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# Characteristics and formation mechanism of Land use conflicts in northern Anhui: A Case study of Funan county

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ABSTRACT

The rapid development of global urbanization and industrialization not only promotes a significant improvement in the level of socio-economic development, but also exacerbates the complexity and vulnerability of regional land resource utilization, resulting in frequent land use conflicts and seriously constraining the sustainable development of regional socio-economic and ecological environment. Taking Funan County as an example, based on interpretation data of Landsat TM/ETM remote sensing image data from 1980 to 2020, this paper analyses the temporal and spatial evolution characteristics of land use conflict in Funan County from 1980 to 2020 using the ArcGIS spatial analysis method, land use conflict measurement model, geographically weighted regression and geographical detector and then deeply analyses the main factors affecting land use conflict in Funan County and its driving mechanisms. In descending order, land use types undergoing the most change include cultivated land, urban and rural construction land, grassland, forestland and water area. The results of land use change are mainly the occupation of cultivated land by construction land, water area and forestland. Overall land use conflict in Funan County is serious with approximately 80 % of land use in the county in conflict, the severe land use conflict is mostly concentrated in urban and township built-up areas, and there is an increase trend year by year. Land use conflict is the result of multiple factors. Policy, economic development, and the social population and natural environment are the key driving factors behind land use conflict, which have a significant impact on the direction, location, scale and rate of land use transfer.Accurately identifying regional land use changes and conflicts and exploring the driving mechanism behind land use conflicts are of great significance for achieving the sustainable development of regional social economies and ecological environments.

## 1. Introduction

In the context of the "Anthropocene", global human land relations are becoming increasingly tense, and the competition between different entities for limited land resources has made land use conflicts a prominent issue that is widespread worldwide.Land use/cover change is a complex process in which humans continuously allocate regional natural, social, and economic factors of regional land use to meet the needs of social and economic development [1]. As a prominent spatial manifestation of the contradiction between human

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and land relations [2]; [3], land use conflicts have a close interactive feedback effect on various aspects such as biodiversity and social stability, and are an important lever for promoting the achievement of international sustainable development goals (SDGs).Amid the rapid advancement of new urbanization and industrialization, China's social and economic development has entered a period of deep transformation. The continuous growth of land demand in urban and rural areas in China has intensified the process of land use change, which has led to a highly dynamic transformation of regional land use in depth and breadth [4], thus triggering a series of resource and environmental problems, such as significant land use conflicts, ecosystem decline, and landscape fragmentation, which seriously restrict the sustainable development of future land space [5,6]. As a key research topic of geography and its related disciplines, the study of land use conflicts is of great significance for coordinating regional man-land relationship, protecting regional ecological environment, optimizing the allocation of land spatial resources, and promoting sustainable social and economic development [7].

At present, land use conflict has become a major problem affecting the sustainable development of populations, resources and environments [8]. By constructing different research methods, such as the land use dynamic degree model, land use comprehensive index model, land use conflict intensity model [9] and landscape index model, domestic and foreign scholars have carried out much research on the spatial and temporal evolution characteristics of land use change and land use conflict [10]; [11], influencing factors and driving forces [12], land use layout optimization [13], land use change prediction [14,15] and scenario simulation [16], ecosystem service value change [17,18], ecological environment effects [19] and other aspects. Based on remote sensing, geographic information systems and other advanced technologies, the spatial and temporal change processes of regional land use are displayed in the form of map units [20,21]. The research scope covers different scales of economically developed and ecologically fragile areas, such as urban agglomerations [22], economic belts [23], watersheds [5], provinces [24], and the Loess Plateau [25]. Land use conflicts stem from the contradiction between supply and demand of different types of land use [26], and are the disharmonious state of land use structures in meeting diverse human needs.With the rapid development of social economy and the intensification of human activities, a large amount of high-quality land resources such as ecological land and agricultural land are gradually being encroached upon by construction land. The frequent development and utilization of land resources by humans have led to increasingly significant regional land use conflicts [27],which have become a key issues of global concern [28]; [29]. Scholars believe that land use change has an significant impact on the patterns of ecosystems, changing the ability of ecosystems to provide products and services and resulting in significant land use ecological conflict. Some scholars have pointed out that land use conflict is the inconsistency and disharmony of relevant actors in land use modes and quantities occurring in the process of land resource utilization [30]. It is a social phenomenon of conflict of interest resulting from differences in land property rights [31]. Although different scholars highlight different emphases in defining land use conflict, all definitions refer to the competition of relevant actors for limited land resources and state that the essence of land use conflict is a conflict of rights and interests represented by land use conflict. In addition, due to significant differences in land use patterns and development intensity, regional land use conflicts tend to show a layer-by-layer decreasing distribution from urban to rural areas [32]. The urbanization process, farmland protection system, and natural environmental factors such as terrain elevation are the main driving forces driving regional land use changes and resulting in land use conflicts [33]; [34]. Based on different perspectives such as planning, policies, systems, and land markets [35,36], scholars have revealed the driving mechanisms of land use conflict changes. They believe that policy oriented land capitalization is the fundamental driving force behind land use change, while the dual fragmentation of urban and rural land markets severely restricts the structure and efficiency of land use, resulting in waste of land resources, land fragmentation and the aggravation of spatial conflict [37].

The existing research mostly analyses land use change and its influencing factors in economically developed areas at the macro scale, while less research involves the micro scale, especially in terms of land use in underdeveloped areas. In addition, current research pays more attention to the evolution of land use spatial and temporal patterns, while the analysis of land use conflict is relatively scarce. When analysing the influencing factors of regional land use conflict, existing research focuses on single natural factors such as elevation and topography, mainly through qualitative analysis, while providing insufficient quantitative support and a lack of in-depth analysis of the mechanisms of various influencing factors.

Funan County, located along the Huaihe River Basin, is a typical populous county in China. Terrain in the area is flat. the Huaihe River flood storage area accounts for a large proportion, the ecological environment sensitivity is high; contradictions between the population, resources and the environment are significant. therefore, the land use conflict is remarkable, seriously restricts the regional social and economic development. Based on this, this paper takes Funan County as an example, uses remote sensing satellite image data and GIS spatial analysis technology to monitor land use changes in Funan County over the past 40 years, analyses the spatial and temporal patterns and evolution characteristics of land use change and land use conflict in Funan County, deeply analyses the main factors and driving mechanisms affecting land use conflict in Funan County, and provides guidance on regional land use structure optimization and land space planning.

## 2. Research area and data sources

### 2.1. Research area

Funan County belongs to the city of Fuyang in Anhui Province. It is located in the northwestern area of Anhui Province on the northern bank of the upper and middle reaches of the Huaihe River between 115°16′30″ - 115°57′18″E and 32°24′19″ - 32°54′40″N; county terrain diversity can be divided into hillocks, slopes, and bay three categories, showing a 'Most flat, small uneven' geomorphic features (Fig. 1). By the end of 2020, Funan County included 28 townships and 1 provincial economic development zone; the annual gross domestic product (GDP) reached 28.95 billion, and a registered population reached 1.741 million while permanent population amounted to 1.1836 million.

### 2.2. Data sources

Five periods of land use remote sensing data for Funan County from 1980 to 2020, night light data and GDP spatial distribution grid data for 2020 are derived from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences (http://www.resdc.cn). The land use data are based on Landsat TM/ETM remote sensing images of each period as the main data source and are generated by manual visual interpretation with an accuracy of 30 m. According to land resources and their attributes, land use types are divided into six categories: cultivated land, forestland, grassland, water area, urban and rural construction land and unused land. Socioeconomic data such as industrial output value above scale, fixed asset investment and the per capita disposable income of rural residents are mainly derived from the 2020 'Funan County Statistical Yearbook'; elevation, slope, vegetation coverage intensity and ecological service value data are derived from the geospatial data cloud official website (http://www.gscloud.cn/); county flood storage and detention area ranges are determined according to the 'Funan County Master Plan' (2015–2030). The POI data of enterprise factory distribution are based on the API interface of the Gaode map obtained from the corresponding URL and written in Python language for crawling.

