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Understanding government support for rural development in Hubei Province, China

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Quantifying the spatiotemporal characteristics of government support for rural development is crucial for accurately optimizing or formulating policies for rural development, but research identifying government support for rural development at the geospatial scale has not yet emerged. This paper used Hubei Province, China, as the study area and constructed indicators of government support for rural development based on the intensity of support, the spatial direction of support, and the spatial agglomeration of support based on the characteristics of legal rural construction land allocation. Panel data regression was used to quantify the direction of rural development that requires the allocation of rural construction land based on government support. The results showed that government support for rural development through legal rural construction land allocation has strong spatiotemporal characteristics: From 2009 to 2018, the intensity of support grew, the spatial direction of support was regular, and government support was increasingly manifested as local agglomeration. The orientations of government support through legal rural construction land allocation for rural development include farmers' production, farmers' livelihoods and social security. This research provides a reference for quantifying government support through legal rural construction land allocation for rural development and the direction of government support.

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Introduction

Construction land is the basic carrier of human activities, and both urban and rural development lead to the expansion of construction land. However, unlike the highly complex economic and social activities involved in urban development, rural development involves relatively simple economic and social activities. Additionally, most activities revolve around the productive or ecological functions of scattered arable land, garden land, forestland, etc. (Abreu et al. 2019; Li et al. 2019). These activities are accompanied by the occurrence of rural construction land allocation and lead to the complexity and fragmentation of the distribution of rural construction land expansion.

Although there are differences in the land institutions of different countries around the world, the subjects with the right to allocate land involve only the government and private individuals. Therefore, based on the geographical distribution of rural construction land expansion, the spatial differentiation of different subjects' support for rural development can be characterized. In China, the government has the absolute right to allocate rural construction land, and patches of rural construction land expansion, which are known as legal rural construction land expansion (LRCLE), are included in the land use change survey database, and other rural construction land expansion is illegal and not allowed. Therefore, the construction of relevant indicators based on the characteristics of patches of LRCLE can reflect the characteristics of government support for rural development, and an analysis of the drivers of LRCLE can reveal the direction of government support for rural development.

Numerous scholars have conducted a series of studies on rural development. With respect to the participation of different subjects in rural development, the government, social capital and villagers are the main participants in rural development (Pisani and Micheletti, 2020; Ibietan, 2010; Furmankiewicz and Macken-Walsh, 2016). The government plays a key role in promoting social capital and villagers in rural development, and in many cases, it plays a role in trust endorsement (Olmedo and O'Shaughnessy, 2022). At the same time, some studies have shown that small and medium-sized enterprises (SMEs) are also important participants in rural development. However, their participation cannot be separated from the support of friendly financing channels provided by the government (Manzoor et al. 2021; Lal, 2019). Some scholars have also studied the importance of strengthening government support in an agricultural-based economy such as Uganda, and they have reported the impact of the different powers of the central government and local government on rural development (Kakumba, 2010; Dixon, 1990). Such scholars propose the need to reconstruct the power of the local government to promote rural development (Douglas, 2005; Lowe et al. 2019). Based on the research on the impact of rural policies on rural development, rural development cannot be separated from the support of financial policies, agricultural development policies, smart village policies, etc. (Górecka et al. 2021; Mack et al. 2021; Turchaeva and Golovach, 2021; Lambarraa-Lehnhardt et al. 2021). Additionally, the formulation of these policies is generally led by the government. In summary, we acknowledge that government support plays a fundamental role in rural development.

Research on the relationship between land use transition and rural development shows that rural development will ultimately lead to land use change or transition and that land use change or transition will drive or promote rural development; thus, they are closely related (Long et al. 2011; Liu and Long, 2016; Long and Qu, 2018). One of the closest types of interactions in rural development and land use is the interaction between rural construction land and rural development (Tian et al. 2018; Zhu et al. 2018; Tu et al. 2018). Research on rural development evaluation shows that rural development can basically be divided into farmland-based agricultural development, garden-based agricultural development, woodland-based agricultural development, and other natural resource-based rural development (De Toni et al. 2021; Zhou et al. 2020; Woyesa and Kumar, 2020). Such development is accompanied by a large demand for rural construction land for rural roads and other infrastructure, rural public services, e-commerce development, improvement in rural housing conditions, the primary processing of agricultural products, and rural tourism, leading to rural construction land expansion. At the same time, the driving effect of rural economic and social development on rural construction land expansion shows that the correlations between various economic and social factors and rural construction land expansion are different. That is, the direction of rural construction land allocation to support rural development is selective (Song and Liu, 2014; Cao et al. 2017; Chen et al. 2017). Conversely, rural construction land expansion can reflect rural development, but the direction of representation may be different (Fig. 1).

In summary, almost all aspects of rural development require the allocation of rural construction land as a spatial carrier, almost all aspects of rural development require government support, and only the government can allocate rural construction

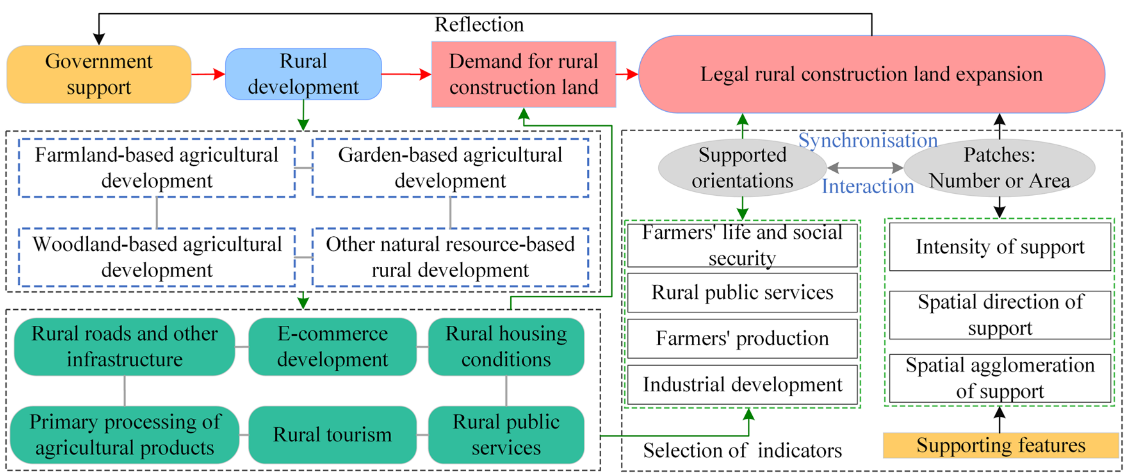

Fig. 1 Theoretical analytical framework of this study.

