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Diversification and Spatial Differentiation of Villages' Functional Types in the New Period of China: Results from Hierarchical Urban-Rural Spatial Relations and Townships Size

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Abstract: In recent years, in rural geographic studies, the topic of multifunctions of rural areas has been gaining increasing interest, especially in China, which, as an agricultural power, is undergoing new urbanization and rural revitalization. As far as China is concerned, to classify administrative villages from the perspective of their functions will contribute to scientifically guiding the configuration of urban-rural factors in terms of different regions and villages multifunctional types. This paper takes 3042 administrative villages of Tai'an city of Shandong province in eastern China as its basic study units and establishes a mapping system between land use types and rural territorial sub-functions, identifies their multifunctional types via cluster analysis, quantitatively analyzes their influencing factors with multivariate logistic regression, and summarizes their spatial structure characteristics. The results show that: 3042 administrative villages in Tai'an city can be functionally classified into seven types. The village multifunctional types are jointly decided by cities and natural production conditions. The distribution of all types of villages shows a "non-agricultural production to agricultural production" outward expansion structure. Our study can expand the research contents and methods of rural territorial multifunction.

Keywords: multifunctional types of villages; influencing factors; spatial structure; urban-rural relations; Tai'an city of China

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Citation: Yang, X.; Wang, M. Diversification and Spatial Differentiation of Villages' Functional Types in the New Period of China: Results from Hierarchical Urban-Rural Spatial Relations and Townships Size. *Land* **2022**, *11*, 171. https://doi.org/10.3390/land11020171

Academic Editors: Tao Liu, Qiujie Shi, Raymond Yu Wang and Guangzhong Cao

Received: 27 December 2021
Accepted: 17 January 2022
Published: 21 January 2022

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1. Introduction

The urban-rural relationship is the most fundamental aspect of economic and social relations [1]. The functions of urban and rural areas are different and the relations between the two are evolving as factors flow between them, which make rural areas constantly evolve [2–4].

The development of rural areas and agriculture have gone through stages of resource capitalism-productivism-post-productivism-multifunctionalism [5]. In the early period, rural functions were considered equivalent to agricultural production functions [6,7]. With further discussion on the concept of rural areas, Cloke (1984) believes that rural areas exist on the basis of agricultural and forestry production, contain lots of small and lower-ranking settlements, and engender a way of life [8]. Rural environment can be subdivided conceptually into functional elements of rural land use and economic development, rural settlements, rural society, communities, and so on and thus displays multifunctions of production, life, ecology, culture, and so on [9,10]. After the 1970s, post-productivism argues that rural consumption, post-productivity, and other non-productive functions of agriculture had replaced productive functions [11,12]. Until the concept of multifunctional agriculture was introduced, which emphasized the pluralistic contribution of agriculture to territorial economic development, environmental management, and rural social survival [13,14], the multidimensional coexistence of productivism and post-productivism actions and reflections became a new trend [15]. As globalization, urbanization, informatization, and marketization continue to spread to rural areas, various factors are transferred from urban

to rural markets [1,2], resulting in a fundamental shift in the economy, culture, and society of rural areas and diversification of rural settlements, land resources, and rurality [16]. Thus, a consensus gradually emerges that multifunctional agriculture cannot fully represent multifunctional rural areas. Marsden (1999) argues that rural development changes and integrates traditional agricultural production and management practices as a result of the restructuring of production and consumption functions [17]. On this basis, Wilson (2001) believes that rural multifunctional studies can only truly reveal and summarize the characteristics of rural territorial development and change if they go beyond the specific field of agricultural production [15], and John Holmes proposes a "multifunctional rural transition" [18]. Hoggart and Paniagua (2001) argue that rural multifunctional transformation is a big change rather than a restructuring [19,20], and it has significant advantages in portraying the multifactor transformational development of rural territories in terms of population, technology, and environment [21]. Especially in China, where the urbanization rate exceeds 60% and the rural revitalization strategy is being implemented and the result of rural multifunctional transformation, i.e., rural territorial multifunctionality, has become a hot topic in rural geography research in recent years.

Rural territorial multifunctions are multifunctional attributes displayed by different rural territorial units in a larger regional space to meet their internal and external needs [22]. Current research mainly adopts the index system evaluation method [23–26] and the value accounting method [27,28] to measure the richness and intensity of sub-functions. Foreign research often takes typical villages, communities, or individual farms as their objects of study [29–31] and focuses on connotation and transformation [32–35], the systematicness and endogenous mechanism of the village functions [36,37], and the governance and policy making of villages [38–43]. Their scale of study objects now show the tendency to be of larger scales [44,45]. Chinese domestic research mainly takes counties as their smallest study unit and usually focuses on issues such as the identification and evaluation of rural territorial sub-functions [22,46] as well as spatial distribution and evolution [47–49]. Existing research finds that under the joint influence of natural, social, and economic conditions of different regions, rural territorial sub-functions show multiple interactive relations and spatially a certain stepping, clustering and synergy pattern [24,36,37]. However, the key manifestations of rural participation in urban-rural territorial divisions of labor are the multifunctional types formed by interactions among rural territorial sub-functions of different intensities and types [37,50,51]. Although existing research mainly adopts a descriptive statistical analysis and regards multifunctional types of a certain geographical area as a combination of sub-functions to discern the types of rural territorial multifunctions [11,52,53] and only classifies villages in a simple way in terms of function [54–56], they fail to discuss in depth the spatial differentiation characteristics and the influencing factors of village types with multifunctions. As a matter of fact, the different functional village types are formed under the joint influence of villages' own conditions and urban-rural spatial relations. The existing research fails to discuss in depth the important roles of cities or towns in the formation of rural territorial multifunctional types and thus fails to systematically explain the regularity and differences in the differentiation of rural territorial functional types as they only take counties as their smallest study unit or take typical villages as their objects of study, while studies that focus on urban-rural relations lack attention to the multifunctional types of rural territories [57–60].

In comparison, foreign studies are smaller in scale and go deeper, which is conducive to exploring the endogenous mechanisms of rural multifunctions. However, research in China often focuses more on larger scale research objects and external laws, making the research more suitable for directly guiding local development. However, scholars have realized that the development of rural areas in China significantly differs from that in western countries, and the foreign explanations of the endogenous mechanism of rural functions cannot be fully applied to China and require in-depth study in terms of the development characteristics of the basic units and ways of working against the national conditions and development stage of China. Only by doing so, can we make a better

judgment on the trend of the evolution of external laws and can our research be really conducive to guiding China in making rural revitalization strategy.

