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Spatiotemporal Characteristic of Biantun toponymical landscape: evolution of Biantun culture in Yunnan, China

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Abstract: The unique geographical environment of Yunnan Province in China and large-scale waves of Han migration during the Ming Dynasty contributed to the emergence and development of the Biantun culture. The toponym is the carrier of the Biantun culture: it records the integration process between the Central Plains and native Yunnan cultures. Based on the GIS spatiotemporal analysis of toponyms in Yunnan, this study reproduced the settlement characteristics of Biantun toponyms (BTT) and the spatial development of the Biantun culture in the Ming and Qing Dynasties. In addition, we've developed toponymical landscape index to represent the degree of spatial integration between the BTT and ethnic minority toponyms in Yunnan and explore the spatial characteristics of the integration of Han immigrants and local ethnic minorities. The results show that the spatial distribution of the BTT is consistent with the site selection of the central plains immigrants station troops to open up wasteland in Yunnan during the Ming and Qing Dynasties, and the centroids of BTT spread to outskirts and intermontane area from central towns. In Dali, Kunming, Qujing regions, etc present the distribution characteristics of the mixed of BTT and ethnic minority toponyms, and a higher degree of Sinicization in the central urban areas. This study used GIS applications for historical and cultural research and established the connection among Biantun culture and spatiotemporal data. Exploring evolution of Biantun cultural development through the spatial characteristics of toponymical landscape can help adjust policies for he development and protection of the Biantun cultural resources.

Keywords: Biantun culture; toponymical landscape; spatiotemporal characteristics; integration index

Introduction

Han immigrants who migrated to frontier areas in China underwent a process of settling in towns and villages, engaged in creative production, worked/lived with local ethnic groups, exchanged cultures, and developed in tandem, resulting in ethnic integration ¹. Biantun culture is a typical immigrant culture of cultivation and guarding borders formed by the Han people who migrated and settled in border areas; it merges their original Central Plains culture with those of border regions and national traditional cultures ². Yunnan is a border province that has been important for ethnic migration and cultural exchange since ancient times. During the Ming Dynasty, military immigrants arrived in Yunnan because of wars. The population structure, ethnic distribution, production relations, political system and cultural orientation of Yunnan society experienced epoch-making changes as Han immigrants settled in various localities and gradually integrated with local ethnic groups. Starting with Yongsheng County, Yunnan Province has become the most representative area for research into Biantun culture.

41 The study of Biantun culture started late, most existing studies are limited to reviews and
42 discussions on cultural connotation and historical evolution. The Biantun toponyms (BTT) arose from
43 the development of the Biantun culture. Toponyms not only represent geographical locations, but also
44 represent spatial entities. In different time scales, in addition to their original meanings, there are also
45 local historical, cultural, social, and national meanings. The ‘GIS + toponym’ research model for
46 relearning place names from a new perspective, and in particular, toponyms with spatiotemporal
47 information characteristics, we carry out the study of Yunnan Biantun culture in this model. Many
48 scholars have made rich research results in this field.³⁻¹⁰ The geographer David Mark expanded the
49 investigation of toponyms from ethnophysiography research on Malay names, mountain names, and
50 other features¹¹. Studies of minority place names have included the use of GIS’ geometric center
51 analysis and spatial orientation distribution technology to obtain a possible historical distribution of
52 Zhuang toponyms in Guangxi Province^{12,13}. GIS was used to analyze the spatial patterns of Zhuang,
53 Cantonese, Min Nan, and Hakka toponyms, and to compare historical data between ancient and
54 modern times for the study of historical population and landscape evolution of various ethnic groups
55¹⁴. Wang et al. explored the spatiotemporal evolutionary characteristics of county-level administrative
56 toponyms and cultural landscapes in China’s eastern plains¹⁵.

57 Toponym symbol have inherited the unique local historical culture in the long process of historical
58 development. The distinctive naming method of BTT makes it an obvious landmark of Biantun culture.
59 The study of toponymical landscape can provide a theoretical basis for the research on the spread of
60 Yunnan Biantun culture and the development of social structure and ethnic integration.

61 **Materials and Methods**

62 **BTT data**

63 Yunnan is located on the southwestern border of China (Fig. 1). During the early Ming Dynasty,
64 wars in Yunnan were frequent and living conditions were extremely unstable. During the Hongwu
65 years, military immigration of Han ethnic migrants occurred on a large scale. During Yunnan
66 unification and while consolidating the southwest frontier, the institutionalization of land reclamation
67 and crop farming by stationed troops resulted in the mass migration of Han people to Yunnan. Most
68 of the military migrants were concentrated in central towns; Tuntian (where troops are stationed and
69 opened up wasteland) districts were concentrated in the suburbs of important towns.

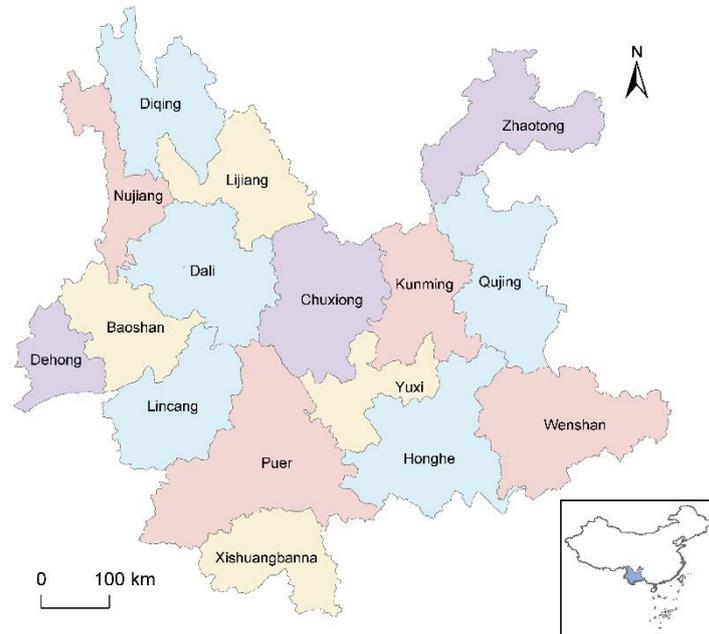


Fig.1 Location of Yunnan

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72 According to the Ming Dynasty system, Ying was the basic unit of the army, and Tun was an
 73 army resettlement system managed by the metropolis¹⁶. Halfway through the Ming Dynasty,
 74 conditions in Yunnan began to stabilize. Initially, Han immigrants began settling large-scale
 75 settlements on the outskirts of towns, followed by remote areas of flat land. The main Tuntian sites of
 76 the middle Ming Dynasty were named based on military units, including Wei, Suo, Qianhu, and Baihu,
 77 where the grade hierarchy was Wei > Suo > Qianhu > Baihu. According to an order from Zhu
 78 Yuanzhang (the Ming emperor), the armies of Wei and Suo had to be self-sufficient; this required one-
 79 seventh of the army to farm and one-third to guard the city. Military yards around the Wei and Suo
 80 provided an economic source. Furthermore, the military yards of Yunnan reflected the emergence of
 81 toponyms during the middle Ming Dynasty, and were named after senior military chiefs' surnames
 82 and suffixed with lower-level transportation trunk facilities and organization; for example, "post" (Yi),
 83 "fort" (Bao), "shop" (Pu), "sentry" (Shao), and others.

84 Beginning half-way through the Ming Dynasty and towards its end, along with the
 85 comprehensive development of immigrant agriculture, military yards moved to city outskirts,
 86 intermontane basins, and to mid-mountain areas. The original large-scale military yards were not
 87 suitable for agricultural development and production under the new terrain, which prompted the
 88 original basic organization of the Tuntian to shrink, and small organizational units such as Qi, Wu, and
 89 Guan to appear. The toponyms that appeared at this time included the surname of the chief of the Qi,
 90 the Guan, and the Wu, and the lower-level organizational units.

91 By the end of the Ming and early Qing dynasties, conditions in Yunnan were more stable; the
 92 population continued to increase and the branches of large clans began to spread. At this time, military-
 93 based toponyms faded, and some toponyms added the word "village" (Cun) after the words used in
 94 the original military units. Owing to a series of insurrections and border conflicts during the Qing
 95 Dynasty, a large number of military immigrants moved to Yunnan and settled in rural areas. In addition,
 96 they followed the floating official system of the Ming Dynasty and the upsurge in commerce, resulting
 97 in a large number of settlements wherein the Han nationality and a minority nationality merged¹⁷.