land. In China, this process is called legal rural construction land expansion. Therefore, understanding government support through legal rural construction land allocation for rural development is feasible, but there is a lack of research on this topic. This study constructs indicators of government support for rural development based on the intensity of support, the spatial direction of support, and the spatial agglomeration of support based on patches of legal rural construction land expansion. Taking into account existing evaluation indicators of rural development, an indicator system for government support for rural development in four dimensions—industrial development, farmers' production, rural public services, and farmers' life and social security—is constructed. Finally, the indicators and the indicator system are combined to quantify the characteristics and directions of government support for rural development that requires rural construction land allocation.

Materials and methods

Study area and data sources

Study area. Hubei Province is situated in the central region of the Yangtze River and shares borders with Anhui in the east, Jiangxi and Hunan in the south, Chongqing in the west, Shaanxi in the northwest, and Henan in the north. At the end of 2020, the permanent population of Hubei Province reached 57.75 million, including 36.32 million urban residents and 21.43 million rural residents. Additionally, the number of rural residents ranks 11th out of 31 provincial-level administrative regions in mainland China. Furthermore, the total agricultural output of Hubei Province reached 730.36 billion yuan, making Hubei the 7th largest agricultural province in China. With a total area of 185,900 km^2, Hubei has 13 prefecture-level administrative regions, namely, Wuhan, Huangshi, Shiyan, Yichang, Xiangyang, Ezhou, Jingmen, Xiaogan, Jingzhou, Huanggang, Xianning, Suizhou, and Enshi, which include 103 county-level cities (Fig. 2). This study excluded urban areas involving county-level administrative regions, and the remaining 70 county-level units away outside cities were selected.

Data sources. The data in this paper include spatial vector data and statistical data. The spatial vector data are rural construction land approved by the government from 2009 to 2018. Such land consists of patches that include the registered number of approvals, the date of change, the area, and the spatial location of rural construction land. These data are included in the land use change survey database and come from the Ministry of Natural Resources of Hubei Province. Statistical data on socioeconomic development and resource and environmental protection and utilization are obtained from the Hubei Statistical Yearbook (2010–2020), the China Statistical Yearbook (county-level) (2010–2020), and the statistical bulletins of Hubei Province (2009–2020).

Indicator system

Characteristics of government support for rural development based on the patches of LRCLE

Intensity of support: Area change: The dynamic degree of single land use (DDSLU) was selected to describe the area change of legal rural construction land (Liu et al. 2014), which characterizes the intensity of government support. The ratio of the area of the legal rural construction land increment to the area in the base period was calculated to characterize the intensity of LRCLE over a certain period in different units. The formula for calculating the DDSLU of the legal rural construction land increment is as follows:

$$S = \frac{S_a - S_b}{S_b} * \frac{1}{\Delta t} \tag{1}$$

where S is the ratio of the area of legal rural construction land increment to the area in the base period during different periods; S_b and S_a are the areas of legal rural construction land at the beginning and end of the monitoring period, respectively; and Δt is the monitoring period. Changes in the area of legal rural construction land over the past ten years were divided into three periods (2009–2011, 2012–2014, and 2015–2018).

Spatial direction of support: Directional distribution: Analysis of the change in spatial distribution direction refers to the outline and dominant direction of regional economic attributes or geographical elements in the spatial distribution, and the standard deviation ellipse (SDE) is one of the classic approaches for analyzing the characteristics of spatial distribution direction. Therefore, the SDE is chosen to quantitatively explain the centrality, distribution, directionality and spatial form of the spatial distribution of the legal rural construction land increment from the global and spatial perspectives (Du et al. 2019). The form of the SDE is as follows:

$$SDE_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n}} \tag{2}$$

$$SDE_y = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \bar{Y})^2}{n}} \tag{3}$$

where x_i and y_i are the coordinates of element i, $\{\bar{X},\bar{Y}\}$ represents the average center of elements, and n is equal to the total number of elements. The calculation method of the rotation angle is as follows:

$$\tan\theta = \frac{A + B}{C} \tag{4}$$

$$A = \left(\sum_{i=1}^{n}\tilde{x}_i^2 - \sum_{i=1}^{n}\tilde{y}_i^2\right) \tag{5}$$

$$B = \sqrt{\left(\sum_{i=1}^{n}\tilde{x}_i^2 - \sum_{i=1}^{n}\tilde{y}_i^2\right)^2 + 4\left(\sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i\right)^2} \tag{6}$$

$$C = 2\sum_{i=1}^{n}\tilde{x}_i\tilde{y}_i \tag{7}$$

where x_i and y_i are the coordinates of the average center of x_i and y_i, respectively. The standard deviation of the x-axis and y-axis is as follows:

$$\sigma_x = \sqrt{2}\sqrt{\frac{\sum_{i=1}^{n}(\tilde{x}_i\cos\theta - \tilde{y}_i\sin\theta)^2}{n}} \tag{8}$$

$$\sigma_y = \sqrt{2}\sqrt{\frac{\sum_{i=1}^{n}(\tilde{x}_i\sin\theta + \tilde{y}_i\cos\theta)^2}{n}} \tag{9}$$

The geometric center of gravity of each added legal rural construction land patch was taken as the coordinate position. Additionally, the proportion of the area of each added rural construction land patch in the total area of added rural construction land patches was used as the weight for calculating the SDE of legal rural construction land expansion.