Recently, research on multifunctions that take villages as the smallest study unit are increasing and find that villages' sub-functions are remarkably influenced by cities [24]. Spatially, the levels of villages' multifunctions decrease as their distances to cities increase [14], and villages' non-agricultural functions like social security functions and economic functions are distributed close to cities [39,44,61]. Although the above-mentioned progresses have proven the distinctive role played by cities in the differentiation of village multifunctions, they still have not explored in depth the specific mechanisms of urban action on the formation of village functions. As village data is hard to access, the method of identifying rural territorial sub-functions is still limited to the evaluation method, in which the researchers' experience affects the numbering of villages' sub-functional types and the construction of the evaluation index systems. Thus, different researchers draw varying conclusions.

Research on the multifunctions of rural land use believes that land use functions and land use types display a direct mapping relation [62–64] and firstly adopted a land use type identification method to identify rural land use sub-functions [65–71]. Spatial production theories also believe that land is where villages' activities take place, land use types are the results of land spatial production, and the composite structure of all villages' land use types after mapping and interaction is the manifestation of village multifunctional types. Comparatively speaking, land use data has a comprehensive representation and sole dimensionality and is ubiquitous and comparable. Identifying villages' sub-functions based on land use data will get more comprehensive and subjective results. This paper thus tries to introduce the land use type identification method into the study of village multifunctional types.

The focus on rural territorial multifunctional types can generate the following contributions. First, to solve the problem that existing research has not clearly identified the structure of rural territorial multifunctional types at a small scale, this paper takes smaller units as its research units. It takes a prefecture city as its research area and the administrative villages within it as basic research units to identify the structure of rural territorial functional types at a city level. Second, by adopting a new data-collecting method, i.e., a land use identification method, this paper solves the problem that the villages-based rural territorial multifunctions research is difficult to conduct due to lack of data. This paper establishes the connections between two sets of research systems, which are the land use multifunctions and the rural territorial multifunctions. Third, this paper identifies rural territorial multifunctional types, the regularity of the spatial differentiation among different types of multifunctional villages, and the roles of cities in the formation of multifunctional village types. By coordinating rural-urban functional zoning and guiding rural-urban factors allocation in Tai'an city of China, this study will be conducive to realizing an integrated rural-urban development and to advancing rural revitalization in the context of new urbanization.

Based on the above-mentioned insights, this paper chooses the villages in a representative region of eastern China as its study object. Starting from the perspective that land is the arena where rural territorial functions are performed, this paper establishes a mapping relationship between rural territorial multifunctions and land use types. Based on the interactions between the above functions and among villages, this paper summarizes villages' dominant functional types, identifies spatial distribution characteristics of each functional village type, and discusses the important roles of cities in the formation of village functions from the perspective of the urban-rural relationship.

2. Study Area

Tai'an city of Shandong province in eastern China is a proper area for the study of multifunctional village types. The relief of Tai'an city decreases from northeast to southwest and is endowed with complete landform types including mountains, hills, plains, and lakes (Figure 1). With a road network density of 55km/100 km^2 and four highways, including G3, G22, G35, and S30, the roads are well developed within the city. The city is endowed with

rich water resources with 466 rivers and Dongping Lake, the second largest freshwater lake in Shandong province and of 300 million cubic meters. Tai'an is also abundant in mineral resources because it conserves more than 50 kinds of proven mineral resources, accounting for about 38% of solid mineral reserves in Shandong province. Tai'an has 74 A-level tourist attractions in total and the Daiyue district within it is rated as a national demonstration county for leisure agriculture and rural tourism. In 2018, Tai'an ranked the 42nd in the list of China's top 100 prefecture-level cities in terms of GDP. Its three-industry structure was 7.8%: 44.2%: 48.0% and its urbanization rate was 61.87 %, slightly higher than the national level of 59.58% and almost the same as Shandong's 61.18%.

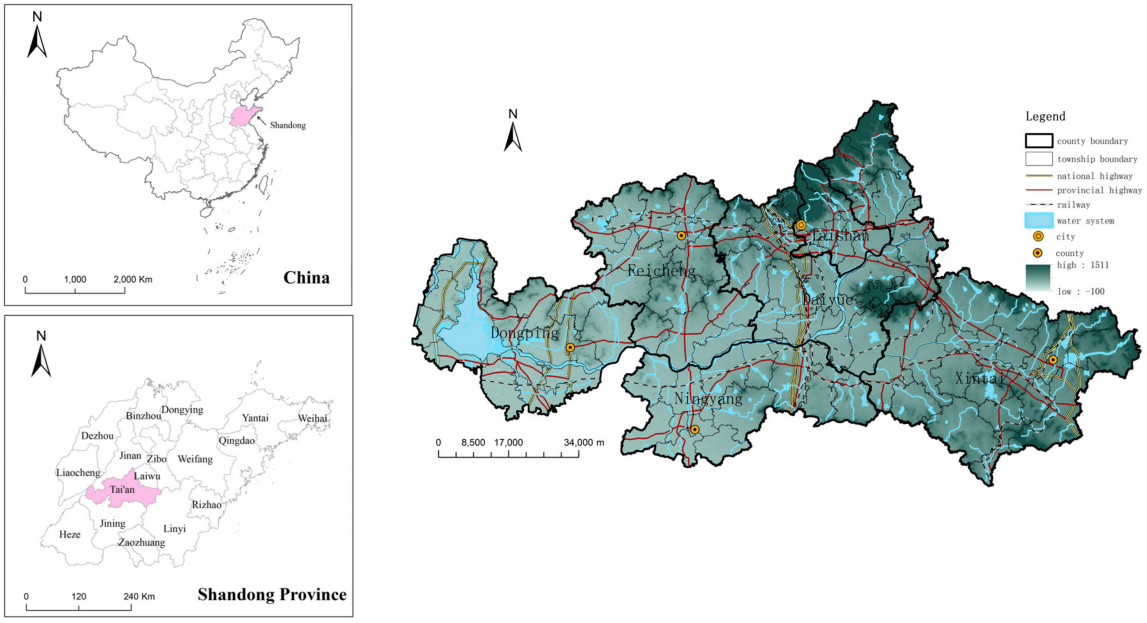


Figure 1. Location and topographic of Tai'an city.

3. Materials and Methods

3.1. Data Sources

The 3640 administrative villages in Tai'an city were used as the study objects (including the villages where governments of villages and towns are located), and 403,800 land plaques were used as the smallest space carrier of rural territorial functions, where the land use data were derived from the data of the third land use survey of Tai'an city. The population data is collected from Tai'an Statistical Yearbook (2019) and China's Township Development Trend Survey (2018) issued by Peking University. The survey covers the total villages in Tai'an, including items such as village population, land use, planted crops, and agricultural facilities. Geographic data such as the data of terrain and rivers is taken from the Geospatial Data Cloud Platform (http://www.gscloud.cn) on 10 May 2021 and the spatial resolution of DEM data is 30-m. Vector data, such as administrative divisions and roads, are collected from the National Catalogue Service for Geographic Information of China (http://www.webmap.cn) on 10 May 2021.