To avoid the fragmentation of spatial units in the study area, according to the calculation requirements of Fragstats 4.2 software and the current conditions of the study area, a 1 km × 1 km grid was constructed as an evaluation unit using the fishing net tool in ArcGIS 10.8. Funan County was divided into 1995 spatial evaluation units. The area of each complete unit is 1 $km^2$, and spatial patches not filled with cells at the edges of the administrative region are calculated according to the area of the complete unit.

## 3. Research Framework and methods

### 3.1. Theoretical framework

The man-land relationship refers to the impact of human activities on the geographical environment and the reaction of the changed geographical environment to human activities, that is, interactions and feedback between man and land [38]. Its core objective is to coordinate the contradiction between regional social and economic development and the natural environment and to realize the coordinated development of man and nature [39]. In the man-land relationship system, 'man' refers to the social and economic activities of human beings. 'Land' is the sum of the geographical environment, including the natural environment and social environment, and it is the nonmaterial basis and space carrier affecting the survival and development of human beings [40]. Land use is an important tool of human activity acting on the geographical environment, and its essence is the interaction of man-land relationships in a certain area [41]. The natural environment provides the background conditions for land use, and land use will also have positive or negative effects on the natural environment. Social and economic development plays an important guiding and driving role in land use, and land use also promotes or inhibits social and economic development (Fig. 2).

The rapid development of the regional social economy has a strong demand for land resources [42], which constantly changes the modes, breadth and depth of interactions between human and land systems, resulting in a mismatch between regional population distribution and construction land layout, an imbalance between land development intensity and resource and environment carrying

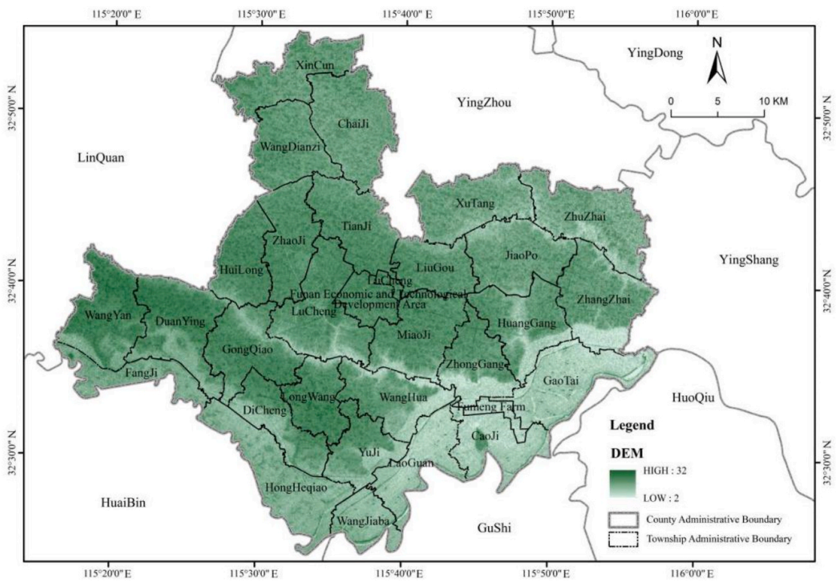


**Fig. 1.** Location of the study area.

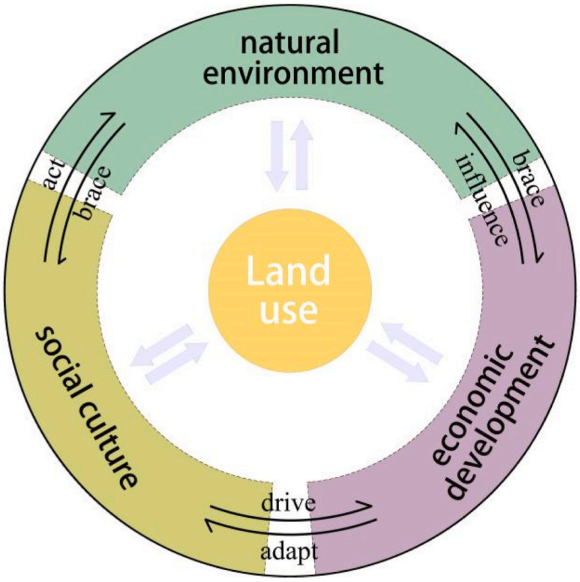


**Fig. 2.** Schematic diagram of interaction between land use and geographical environment.

capacity, and a serious gap between production modes and ecological civilization construction requirements, leading to land use and regional development problems such as regional land use structure imbalances, ecological environment conflict and prominent social subject contradictions. Therefore, based on the theory of man-land relationships, it is of great strategic significance to analyse the spatial and temporal characteristics of regional land use conflict and its mechanisms of action for the scientific and effective formulation of regional land space control strategies and the realization of the sustainable development of the social economy and ecological environment in Funan County [43].

### 3.2. Methods

By constructing a measurement model of land use dynamics degree and conflict and using statistical analysis and the ArcGIS spatial analysis method, the spatial and temporal evolution characteristics of land use conflict in Funan County are analysed, as well as the basic rules and main trends of land use conflict. Then, using the GWR model and a geographic detector, the main influencing factors of land use conflict and its mechanisms are analysed.

#### 3.2.1. Measurement model of Land use dynamic degree

The dynamic degree of land use is used to reflect the degree of change in regional land use types. The calculation formula is as follows.

$$\mathrm{M} = \frac{N_b - N_a}{N_a} \times \frac{1}{R} \times 100\%$$

In the formula, $M$ is the change rate of a single type of land use; $N_a$ is the number of land types in the initial year; $N_b$ is the number of land types in the last year; and $R$ is the study period.

$$\mathrm{M}_l = \left( \frac{\sum_{i=1}^{n} |N_{bi} - N_{ai}|}{\sum_{i=1}^{n} N_{ai}} \right) \times \frac{1}{R} \times 100\%$$

In the formula, $M_l$ is the comprehensive land use change rate; $N_{ai}$ is the number of land types in the starting year; the number of land types at the end of the period is denoted by $N_{bi;}$ and $R$ is the study period.

#### 3.2.2. Land use conflict measurement model

Land use systems have characteristics of complexity, vulnerability and stability. Referring to the existing research and the current state of resources and the environment in Funan County, this paper adopts the equal weight method to construct a measurement model of land use conflict from the three aspects of land use interference (G), vulnerability (C) and stability (W) to measure land use conflict strength (LUCS) and realize the spatial visualization of land use conflict in Funan County. The calculation formula is as follows:

$$L = \frac{1}{3}G + \frac{1}{3}C - \frac{1}{3}W$$

To eliminate the dimensional difference, the calculation results of land use disturbance, vulnerability and stability are normalized. Land use conflict is divided into five grades: stable control [0–0.12), basic control [0.12–0.24), mild conflict [0.24–0.36), moderate conflict [0.36–0.48) and severe conflict [0.48–0.60].