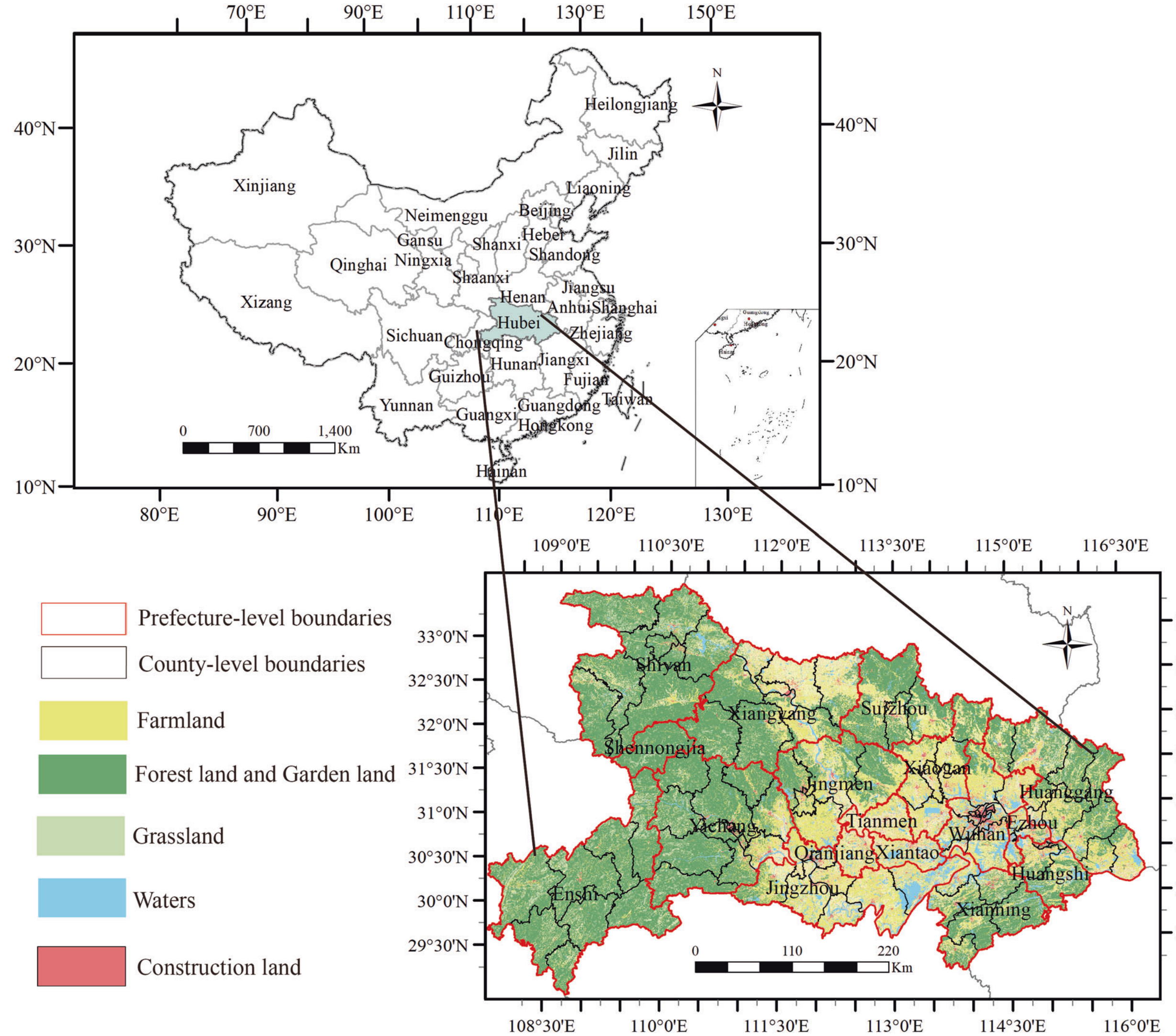

Fig. 2 Location of Hubei Province in China and evaluation units.

Spatial agglomeration of support: Distribution of quantity and the landscape pattern: It is difficult to use the administrative division as the unit to reveal local agglomeration. The number of patches determined by grid analysis is often used to analyze the characteristics of local agglomeration or the distribution of hot spots. Therefore, considering the cell of the grid involved in research on relevant rural construction land (Yang et al. 2015), this study used a 10 km × 10 km grid to count the number of added legal rural construction land patches. Additionally, the discrete degree of legal rural construction land expansion (DDLRCLE) was defined as the number of added legal rural construction land patches in each grid cell. The change in the DDLRCLE describes the local spatiotemporal process of rural construction land expansion.

The landscape pattern index is widely used to describe the spatiotemporal characteristics of the landscape. It specifically refers to natural or man-made formations. The index can be divided into three scales, namely, the patch, class, and landscape scales (Yohannes et al. 2021). Considering that this paper focuses on a single type of land use change, a class-level index was selected to calculate the morphological characteristics of added legal rural construction land patches at the microscopic scale. This index includes patch density (PD), edge density (ED), the largest patch index (LPI), the landscape shape index (LSI), the fractal index distribution (FRAC_AM) and the Euclidean nearest-neighbor distance (ENN_AM). The LPI, LSI, and FRAC_AM represent morphological characteristics, while PD, ED, and the ENN_AM represent structural characteristics. The relationships between different grouped indices are mutually validated.

Orientations of rural development. Based on the theoretical analytical framework, taking into account studies on the indicators used to evaluate rural development (Peng and Wang, 2020; Long et al. 2022; Li et al. 2021), an indicator system was established based on the dimensions of farmers' life and social security, rural public services, farmers' production, and industrial development, which reflect the direction of rural development. The indicator system is shown in Table 1.