98 Through the integration of relevant historical materials and documents, thirteen types of place
 99 names (Yin, Tun, Wei, Suo, Baihu, Qianhu, Qi, Guan, Wu, Yi, Pu, Bao, and Shao) were selected in
 100 this study, with the Ming and Qing dynasties as the research time node. Based on the BTT screening
 101 procedure¹⁸⁻²³, 1563 toponyms in Yunnan Province were extracted.

102 The second national toponymic census in China obtained the attribute content of place name
 103 origin (placeOrigi) and meaning (placeMeani), historical evolution (placeHisto), geographical entity
 104 overview and other attributes through data collation and field investigation. The meanings of toponyms
 105 indicate their natural, social, humanistic and economic significance. The historical evolution describes
 106 the changes in the creation and modification of toponyms. The information regarding Yunnan rural
 107 settlements, urban settlements, and mountain names was obtained from the National Database for
 108 Geographical Names of China (<http://dmfw.mca.gov.cn/>), as presented in Table 1.

109 **Table 1** Toponym information of second national toponymic census in China

Field name	Detail
standard a	Daying
placeType	Rural settlement
placeOrigi	Named for historical events. Also because of the Liangwang River around the vil- lage, the former forest was lush and the scenery was beautiful, it was refined into Huanxiu Village in the early Qing Dynasty, however the folk still call it Daying.
placeMeani	The Ming general Mu Ying conquered Queen Liang, and in the 19th year of Hongwu (1386 A.D.), he stationed troops there, and the camp was large.
placeHisto	After the 19th year of Hongwu of Ming (1386), Mu Ying's troops had stationed their troops and hoarded supplies here, and because of the large number of troops, they were named Daying.
lon	102.827
lat	24.7887

110 Owing to changes in place names, current place names may not be identified by the
 111 aforementioned key words. Therefore, the following steps were used to determine whether the place
 112 name was a BTT:

113 (1) Identification of place name attributes.

114 Natural language processing integrates disciplines such as cognitive science, linguistics, and
 115 computer science to solve problems such as information retrieval, information extraction, and
 116 automatic abstraction. As a basic natural language processing technique, Chinese word segmentation
 117 recombines consecutive word sequences into word sequences according to certain specifications and
 118 performs preliminary attribute processing for screening of BTT²⁴. The villages, urban settlements,
 119 and mountains formed by the places of stationed troops and military facilities during the Ming and
 120 Qing Dynasties were judged as the BTT and were extracted based on the keywords such as garrison,
 121 station troops, and set up sentry post. The creation time of toponym is extracted from the historical
 122 evolution field. If there is no exact year of the toponym in the field, the Tuntian time is extracted from
 123 the two fields of place name meaning and historical evolution.

124 (2) Search historical documents

125 If the creation time of toponym and Tuntian time are not known, gazetteers and related documents
 126 are checked and the time corresponding to the time of the local historical military immigrants is
 127 adopted.

128 **Research methods**

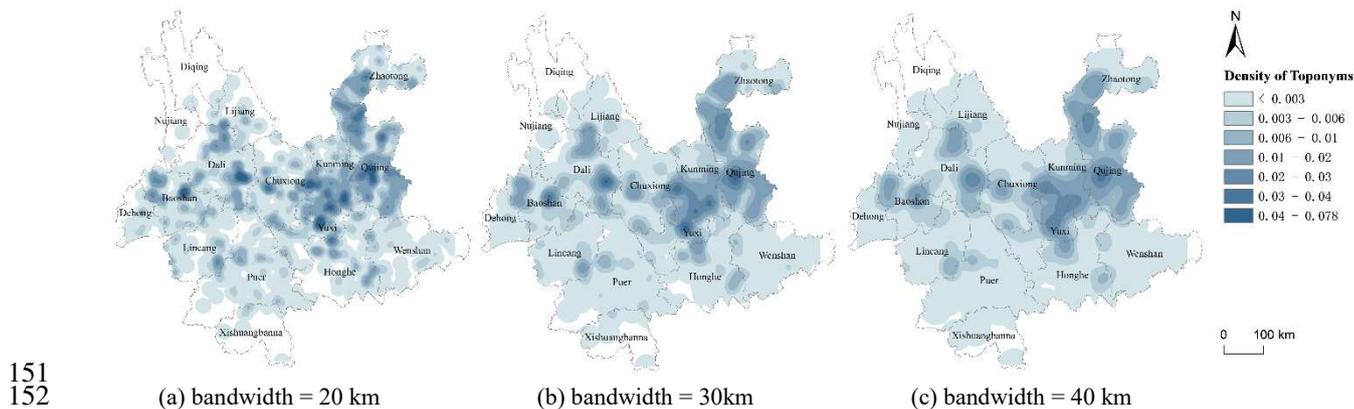
129 Density analysis

130 BTT are dot distributions. Based on the clustering characteristics, the spatial model of the BTT
 131 distribution in different periods can be studied using the density characteristics of its points. In this
 132 study, the kernel density estimation (KDE) method was used to map the spatial clustering
 133 characteristics of all BTT and the small spatial scales of BTT in different periods. Additional
 134 exploration of the overall trend of BTT based on the KDE method used a moving cell to estimate the
 135 density of a point or a line pattern. The density property of the location area can be obtained using
 136 KDE, which is characterized by assigning weights to all points by using the kernel function to create
 137 a smooth distribution of results. The kernel density is calculated as follows:

$$138 \quad f(x) = \frac{1}{nh} \sum_{i=1}^n K\left[\frac{1}{h}(x_i - \bar{x})\right] \quad (1)$$

139 where $K[\]$ is the kernel function, n is the number of known points in the bandwidth range, $h > 0$
 140 is the bandwidth, and x_i is the position coordinate on the point i ($i = 1, 2, \dots, n$).

141 Considering the complicated terrain of Yunnan, we selected a mountain range with large
 142 undulations to calculate the average distance between each pair, and finally selected bandwidths of 20
 143 km, 30 km, and 40 km for comparison (Fig. 2) to determine the optimal bandwidth and analyze the
 144 distribution characteristics of BTT. It can be observed from the figure that the maximum density value
 145 with a bandwidth of 20 km is 0.078, the maximum density value with a bandwidth of 30 km is 0.043,
 146 and the maximum density value with a bandwidth of 40 km is 0.034. In KDE, the smaller the
 147 bandwidth, the greater the density value within the bandwidth, and more highlight the density value;
 148 the larger the bandwidth, the smaller the density value within the bandwidth and the smoother the
 149 density value gradient. With 30 km as the bandwidth, it can clearly identify the density center of BTT
 150 and reflect the degree difference of the kernel density of the toponym.



153 Fig.2 Kernel density of BTT with bandwidth of 20km, 30km, 40km

154 Emerging Hot Spot Analysis

155 Emerging hot spot analysis (EHSA) examines the clustering of points over time. It uses a space
 156 time cube to generate the analysis based on the Getis-Ord G_i^* statistic²⁵. A space–time cube creates
 157 layers where data is categorized by its x and y coordinates for its geographic location and z coordinates
 158 for its year. The space–time cube uses the Mann–Kendall trend test to determine the statistical
 159 significance of how the points are changing²⁶. In this study, the input of the time step parameter was
 160 adjusted based on this algorithm; therefore, the time domain can be set flexibly. The analyses were
 161 performed in four time domains: early Ming (1368–1435), Mingzhong (1436–1582), Minghou (1583–

162 1644), Qing Dynasty (1645–1912).

163 The Getis-Ord local statistic is given as

164
$$G_i^* = \frac{\sum_{j=1}^n w_{i,j} x_j - \bar{X} \sum_{j=1}^n w_{i,j}}{S \sqrt{\frac{[n \sum_{j=1}^n w_{i,j}^2 - (\sum_{j=1}^n w_{i,j})^2]}{n-1}}} \quad (2)$$

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$$\bar{X} = \frac{\sum_{j=1}^n w_{i,j}}{n}, S = \sqrt{\frac{\sum_{j=1}^n x_j^2}{n} - (\bar{X})^2} \quad (3)$$

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167 where x_j is the attribute value for feature j , $w_{i,j}$ is the spatial weight between i and j , n is equal to the
168 total number of feature, and the G_i^* statistic is a z-score; no further calculations are required.