(1) Level of interference land use

The level of land use interference (G) is used to measure the degree of mutual interference between different types of land use in the region. The area-weighted fractal dimension (AWMPFD) is usually used to measure the degree of mutual interference between different types of land use in a region. The higher the area-weighted fractal dimension of the evaluation cell is, the more likely the landscape patch in the cell is to be disturbed by the neighbourhood patch and the more complex the land use structure is. The calculation formula is as follows:

$$G_{\text{AWMPFD}} = \sum_{x=1}^{a}\sum_{y=1}^{b}\left\{\frac{2\ln(0.25Z_{xy})}{\ln M_{xy}} \times \frac{M_{xy}}{T}\right\}$$

In the formula, $Z_{xy}$ represents the perimeter of the $y$ patch of the $x$ land use type, $M_{xy}$ represents the area of the $y$ patch of the $x$ land use type, and $T$ is the total area of the land system.

(2) Land use vulnerability

Land use vulnerability (C) is the sensitivity of the current land use pattern to external pressure and is used to reflect the ability of land use types in the evaluation cell to resist external interference [44]. As different land use types have different responses to spatial conflicts, this paper refers to the existing research [45] and assigns vulnerability levels of forestland, grassland, cultivated land, water area, unused land and urban and rural construction land as 1, 2, 3, 4, 5, 6, respectively. The calculation formula is as follows:

$$C = \sum_{x=1}^{b} E_x \times \frac{m_x}{T}, (b = 6)$$

In the formula, $x$ is the total number of land use types; $E_x$ and $m_x$ represent the vulnerability and unit area of $x$ land use types, respectively; and $T$ is the total area of the land system.

(3) Land use stability

Landscape fragmentation (PD) is used to reflect the stability of land resources. The greater the landscape fragmentation level is, the worse the stability of the land use system is and the stronger spatial conflict is. Therefore, this paper uses the reciprocal of landscape fragmentation to represent land use stability. The calculation formula is as follows:

$$PD = \frac{m_x}{T}, W = 1/PD$$

In the formula, $m_x$ is the number of patches of land use type $x$, and $T$ is the total area of the land system.

### 3.2.3. Geographically weighted regression model

Geographically weighted regression (GWR) is a geostatistical method for which Fotheringham et al. added the geographical location of the data to the regression parameters based on the traditional ordinary least squares (OLS) model, taking into account the spatial weight of adjacent points and allowing local parameter estimation [46]. GWR is used to explore the spatial heterogeneity of the influencing factors of land use conflict. The calculation formula is as follows:

$$Z_n = \alpha_0(\rho_n, \delta_n) + \sum_k \alpha_k(\rho_n, \delta_n)M_{nk} + \theta_n$$

In the formula, $Z_n$ is the spatial conflict index of the $n$th cell; $(\rho_n, \delta_n)$ is the spatial location of the $n$th cell; $\alpha_0$ is the fixed effect intercept at $(\rho_n, \delta_n)$; $M_{nk}$ is the value of the influencing factor k of the nth cell; $\alpha_k$ is the regression coefficient of $M_{nk}$; and $\theta_n$ is the random error.

### 3.2.4. Geographical detector

A geographical detector is used to detect consistency in the spatial distribution pattern between influencing factors and explained variables to reveal the driving effects of different influencing factors on land use conflict intensity [47]. In this paper, we use factor detection and interaction detection via the geographical detector to explore the degree of interpretation of an independent variable factor X to the dependent variable Y (land use conflict) by calculating the q value and further evaluate whether there is an interaction between the independent variables. The explanatory power of a factor X to the independent variable Y is calculated as follows [48]:

$$q = 1 - \frac{\sum_{h=1}^{L} N_{h\delta_h}{}^2}{N_{\delta}{}^2}$$

In the formula, $q$ is the degree of interpretation of the independent variable factor $X$ to the spatial differentiation of the dependent variable $Y$. The greater the value of $0 \le q \le 1$ is, the greater the impact of the factor on land use conflict in Funan County is; $L$ is the number of categories or layers of each independent variable factor, $N$ and $N_h$ are the number of subregion unit grids selected for the global and $h$th categories or layers, respectively; and $\delta^2$ and $\delta_H^2$ are the variance in land use conflict in the whole region and subregion, respectively.

## 4. Results

### 4.1. Analysis of Land use change characteristics

Combined with the remote sensing image interpretation map, a land use change map of Funan County from 1980 to 2020 was obtained by ArcGIS 10.8 software visual analysis (Fig. 3). As shown in Fig. 3, over nearly 40 years, both urban and rural residential land in Funan County has expanded outward to varying degrees. The overall change in land use characteristics of arable land and grassland area in Funan County decreased, and forestland, water and urban and rural construction land area increased. The area of cultivated land and grassland decreased from 150567.27 hm$^2$ to 0.45 hm$^2$ in 1980–145400.49 hm$^2$ and 0.18 hm$^2$ in 2020, respectively. The area of forestland, water area and urban and rural construction land increased from 58.38 hm$^2$, 831.24 hm$^2$ and 28617.48 hm$^2$ in 1980 to 106.74 hm$^2$, 2096.55 hm$^2$ and 32436.27 hm$^2$ in 2020, respectively. The proportion of cultivated land, forestland, grassland, water area and urban and rural construction land in the total land use area changed from 83.61 %, 0.03 %, 0.0002 %, 0.46 % and 15.89 % in 1980 to 80.76 %, 0.06 %, 0.00009 %, 1.16 % and 18.02 % in 2020, and the land use structure did not change significantly.

According to the statistics of land use change and dynamic degree (Table 2), the area of land use type dynamic change in Funan County from 1980 to 2020 was 10299.519 hm$^2$, accounting for 5.72 % of the total area of the county. The analysis of land use change over 5 periods shows that the dynamic degree of water area was the highest, increasing by 1265.31 hm$^2$ in 40 years, mainly through cultivated land transfer and partly due to construction land and grassland transfer. The dynamic degree of forestland and grassland fluctuated. From 2010 to 2020, this area decreased by 29 hm$^2$ and 0.36 hm$^2$, respectively, mainly being converted to water area. The dynamic degree of urban and rural construction land increased steadily by 3818.79 hm$^2$ over 40 years. The dynamic degree of cultivated land Growth to Negative Direction, with an average annual decrease of 129.17 hm$^2$ from 1980 to 2020, with this land use mainly being converted to urban and rural construction land and to forestland and water area to a lesser degree.