3.2. Analysis Methods

As shown in Figure 2, the analysis is composed of two steps.

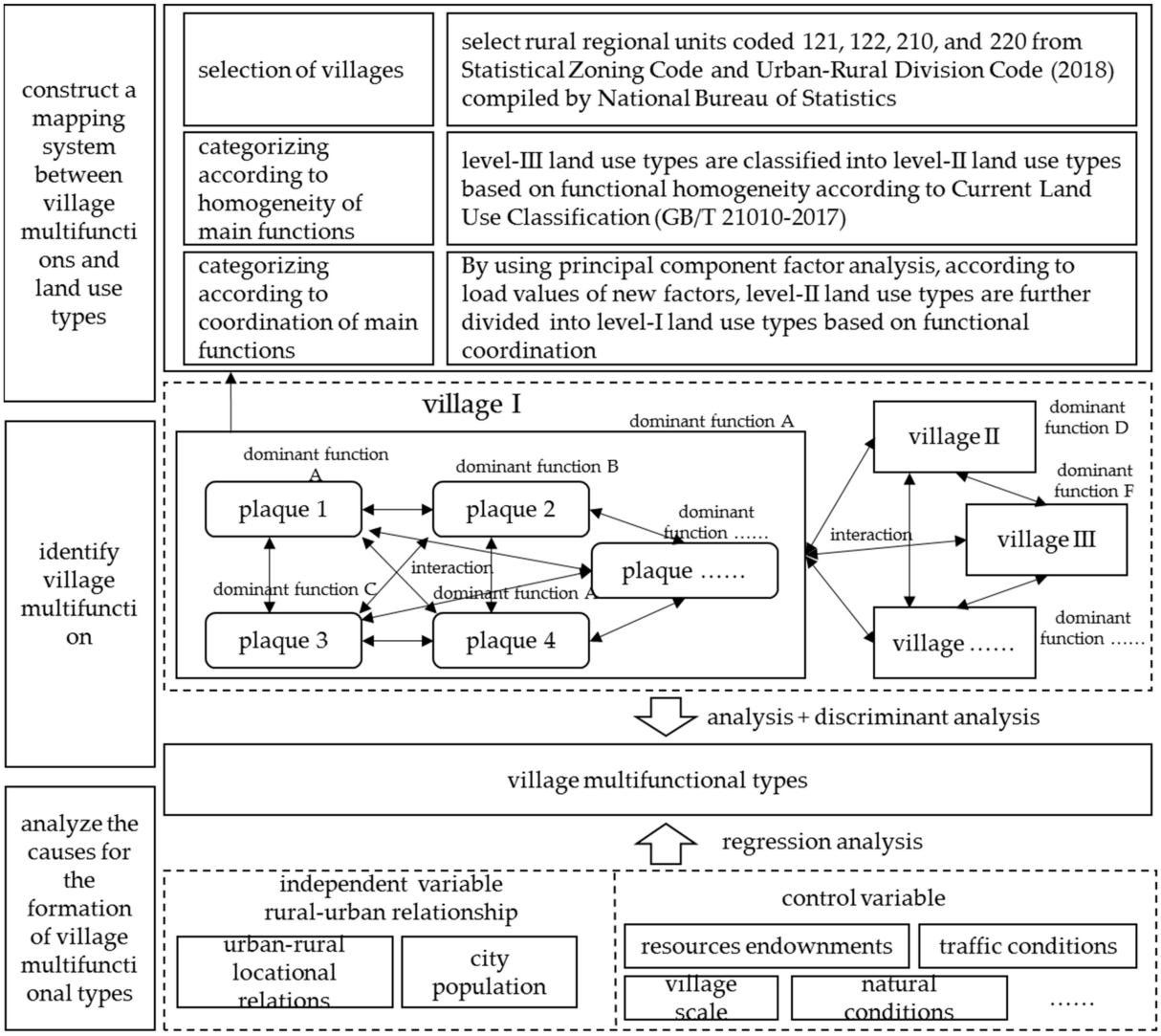


Figure 2. Roadmap of our analysis.

3.2.1. Identification of Village Multifunctional Types

First, 3042 administrative villages with urban-rural classification codes of 121, 122, 210, and 220 are selected and they are coded in the Statistical Zoning Code and Urban-Rural Division Code (2018) compiled by the National Bureau of Statistics.

Second, identification of rural territorial sub-functions is carried out. Based on the hierarchical relationship between the interactions of land use types, the rural territorial sub-functions are identified by establishing a mapping system between rural territorial sub-functions and land use types. First, level-III land use types (basic land use types) are combined and categorized into level-II land use types according to the Current Land Use Classification (GB/T 21010-2017), the hierarchical relationship of land use types, and to the homogeneity of the main functions [68]. Second, level-II land use types are combined and categorized into level-I land use types which have distinctive dominant functions in line with the principle of co-occurrence and coordination among main functions. Finally, a mapping system between level-I land use types and rural territorial sub-functions is established.

Third, measurement of village sub-functional intensity is conducted. Based on external manifestations of villages' multi-functions, the location entropy is employed to measure the intensity of each sub-function of villages. The calculation formula is the following:

$$LQ_{ij} = \frac{\frac{q_{ij}}{q_j}}{\frac{q_i}{q}} \quad (1)$$

Of the formula, LQ_{ij} represents the intensity of village j's function i in a certain geographical range, q_{ij} stands for the scale of land use type that is mapped by function i of village j, q_j is the scale of all land use types in village j, q_i is the scale of land use type that is mapped by function i in a certain geographical range, and q is the scale of all land use types in a certain geographical range.

Fourth, identification of village multifunctional types takes place. Considering the interactions among villages sub-functions and among villages themselves and following the principle of keeping maximal similarities in a village's structure of functional types (the composition structure of the intensities of sub-functions) and maximizing differences among different functional types of villages, by adopting a hierarchical clustering method and Fisher's discriminant method, the optimal number of village multifunctional types is determined.

3.2.2. Identification of Influencing Factor

(1) Selection of Variables

Selection of dependent variables. Village multifunctional types, a kind of categorical variable, are considered as dependent variables.

Selection of independent variables. From the perspective of urban-rural relations, indicators that manifest urban demand scales and urban-rural allocation distance of production factors, are selected as the core variables to show the roles played by cities in the formation of village function types. (1) The city's scale determines the content and scale of market demand and provides the corresponding service content and capacity for rural areas. The population residing in the built-up area shows the scale of the city or town. (2) Urban-rural locational conditions can reflect the relationship between villages and their main markets or service centers. The distance of urban-rural allocation of production factors directly determines the possibility and economy of urban-rural flow of production factors. The distances between a city and a village, between the capital of a county and a village, and between a town and a village are selected to measure the locational relationship between villages and urban areas at different levels (Table 1).