Panel data regression. Based on panel data from county-level administrative regions in Hubei Province, a panel data regression model was constructed after a unit root test and variance inflation factor test. This model can identify the direction of government support by legal rural construction land allocation for rural development.

Unit root test: Augmented Dickey–Fuller test (ADF). When using a time series model, the time series must be smooth.

Table 1 Indicator system for rural development.

Dimensions of rural development	Variables	Connotation	Unit
Farmers' life and social security	Population of permanent residents (PPR)	Rural population growth generates a higher demand for rural residential land, which needs to be allowed and allocated by the government.	10,000 people
	Per capita disposable income of rural permanent residents (PCDIRPR)	An increase in farmers' income improves the construction of improved housing, which requires the government to allocate land for construction.	Yuan
	Area of cultivated land (ACL)	If the area of cultivated land is large, government conservation is stronger and may act as a disincentive for legal rural construction land expansion.	Hectare
	Total power of agricultural machinery (TPAM)	This indicator reflects the extent to which the government is interested in enhancing the modernization of agriculture and can reflect the importance that it attaches to rural development in a region.	10 MW
Rural public services	General budget expenditure of the local government (GBELG)	These indicators reflect government investment in rural infrastructure, public services, and industrial development.	10,000 yuan
	Rural investment in fixed assets (RIFA)		10,000 yuan
Farmers' production	Total grain output (TGO)	These indicators reflect the main directions of farmers' production activities, which may need to be complemented by the allocation of land for rural construction.	Ton
	Cotton production output (CPO)		Ton
	Oilseed production output (OPO)		Ton
	Total meat production output (TMPO)		Ton
Industrial development	Gross domestic product of the primary industry (GDPPI)	Rural revitalization promotes the primary, secondary and tertiary industries in rural areas, but there are differences in the directions of government support in different regions.	10,000 yuan
	Gross domestic product of the secondary industry (GDPSI)		10,000 yuan
	Gross domestic product of the tertiary industry (GDPTI)		10,000 yuan

Therefore, the first step needs to be a smoothness test, and a commonly used rigorous statistical test is the ADF test, which is a unit root test. If a unit root exists, this result indicates that the time series is unbalanced. If there is a unit root, that is, the time series data are not stationary, then panel data regression is usually not possible. However, the data can be differentiated, and two differences are generally performed. The second-order difference is a second difference based on the first-order difference. If the second-order difference is still not stationary, then the data are poor, and further differences are usually not performed because they are no longer practically significant.

Variance inflation factor (VIF) test. Multicollinearity refers to the distortion of model estimates or difficulty in conducting accurate estimations due to the high degree of correlation between the explanatory variables in a linear regression model. The VIF was chosen to test whether there was multicollinearity in the indicators of the orientations of rural development.

The variance of the parameter estimates is as follows:

$$Var(\hat{\beta}_i) = \frac{\delta^2}{\sum_{t=1}^{n}\left(x_{it} - \bar{x}_i\right)^2}\frac{1}{1 - R_i^2} \tag{10}$$

where R_i^2 is the explanatory variable of i as the dependent variable. The goodness of fit after regression on the other explanatory variables is as follows:

$$x_{ij} = \alpha_0 + \alpha_1 x_{1j} + \alpha_2 x_{2j} + \cdots + v_j \tag{11}$$

The second half is removed separately to obtain the variance inflation factor (VIF):

$$VIF = \frac{1}{1 - R_k^2} \tag{12}$$

If x_i and the other explanatory variables are more multicollinear, then the larger the value of R_i^2 is, the larger the value of the VIF. If $VIF > 10$, we judge that explanatory variable i and the other explanatory variables may have serious cointegration problems.

Panel data regression. Panel data regression is usually divided into three categories: pooled regression (pooled) models, fixed effect (FE) models, and random effect (RE) models. Among them, FE models are further divided into time fixed effect (one-way FE), individual fixed effect (one-way FE) and time-individual fixed effect (two-way FE) models. The basic equations for pooled, time fixed effect, individual fixed effect, and time-individual fixed effect models are as follows:

$$y_{it} = \alpha + x_{it}\beta + \mu_{it}\ i = 1, 2, \cdots N; j = 1, 2, \cdots T \tag{13}$$

$$y_{it} = \lambda_t + \sum_{k=2}^{K} \beta_k x_{kit} + \mu_{it} \tag{14}$$

$$y_{it} = \gamma_t + \sum_{k=2}^{K} \beta_k x_{kit} + \mu_{it} \tag{15}$$

$$y_{it} = \lambda_i + \gamma_t + \sum_{k=2}^{K} \beta_k x_{kit} + \mu_{it} \tag{16}$$

The most suitable model is selected based on the F test and the Breusch–Pagan and Hausman tests. The F test is used to compare

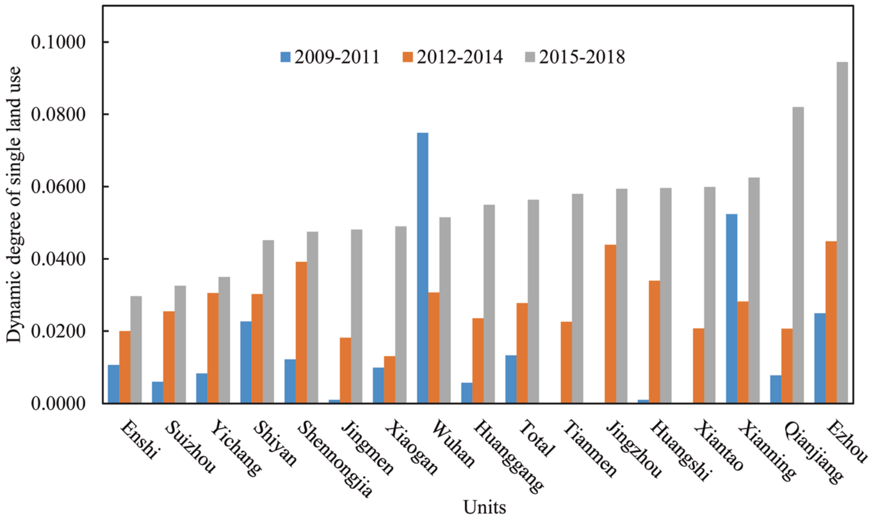

Fig. 3 The intensity of government support through legal rural construction land allocation for rural development from 2009 to 2018 in Hubei Province.