169 Standard Deviation Ellipse

170 The standard deviation ellipse (SDE) model is commonly used to analyze spatial distribution
171 characteristics of a point data set; it also analyzes the direction and distribution of points. The long and
172 short axes of the ellipse indicate the directions of maximum and minimum diffusion, respectively. The
173 smaller the area, the closer the distribution is to the center of gravity and the more it represents a
174 concentrated distribution. Elliptical deflection angles of $0^\circ/180^\circ$ and 90° indicate a dominant north-
175 south or east-west direction, respectively.

176 Integration index

177 The integration degree can be interpreted as pattern difference of integration of the spatial
178 distribution of the BTT and ethnic minority toponyms. First, extract the overall hierarchical cluster
179 structure by clustering all toponym points, the distance density constrained clustering method based
180 on Delaunay triangulation is used to extract the point cluster structure in this study²⁷. According to
181 the clustering results, the Voronoi region generated by the all toponym points is merged to obtain the
182 distribution region of each point cluster. After counting the number of BTT and ethnic minority
183 toponyms in each region of each point cluster, we denote H_i as the integration degree of two kinds of
184 toponyms in spatial distribution:

185
$$H_i = \frac{n_e}{N_i} - \frac{n_b}{N_i} \quad (4)$$

186 where N_i is the total number of toponyms in point cluster i , n_e are the number of ethnic minority toponyms
187 and BTT in the region, H_i ranges from -1 to 1 .

188 Results and discussion

189 Spatiotemporal distributional characteristics of the BTT and Biantun cultural 190 landscape

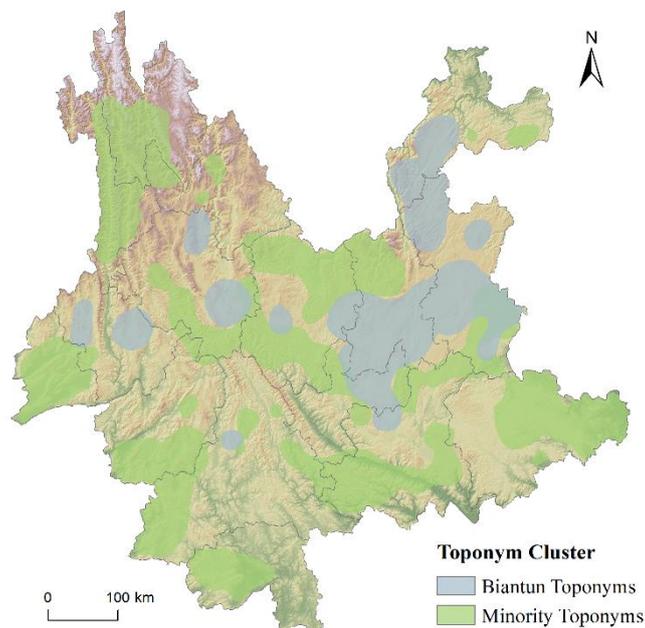
191 The KDE was performed on all the BTT in Yunnan Province. As shown in Fig. 2 (b), the core
192 (i.e., the highest kernel density distribution) is at the junction of Chuxiong, Kunming, Qujing, and
193 Yuxi. The density center is in the northwest of the junction. The BTT cluster distribution is closely
194 related to the cultivated fields of a garrison of military immigrants of the Ming Dynasty. As the core
195 of military and political affairs of Yunnan, central Yunnan became a region of strong defense and
196 development during the Ming Dynasty. However, western Yunnan, where the migration distribution is

197 the most extensive, has a polycentric characteristic. The initial conquest of the Army in Yunnan was
198 the capturing of Qujing. This area became an important checkpoint for East Yunnan, forming a military
199 immigration area in Eastern Yunnan for Han migrants. The main traffic line from Yunnan to the interior
200 is located in northeastern Yunnan; therefore, this area contains the inner core Han settlements.

201 The development of Biantun culture is a microcosm of the gradual integration of the Han
202 nationality and border minority nationalities. Initially, Yunnan was almost a fully agricultural society
203 with low productivity. During the Han and Jin dynasties, the prefectures and counties of the central
204 dynasty increased in Yunnan and the first wave of Han migration occurred. This had a significant
205 impact on the social structure and culture of the region. Subsequently, the Biantun culture continued
206 to develop through several dynasties, and especially during the Ming and Qing dynasties.

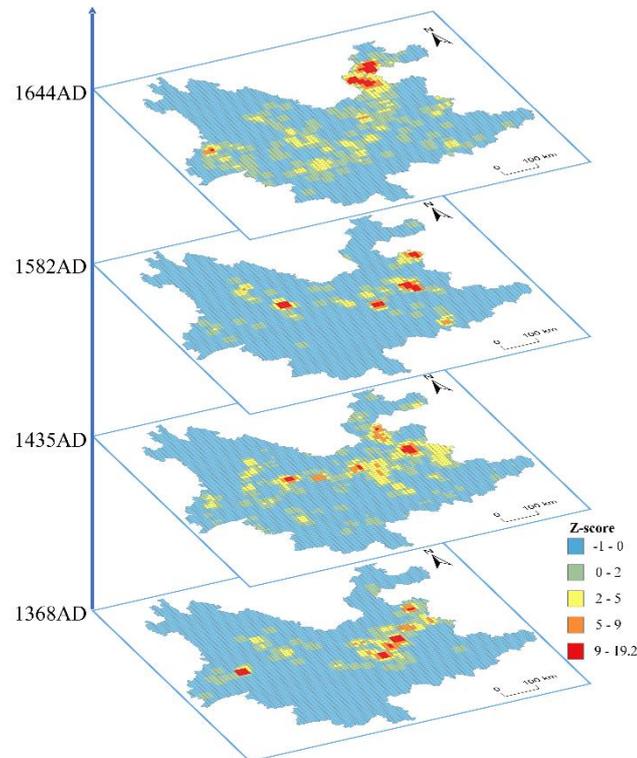
207 To strengthen the rule of native ethnic groups in Yunnan, the rulers of successive dynasties
208 continuously expanded the living areas of Han immigrants, and concurrently spread the Han culture
209 and implemented the policy of Sinicization. This policy promoted cultural exchange and integration
210 between the Han people and native peoples of Yunnan to some extent; however, it was a gradual and
211 unbalanced process. The density map of BTT clearly shows the spatial development of this process.
212 The integration degree between central and north-eastern Yunnan Province is high, whereas that
213 among the northwest, southeast, and southwest areas is low.

214 Based on analysis of the formation conditions of the BTT, the settlement of Han immigrants with
215 a certain scale was the basis for the increase in BTT, particularly in areas that were suitable for
216 agricultural development and production. Owing to their primitive lifestyle, local ethnic minorities in
217 Yunnan were mainly distributed in mountainous areas far from towns; thus, there is a clear spatial
218 difference between the BTT and ethnic minority toponym cluster regions. The high value regions of
219 the result of KDE of ethnic minority toponyms were extracted in this study. Compared with the
220 distribution of BTT (Fig. 3), there are obvious differences in the distribution of the two types of
221 toponyms. The cluster regions of BTT are mostly distributed in the basins of the central, eastern,
222 western, and northeastern regions; ethnic minority toponyms mainly occur in marginal areas, and
223 mostly in hilly and mountainous areas. The results are consistent with the literature and history records
224 (Lu 1999)



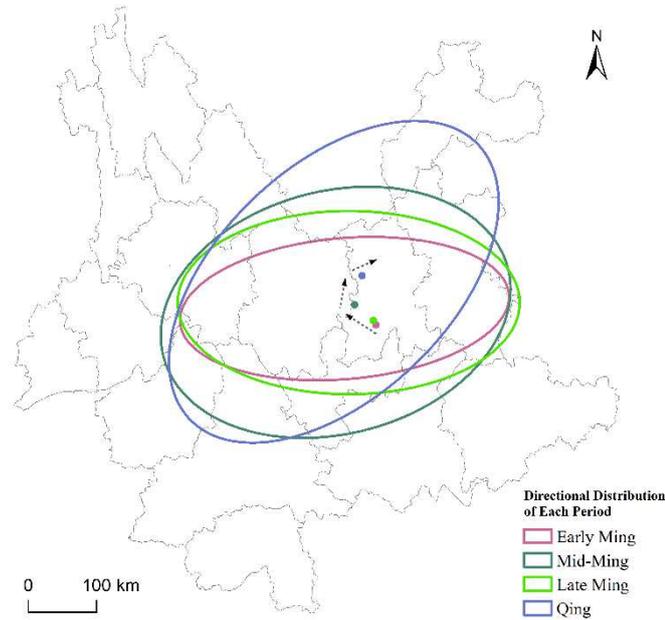
226 Fig.3 Cluster regions of Biantun toponyms (BTT) and minority toponyms

227 The Getis-Ord-Gi* statistic takes in attribute values and spatial weights in order to determine
228 statistical significance with a z-score. This z-score is used to determine where high or low
229 concentrations of values are spatially clustered. For statistically significant positive z-scores, the larger
230 the z-score, the more intense the clustering of high values (hot spot). For statistically significant
231 negative z-scores, the smaller the z-score, the more intense the clustering of low values (cold
232 spot). Fig. 4 shows the results of the EHSA Z_score (hot spot) in the four periods of BTT. The red area
233 is the hot spot area and the area where the BTT gather.