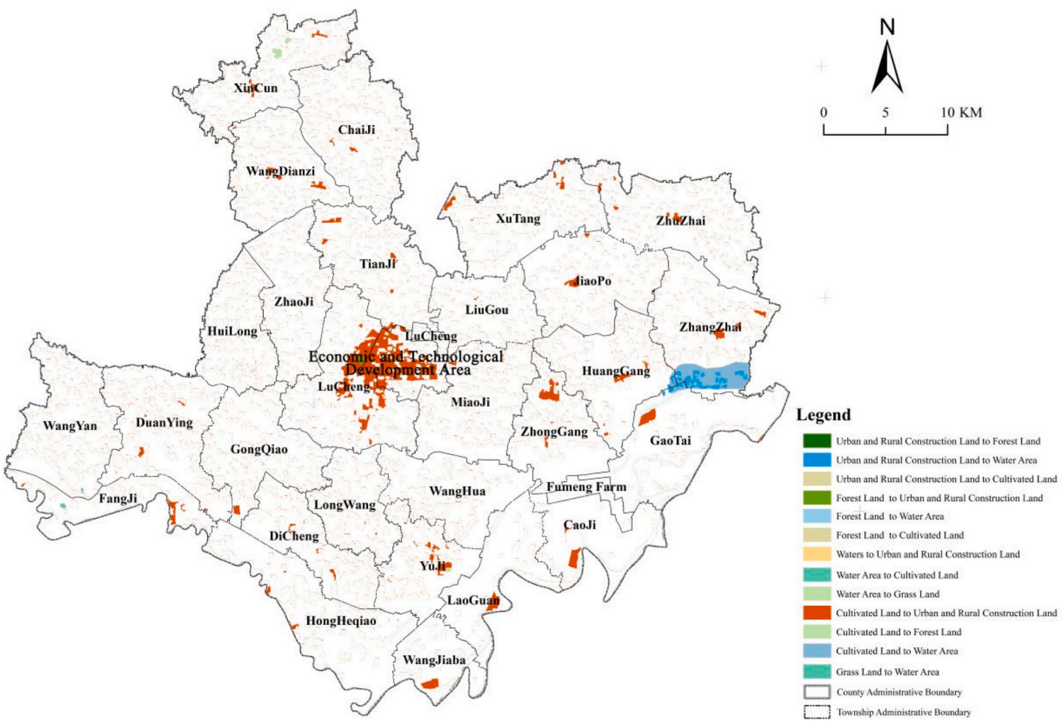


**Fig. 3.** Land use change in Funan County from 1980 to 2020.

**Table 1**
Judgment basis of interaction.

| Judgment Basis | Interaction |
|---|---|
| $q(X_1 \cap X_2) < \min[(q(X_1), q(X_2)]$ | Nonlinear weakening |
| $\min[q(X_1), q(X_2)] < q(X_1 \cap X_2) < \max[q(X_1), q(X_2)]$ | Single factor nonlinear weakening |
| $q(X_1 \cap X_2) > \max[q(X_1), q(X_2)]$ | Two-factor enhancement |
| $q(X_1 \cap X_2) = q(X_1) + q(X_2)$ | Independence |
| $q(X_1 \cap X_2) > q(X_1) + q(X_2)$ | Non-linear enhancement |

**Table 2**
Land use change and dynamic degree in Funan County from 1980 to 2020.

| Land use type | 1980–1990 | | 1990–2000 | | 2000–2010 | | 2010–2020 | | 1980–2020 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Area/hm$^2$ | M/% | Area/hm$^2$ | M/% | Area/hm$^2$ | M/% | Area/hm$^2$ | M/% | Area/hm$^2$ | M/% |
| Cultivated land | −447.12 | −0.01 | −2044.41 | −0.07 | −1717.68 | −0.11 | −3001.98 | −0.20 | −5166.78 | −0.09 |
| Forest land | 44.73 | 3.83 | 62.29 | 4.24 | 32.63 | 3.16 | −29.00 | −2.14 | 48.36 | 2.07 |
| Grassland | 0.00 | 0.00 | 0.09 | 1.00 | 0.09 | 2.00 | −0.36 | −6.67 | −0.27 | −1.50 |
| Water area | 0.69 | 0.00 | 31.93 | 0.19 | 31.00 | 0.37 | 1233.62 | 14.30 | 1265.31 | 3.81 |
| Urban and rural construction land | 401.79 | 0.07 | 1949.39 | 0.34 | 1653.15 | 0.57 | 1763.85 | 0.58 | 3818.79 | 0.33 |
| Synthesis | 894.34 | 0.05 | 4088.11 | 0.23 | 3434.55 | 0.19 | 6028.81 | 0.33 | 10299.51 | 0.14 |

## 4.2. Spatial-temporal evolution analysis of land use conflict

### 4.2.1. Time-varying complexity of conflict types

According to the measurement model of land use conflict, the land use conflict index of Funan County for 1980 to 2020 was calculated, and land use conflict was divided into five types based on the equidistant method of ArcGIS 10.8 spatial analysis software. From the number and proportion of different types of land use conflict cells (Table 3), land use conflict inFunan County was serious, and the most intense land use conflict occurred from 2010 to 2020.

From 1980 to 2020, approximately 85 % of the land in Funan County showed varying degrees of conflict, and only 17 % of land use was stable and basically controllable. In 1980, the number of units with moderate land use conflict in Funan County was as high as 1313, accounting for 65.81 % of the total number of county units. Land use mild conflict and basically controllable conditions followed, accounting for 15.49 % and 13.78 %, respectively. In the past 40 years, the number and proportion of moderate conflict cells in land use in Funan County have shown a downwards trend from 65.81 % in 1980 to 62.91 % in 2020, but this has mainly changed to severe conflict in land use. In general, the number of units with mild and severe land use conflict in Funan County continued to increase from 1980 to 2020, especially the number of units with severe land use conflict, which increased nearly 2 fold, indicating that the degree of land use conflict in Funan County was still increasing with a trend of gradual transition from moderate to severe conflict.

### 4.2.2. Significant spatial differentiation of conflict types

By visualizing land use conflict in Funan County from 1980 to 2020 (Fig. 4) and comparing it to the spatial distribution map of land use change in the county, we found that the degree of land use conflict is closely related to the intensity of land use change. The more pronounced regional land use change is, the more severe spatial conflict and instability of land use become. As shown in Fig. 4, in the past 40 years, the land use of each township in the northern part of Funan County has been relatively stable, and the whole area has been in a stable and controllable state. The land use types of such townships are relatively singular, and landscape continuity is strong. Therefore, the land use conflict index is low, such as in the towns of Xincun and Chaiji and the township of Wangdianzi as well as some areas of the township of Longwang Township and the towns of Dicheng and Hongheqiao in the south. Mild conflict cells of land use are distributed around stably controllable and basically controllable cells, forming a buffer zone of moderate conflict and basically controllable cells of land use. Moderate conflict cells of land use are the most widely distributed and relatively stable, basically covering the western part of the county and the eastern townships. Severe conflict cells are mostly concentrated in the central urban area of the county and economic development zone and show a significant trend of expansion; at the same time, some cells are scattered in the central towns of each township. With rapid urbanization, economic construction activities in central urban areas and

**Table 3**
Number and proportion of land use conflict types in Funan County from 1980 to 2020.

| Year | Stable control | | Basic control | | Mild conflict | | Moderate conflict | | Sever conflict | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Units | Ratio | Units | Ratio | Units | Ratio | Units | Ratio | Units | Ratio |
| 1980 | 57 | 2.86 | 275 | 13.78 | 309 | 15.49 | 1313 | 65.81 | 41 | 2.06 |
| 1990 | 57 | 2.86 | 277 | 13.88 | 309 | 15.49 | 1296 | 64.96 | 56 | 2.81 |
| 2000 | 57 | 2.86 | 274 | 13.73 | 309 | 15.49 | 1296 | 64.96 | 59 | 2.96 |
| 2010 | 57 | 2.86 | 272 | 13.63 | 320 | 16.04 | 1289 | 64.61 | 57 | 2.86 |
| 2020 | 69 | 3.46 | 276 | 13.83 | 315 | 15.79 | 1255 | 62.91 | 80 | 4.01 |