Table 2 Changes in the landscape pattern in Hubei Province from 2009 to 2018.

Types	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
LPI	4.59	0.72	1.87	0.45	1.34	0.35	0.40	0.33	0.22	0.44
LSI	33.43	156.53	163.03	230.30	152.85	172.08	197.03	209.67	228.49	190.45
FRAC_AM	1.06	1.09	1.10	1.09	1.13	1.12	1.13	1.12	1.12	1.12
PD	121.25	136.16	128.85	178.02	120.41	66.03	59.96	54.13	49.43	61.89
ED	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ENN_AM	2560.17	336.89	428.75	399.52	291.94	462.49	408.88	461.53	385.22	341.27

for FE model and pooled model selection, and a P value less than 0.05 indicates that the FE model is better; vice versa, the pooled model is used. The Breusch–Pagan test is used to compare for RE model and pooled model selection, and a P value less than 0.05 indicates that the RE model is superior; in the opposite case, the pooled model is used. The Hausman test is used to compare for FE model and RE model selection. A P value less than 0.05 implies that the FE model is better; vice versa, the RE model is used.

Results

Intensity of government support. The average values of the dynamic degree of single land use (DDSLU) were 0.0147, 0.0281, and 0.0573 in the 2009–2011, 2012–2014, and 2015–2018 periods, respectively. These results indicate that the value of the DDSLU in Hubei Province increased annually from 2009 to 2018. During the 2009–2011 period, Wuhan had the largest DDSLU, Xiantao had the smallest DDSLU, and the DDSLU values were 0.0749 and 0.0000, respectively. From 2012 to 2014, Ezhou had the largest DDSLU, and Xiaogan had the lowest DDSLU, with values of 0.0449 and 0.0131, respectively. In the 2015–2018 period, Xiangyang had the largest DDSLU, and Enshi had the least DDSLU, with values of 0.1057 and 0.0297, respectively. The results indicate that the largest DDSLU of legal rural construction land in different units was constantly increasing and was concentrated in the metropolis and gradually expanded to cities around the metropolis. The smallest DDSLU of legal rural construction land in different units was also constantly increasing and was concentrated in mountainous areas that are far from the metropolis. Furthermore, the intensity of government support for rural development increased in different localities (Fig. 3).

Spatial direction of government support. Basic parameters of the spatial distribution of legal rural construction land expansion in Hubei Province, such as Shape-Area, Shape-Length, CenterX, CenterY, XStdDist, YStdDist, and Rotation, were calculated. Ellipticity was calculated by XStdDist and YStdDist, and the center of gravity was determined by CenterX and CenterY. The results are shown in Fig. 4. The Shape-Area of the scope of legal rural construction land expansion in 2012 and 2018 was larger, but the scope of expansion in 2013 was the smallest. XStdDist and YStdDist increased over time, but ellipticity showed a general trend consisting of a fluctuating decline. That is, ellipticity was larger in 2009 and 2010 but was smaller in 2013. The maximum rotation values occurred in 2011 and 2017, and the minimum occurred in 2009. The distribution of the center of gravity for legal rural construction land expansion gradually shifted to the northwest. In summary, the effects of the spatial distribution of legal rural construction land expansion were obvious and had clear directionality.

Spatial agglomeration of government support. Grids with different discrete degrees of legal rural construction land expansion (DDLRCLEs) were divided into ten levels in Hubei Province. The results are shown in Fig. 5. The number of grids with a DDLRCLE of zero decreased annually, the proportion of which gradually decreased from 47.32% in 2009 to 28.83% in 2018. The number of grids with DDLRCLEs of 1–5 and 6–10 showed an increasing trend and began to decrease after 2016. The number of grids with DDLRCLEs of 11–15 and 16–20 increased from 2009 to 2017 and decreased in 2018. The number of grids with DDLRCLEs of 21–25 and 26–30 showed a strong trend of fluctuating growth. The number of grids with DDLRCLEs of 31–50 and 50–100 reached a small peak in 2012, and all showed a strong trend of