Selection of control variables. The scale of the village, terrain conditions, traffic conditions, and characteristic local resources are selected as control variables which are objective, stable, universal, and can manifest the basic conditions of villages. A village's scale, as a basic element of village functions, is measured by the area and population of a village. Terrain conditions, as decisive factors of a village's functions and as causes for many natural environmental conditions, are measured by the degree of relief. Traffic conditions, as a basic support for the social and economic interrelation between rural and urban areas, can affect the formation of village functions and are measured by village road accessibility and traffic convenience degree, which can be calculated with the distance of a village to national highways and the road network density within a village at an administrative scale. Characteristic local resources are the prerequisites for villages to perform their own distinctive functions and are represented by water, mineral, and tourism resources.

Table 1. Variable Selection Table.

Variables	Type	Indicators	Remarks
Dependent variable	Multifunctional types	Type I Type II	Please refer to Section 4.2
Independent variable	Urban-rural locational conditions	Town-to-village distances [1]	Linear distance from the geographical geometric center of an administrative village to the administrative center of the township it belongs to
		County-to-village distances [1]	Linear distance from the geographical geometric center of an administrative village to the administrative center of the district/county it belongs to
		City-to-village distances [1]	Linear distance from the geographical geometric center of an administrative village to the administrative center of the city it belongs to
	Township and county scale	Population of township built-up area [2]	Resident population of township built-up area
		Population of county built-up area [3]	Resident population of district/county built-up area
Control variables	Village scale	Village area [4]	Area of each administrative village
		Village population [2]	Total population of each administrative village
	Terrain conditions	Relief [5]	Difference between the highest and the lowest altitude of a village
	Traffic conditions	Distances to national highways [1]	Nearest distance from the geographical geometric center of each administrative village to the national highway
		Internal road network density of villages [1]	Six levels of roads are included and they are highways, national roads, provincial roads, city roads, county roads, and township roads.
	Characteristic local resources	Distances to water system [1]	Nearest distance from the geographical geometric center of each administrative village to the water system
		Mineral resources endowment [6]	Number of mineral enterprises of each administrative village
		Tourism resources endowment [6]	Number of tourist attractions of each administrative village

Data was collected from [1] = National Catalogue Service for Geographic Information; [2] = China's Township Development Dynamics Survey (2018); [3] = Tai'an Statistical Yearbook (2019); [4] = the third land use survey of Tai'an city (2018); [5] = Geospatial Data Cloud; and [6] = Gaode map.

(2) Selection of Models

A logistic regression analysis model is employed to analyze the relationship between the probability of event occurrence and independent variables, and it is more suitable for the analysis of the problem in which the dependent variables are categorical ones. As the number of village multifunctional types may be plural, a multivariate logistic regression model is chosen to analyze influencing factors. The model is as follows:

$$\text{Log } it(P_i) = Ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{j=1}^{n}\beta_j x_{ji} \quad (2)$$

Of the model, P_i is the probability that the village multifunctional type becomes i kinds of types; x_{ji} is an independent variable, i.e., various factors that influence the formation of the village multifunctional types; β_0 is a constant term; and β_j is a regression parameter, representing the contribution rate of various factors to P_i.

4. Results

4.1. Rural Territorial Sub-Functions Mapped by Land Use Types

4.1.1. Level-III Land Use Types Are Combined and Categorized According to Homogeneity

The 32 basic land use types (level-III land use types) which show a homogeneity in their subject functions are amalgamated into 8 level-II land use types. To refine the internal division of rural productions, 12 level-III land use types, including irrigated land, dry land, land for commercial and business facilities, and land for science, education, culture, and health, are retained. Finally, 20 level-II land use types are sorted out (Table 2) without the special use of land.

Table 2. Mapping relations between rural territorial sub-functions and land use types.

Rural Territorial Sub-Functions	Land Use Types		
	Level-I Type	**Level-II Type**	**Level-III Type**
Service function	Land for the public, commerce, and business	Land for institutions and press	Land for institutions and press
		Land for science, science, education, culture, and health	Land for science, education, culture, and health and for higher education
		Land for public facilities	Land for public facilities
		Land for public squares	Land for public squares
		Parks and green plots	Parks and green plots
		Land for commercial and business facility	Land for commercial and business facilities
Industrial production function	Land for industrial storage and transportation	Industrial land	Industrial land
		Logistics warehousing land	Logistics warehousing land
		Land for transportation	Roads, highways, land for transportation service stations, land for pipeline transportation, and ports and wharves
Comprehensive function of forest and garden production and ecological conservation	Forest land and garden plots	Forest land	Arbor land, shrub land, bamboo land, other forest, other grassland
		Garden plots	Orchards, tea gardens, other gardens
Dry farming and mining production function	Dry land and mining land	Dry land	Dry land
		Mining land	Mining land
		Unused land	Bare land, bare rock gravel land, sand, and vacant land
Comprehensive function of production and ecological conservation of paddy agriculture and fishery	Paddy field and water area	Paddy field	Paddy field
		Land for water system and facilities	River surfaces, reservoirs, hydraulic construction land, lakes, inland beaches, pond surfaces, aquaculture ponds, main channels and ditches
Irrigating farming and facility agricultural function	Irrigated land and facility farmland	Irrigated land	Irrigated land
		Facility farmland	Facility farmland
Living function	Land for living	Homestead and roads of villages	Rural homestead and roads
		Land for urban residence and roads	Rural residential land, land for roads of cities and towns

4.1.2. Level-II Land Use Types Are Combined and Categorized According to Co-Occurrence and Synergy

The residential land and land for internal roads as villages' basic functions are directly combined and not considered in this paper as the mulitifunctional types of villages (Table 2) because they are commonplace and can provide a living guarantee for villagers. For the rest of the 18 level-II land use types, we use the principal component factor analysis method

and the Kaiser standardized maximum variance method to rotate the original variable load matrix and finally obtain a new factor load matrix table (Table 3) after seven times of rotation and the iteration converging. At this point, the KMO value is 0.789, and the significance test level is 0.000. According to the load contribution value of each level-II land use type to the new factor in the rotated component matrix, the eighteen level-II land use types are amalgamated into six level-I types, and thus, the mapping system between level-I types and rural territorial sub-functions is established (Table 2).

Table 3. Component matrix after factor analysis rotation.

