Until 2010, Europe and Asia host all other Global Geoparks except one Global Geopark in Brazil established in 2006. Until 2010, Canada established the first Global Geopark in North America, Geopark-Stonehammer Global Geopark. In 2014, Morocco established the first Global Geopark-M’Goun UNESCO Global Geopark in Africa. Since then, all the continents, except Oceania and Antarctica, have their own Global Geoparks.

**Latitude and Longitude Distribution Characteristics** The distribution of UNESCO Global Geoparks varies greatly in longitude, most of Global Geoparks (155 of 169) are located in the Eastern Hemisphere ($0^\circ$-$160^\circ$E) and a few (14 of 169) are located in the Western Hemisphere (Table 2). The longitudinal distribution of UGGPs is very similar to their distribution across continents, as Europe and most of Asia are in the Eastern Hemisphere.

Turning to the latitudinal distribution of UNESCO Global Geoparks, most of UGGPs are located in the Northern Hemisphere (151 of 169) and a few in the Southern Hemisphere (11 of 169) (Table 3). In the mid-longitude region ($30^\circ$-$60^\circ$N, $30^\circ$-$60^\circ$S), there are 125 Global Geoparks (Table 4). Since the majority of land is in the Northern Hemisphere, this distribution of UGGPs in latitude resembles the distribution of UGGPs in continents and longitudes.

**Temporal Evolution Characteristics**

Generally, the number of UNESCO Global Geoparks has been steadily increasing. Since the establishment of first Global Geopark in 2004, in the course of 17 years, there are no new members only in 2008 and 2016 (Table 5, Chart 2). The increased number is from 7 to 13 averagely. In 2020, the number of new UNESCO Global Geoparks reaches 15, which the highest number in these years. In contrast, in 2021, only 8 new UNESCO Global Geoparks are announced, as the assessment and revalidation of Geoparks is greatly limited by the COVID-19 pandemic (Chart 3).

The distribution of Global Geoparks in each continent is uneven, as the growth of new UNESCO Global Geoparks varies from continent to continent. In Europe and Asia, the growth rate is faster. In Europe, the number of new UNESCO Global Geoparks is five to seven per year. In Asia, including two new UNESCO Global Geoparks in China every year, other countries as Japan, Vietnam, Korea, and Indonesia are also actively building UNESCO Global Geoparks (Chart 4). By 2021, there are 24 UNESCO Global Geoparks in other areas of Asia, except China.

Turning to the regions where UNESCO Global Geoparks are less developed, the first Global Geopark was nominated in North America in 2010, and the second in 2014. By 2020, seven UNESCO
Global Geoparks are located in North America, five of them are in Canada and two in Mexico. South America hosts five, with the first in 2006, the second in 2013, and rest in 2018. The development of UNESCO Global Geoparks in Africa is the slowest; only Morocco and Tanzania managed to establish their own UNESCO Global Geoparks in 2014 and 2018, respectively (Chart 5).

The Spatial and Temporal Distribution Pattern and Evolution of UNESCO Global Geoparks

Spatial Distribution

A global calculation of the distribution centers of UNESCO Global Geoparks in 2004, 2010, 2015, and 2021 revealed that the centers from 2004 to 2010 shifted eastward. This shift may be influenced by increase of UGGps in China. In 2015 and 2020, the central point gradually shifted westward, which may be related to the recognition of UNESCO Global Geopark and construction of UGGps in Latin America and Africa (Fig. 1).

According to the results of standard deviation of ellipse, there is no significant change in the direction of the global distribution of UGGps from 2004 to 2021, which is basically close to east–west direction with an expanding distribution (Fig. 2).