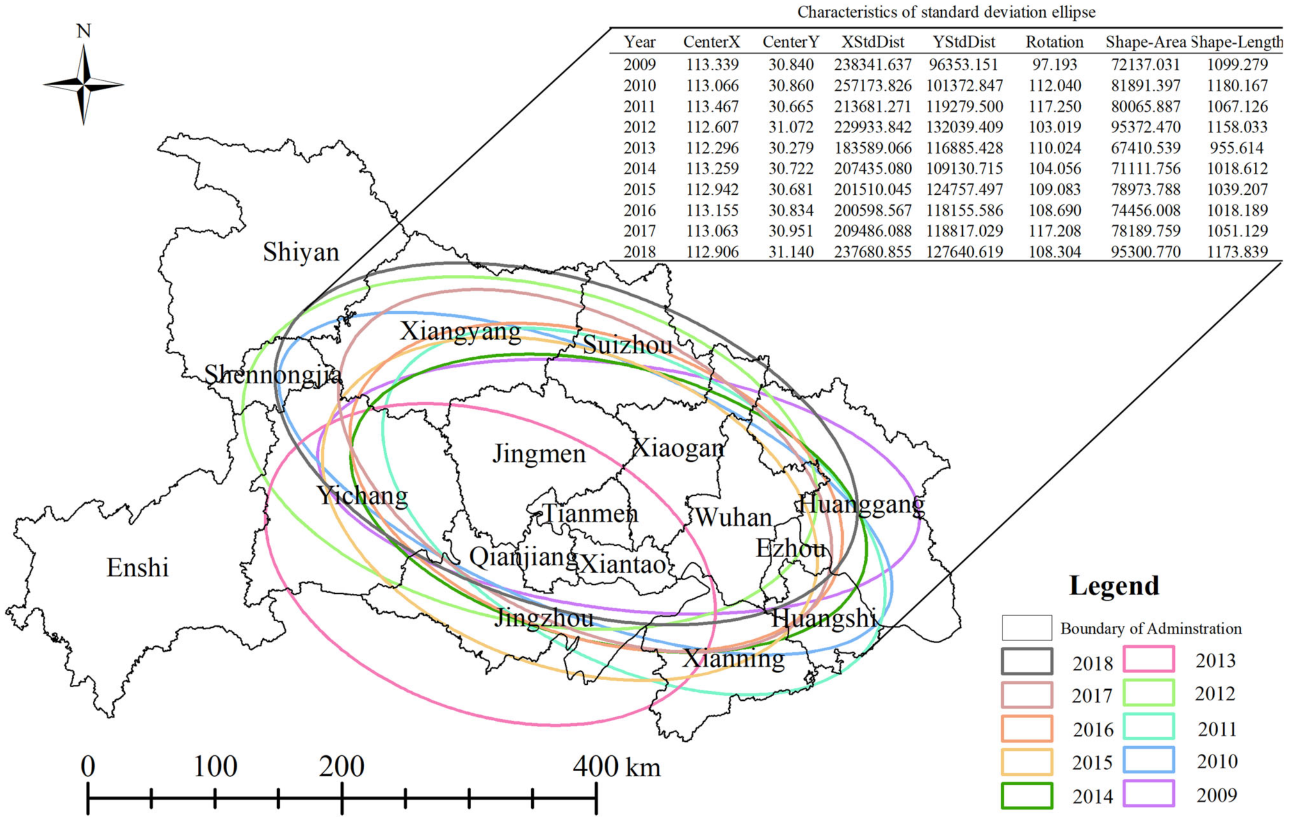

Fig. 4 Spatial direction of government support through legal rural construction land allocation for rural development in Hubei Province from 2009 to 2018.

Table 3 Results of the ADF and VIF tests for the dependent and independent variables.

Variables	*t*	*P*	Thresholds			VIF
			1%	5%	10%	
PPR	−7.766	0.000***	−3.44	−2.866	−2.569	4.828
PCDIRPR	−1.368	0.097*	−3.44	−2.866	−2.569	3.397
ACL	−2.198	0.005***	−3.44	−2.866	−2.569	6.661
TPAM	−6.672	0.000***	−3.44	−2.866	−2.569	1.750
GBELG	−3.102	0.026**	−3.44	−2.866	−2.569	6.382
RIFA	−2.785	0.060*	−3.44	−2.866	−2.569	5.104
TGO	−4.71	0.000***	−3.44	−2.866	−2.569	7.951
CPO	−3.522	0.007***	−3.44	−2.866	−2.569	2.667
OPO	−7.195	0.000***	−3.44	−2.866	−2.569	2.768
TMPO	−5.994	0.000***	−3.44	−2.866	−2.569	2.756
GDPPI	−3.59	0.006***	−3.44	−2.866	−2.569	8.999
GDPSI	−4.758	0.000***	−3.44	−2.866	−2.569	6.680
GDPTI	−2.707	0.073*	−3.44	−2.866	−2.569	8.308
Number of LRCLE patches	−8.232	0.000***	−3.44	−2.866	−2.569	-
Area of LRCLE patches	−20.297	0.000***	−3.44	−2.866	−2.569	-

***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

fluctuating growth. However, the number of grids with a DDLRCLE larger than 100 showed a downward trend, and the number in 2018 was already lower than that in 2010.

The value of each landscape pattern index from 2009 to 2018 was calculated. The results are shown in Table 2. PD in Hubei Province peaked in 2012 and was stable from 2014 to 2018. However, the ED of added legal rural construction land patches was zero from 2009 to 2018. The largest LPI appeared in 2009, and the LPI value stabilized after 2014. The LSI increased continuously from 2009 to 2012 and showed a slow growth trend after declining in 2013. The FRAC_AM was stable from 2009 to 2018, and the maximum value occurred in 2013. The ENN_AM value in 2009 was the highest, and the values for other years were stable. The results show that the independence of the expansion of each legal rural construction land patch strengthened from 2009 to 2018. Although patches shrank, the patch morphology became more complex, which demonstrates the increasing sophistication of government support for rural development through legal rural construction land allocation.

Table 4 Panel data regression selection based on the area of LRCLE.

Testing type	Statistics	*P*	Results
F test	1.672	0.001***	FE
Breusch–Pagan test	0.002	1.000	Pooled
Hausman test	66.479	0.000***	FE

*** represents significance at the 1% level.

Orientations of government support through legal rural construction land allocation for rural development. The results of the unit root test (ADF) and variance inflation factor (VIF) test are shown in Table 3. All dependent and independent variables pass the ADF test, which indicates that the time series of the panel data are stationary. Furthermore, the VIFs of all the independent variables in the indicators of the orientations of rural development are less than 10, indicating that there is no covariance between all the independent variables.