Level-II Land Use Types	Common Factor 1 Land for the Public, Commerce, and Business	Common Factor 2 Land for Industrial Storage and Transportation	Common Factor 3 Forest Land and Garden Plots	Common Factor 4 Dry Land and Mining Land	Common Factor 5 Paddy Field and Water Area	Common Factor 6 Irrigated Land and Facility Farmland
Dry land	0.004	−0.179	0.229	**0.599**	−0.120	0.315
Paddy field	−0.009	−0.027	−0.04	−0.004	**0.843**	−0.073
Irrigated land	0.032	0.176	−0.276	−0.25	0.161	**0.587**
Facility farmland	0.016	0.057	0.038	0.125	0.049	**0.794**
Forest land	0.028	0.062	**0.756**	0.322	0.085	0.120
Garden plots	−0.01	0.042	**0.824**	−0.035	0.018	−0.167
Mining land	−0.004	0.298	−0.227	**0.726**	0.062	−0.095
Industrial land	0.245	**0.703**	−0.097	0.103	0.022	−0.057
Logistics warehousing land	0.060	**0.696**	0.026	−0.027	−0.019	0.033
Land for transportation	0.073	**0.598**	0.171	−0.019	−0.013	0.280
Land for institutions and press	**0.887**	0.04	−0.016	−0.001	0.001	0.009
Land for science, education, culture, and health	**0.762**	0.147	0.010	0.030	0.026	0.107
Land for public facility	**0.58**	0.236	0.027	−0.026	−0.004	−0.034
Land for public squares	**0.659**	−0.005	−0.017	0.025	−0.01	0.066
Parks and green plots	**0.884**	−0.098	−0.020	−0.002	−0.006	−0.066
Land for commercial and business facility	**0.796**	0.210	0.039	−0.032	0.038	−0.025
Land for water system and facilities	0.037	0.014	0.136	0.035	**0.760**	0.267
Unused land	−0.001	−0.041	0.248	**0.585**	0.051	−0.073

(1) Common factor 1: land for the public, commerce, and business—service function.

There are six land use types with a load value of over 0.500. They are land for institutions, press, and publication, land for science, education, culture, and health, land for public facilities, land for squares, land for parks and green plots, and land for commercial services. Among them, the former five types belong to public service lands and can reflect such main functions as social, living, and production-living functions [68–70]. The land for commercial service mainly meets commercial production, mapping the production function [68,69]. Therefore, we name the first common factor as the land for the public, commerce, and business to map the sub-function of rural territory, the service function, avoiding the unclear attribution of production, living, and social functions within the administrative range of a village.

(2) Common factor 2: land for industrial storage and transportation—industrial productions function.

The industrial land, logistics warehousing land, and land for transportation have a load value of over 0.500. Industrial land and logistics warehousing land are directly used in industrial production and storage, mapping a production function [68–70]. Land for transportation serves a wide range of objects and can map production, social, living, and living—non-agricultural production functions [68–71]. Roads that belong to land for transportation here refer to the roads outside villages and do not include those inside villages and mainly serve industrial production and logistic storage. Thus, the second common factor is named by us as land for industrial storage and transportation to map the sub-function of industrial productions function happening in rural territory.

(3) Common factor 3: forest land and garden plots—production of woods and gardens and ecological conservation.

The forest land and garden plots have a load value of over 0.700, showing a strong synergy and co-occurrence relationship and performing the functions of both wood and

fruit production and ecological conservation [68,69]. The naming of the third common factor is forest land and garden plots, mapping a comprehensive function of production of woods and gardens and ecological conservation in rural areas.

(4) Common factor 4: dry land and mining land—dry agriculture and mining production function.

The dry land, mining land, and unused land have a load value of over 0.500. The three land use types show a strong co-occurrence and synergy relationship and an outstanding territoriality in Tai'an city. The exploitations of coal and iron as key mining sectors of Tai'an city are mainly distributed in hilly areas. Most mining activities are conducted underground and the surface operation areas are quite small. Other exposed areas in mining areas are mostly used for dry farming agricultural production or ecological conservation. The naming of the fourth common factor is dry land and mining land, mapping the subject function of dry agriculture and mining production.

(5) Common factor 5: paddy field and water area—paddy agriculture and fishery production-ecological conservation function.

The paddy fields and land for water and facilities which show a strong dependence on water resources have a load value of over 0.700, reflecting a strong synergy and co-occurrence relationship. Paddy field has a clear function of paddy agricultural production while land for water and facilities possesses the functions of both ecological conservation [68–70] and fishery production [69]. The naming of the fifth common factor is paddy field and water area, mapping the comprehensive functions of paddy agriculture and fishery production-ecological conservation.

(6) Common factor 6: irrigated land and facility farmland—irrigating agriculture and facility agriculture production function.

The irrigated land and facility farmland have a load value of over 0.500. The main production mode of the two land use types is to achieve a stable and high yield of irrigating agriculture through a construction of related facilities. The naming of the sixth common factor is irrigated land and facility agriculture land, mapping the production function of irrigating agriculture and facility agriculture.

4.2. Structure of Administrative Village Multifunctional Types

Formula (1) is adopted to calculate the intensity of sub-functions of each village. The agglomerative algorithm is used to conduct cluster analysis, the Euclidean distance is adopted to measure the structural similarity of village's sub-functions, and Ward's minimum variance method is used to construct the hierarchical structure relations between village multifunctional types. With Fisher's method, it is found that when the number of village functional types is seven, the constructed discriminant function can explain all the variance and the significance level of Wilks' Lambda test is 0.000.

There are seven administrative village multifunctional types in Tai'an city (Figure 3), among which there is one integrated-function type with balanced functions of both industrial production and service (ISIVs) and six single-function dominant types, and the average intensity of the dominant function in a single-function dominant type is 3.37 times the secondary dominant function within the same village type. Named according to the dominant function, the single-function dominant type villages are industry-oriented villages (IVs, abbreviation), service-oriented villages (SVs), paddy farming and fishery-oriented villages (PFFVs), irrigating farming and facility agriculture-oriented villages (IFFAVs), dry farming and mining-oriented villages (DFMVs), and forest and garden-oriented villages (FGVs).