234 Fig.4 Emerging hot spot analysis z-score
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236 Fig. 5 shows the SDE of BTT points in each period. Although place names found in earlier eras
237 still exist in later eras, the calculation of the geometric center of each era was based on new place
238 names to analyze the distribution characteristics of new place names in each era more clearly.



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Fig.5 Directional distribution of Biantun toponyms (BTT) in the four periods, arrows indicate the direction change of the distribution of toponyms

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From Fig. 4 and Fig. 5, the clustering center of place names for the four periods are distributed in the west of Kunming, which is center of Yunnan Province. Compared with the early Ming Dynasty, the distributions of place names in the next three periods show further expansion. The BTT distribution evolved from the center of Yunnan Province to surrounding areas over time, gradually expanding from central towns and integrating with indigenous peoples.

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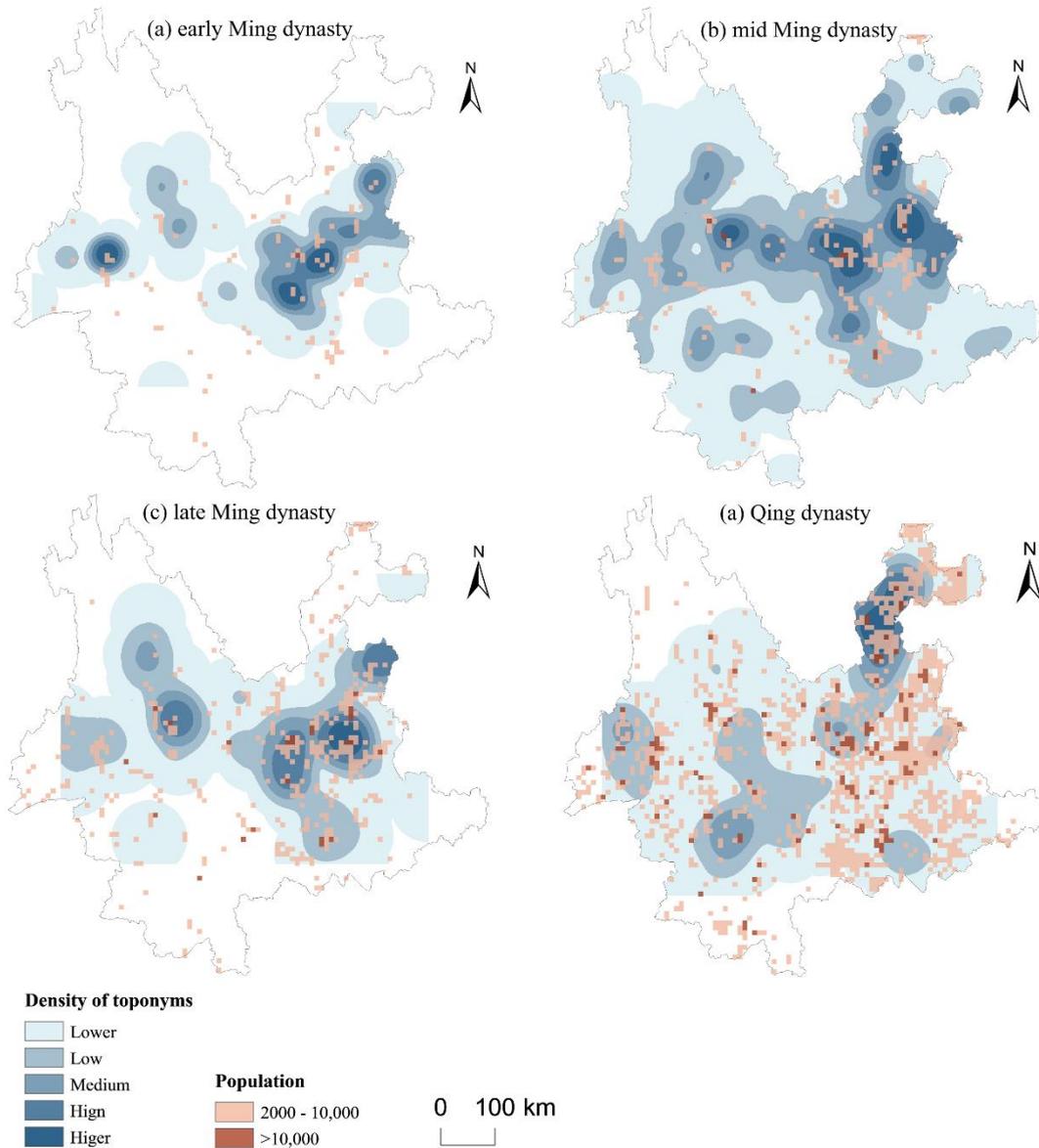
From the early to middle Ming Dynasty, the distribution of place names was from the southwest to the northeast. In the middle and later periods of the Ming Dynasty, the clustering center of toponyms developed to the southeast, and the distribution direction was west to east. From middle to late periods of the Ming Dynasty, there is no significant change in the distribution of the clustering center of toponyms and the distribution direction showed east–west horizontal development. By the Qing Dynasty, the distribution direction had clearly developed to the northeast. The BTT in each period differed significantly, indicating that the borderland policies in Yunnan Province differed in the four periods.

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Spatiotemporal evolutionary characteristics of BTT and Biantun cultural landscape

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Fig. 6 shows the spatiotemporal changes in population during each dynasty. Maps show the number of people in a 9 km × 9 km grid cell, obtained from the history of the global environment (HYDE) database. The low population in the early Ming dynasty may reflect the unstable situation in Yunnan, which may have made it difficult to count the actual population. In the middle Ming Dynasty, there was a large increase and expansion in both the number of people and spatial then distribution, which was possibly caused by a delay in the population statistics relative to the actual population.



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Fig.6 Spatiotemporal evolution of Biantun toponyms (BTT) and population in Yunnan Province

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As shown in Fig. 6, the population density of central, western, and northeastern Yunnan increased significantly from the early to middle periods of the Ming Dynasty, which is consistent with the large number of military immigrants moving to Yunnan. The distributional area is also consistent with the garrisons established in the early period of the Ming dynasty. In the middle and late periods of the Ming Dynasty, as Han immigrants entering Yunnan formed stable settlements, the population density increased significantly, and the distribution range expanded from the center to ethnic minority areas. The integration of various ethnic groups in frontier areas during the Qing Dynasty was strengthened compared with the previous generation. Many Han migrants expanded their families in Yunnan. The official system and phenomenon of Shangtun also significantly increased the number of immigrants who moved to Yunnan.

The highest density of BTT was mainly distributed in the Qujing–Kunming–Yuxi area during the early Ming Dynasty. Ming Dynasty policy on the defense of towns in Yunnan began first in the

276 hinterlands of central Yunnan; this area also became the earliest named area of the BTT. In the middle
277 period of the Ming Dynasty, the BTT distribution expanded to western, northeastern, and southeastern
278 Yunnan and extended from the suburbs to the outskirts of towns. Various regulations were established
279 in this era. The immigration settlement area was essentially formed and most BTT were derived and
280 named during this period. In the late period of the Ming Dynasty, there were no significant changes in
281 the geographical names of the frontiers. It was common to use the surname of the chief military officer
282 for the names of newly added Tuntian sites at lower levels.