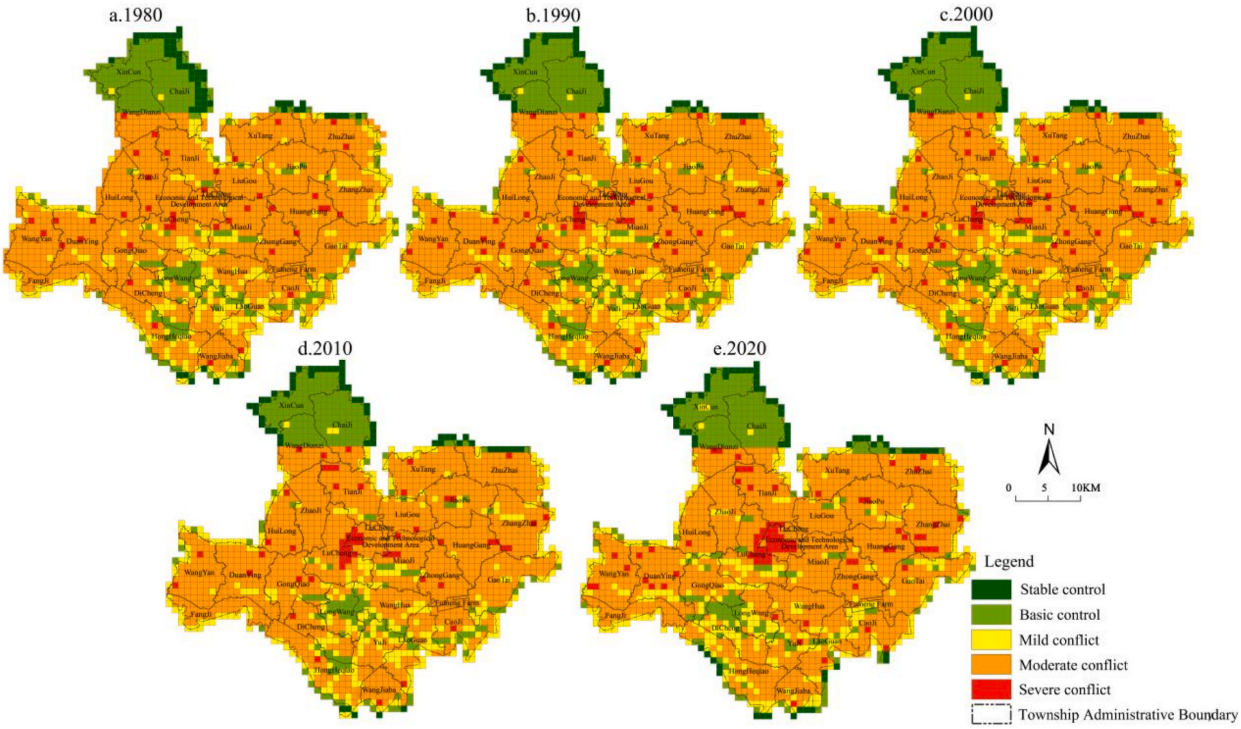


**Fig. 4.** Spatial distribution characteristics of land use conflict in Funan County from 1980 to 2020.

towns have become more frequent, and land use complexity is high. The agglomeration development and rapid expansion of construction land have aggravated landscape fragmentation, resulting in prominent spatial vulnerability and reduced stability of land use.

### *4.3. Analysis of influencing factors of Land use conflict*

#### *4.3.1. Influence factor variable screening*

The social economy, human activities and natural environmental factors are the main driving forces behind regional land use change.

In this paper, the Funan County land use conflict index is used as the explained variable following existing research [49]; [50]. From the aspects of the social economy, human activities and the natural environment, GDP ($X_1$), urbanization rate ($X_2$), fixed asset investment ($X_3$), enterprise density ($X_4$), industrial output value ($X_5$), per capita disposable income of rural residents ($X_6$), distance from main roads ($X_7$), distance from a central city ($X_8$), distance from a flood storage area ($X_9$), distance from a water system ($X_{10}$), proportion of construction land ($X_{11}$), land use intensity ($X_{12}$), population density ($X_{13}$), population activity intensity ($X_{14}$), road network density ($X_{15}$), elevation ($X_{16}$), slope ($X_{17}$), slope direction ($X_{18}$), ecological service value ($X_{19}$), and NVDI index ($X_{20}$) measures and 20 other factors were selected as independent variables of influencing factors. To match the spatial resolution of the impact factor

**Table 4**
OLS calculation results.

| Impact factor variables | Index interpretation | Regression coefficient | VIF | Direction |
|---|---|---|---|---|
| GDP ( $X_1$ ) | Regional GDP (ten thousand yuan) | 0.001 | 1.5291 | + |
| Urbanization rate ( $X_2$ ) | Unit urbanization rate (%) | 0.071 | 3.068 | + |
| Fixed asset investment ( $X_3$ ) | Fixed asset investment in each cell (ten thousand yuan) | 0.001 | 2.9361 | + |
| Industrial output value ( $X_5$ ) | Industrial output value above designated size within the unit (ten thousand yuan) | 0.001 | 3.6114 | – |
| Distance from the main road ( $X_7$ ) | Space distance between units and highways, national highways, provincial highways, first-class urban roads and county roads | 0.001 | 1.4769 | + |
| Distance from the central city ( $X_8$ ) | Spatial distance of units from county and town center | −0.001 | 1.3976 | – |
| Distance from the Mengwa flood storage area ( $X_9$ ) | Spatial distance of units from the Mengwa flood storage area | −0.001 | 1.3194 | – |
| Elevation ( $X_{16}$ ) | Unit elevation value | 0.005 | 4.7688 | + |
| NVDI index ( $X_{20}$ ) | Unit NVDI index | −0.043 | 1.7664 | – |

variable (X) with the explained variable (the land use conflict index), the above impact factor variables were resampled at a unit size of 1 km × 1 km.

To avoid the distortion of model estimation due to strong correlations between different indicators, this paper uses an OLS regression model to measure the impact of the above 20 factors on the explained variable (the land use conflict index) and its significance level. At the same time, the variance inflation factor (VIF) is used to diagnose the global and local collinearity of the above factors, and redundant variables with a variance inflation factor (VIF) of greater than 7.5 are excluded to improve the accuracy of the model and avoid the deviation of the regression results [51].Nine significant influencing factors, such as GDP ($X_1$), urbanization rate ($X_2$), fixed asset investment ($X_3$), industrial output value ($X_5$), distance from main roads ($X_7$), distance from central urban area ($X_8$), distance from flood storage area ($X_9$), elevation ($X_{16}$), and NVDI index ($X_{20}$), were selected to evaluate the influencing factors of the spatial and temporal differentiation of land use conflict (Table 4). Among them, the urbanization rate and NVDI index have the greatest influence on land use conflict in Funan County, which also confirms that social and economic factors and natural environmental factors are the main driving forces behind land use conflict.

### 4.3.2. The intensity and distribution of the main influencing factors

To further analyse the impacts of various influencing factors on land use conflicts in different areas, the geographically weighted regression (GWR) model was used to perform a spatial regression analysis of nine nonredundant significant influencing factors, including GDP ($X_1$), urbanization rate ($X_2$), fixed asset investment ($X_3$), industrial output value ($X_5$), distance from main roads ($X_7$), distance from a central city ($X_8$), distance from the Mengwa flood storage area ($X_9$), elevation ($X_{16}$), and NVDI index ($X_{20}$). The results show that the intensity of different influencing factors on different spaces shows spatial imbalance; that is, the effect of land use conflict