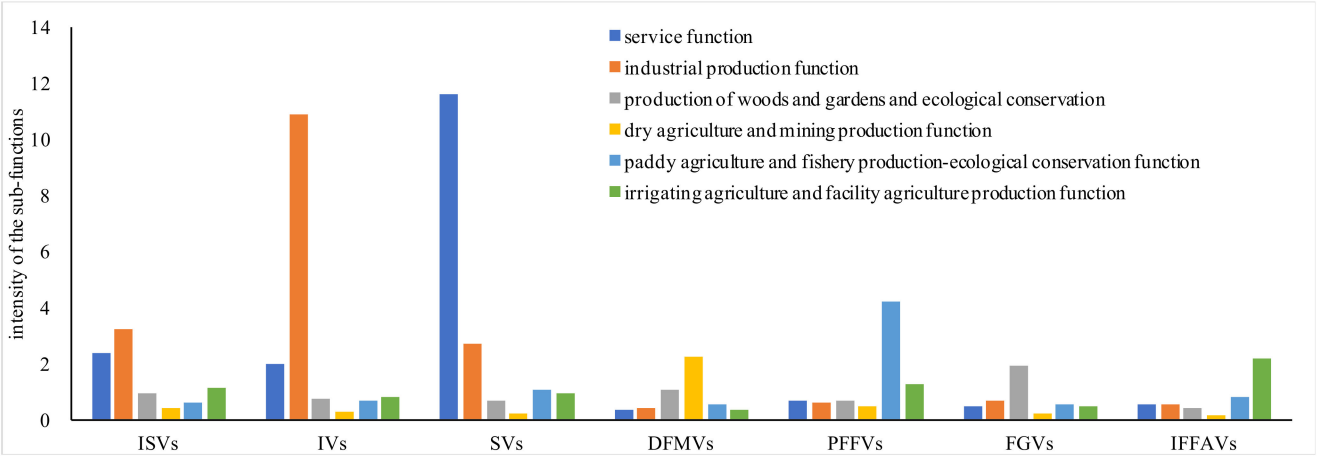


Figure 3. Statistical chart of the average functional intensity of each village type.

The numbers of all the types of villages in districts and counties of Tai'an city are shown in Table 4. First, IFFAVs and DFMVs are the two major types of villages in Tai'an city, accounting for 33.63% and 30.28% of the total villages respectively. Second, the distributions of IVs, SVs, and ISIVs in districts and counties are relatively balanced and their number differences are quite small. Third, the PFFVs, DFMVs, and DFMVs are relatively concentrated in Dongping county, Xintai city (a county-level city) and Daiyue district (at county level), accounting for 44.90%, 46.15%, and 44.09% of the same types of villages in Tai'an city respectively.

Table 4. District and county distribution of the multifunctional types of villages.

Types / Counties	IVs	SVs	ISIVs	PFFVs	IFFAVs	DFMVs	FGVs	Total
Daiyue district	9	21	40	44	160	122	164	560
Taishan district	9	10	21	1	5	0	47	93
Dongping county	8	37	36	132	303	120	31	667
Fengcheng city (at county level)	15	10	35	40	216	134	56	506
Ningyang county	26	15	41	35	241	120	9	487
Xintai city (at county level)	24	24	51	42	98	425	65	729
Total	91	117	224	294	1023	921	372	3042

In addition, it is also found that some functions have obvious synergistic and concomitant characteristics, such as the intensity values of the industrial production function and the service function of IVs, SVs, and ISVs are all greater than 1, and the intensity value of the comprehensive function of forest and garden production and ecological conservation of DFMVs is greater than 1, and the intensity value of the irrigating farming and facility agricultural function of PFFVs is also greater than 1.

4.3. Influencing Factors of Administrative Village Multifunctional Types

Among all the types of villages in Tai'an city, IFFAVs are of the largest in number, are distributed most widely, and their influencing factors have relative balanced eigenvalues. Thus, choosing IFFAVs as the reference type, this paper uses multivariate sequence logistics regression to analyze the key influencing factors of the other six types of villages. Table 5 shows the results of the regression analysis. The Cox and Snell pseudo-R^2 and Nagelkerke pseudo-R^2 values are 0.555 and 0.577, respectively, and the significance levels in the likelihood ratio test and Pearson goodness of fit are 0.000. The overall fit is good, and all factors excluding mineral resource endowment pass the likelihood ratio test.

Table 5. Logistic regression results.

Variables			Equation Regression Coefficient					
			ISIVs	IVs	SVs	PFFVs	DFMVs	FGVs
	Intercept distance		**11.758** ***	8.846 *	−9.213	−3.670	−8.412 **	9.140 **
Independent variables	Urban-rural locational relations	Town-to-village distances	**−0.284** ***	−0.001	**−0.464** ***	**0.301** ***	0.175 **	0.083
		County-to-village distances	**−0.466** ***	−0.091	0.078	**0.993** ***	**0.836** ***	1.221 ***
		City-to-village distances	**−1.262** ***	**−2.707** ***	−1.289 ***	**−1.589** ***	0.231	−3.169 ***
	Township size	Population of township built-up area	0.358 **	**1.400** ***	0.805 ***	0.037	0.237 *	−0.154
		Population of county built-up area	0.125	**1.120** ***	0.259	**0.702** ***	−0.134	**0.473** ***
Control variables	Village size	Village area	0.008	0.591	**−3.112** ***	**2.542** ***	**1.868** ***	0.400
		Village population	0.180	−1.048 **	**1.800** ***	**−1.753** ***	**−1.113** ***	−0.450
	Topographical conditions	Relief	**2.131** ***	0.594	**2.398** ***	**3.172** ***	**1.992** ***	**4.275** ***
	Traffic conditions	Distances to national highways	**−0.713** ***	**−0.736** ***	**−0.649** ***	−0.065	**−0.331** ***	**−0.448** ***
		Road network density	**1.130** ***	0.908 *	**1.237** ***	0.582 **	0.087	**0.944** ***
		Distances to water system	0.014	0.119	0.107	0.209 **	**−0.290** ***	0.229 **
	Characteristic local resources	Mineral resources endowment	0.916	1.763	1.836	−16.848	0.880	−17.744
		Tourism resources endowment	0.346	1.193 **	**1.453** ***	0.244	0.743 *	0.459

Note: "***, **, *" indicates significant at 1%, 5%, and 10% levels, respectively.

(1) Industry-oriented villages (IVs)

Comparing with IFFAVs, three findings are as follows (Figure 4a). First, IVs are closer to the built-up areas of cities than IFFAVs and have an inclination to higher-level cities, because their influence coefficients of city-to-village distance are significantly negative, while the absolute value of the influence coefficient ranks second in all types. Second, IVs are closely related to urban markets, because the identification of IVs is remarkably and positively affected by the sizes of population living in the built-up areas of towns and cities to which IVs are affiliated. Third, at county and township levels, IVs and IFFAVs are of similar distances to the respective townships to which they are affiliated. It thus can be concluded that the villages closer to high-ranking and large-scale towns and cities find it easier to undertake urban industrial transfer and develop non-agricultural industries by taking advantage of their lower production costs than urban areas, proximity to more high-ranking consumer markets, and traffic arteries.