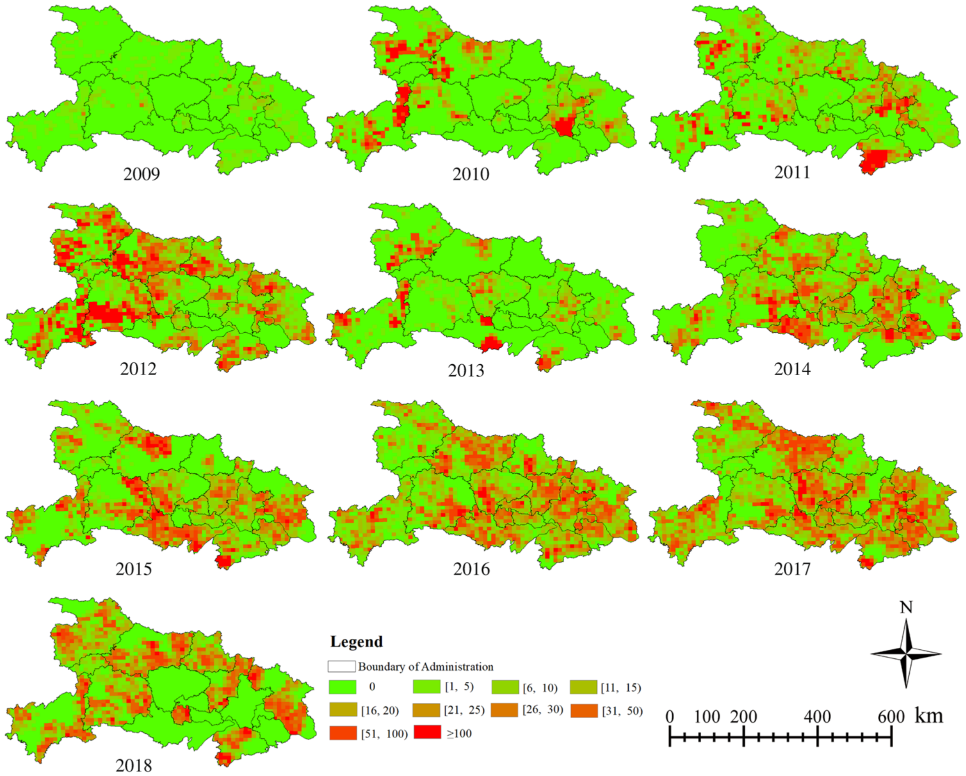

Fig. 5 Spatial agglomeration of government support through legal rural construction land allocation for rural development in Hubei Province from 2009 to 2018.

The area of legal rural construction land expansion in each county from 2009 to 2018 was used as the dependent variable, and the indicators of rural development were used as the independent variables. The results of the F test, Breusch-Pagan test and Hausman test indicate that a fixed effect model should be chosen for panel data regression (Table 4).

The model selection results show that the driving effect of rural development on the area of legal rural construction land expansion is affected by both special individuals and different times. From the perspective of individual fixed effects, PPR, GDPPI, OPO, ACL, and TMPO have positive effects on legal rural construction land expansion, but GDPSI and CPO have negative effects on legal rural construction land expansion. Furthermore, the effects of PPR and OPO are greater. From the perspective of time fixed effect regression, PCDIRPR, ACL, and OPO have positive effects on the expansion of legal rural construction land, but CPO has a negative effect. Furthermore, the effects of PCDIRPR and ACL are greater. From the perspective of the time-individual fixed effect, CPO, OPO, and TMPO have effects on legal rural construction land expansion, but OPO has the largest effect on legal rural construction land expansion (Table 5).

At the same time, the number of legal rural construction land expansion patches in each county from 2009 to 2018 was used as the dependent variable, and the indicators of the orientations for rural development were used as the independent variables. The F test, Breusch-Pagan test and Hausman test were also performed. The results indicate that there were no individual or temporal effects between the number of LRCLE patches and different rural development orientations. Additionally, a pooled effect model was chosen for panel data regression (Table 6).

PPR, PCDIRPR, GDPPI, ACL, TGO, and TMPO have effects on the number of patches of LRCLE, where the effects of PPR, PCDIRPR, and TGO are negative. Furthermore, PCDIRPR and GDPPI have significant impacts on the number of LRCLE patches (Table 7).

Discussion

Government support through legal rural construction land allocation for rural development shows strong spatiotemporal characteristics. The area of legal rural construction land in different units constantly increased between 2009 and 2018, the government fully supported rural development, and the intensity of this support increased from 2009 to 2018. The effects of the spatial distribution of legal rural construction land expansion are obvious and have clear directionality. The spatiotemporal pattern of added legal rural construction land patches exhibited a trend of local agglomeration in all directions, demonstrating that government support for rural development tended to continue to agglomerate in all units of Hubei Province. The independence of the expansion of each legal rural construction land patch strengthened from 2009 to 2018, the patches shrank, and the patch morphology became more complex. These findings indicate that there was a trend of caution in government support for rural development under the background of strict control of growth in construction land. This result has not been captured in existing studies on the spatiotemporal characteristics of changes in rural construction land (Zhang & Wang, 2022; Feng et al. 2019).

China has adopted a series of policies, including "Linking the Decrease in Rural Construction Land with the Increase in Urban Construction Land", the "Economic and Intensive Use of Urban Land Policy" and the "Strict Protection of Basic Farmland", to control rural construction land expansion (Huang et al. 2014; Song and Liu, 2014). These policies have promoted the intensive use of rural

Table 5 Panel data regression on the area of LRCLE and the orientations of rural development.

Variables	Individual fixed effect model (one-way FE)		Time fixed effect model (one-way FE)		Time-individual fixed effect model (two-way FE)	
	Coeff.	t	Coeff.	t	Coeff.	t
const	0.000	0.000	0.000	0.000	0.000	0.000
PPR	1.741	2.342**	0.076	0.972	1.671	1.496
PCDIRPR	−0.111	−0.915	0.261	2.276**	0.505	1.39
GDPPI	0.412	2.22**	0.11	1.039	0.229	1.099
GDPSI	−0.378	−2.043**	−0.143	−1.084	−0.496	−1.055
GDPTI	0.277	1.544	0.102	0.998	0.398	1.294
GBELG	0.012	0.074	−0.084	−0.734	−0.106	−0.753
RIFA	−0.025	−0.220	0.09	0.891	−0.03	−0.2
ACL	0.198	1.652*	0.295	2.729***	0.309	1.03
TPAM	0.139	0.723	−0.045	−0.922	0.218	1.162
TGO	−0.109	−0.414	−0.154	−1.437	−0.111	−0.35
CPO	−0.52	−5.442***	−0.204	−3.443***	−0.451	−3.947***
OPO	0.61	2.918***	0.113	1.977**	0.706	2.45**
TMPO	0.348	2.312**	0.024	0.414	0.382	1.964*
R^2	0.666		0.581		0.491	
Test	$F = 11.361$ $P = 0.000$***		$F = 8.276$ $P = 0.000$***		$F = 6.765$ $P = 0.000$***	

***, **, and * represent significance at the 1%, 5%, and 10% levels, respectively.

Table 6 Panel data regression selection based on the number of patches of LRCLE.