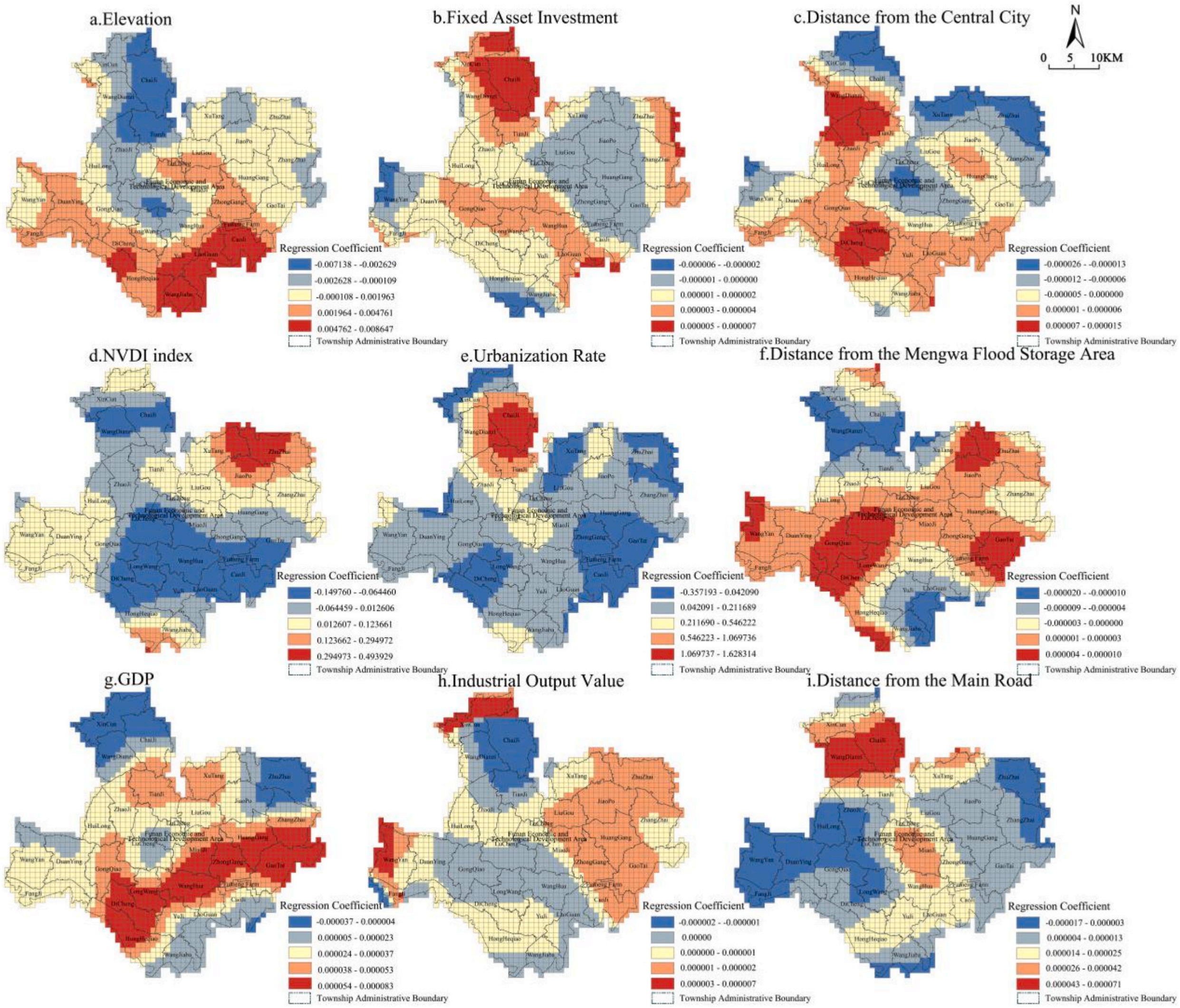


**Fig. 5.** Regression coefficient distribution of influencing factors of land use conflict in Funan County in 2020.

in Funan County exhibits strong spatial heterogeneity (Fig. 5).

Fixed asset investment, urbanization rate, elevation, GDP, and distance from main roads measures have a significant positive impact on land use conflict; industrial output value, distance from the Mengwa flood storage area, distance from a central city and NVDI index measures have a significant negative impact on land use conflict. Among these, the level of GDP development has a more significant impact in the towns of Dicheng, Wanghua, and Zhonggang and the townships of Longwang and Gaotai; the urbanization rate and fixed asset investment have the most significant impact on the town of Chaiji; main roads have a more significant impact on the town of Chaiji and the township of Wangdianzi; the distance from a central urban area has a more significant impact on the intersections of the towns of Dicheng, Zhaoji and Tianji and the townships of Longwang and Wangdianzi; the distance from a flood storage area has a significant impact on the townships of Gaotai, Gongqiao, and Longwang and the towns of Dicheng and Lucheng; elevation has a significant impact on the towns of Wangjiaba and Caoji and the township of Laoguan in the southwestern area of the county; and the NVDI index has a significant impact on the township of Xutang and the towns of Zhuzhai and Jiaopo in the northern part of the county.

#### *4.3.3. Interaction detection of influencing factors*

By using geographical detectors and based on the judgment criteria for the interaction of influencing factors in Table 1, further analyse the interaction of influencing factors in the spatial differentiation of land use conflicts in Funan County. The results show that the influence of the above influencing factors on land use conflict in Funan County was not simply additive but showed a two-factor enhancement or nonlinear enhancement relationship (Table 5). Although the effects of different factors on land use conflict vary, they promote each other in the process of land use change. Among them, the interaction of urbanization rates, fixed asset investment and distance from the Mengwa flood storage area has the strongest influence on land use conflict in Funan County; that is, the spatial differentiation of land use conflict is not caused by a single influencing factor but is instead the result of different influencing factors.

### *4.4. Analysis of the formation mechanisms of Land use conflict*

The driving and restraining mechanisms of land use conflict are complex [52]. In addition to being driven by the above natural, economic and social factors, macrolevel policy systems and relevant stakeholders are also important driving forces affecting the degree of land use conflict (Fig. 6).

#### *4.4.1. The important guiding role of the policy system*

National and regional development policy and planning are macrolevel strategic activities that shape the future development of the region and play a role in promoting and regulating the direction of regional land use. Regional economic and industrial development policies have promoted processes of regional economic modernization and urbanization, directly affecting the growth of the regional population and the direction of population migration [53], rendering policy-oriented regional land function diversity and utilization intensity more significant and causing the risk of regional land use conflict to increase. According to the measurement results of land use conflict in Funan County (Fig. 4), land use conflict in Funan County is more intense in central urban and township areas, showing characteristics of severe conflict. Since the establishment of the Funan County Economic and Technological Development Zone in 2006, population, industry and other resource elements have shifted to the economic development zone on a large scale. The initiation of a large number of construction projects has led the construction land of the economic development zone to continuously encroach on surrounding cultivated land, forestland and other land such that the land use conflict area increased significantly between 2000 and 2020. In terms of institutional arrangements, due to a lack of regulation early on, a large amount of ecological and agricultural space