Spatial Point Pattern Analysis

Nearest Neighbor Analysis Table 6 shows the result of the nearest neighbor analysis. It shows that the $z$-score of the nearest neighbor index of the spatial distribution of

| Continent   | 2004 | 2010 | 2015 | 2021 |
|-------------|------|------|------|------|
|            | Number | Ratio (%) | Number | Ratio (%) | Number | Ratio (%) | Number | Ratio (%) |
| Europe     | 12 | 60.0 | 39 | 54.1 | 66 | 56.4 | 88 | 52.1 |
| Asia       | 8 | 40.0 | 31 | 43.1 | 46 | 39.3 | 66 | 39.1 |
| North America | 0 | 0.0 | 1 | 1.4 | 2 | 1.7 | 7 | 4.1 |
| South America | 0 | 0.0 | 1 | 1.4 | 2 | 1.7 | 6 | 3.5 |
| Africa     | 0 | 0.0 | 0 | 0.0 | 1 | 0.9 | 2 | 1.2 |

| Hemisphere | 2004 | 2010 | 2015 | 2021 |
|------------|------|------|------|------|
|            | Number | Ratio (%) | Number | Ratio (%) | Number | Ratio (%) | Number | Ratio (%) |
| Eastern    | 20 | 100.0 | 70 | 97.2 | 111 | 94.9 | 155 | 91.7 |
| Western    | 0 | 0.0 | 2 | 2.8 | 6 | 5.1 | 14 | 8.3 |

| Hemisphere | 2004 | 2010 | 2015 | 2021 |
|------------|------|------|------|------|
|            | Number | Ratio (%) | Number | Ratio (%) | Number | Ratio (%) | Number | Ratio (%) |
| Northern   | 20 | 100 | 71 | 98.7 | 113 | 96.6 | 158 | 93.5 |
| Southern   | 0 | 0.0 | 1 | 1.3 | 4 | 3.4 | 11 | 6.5 |

| Latitude | 2004 | 2010 | 2015 | 2021 |
|----------|------|------|------|------|
|          | Number | Ratio (%) | Number | Ratio (%) | Number | Ratio (%) | Number | Ratio (%) |
| Low      | 4 | 20.0 | 15 | 20.8 | 23 | 19.7 | 38 | 22.5 |
| Middle   | 16 | 80.0 | 55 | 76.4 | 90 | 76.9 | 125 | 73.9 |
| High     | 0 | 0.0 | 2 | 2.8 | 4 | 3.4 | 6 | 3.6 |

| Year | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 |
|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Number | 20 | 31 | 43 | 50 | 50 | 59 | 73 | 82 | 87 | 97 | 108 | 117 | 117 | 125 | 138 | 146 | 161 | 169 |
UNESCO Global Geopark in 2004 is −2.76, which is a negative value, and the $p$ value is $0.006 < 0.01$, indicating that the distribution of Geoparks in 2004 shows a relatively obvious clustering. It can also be concluded from the report graph that the result corresponds to blue area in the graph, which is a significant agglomeration.
In 2010, the $z$-score of UNESCO Global Geoparks is $-4.57$, and the $p$ value is $0.000005$, which proves that the distribution is more concentrated. In 2015, the $z$-score is $-9.12$, and the $p$ value is much less than 0.01. It indicates that the distribution is more clustered. The $z$-score in 2021 is $-9.62$, and the $p$ value is much less than 0.01, which proves that the distribution is becoming dense.

In conclusion, this indicates that the spatial distribution of UNESCO Global Geoparks is becoming more concentrated.
over time. In other words, the development of UNESCO Global Geoparks has become more centralized (Fig. 3).

**Multi-distance Spatial Cluster Analysis**

The calculation results are shown in Fig. 4, where the blue diagonal line is the expected value, and red curve is the observed value. When the observed curve is higher than the expected value diagonal, it means agglomeration, otherwise, divergence. Therefore, the results show that for 2004, UGGPs present agglomeration distribution in spatial scale below 2500 km. In the range beyond 2500 km, there is a divergence profile. This indicates in 2004, at the global scale, the aggregation scale of UGGPs is 2500 km; in 2010, the aggregation scale is about 4700 km, which is consistent with the increase in degree of aggregation in the nearest neighbor analysis; in 2015, the aggregation scale increases to 7700 km; in 2021, the aggregate scale is approximately 7500 km, which may be related to the fact that more countries are starting to build UNESCO Global Geoparks.