Testing type	Statistics	P	Results
F test	1.277	0.073*	Pooled
Breusch–Pagan test	0.298	1.000	Pooled
Hausman test	16.797	0.209	RE

* represents significance at the 10% level.

Table 7 Pooled effects regression on the number of patches of LRCLE and the orientations of rural development.

Variables	Coeff.	t
const	0.000	0.000
PPR	−0.161	−1.879*
PCDIRPR	−0.197	−2.475**
GDPPI	0.265	2.357**
GDPSI	−0.151	−1.36
GDPTI	−0.005	−0.048
GBELG	0.07	0.559
RIFA	0.064	0.755
ACL	0.192	1.987**
TPAM	0.003	0.056
TGO	−0.252	−2.332**
CPO	−0.073	−1.133
OPO	−0.013	−0.215
TMPO	0.123	1.972**
R^2	0.625	
Test	$F = 2.14$ $P = 0.011$**	

** and * represent significance at the 1% and 5% levels, respectively.

construction land, and there is an excessive emphasis on controlling the expansion of urban construction land and consolidating inefficient rural construction land (Fang & Tian, 2020; Zhang et al. 2022; Zhang et al. 2022). However, the continuous expansion of legal rural construction land has continued, greatly reducing the effectiveness of related policies. Furthermore, the quota allocation system for construction land leads to a lack of quotas for urban construction land in local governments, which leads to the fact that a large amount of added rural construction land has the function of urban construction land to strive for more space for urban development (Zhang et al. 2021). These findings are also found in relevant studies on land use transition, and the invisible transition is the reason for the expansion of legal rural construction land (Long et al. 2011; Liu et al. 2008).

Specific orientations of government support through legal rural construction land allocation for rural development. The largest area of legal rural construction land expansion is generated in support of farmers' production, followed by farmers' livelihoods and social security. Cotton production output (CPO) suppresses changes in the area of legal rural construction land. The area of cultivated land (ACL), oilseed production output (OPO), and total meat production output (TMPO) have positive effects on legal rural construction land expansion, suggesting that in allocating rural construction land, the most immediate purpose of the government is to support the most immediate food production and its related elements. However, most previous studies were based on the entirety of rural construction land and found that economic development has led to the continuous expansion of rural construction land (He et al. 2019; Liu et al. 2018). This finding shows that rural development is independent of the legal rural construction land allocation in rural areas, which is obviously highly inconsistent with the law of continuous expansion of urban construction land in the process of urban economic development (Zhu and He, 2021; Zhou et al. 2021).

Furthermore, the population of permanent residents (PPR), the per capita disposable income of rural permanent residents (PCDIRPR), the gross domestic product of the primary industry (GDPPI), the area of cultivated land (ACL), total grain output (TGO), and total meat production output (TMPO) have effects on the number of LRCLE patches. Here, the effects of PPR, PCDIRPR, and TGO are negative; GDPPI and TMPO have positive effects on the number of LRCLE patches. Compared with the directions of government support through the area of legal rural construction land allocation for rural development, the number of legal rural construction land expansion patches is consistent with the findings of research on the influencing factors of rural construction land expansion. Specifically, rural construction land is influenced by factors such as GDPPI and PPR (Zhu and He, 2021; Zhou et al. 2021).

Conclusions

The intensity of government support through legal rural construction land allocation for rural development increased from 2009 to 2018 and was concentrated in the metropolis and gradually expanded to regions around the metropolis. The spatial direction of government support through legal rural construction land allocation for rural development was clear. Government support through legal rural construction land allocation for rural development was characterized by local agglomeration from a single center to multiple centers over time. There was a trend of caution in government support through legal rural construction land allocation for rural development under the background of strict control of growth in construction land.

There were differences in the direction of government support for rural development requiring an area or amount of legal rural construction land allocation. This finding indicates that government support for rural development was not always in pursuit of increasing the area for construction land and that there may have been more demand for quantity, which also explains the fragmentation of rural construction land expansion patches. The area of cultivated land (ACL) and total meat production output (TMPO) were the directions of rural development requiring both an amount and area of legal rural construction land allocation.

The government has implemented a series of policies to control rural construction land expansion, and these policies have promoted the intensive use of land resources. However, there is too much emphasis on controlling the expansion of urban construction land and consolidating inefficient rural construction land. Additionally, the continuous expansion of legal rural construction land with government support continues to occur, greatly reducing the effectiveness of related policies.

Data availability

The original dataset of legal rural construction land allocation in Hubei Province, China was generated in the study are included in the article/(Supporting Materials S1. Dataset), no other datasets were generated or analyzed in the current study, further inquiries can be directed to the corresponding author.

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Author contributions

All persons who meet authorship criteria are listed as authors, and all authors certify that they have participated sufficiently in the work to take public responsibility for the content. In particular, the specific contributions made by each author are as follows: Conceptualization: HZ; data curation: ZW; formal analysis: JC; writing—original draft: HZ; software: JC; and writing—review and editing: HZ and ZW. All authors have read and agreed to the published version of the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was not required, as the study did not involve human participants.

Informed consent

Informed consent was not required, as this article does not contain any studies with human participants performed by any of the authors.

Additional information

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