283 By the Qing Dynasty, the distribution had developed towards intermontane basins, mid-mountain,
284 and mountainous areas. There were many uprisings and anti-aggression struggles during Qing rule and
285 a considerable number of military immigrants remained in Yunnan. The turning point in immigration,
286 the Shangtun phenomenon, left a large number of settlements in Yunnan.

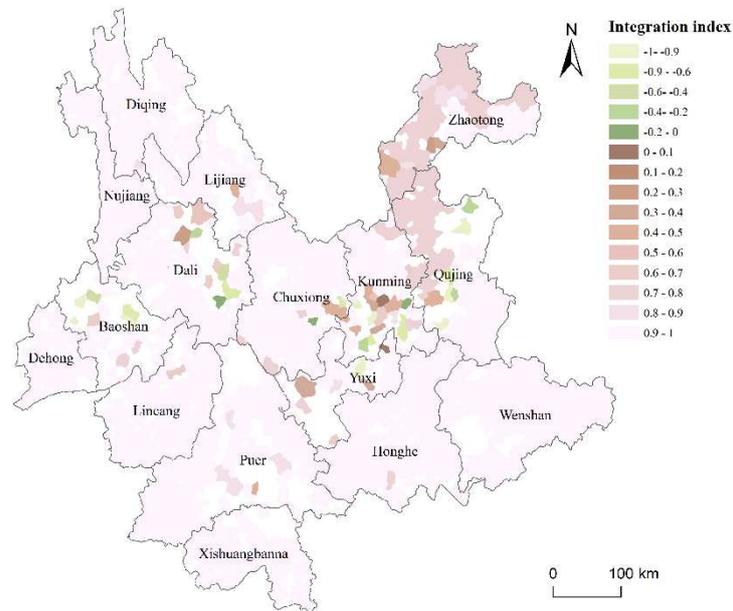
287 Based on the spatiotemporal distribution of population and BTT in each period, the evolutionary
288 relation between Han migration and the BTT was established. The expansion and evolution of
289 distribution in space and time were largely consistent. The large numbers of Ming Dynasty Han
290 immigrants who moved to the remote regions resulted in greater prosperity Biantun culture, as
291 reflected in the place names. The evolution of the spatial distribution of toponyms also evolved with
292 the development in Tuntian regions; from the central hinterland of Yunnan, it gradually extended away
293 to marginal mountain areas and penetrated into ethnic minority areas.

294 **Spatial characteristics of toponymical landscape**

295 According to Equation (4), calculate and visualize the integration index of each region of point
296 cluster(Fig.7). $H_i > 0$ means that there are more ethnic minority toponyms than BTT in the region, and
297 vice versa. The closer the H_i value is to 0, the closer the number of the two types of toponyms in the
298 region, the higher the integration degree of the spatial distribution. It shows that the landscape Char-
299 aracteristics of the mixed residence of Han and Minority are more prominent.

300 The point cluster regions with H_i values between 0.6 and -0.6 are mainly distributed in Dali,
301 Chuxiong-Kunming-Qujing area, and Baoshan, Yuxi, Zhaotong, etc are also distributed. This is simi-
302 lar to the result of kin Fig. 2 (b), which corresponds to the extremely unbalanced settlement distribution
303 of Han immigrants in Yunnan in Ming Dynasty. When Yunnan was suppressed in the early Ming
304 Dynasty, the imperial court took the strategy of occupying the central cities and towns first, conquering
305 Kunming, Dali, Chuxiong, Lin'an, Qujing and other military and political towns, then sta-
306 tion troops to open up wasteland. The newly built military and political towns became the most im-
307 portant settlements of Han immigrants in Yunnan in the early Ming Dynasty, and constantly absorbed
308 other kinds of immigrants to settle in the cities (Lu 1999). Immigrants are mainly distributed in towns
309 and in basin of Tuntian, The Han immigrants who settled in the Fort and Sentry on the traffic road in
310 the remote mountainous area were scattered. From the perspective of toponymic landscape, In Dali,
311 Chuxiong, Kunming, Qujing, and Baoshan (called Jinchi in the Ming Dynasty), there are more cluster
312 regions that are dominated by BTT. Lin'an (Jianshui) district presents the spatial distribution charac-
313 teristics of minority toponyms are the majority. The deployment of the Ming Dynasty's immigrants to
314 garrison Yunnan is reflected in the distribution of geographical names.

315 As a result, the ethnic integration in the central towns and the basin districts will be dominated
316 by sinicization, while that Han immigrants settled in mountainous and remote areas will integrate into
317 ethnic minorities. The spatial characteristics of the index of toponyms integration degree calculated in
318 this paper show this, and the visualization results show the landscape differences of the integration
319 degree of the two kinds of toponyms.



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Fig.7 Spatialization results of integration index(H_i), blank areas are areas where toponyms are distributed discretely

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Conclusions

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Place names are physical carriers and witnesses of the Biantun culture. They retain the process of mutual influence, penetration, and absorption between the cultures of the Central Plains and border region. However, with the development of urbanization and the replacement of place names, some historical place names are facing extinction. This has a significant impact on the protection of traditional landscapes and local historical culture and implies that investigations of the development and historical significance of Biantun culture lack physical elements. Based on GIS spatial analysis, the course of historical development of place names can be intuitively understood, and, in turn, the development of early Han immigration and ethnic integration. The results of this study provide a reference for the protection of toponymical landscape.

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As a frontier region, Yunnan represents the origin and development of the Biantun culture. The migration of military Hans during the Ming and Qing dynasties and a large number of commercial immigrants in the Qing Dynasty contributed to the prosperity and development of Biantun culture in Yunnan and the genesis of a large number of BTT. Historically, the BTT began to develop in the early periods of the Ming Dynasty. Yunnan was stable in the middle periods of the Ming Dynasty, and a large number of military villages were named. In the later periods of the Ming Dynasty, a small number of names were generated. Spatially, the distribution of the BTT extends from the Kunming–Qujing area to the western, eastern, southwestern, and north-eastern regions of Yunnan, developing from the suburbs of central towns to the intermontane basins and mountainous areas.

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National integration is an important prerequisite for the development of Biantun culture. Han immigrants and ethnic minorities live together and interact with each other. Among them, the more developed production technology and the progress of cultural education in the new immigration area will inevitably have a strong impact on the surrounding area, promote the common progress and development of the socio-economic culture of all nationalities in the region. Eventually formed the

347 Biantun culture of the Han culture of the Central Plains and the local minority cultures blend with each
348 other. The integration index proposed in this study measures the integration degree of spatial
349 distribution of BTT and ethnic minority toponyms, and extracts BTT cluster distribution regions, so
350 as to provide spatial data reference for the development and protection of Biantun cultural resources.

351 Our quantitative analysis of the spatiotemporal distribution and evolution of Yunnan BTT can be
352 used as a basis to study the origin and development of the Biantun culture and to explore the value of
353 Biantun culture and its socio-economic impact on future generations. In addition, it is imperative to
354 discover and protect historical elements (buildings, streets, rivers) and intangible cultural heritage,
355 such as the human landscape and traditional crafts. However, some place names in the study area lack
356 detailed records, and data are based on today's place names; in time, many historic place names have
357 been lost or changed. The screening of BTT can further identify and determine place name descriptions
358 at a semantic level²⁸. Further study to link data from social sciences with a GIS approach to classify
359 BTT will improve our knowledge of human influence on the toponymical landscape.

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367 C.: performed the data analyses and wrote the manuscript; Luan, G., Fu, Y., Xie Z.: contributed to
368 analysis and manuscript preparation.