**Kernel Density Estimation**

The location, morphology, and size of UGGp clusters are analyzed through kernel density estimation, it can be seen in Fig. 5, the main centers of geoparks in 2004 are China and Europe; it noted that by 2010, the centers of UGGPs are still dominated by China and Europe, but the morphology of the clusters has changed. The areas of cluster are also relatively larger. In 2015, the morphology of European agglomeration centers is more inclined to Africa. In 2021, the Asian agglomeration center shifts to Southeast due to the development of UNESCO Global Geopark in Southeast Asia (Fig. 5).

**Analysis of Impact Factors**

**Economic Factor**

The number of UNESCO Global Geoparks is related to local economy (Chart 6). In some aspects, a country’s financial

**Table 6** Result of the nearest neighbor analysis

|                | 2004               | 2010               | 2015               | 2021               |
|----------------|--------------------|--------------------|--------------------|--------------------|
| Average observation distance | 551,324,9559 m     | 497,850,5380 m     | 498,901,0011 m     | 462,929,4382 m     |
| Expected average distance     | 813,404,9704 m     | 692,903,4722 m     | 891,842,9463 m     | 767,241,5769 m     |
| Nearest neighbor ratio        | 0.677799           | 0.718499           | 0.559405           | 0.603369           |
| z-score                      | -2.756595          | -4.569586          | -9.117249          | -9.627887          |
| p                            | 0.005841           | 0.000005           | 0.000000           | 0.000000           |
status has a positive correlation with its Global Geoparks (from China to Spain, Iran to Nicaragua). Countries with high GDP are more likely to host more UGGPs. However, the economy is not a decisive factor. Take China, Japan, and Spain as examples (Table 7). In 2019, Japan takes up 5.7880% of the world’s entire GDP and Spain holds 1.5871% only. However, the number of UGGPs in Spain accounts for 9.32% compared to 5.59% for Japan. Therefore, GDP does not determine the development of UNESCO Global Geoparks, although economic factors may provide strong support for infrastructure construction in UNESCO Global Geopark.

**Tectonic Factor**

Tectonic events in geological history have created enormous geological and geomorphological relics. The earth could be
divided into 22 major plates and Euro-Asia Plate is the biggest plate with more than 80% tectonic movements of the UNESCO Global Geoparks.

In the eastern part of Eurasian Plate, the sub-plates and orogenic belts are influenced by the strong subduction of the West Pacific Plates, which led to a great deal of volcanic activities. It contributed to the formation of the Pacific Rim magmatic arc and the continental tectonic belt of the East Asia Plate (Shang, et al, 2011). These activities provide plentiful geoheritages for UGGp establishment. Wudalianchi, Jinpohu, Leiqiong-Le, Yandang Mountain, Taining and Ningde UNESCO Global Geoparks in China, Unzen,
Itoigawa, and Izu Peninsula UGENCO Global Geoparks are all closely related to these tectonic movements (Yu 2006; Dong and Zhang 2011; Yang et al 2011).

Turning to Europe, the Alps are the core of European geology, which is uplifted by one of the three major European tectonic movements, the Alpine Movement. This movement also formed European tectonic background and shaped European geomorphology, creating abundant geoheritage (Frisch 1979; White, 1981). Hence, a large number of UNESCO Global Geoparks in Europe (Adamello-Brenta UGGp, Sesia Val Grande UGGp, Chablais UGGp, Beigua UGGp, Alpi Apuane UGGp, Ore of the Alps UGGp, Karawanken/Karavanke UGGp, Haute-Provence UGGp, etc.) are related to the Alps, the Alpine Chain and geological relics related to the Alpine Movement.

In South America, the Andes Mountain are the most dominant geology unit, creating varieties of geoheritages ranging from tectonics, geomorphology, volcanoes, etc. (Coira et al. 1982; Mégard 1984; Strecker et al. 2007; Horton 2018). Three UGGps (Imbabura UGGp in Ecuador, Colca y Volcanes de Andagua UGGp in Peru, and Küttralkura UGGp in Chile) out of 7 in South America are in Andes Mountain.