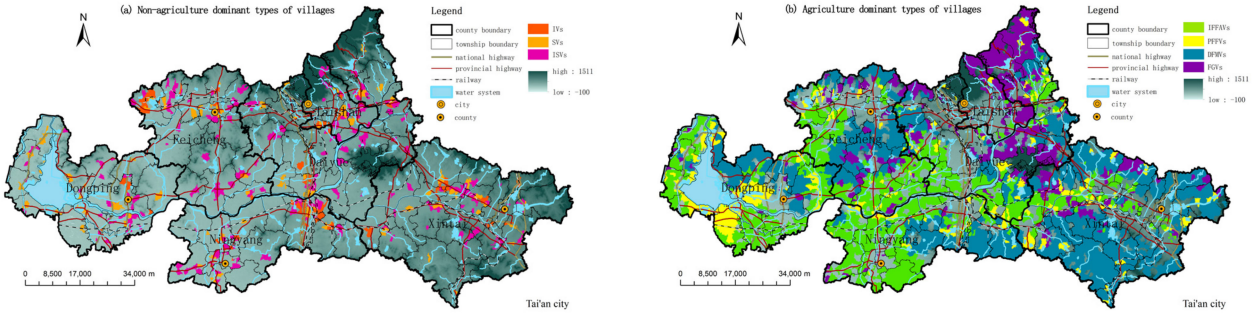


Figure 4. Spatial distribution of various types of villages.

(2) Service-oriented villages (SVs)

Comparing with IFFAVs, four findings are as follows (Figure 4a). First, at a township level, SVs show a clear inclination to township built-up areas with larger populations, which are significantly negatively correlated with township-to-village distance and significantly positively correlated with the population of the built-up area of the township. Obviously, villages that are close to the built-up area of the township with a larger market and that have more population and less land more easily develop specialized service industries through utilizing the advantages such as convenient transportation and rich tourism resources. Second, at the level of Tai'an city, SVs are closer to the city built-up areas and the influence

of city-to-village distance is significant at the 1% level, indicating that they are significantly influenced by service spillover from high-ranking central cities. Third, at the county level, SVs and IFFAVs are of similar distances to the townships to which they are affiliated. Fourth, the mean value of service function intensity of SVs reaches 11.61, indicating that SVs often have the highest level of specialization. Thus, SVs are of the least number and spatially they are distributed among accompanying IVs.

(3) Integrated-function type villages with both industrial production and service (ISIVs).

Comparing with IFFAVs, The ISIVs exhibit similar characteristics as IVs and SVs, such as proximity to cities and towns and more convenient transportation. All indicators characterizing urban-rural location and transportation conditions are significant at the 1% level. In contrast to IVs and SVs, ISIVs show inclination to county built-up areas, the influence coefficient of county-village distance has the largest negative value, and the traffic location conditions emphasize both accessibility and convenience (Figure 4a).

(4) Paddy farming and fishery-oriented villages (PFFVs)

Paddy and fishery productions are water resources-dependent industries and water resources of Tai'an city are located around Dongping Lake reservoir area, Dawen River basin, etc. Comparing with IFFAVs, three findings are as follows (Figure 4b). First, PFFVs as a whole show a characteristic of keeping away from towns and cities, especially far from the township and county built-up areas. The positive effects of town-to-village distances and county-to-village distances are significant at the 5% and 1% levels. Second, the relationship with the size of the urban market is not strong, and the population size of both the township and district built-up areas has no significant effect on it. Third, in areas with relatively abundant water resources, agricultural productions often have the practices of crop rotation and inter-planting in paddy farming, irrigating farming and facility agriculture, shaping an interval distribution pattern between PFFVs and IFFAVs.

(5) Dry farming and mining-oriented villages (DFMVs)

Mining production is a strong resource-dependent industry and dry farming is a rain-fed agriculture mainly based on the production of cash crops such as cereals and beans. Both are mostly distributed in low mountainous and hilly areas and develop together to achieve efficient land use. Compared with IFFAVs, DFMVs are often located in the places far away from the capitals of counties and towns with a larger population, which means that villages with higher altitudes, fewer people, and more land in the distant areas of the counties, or rich in mineral resources, have a higher probability of dry farming and mining production (Figure 4b).

(6) Forest and garden-oriented villages (FGVs)

Compared with IFFAVs, FGVs show a relatively special urban-rural relationship in location (Figure 4b). First, FGVs are farther away from the counties with a large population size. The positive influence of county-to-village distance is significantly higher than that of all the other types of villages. FGVs are typically mountainous villages with the smallest population, most land, and higher altitudes. Subject to the radiation of county built-up areas, remote villages are better positioned for forest and garden production and regional ecological conservation. Second, FGVs are closer to the built-up area of Tai'an city and the negative influence of city-village distance is significantly higher than that of the remaining village types. The urban district of Tai'an city is located on the southern slope of Mount Taishan and shows distinctive local geographical features. Villages closer to the urban area and with similar conditions, based on the market demand and ecological conservation needs of large cities, are more likely to produce such niche crops as sightseeing flowers, green seedlings, special tea and beverage products, and develop urban leisure agriculture, thus forming forest and garden typed recreational zones around the city.

4.4. Spatial Structure of Administrative Village Multifunctional Types

The differences in village functional types are jointly caused by the central towns and natural conditions of production. By measuring the distances from each type of village to the built-up areas of the townships, counties and city which they are affiliated to, we find that all types of villages show an outwardly expanding layer structure and their ranks in the circles are different (Figure 5).

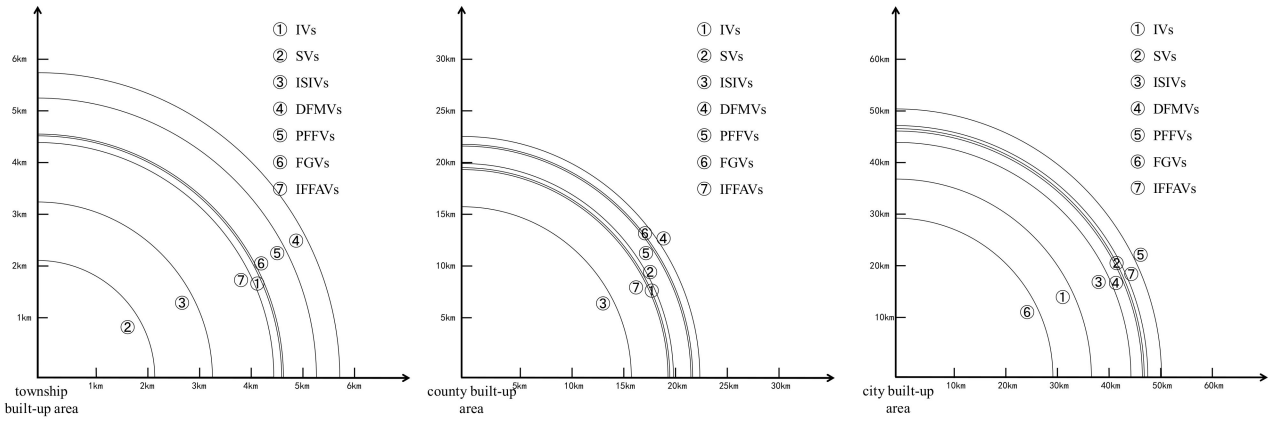


Figure 5. Layer structures of multifunctional village types centering the built-up areas of the townships, counties, and city.