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Figures

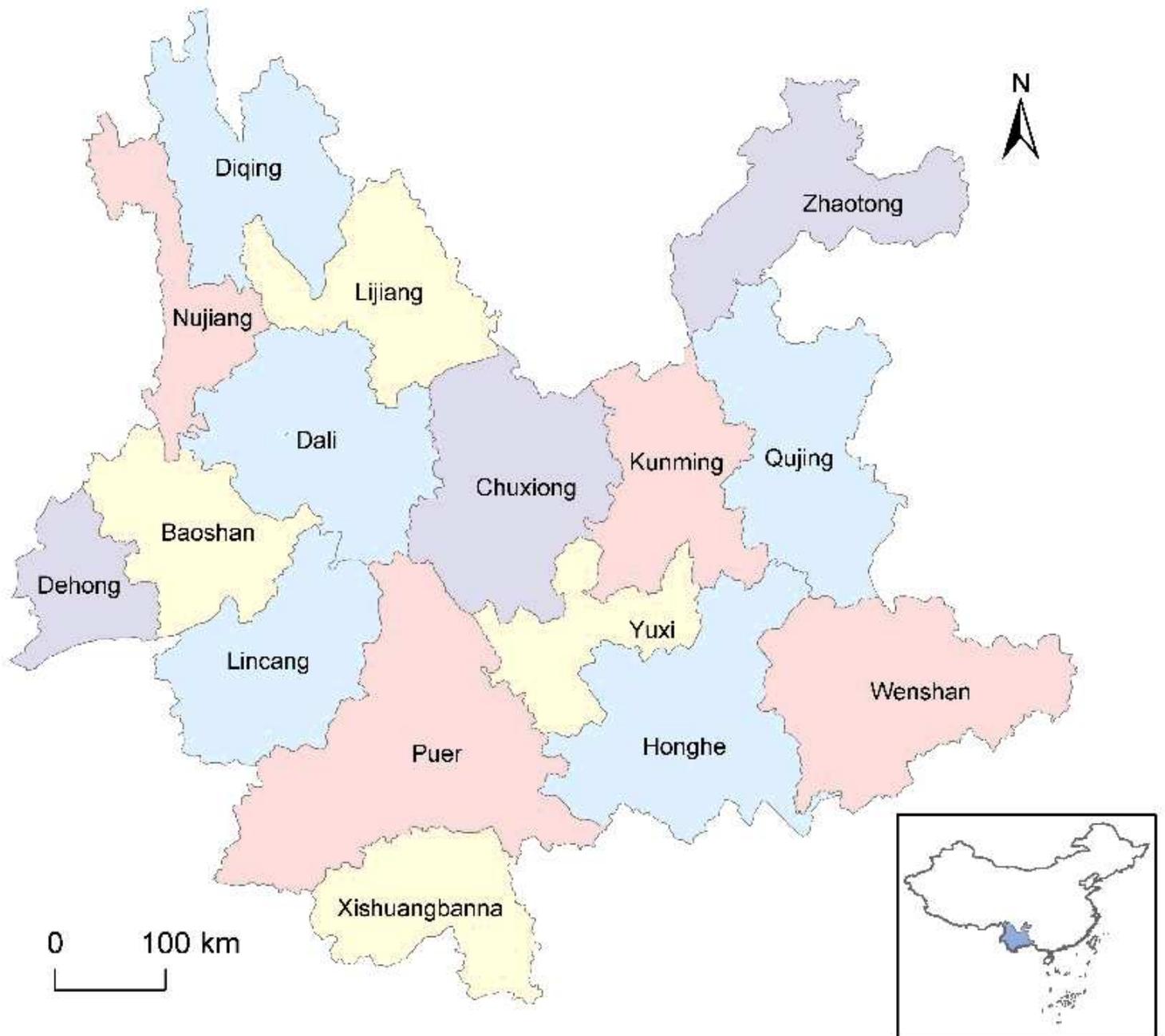


Figure 1

Location of Yunnan Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

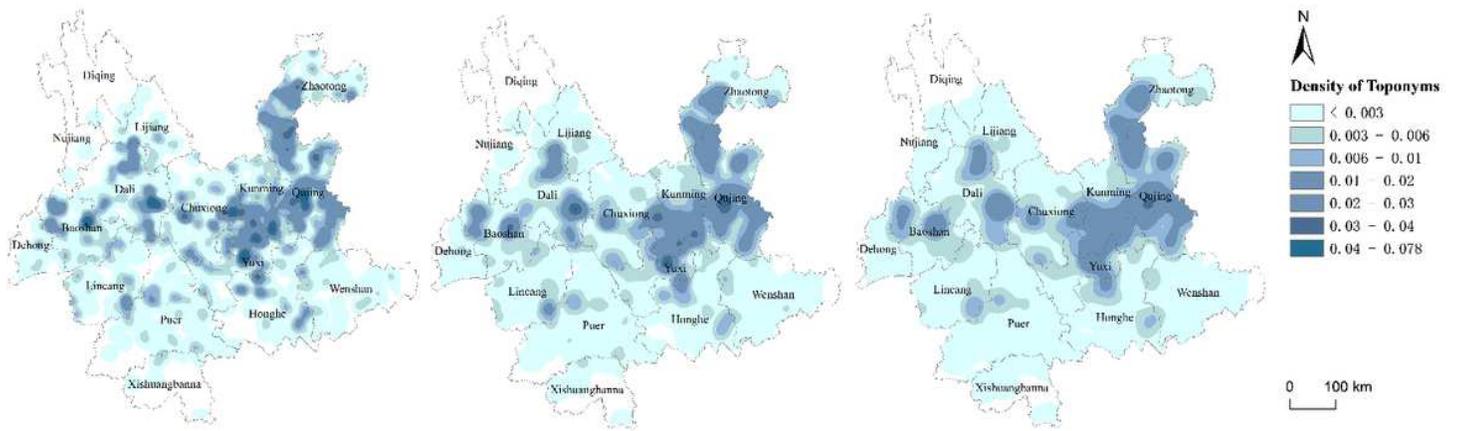


Figure 2

Kernel density of BTT with bandwidth of 20km, 30km, 40km Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

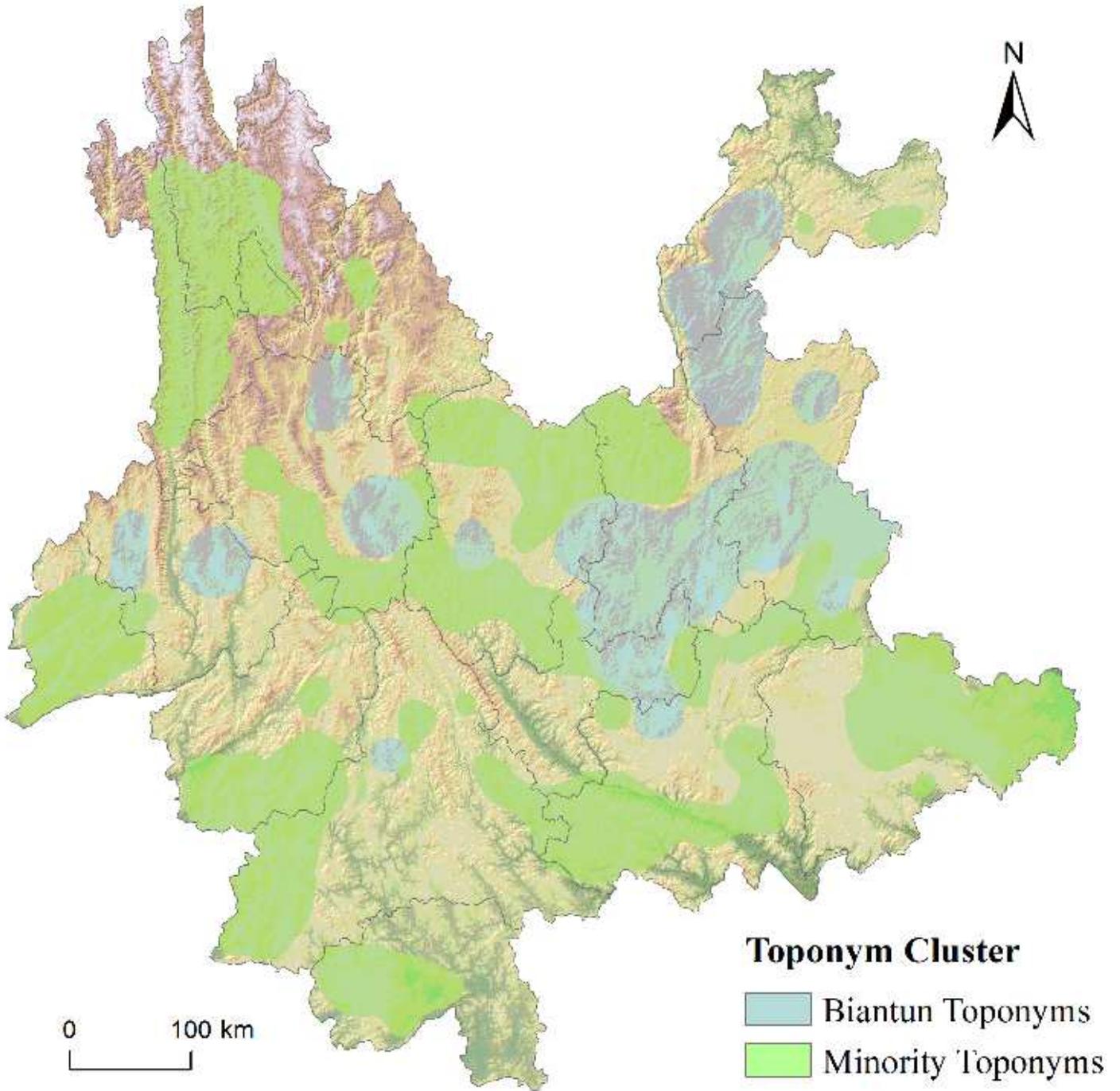


Figure 3

Cluster regions of Biantun toponyms (BTT) and minority toponyms Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