**Table 5**
Interaction detection results of land use conflict influencing factors.

| $X_i \cap X_j$ | $q(X_i)$ | $q(X_j)$ | $q(X_i \cap X_j)$ | Type | $X_i \cap X_j$ | $q(X_i)$ | $q(X_j)$ | $q(X_i \cap X_j)$ | Type |
|---|---|---|---|---|---|---|---|---|---|
| $X_1 \cap X_2$ | 0.112 | 0.170 | 0.211 | BE | $X_3 \cap X_9$ | 0.197 | 0.194 | 0.363 | BE |
| $X_1 \cap X_3$ | 0.112 | 0.197 | 0.284 | BE | $X_3 \cap X1_3$ | 0.197 | 0.122 | 0.295 | BE |
| $X_1 \cap X_5$ | 0.112 | 0.052 | 0.147 | BE | $X_3 \cap X1_6$ | 0.197 | 0.119 | 0.284 | BE |
| $X_1 \cap X_7$ | 0.112 | 0.007 | 0.138 | NE | $X_5 \cap X_7$ | 0.052 | 0.007 | 0.092 | NE |
| $X_1 \cap X_8$ | 0.112 | 0.049 | 0.146 | BE | $X_5 \cap X_8$ | 0.052 | 0.049 | 0.108 | NE |
| $X_1 \cap X_9$ | 0.112 | 0.194 | 0.296 | BE | $X_5 \cap X_9$ | 0.052 | 0.194 | 0.249 | NE |
| $X_1 \cap X_{13}$ | 0.112 | 0.122 | 0.156 | BE | $X_5 \cap X_{13}$ | 0.052 | 0.122 | 0.188 | NE |
| $X_1 \cap X_{16}$ | 0.112 | 0.119 | 0.184 | BE | $X_5 \cap X_{16}$ | 0.052 | 0.119 | 0.164 | BE |
| $X_2 \cap X_3$ | 0.170 | 0.197 | 0.405 | NE | $X_7 \cap X_8$ | 0.007 | 0.049 | 0.103 | NE |
| $X_2 \cap X_5$ | 0.170 | 0.052 | 0.268 | NE | $X_7 \cap X_9$ | 0.007 | 0.194 | 0.238 | NE |
| $X_2 \cap X_7$ | 0.170 | 0.007 | 0.204 | NE | $X_7 \cap X_{13}$ | 0.007 | 0.122 | 0.157 | NE |
| $X_2 \cap X_8$ | 0.170 | 0.049 | 0.214 | BE | $X_7 \cap X_{16}$ | 0.007 | 0.119 | 0.156 | NE |
| $X_2 \cap X_9$ | 0.170 | 0.194 | 0.452 | NE | $X_8 \cap X_9$ | 0.049 | 0.194 | 0.254 | NE |
| $X_2 \cap X_{13}$ | 0.170 | 0.122 | 0.202 | BE | $X_8 \cap X_{13}$ | 0.049 | 0.122 | 0.165 | BE |
| $X_2 \cap X_{16}$ | 0.170 | 0.119 | 0.239 | BE | $X_8 \cap X_{16}$ | 0.049 | 0.119 | 0.163 | BE |
| $X_3 \cap X_5$ | 0.197 | 0.052 | 0.290 | NE | $X_9 \cap X_{13}$ | 0.194 | 0.122 | 0.342 | NE |
| $X_3 \cap X_7$ | 0.197 | 0.007 | 0.238 | NE | $X_9 \cap X_{16}$ | 0.194 | 0.119 | 0.322 | NE |
| $X_3 \cap X_8$ | 0.197 | 0.049 | 0.243 | BE | $X_{13} \cap X_{16}$ | 0.119 | 0.119 | 0.187 | BE |

Note: NE (Nonlinear Enhancement) denotes nonlinear enhancement, BE (Bi-factor Enhancement) denotes two-factor enhancement.

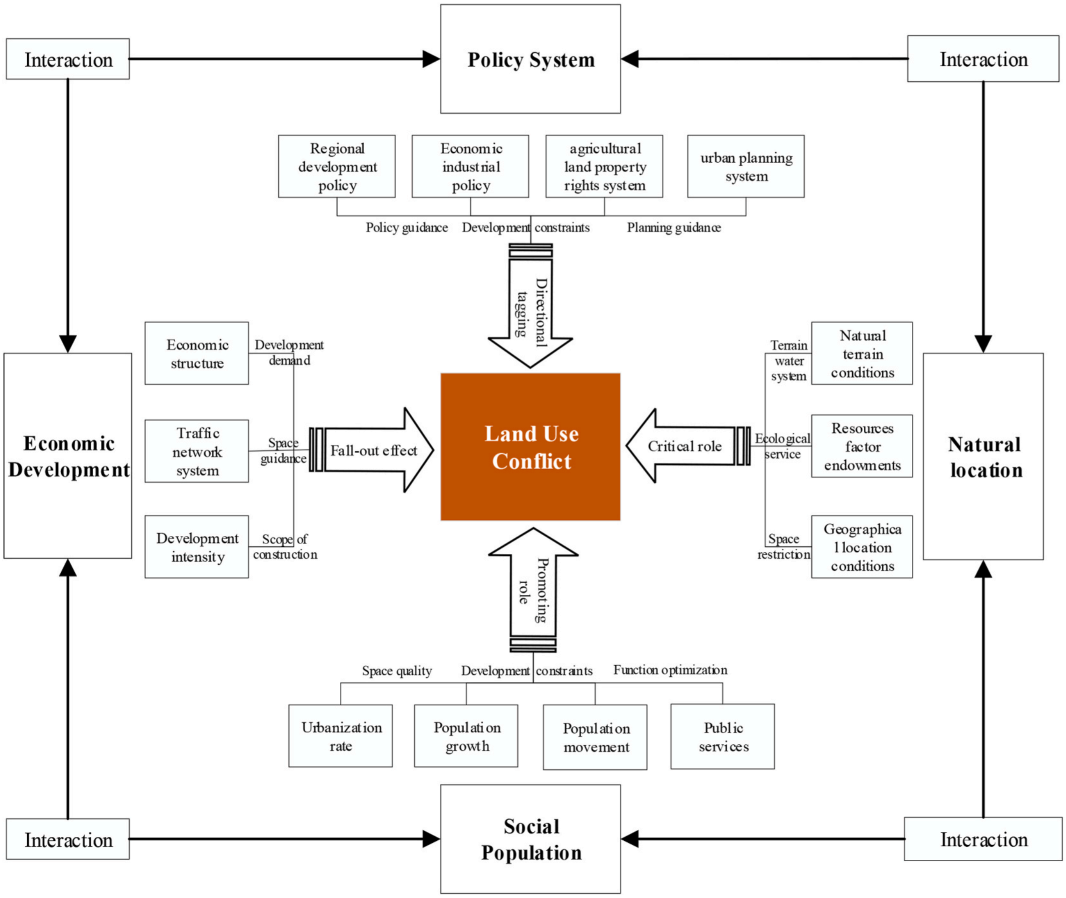


**Fig. 6.** Funan County land use conflict driving mechanism diagram.

was occupied amid the draw of the advantageous location and low development cost of the urban−rural ecotone. The asymmetry of state-owned land and collective land also exacerbated the fragmentation of land use in the urban−rural ecotone, prompting land use conflicts around counties and towns to intensify year by year. In addition, there are serious defects in China's existing rural land laws and regulations and property rights system, resulting in unclear property rights for agricultural land, vague definitions of ownership and use rights, and a lack of long-term and effective land conflict prevention and resolution mechanisms, creating opportunities for local governments to arbitrarily requisition land and village cadres to adjust land at will. At the same time, the limited legal awareness of farmers results in frequent violations of agricultural land contracting and circulation, which greatly increases the likelihood of land use conflicts [54].

#### *4.4.2. Direct inducing effect of economic development*

The results of the intensity measurement of the influencing factors of land use conflict in Funan County show that factors such as fixed asset investment, urbanization rates, GDP development and distance from a main roads such as highways and national highways have a significant impact on land use conflict; that is, economic development is the direct driving factor behind the evolution of land use structures and land use conflict. The results show that the spatial pattern of land use conflict types in Funan County is basically consistent with the pattern of urbanization levels. Units of severe land use conflict are mainly distributed in the economic development zone, the town of Lucheng and various townships and towns with high urbanization levels. The intensity of land use conflict in marginal towns with low urbanization levels is relatively low. As the direct driving force behind regional economic development, the spatial-temporal difference in the fixed asset investment scale is an important cause the spatial-temporal differentiation of land use conflicts. The distance from main roads, such as high-speed roads and national highways, is significantly positively correlated with land use conflicts. The results also show that road traffic construction has a certain inducing effect on land use conflicts, determines the form and development of urban spatial expansion, and threatens the regional ecological environment. With the rapid development of the regional economy, a large number of agricultural populations have gradually flowed into cities and towns, making it difficult for current urban construction land to meet increasing population demand. At the same time, the rapid growth of urban income has increased investment in construction land and stimulated the continuous development of the housing industry, which has aggravated the expansion of urban space and the process of agricultural nonagriculturalization. As a result, urban construction land continues to encroach on cultivated land and reshape regional land use patterns, inevitably leading to land use conflicts [55].