Consequently, it is clear that the distribution of UNESCO Global Geoparks is closely related to tectonic movements, as seen in the Asia–Pacific region, Europe, and the Americas. In other words, tectonic movements have left remarkable geoheritage sites in the area which is more likely to support the construction of UNESCO Global Geoparks.

### Policy Factor

The European Geoparks Network (EGN) was established in 2000 by four European natural sites and reserves, i.e., the Reserve Geologique de Haute-Provence (France), the Petrified Forest of Lesvos (Greece), Geopark Gerolstein/Vulkaneifel (Germany), and the Maestrazgo Cultural Park (Spain) (Frey 2012) to protect geoheritage, alleviate low economic growth, unemployment, and immigration problems (Nikolova and Sinnyovsky 2019) with support from the European Union. Although Geopark originated in Europe, governments of some countries do not fully support Geopark programs (Zhao and Zha 2003b). Due to policy and system, in Europe, the management body of Geoparks could be non-profit organization (some cases from Austria, Netherland, Portugal, and Poland), municipality or public administration as museum (some cases from Greece, Spain, Italy, and Slovakia) (Lukáč et al. 2021), and even some private companies. In Asia, the management structure of UNESCO Global Geoparks might be very different from European Geoparks. In China, the management body of UNESCO Global Geopark has several forms (independent geopark administration under the leadership of local governments, management organization employed to administer both UNESCO Global Geoparks and scenic spots, and administration belonged to government departments). In Japan, most of the Geoparks are managed by local governments (villages, towns, cities, and prefectures) but with a local board of local politicians (mayors or president of local areas), members of different groups, and residents (Watanabe 2018; Cai et al. 2021). In Vietnam, Indonesia, and Malaysia, preparation for building Geoparks began in the 1990s with the significant assistance from their national geology survey and national museum administration (Zhao and Zhao 2008).

The application of UGGp in Europe is bottom-up. From discovery of geoheritage and application to national administration then to UNESCO, this process is almost autonomous (Zouros 2002). However, in China, due to great contribution from Chinese National Geoparks Network, a large number of Chinese National Geoparks are lining up to apply for UNESCO Global Geoparks. Consequently, the selection for application to UNESCO is quite competitive in China (Li and Jiang 2002; Zhao and Zhao 2003b, 2009). This top-down system has more advantages in municipality support and investment, infrastructure construction, and resource allocation.

The establishment of regional Geoparks Network stimulated UGGps growth and influenced their spatial distribution. With the establishment of Global Geoparks Network in 2004 (McKeever et al. 2010; Zouros 2016), from 2004 to 2008, the number of Global Geoparks has skyrocketed especially in Europe and China. Until the establishment of Asia–Pacific Geoparks Network (APGN) in 2009, the idea and concept of Global Geopark began to be popularized and accepted by other countries (Japan, Vietnam, Thailand, etc.) in Asia. APGN is the second regional Geoparks Network in the world, motivating the development of Global Geoparks in Asia and Pacific areas especially through providing the platform for communication and access among geoparks to help the countries which used not to have Global Geoparks (Komoo and Patzak 2008; Dowling 2014). For example, Thailand built the first UNESCO Global Geopark (Satun UGGp) in 2018 (Cheablam et al. 2021). Later, Latin American Caribbean Geoparks Network and African Geoparks Network were founded in 2018 and 2019, respectively (Pásková and Zelenka 2018). Global Geoparks Network (GGN) and regional Geoparks Networks contribute to the

### Table 7 Comparison among GDP and Global Geoparks of China, Spain, and Japan

| Country | 2019 GDP (trillion dollar) | Ratio | Global Geoparks | Ratio |
|---------|---------------------------|-------|-----------------|-------|
| China   | 14.34                     | 16.3362% | 41              | 25.46% |
| Japan   | 5.08                      | 5.7880%  | 9               | 5.59%  |
| Spain   | 1.39                      | 1.5871%  | 15              | 9.32%  |

The table above shows the comparison among GDP and Global Geoparks of China, Spain, and Japan.
development of Global Geoparks, especially in remote and rural areas that are less developed. By hosting workshops, organizing capacity building activities, and training courses, new candidates are willing to apply UNESCO Global Geopark. In 2022, Sweden and Luxembourg had their applications approved and established the first UNESCO Global Geoparks on their territories.