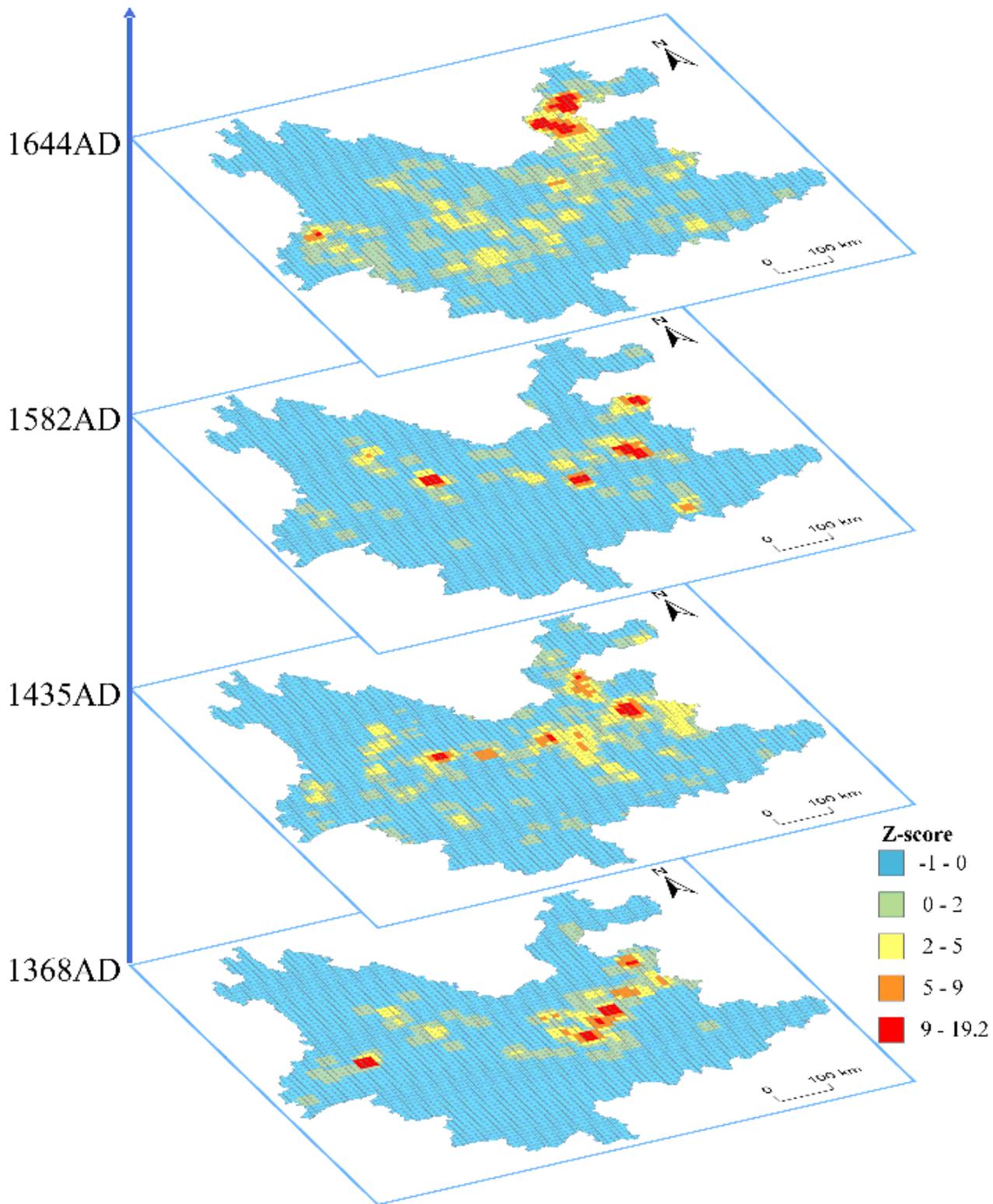


Figure 4

Emerging hot spot analysis z-score Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

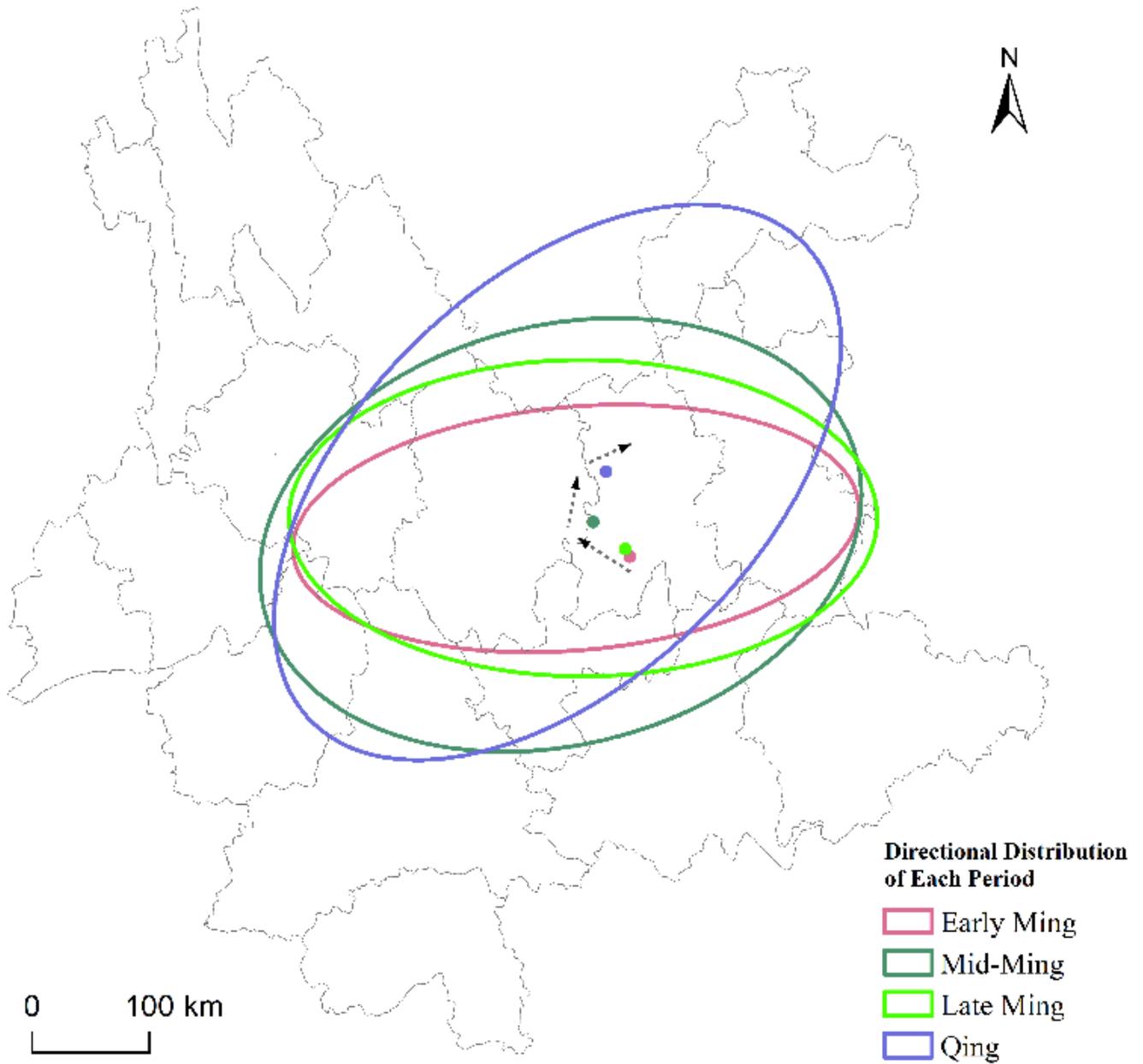


Figure 5

Directional distribution of Biantun toponyms (BTT) in the four periods—arrows indicate the direction change of the distribution of toponyms Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