#### 4.4.3. The strong Impetus of the social population

The sustained growth of the population and its needs has a significant impact on land use processes and is a major driver of conflict occurrence and development [56]. The expansion of the population and high mobility objectively increase the development demands of urban and rural construction space. At the same time, there are widespread phenomena in rural areas of China, such as "housing vacancy", "one household includes more houses" and "new houses are built without demolishing old ones". Some villagers occupy as much land as possible and build more houses to get more compensation for demolition, which encourages the urban and rural construction space to continuously erode surrounding cultivated land, grassland and other land use areas, resulting in ecological and cultivated land landscape fragmentation. In addition, the inconsistency and discordance of land use patterns and quantity among stakeholders of land resource utilization are another manifestation of land use conflict. Local governments, enterprises, urban residents, village collectives and villagers are the main actors and stakeholders of land use change. Due to the multi-suitability of land resources and the limited supply of land, there is competition between land use actors and stakeholders, which is the root cause of land use conflict. The multi-suitability of land resources makes land available for different purposes and meets the needs of different stakeholders. The limited nature of land resources has led to competition among stakeholders for land resources, which has led to prominent land use conflicts.

#### 4.4.4. The key influence of the natural environment

The analysis and measurement results of influencing factors of land use conflict show that natural environmental factors, such as distance from the Mengwa flood storage area, elevation and the NVDI index, as regional background conditions have a strong correlation with the formation and development of land use conflict. The natural environment is an important limiting factor affecting land use structure. Affected by natural water systems and floods, the townships of Gaotai and Laoguan and towns of Wangjiaba and Caoji in the southern area of the county act as flood storage and detention areas when floods occur. Most of the land is difficult to be used as construction land to meet the living needs of residents. To prevent flood disasters, township construction land located in the flood storage and detention area is mostly located in the high-altitude 'Zhuangtai' area, resulting in high population density, limited construction land space and a high degree of pressure. The limited land resources and their economic benefits cause people to sacrifice the environment and engage in the one-sided pursuit of construction land, thus exacerbating the intensity of land use conflict.

## 5. Recommendations

As land is a limited and unevenly distributed key resource, the unlimited growth and inefficient use of land are the root causes of land use conflict [9]. For a long time, under the influence of China's urban–rural dual system mechanism and a tendency for heavy industry to suppress agriculture, the spatial and social contradictions arising from the use of land resources have been significant; with the flow of social, economic and resource factors across administrative boundaries and the enhancement of governance capacity in cross-regional development, land use conflict needs to be given more attention. Taking Funan County as an example, this study reveals spatial interactions between land use conflict and regional social and economic development and natural environmental factors by analysing the spatial and temporal evolution characteristics of land use conflict patterns under the influence of man-land relationship systems. It is of great significance to grasp the direction of land resource allocation and address problems of unbalanced and mismatched regional resource factors. Such work can provide a theoretical basis for small and medium-sized cities to formulate land space control strategies and realize the sustainable development of the social economy and ecological environment. In addition, land use conflict is the comprehensive result of disharmony between man and land. As an important manifestation of land use social conflict, conflict between land use-related actors is a major cause of land use conflict. Analysing the causes of conflicts among relevant actors in the process of land use development and the interaction mechanisms of various actors is helpful for improving the social, economic and ecological benefits of land use. It will be an important research direction to realize the sustainable use of land resources and alleviate land use conflicts in the future.

However, there is still room for improvement and improvement in this study. On the one hand, due to the limited accuracy of available remote sensing data, the land use data of Funan County from 1980 to 2020 in this study mainly used Landsat TM/ETM remote sensing images with a precision of 30 m. In the future, high-precision algorithms should be combined for land use classification to obtain more accurate land use type information in the study area. On the other hand, due to the complexity of the manifestations, influencing factors, and formation mechanisms of land use conflicts, land use conflicts not only consider explicit conflicts such as interference, vulnerability, and stability of land use spatial conflicts, but also involve various implicit conflicts such as ecological conflicts and social conflicts. Therefore, the spatial conflict index calculated in this study may deviate from actual conditions, and a further deepening of such research is urgently needed.

## 6. Conclusion

Taking Funan County as an example, based on data on land use status in five periods from 1980 to 2020 and supported by ArcGIS spatial analysis technology, this paper analyses the spatial and temporal pattern and evolution characteristics of land use dynamic change and conflict in Funan County by measuring dynamic changes and conflict indexes of land use in the study area. Based on the OLS regression model, geographically weighted regression and geographical detector measures, the main influencing factors of land use conflict change, spatial differentiation characteristics and driving mechanisms of influencing factors are revealed. The main conclusions are as follows:

During the period from 1980 to 2020, there was no significant change in the land use structure of Funan County. The dynamic degree of land use types changed in order of arable land, urban and rural construction land, grassland, forestland and water area, which showed that the area of arable land and grassland decreased and the area of forestland, water area and urban and rural construction land increased, mainly due to the occupation of arable land by construction land, water area and forestland.

From 1980 to 2020, the overall degree of land use conflict in Funan County was relatively serious. About 85 % of the cells within the county showed different degrees of land use conflict, of which the proportion of moderate land use conflict was the largest, accounting for about 65 %, and there was a trend towards severe conflict. In terms of the spatial distribution characteristics of the county land use conflict index, stably controllable and basically controllable land use units are mainly located in the towns of Xincun, Chaiji, and Wangdianzi in the northern part of the county and in some township units in the southern area of the county. Moderate conflict units basically cover the west and east parts of the county, and severe conflict units are mainly concentrated in the central urban area and built-up areas of townships.

The impact of land use conflicts in Funan County exhibits a strong spatial heterogeneity, which is the result of multiple factors. Among the nine significant factors, fixed asset investment, urbanization rate, elevation, GDP, and main road distance measures have a significant positive impact on land use conflict; industrial output, distance from the Mengwa flood storage area, distance to a central city and NVDI index measures have significant negative effects on land use conflict. As the key driving forces behind land use conflict, the policy system, economic development, the social population and the natural environment have significant impacts on the direction, scale, intensity and speed of land use transfer.

This article systematically analyzes the characteristics of land use changes in Funan County over the past 40 years, explores the spatiotemporal evolution pattern of land use conflicts in Funan County from both temporal and spatial dimensions, reveals the key factors that cause regional land use conflicts, and deeply analyzes the key factors that cause regional land use conflicts. It elucidates the mechanism of policies, economic development, social population, and natural environment on land use conflicts.The research results are of great significance for improving the land spatial planning of small and medium-sized cities, improving the quality and stability of regional ecosystems, and achieving sustainable use of land resources. They can also provide decision-making support for government departments to formulate land spatial optimization strategies and reasonably delineate land spatial layout based on different types of land use conflicts.

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#### *7.1.1. Research support*

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#### *7.1.2. Relationships*

There are no additional relationships to disclose.

#### *7.1.3. Patents and Intellectual property*

There are no patents to disclose.

#### *7.1.4. Other activities*

There are no additional activities to disclose.

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## Data Availability statement

The land use remote sensing data analysed during the study were collected from the Resource and Environmental Science and Data Center of the Chinese Academy of Sciences. These datasets are sourced from the following public domain resources: http://www.resdc.cn.

## Additional information

No additional information is available for this paper.

## CRediT authorship contribution statement

**Xiaohua Chen:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Shiqiang Wu:** Writing – review editing ， Supervision ， Project administration ， Methodology ， Investigation , Data curation , Visualization , Software , Investigation, Formal analysis. **Jiang Wu:** Visualization, Software, Project administration, Investigation, Formal analysis, Data curation.

## Declaration of competing interest

The authors declare that we have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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