The evaluation of UGGp is a vital quality control mechanism to maintain efficient management and high standard of UGGp. In the first 2 years after the founding of GGN, there were no limitations for candidates from the same country. The number of Global Geoparks in China increased rapidly (4 candidates in 2005, 6 candidates in 2006). At the second International Global Geopark Conference host in Belfast in 2006, a proposal has been adopted that each country should have two candidates for Global Geopark by far every year. This provision sets a limit for candidates from the same country and helped to balance the development of UGGps from a global perspective. Another mechanism is revalidation. Every 4 years from the year of becoming a UGGp, GGN members have a field visit similar to the evaluation visit. The revalidation mechanism is a dynamic monitoring to maintain high quality label of UNESCO Global Geoparks. Therefore, areas with significant geoheritage resources that are not sustainably managed and protected are not supposed to maintain the title due to the revalidation mechanism (Ramsey 2017; Werther 2022).

Discussion

From previous data and charts, number of UGGps has risen at a very rapid speed from 2004 to 2006, and then the trend goes stabilized (2007–2009). With the establishment of regional Geoparks Network (2010–2015), the growth starts to rocket roughly again. During this phase, more countries participated in the application of Global Geoparks. After the recognition by UNESCO in 2015, the UNESCO 2030 Agenda gave more attention to Africa, Latin America, and Caribbean areas (Benado et al. 2019; Megerssa et al. 2019; Herrera-Franco et al. 2020; Scoon 2020; Elkaichi et al. 2021; Kariuki et al. 2021). It is to help local sustainable development, alleviate poverty, and conserve geoheritage through the establishment of UNESCO Global Geoparks (Frasani et al. 2011; Deng and Zou 2021; Lee and Jayakumar, 2021). For regions (Australia, India, etc.) that do not host UNESCO Global Geoparks but have stunning geoheritages of great significance, significant efforts are needed (Joyce 2006, 2010; Brocx and Semeniuk 2015; Briggs et al. 2021; Chauhan et al. 2021; Prabhakar and Radhika 2022). Consequently, the UNESCO Global Geoparks will be expanded to new continents.

Based on analysis and previous research, there are still some problems. For the well-developed regions, (1) the distribution of UGGp in the area is uneven; (2) the international significance of newly applied geoheritage may not be clear; and (3) legal and financial support at national level is not strong enough (Orús and Urqui 2020). For regions like Africa and Latin America, even the application is a very complicated procedure. Since 2005, 59 Geoparks from Latin America applied, however, most of the applications have been rejected (Rosado, 2020). Although the importance of building UNESCO Global Geoparks in Latin America has been highlighted, the process of applying UGGp has also been slow due to the shortage of relevant researches (Gorfinkiel, 2015; Sá, 2017) and lack of management bodies (Gorfinkiel and Santos 2011). Furthermore, COVID-19 pandemic also brings difficulties to Geopark evaluation and revalidation (Martini et al. 2021).

Conclusion

This paper has reviewed the development of UNESCO Global Geoparks since their birth in 2004. By using GIS measures to analyze the evolution of Global Geopark distribution in temporal and spatial indicators, we found that two centers of concentration of UNESCO Global Geoparks are in Europe and Asia. With establishment of UNESCO Global Geoparks in Africa and Latin America, the distribution of UNESCO Global Geoparks is more divergent. Local economies, regional geological backgrounds as well as policies of local governments, the GGN and UNESCO are significant factors influencing the distribution of Geoparks and restricting the construction of Geoparks. Hence, more attention needs to be paid to these factors in the application and construction process of UNESCO Global Geoparks.

Declarations

Competing Interests The authors declare no competing interests.

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