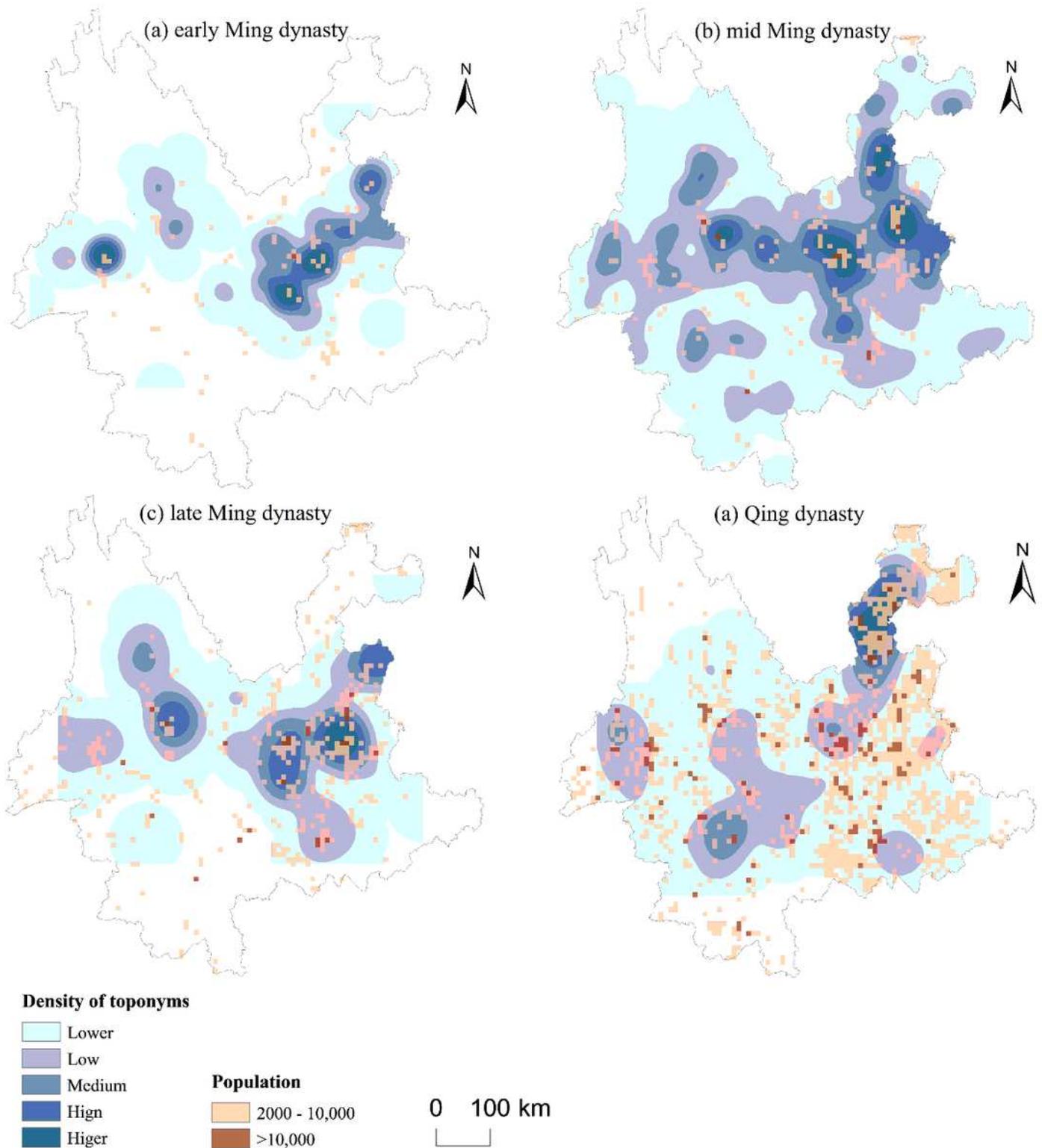


Figure 6

Spatiotemporal evolution of Biantun toponyms (BTT) and population in Yunnan Province Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

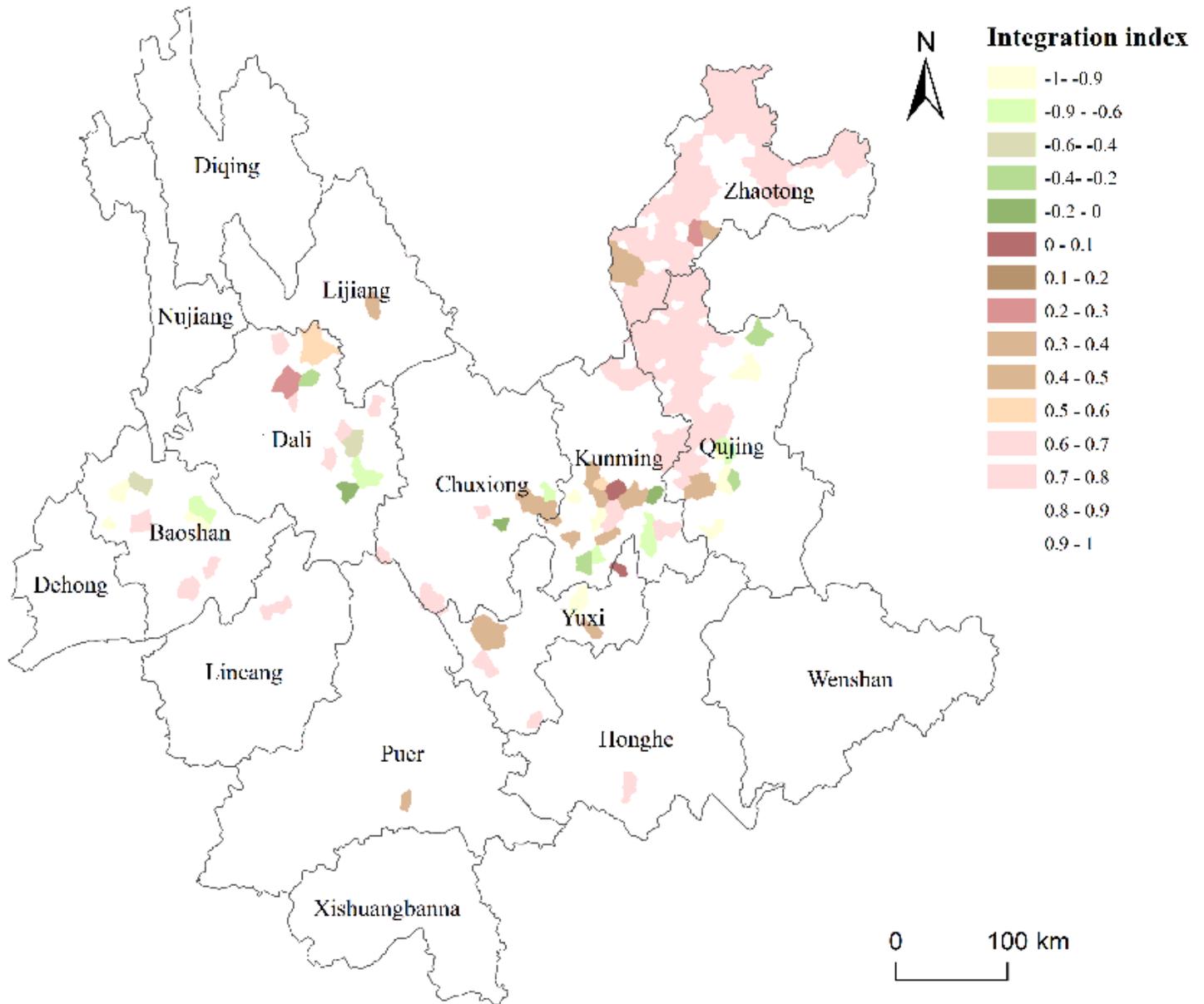


Figure 7

Spatialization results of integration index(H_i), blank areas are areas where toponyms are distributed discretely Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.