When the central built-up area is affiliated to townships, the distance of the townships to all types of villages averages at 4.31 km and the circles show the smallest circle scales. In this regard, based on the feature of inclination to townships, SVs enter the first circle with an average distance of 2.12 km between villages and attached townships. The second circle is the IVs with an average town-to-village distance of 3.23 km and 1.11 km apart from the first circle. IFFAVs, IVs and SVs show smaller differences in distances between town-to-village distances, entering the third to fifth circles respectively. The three circles form an obvious agglomeration belt, and the average town-to-village distances of the three circles is 1.37 km away from the second circle. The relatively adjoining PFFVs and DFMVs enter the outermost circle and expand outward successively. The distance from the outermost circle to the agglomeration belt, which is formed by the third, fourth, and fifth circles, is 1.14 km. The interval distance of major types of village circles or agglomeration belts, centered on the township site, was found to be about 1.20 km.

When the central built-up area is affiliated to counties, the distance of the counties to all types of villages averages at 20.41 km, which is 16.10 km farther than the village-to-township distance, and the circle scales are significantly larger. Especially, ISIVs adjacent to county towns substitute SVs to enter the first circle with an average distance of 16.15 km between villages and the built-up area of the counties which they are affiliated to. IFFAVs, IVs, and SVs are spatially distributed together and have a similar average distance between villages and county towns, while they all belong to plain-dependent villages, forming an obvious agglomeration belt. The average county-to-village distance of the three circles is 19.38 km, with an interval of 3.23 km from the first circle. There is no significant difference in the location of PFFVs, FGVs, and DFMVs. The second obvious agglomeration belt is formed, with the average county-to-village distance of the three circles standing at 22.87 km, with an interval of 3.39 km from the first circle. The interval distance of the major type of village circle or agglomeration belt, centered on the county built-up area site, is found to be about 3.30 km.

When the central built-up area is affiliated to Tai'an city, the distance of the city to all types of villages averages at 43.06 km with the largest circle scales. The city-to-village distance is 22.65 km, farther than the county-to-village distance. More precisely, due to the mountainous location feature of the central city of Tai'an, FGVs enter the circle closest

to the city center, with an average distance of 29.30 km between villages and the central city. Based on the feature of inclination to high-ranking and large-scale cities, the second circle is IVs, with an average city-to-village distance of 37.29 km, which is 7.99 km apart from the first circle. The third circle is ISIVs, with an average city-to-village distance of 44.38 km, which is 7.09 km apart from the second circle. There is no significant difference in the location of DFMVs, SVs, and IFFAVs. An obvious agglomeration belt is formed, with the average city-to-village distance of the three circles standing at 46.73 km and with an interval of 2.35 km from the third circle. Because of their remote locations, PFFVs lie the farthest away from the central city, with an average distance of 50.28 km between villages and the central city, which is 5.90 km apart from the third circle. The interval distance of the major type of village circle, centered on the city site, is found to be about 7.00 km, and an agglomeration belt is distributed in the middle of the third and outermost circles.

The ranks of villages in each circle depend on their urban-rural locational relations between villages themselves (the areas relying on resources) and the central city or towns. Comparing the three-layer structures and the significance levels of the impacts of the urban-rural distances on each village type, two findings are as follows. First, non-agricultural villages are significantly influenced by the central city and are relatively close to the central town in the circle order. IVs mainly rely on market resources and have a directionality to high-level cities. SVs mainly orient to the service objects and have a directionality to townships. ISIVs are mainly market and service objects oriented and have an inclination to county built-up areas. Second, the circle order of agricultural production-oriented villages types (IFFAVs, PFFVs, DFMVs, and FGVs) in the central towns at all levels depends more on the result of the joint action of resource endowment, natural conditions, and urban-rural locations, and the overall spatial structure is distributed with increasing relief.

5. Discussion

5.1. Rural Territorial Muiltfunctions and Land Use Muiltfunctions Have a Mapping Link

By constructing a mapping relationship between rural territorial sub-functions and land use types and according to the hierarchy of interactions between land use types, the paper identifies seven rural territorial sub-functions. Compared with the existing multifunctional land use mapping system composed of "production, living and ecology", the mapping system proposed by this paper is more specific and detailed as the production functions are further divided firstly, which reaffirms the importance of the productive function in rural areas, with a variety of agricultural and non-agricultural production types. Second, this new mapping system always relies on the manifestations of the sub-functions to show the sheerer one-on-one mapping relations among the tiers of land use types. Thus, it can help highlight the functional externalities of land uses and avoid the divergences on the affiliation of land use functions. Third, from the perspective of spatial production, this new mapping system between multifunctional land uses and rural territorial multifunctions further expands the application scope of the land use identification method.

5.2. Diversified Characteristics of Administrative Village Multifunctional Types Are Obvious

The paper identifies and determines seven types of administrative village multifunctional types based on the interactions among villages sub-functions and among villages themselves and by adopting a hierarchical clustering method and Fisher's discriminant method. Compared with the descriptive statistical analysis method, this classification method, firstly, reduces the subjective role as much as possible, which is conducive to the objective identification of the distribution of the number of each village type in the region. It is found that IFFAVs and DFMVs are the dominant functional type of seven types of villages in Tai'an city and the distributions of IVs, SVs, ISIVs, and IFFAVs in each district/county are relatively balanced while PFFVs, DFMVs, and FGVs have a relatively concentrated distribution.

5.3. Administrative Village Multifunctional Types Are Significantly Influenced by Urban-Rural Relations

The paper identifies quantitatively the factors of urban influence on the multifunctional type of administrative villages using logistic regression by taking the multifunctional type of administrative villages as the dependent variable and the indicators that manifest urban demand scales and the urban-rural allocation distance of production factors as the core variables of investigation. The study corroborates on the one hand that urban-rural relations play an important role in the multifunctional type of administrative villages, which is found to be influenced by both urban-rural relations and natural production conditions. On the other hand, it is found that the role of different classes of central cities and towns in different types of villages is characterized by heterogeneity. Specifically, non-agriculture dominant villages are significantly influenced by urban-rural interactions. IVs have a directionality to high-level cities. SVs have a directionality to townships. ISVs have an inclination to county built-up areas. Agriculture-dominant villages are obviously restricted by their natural conditions and urban-rural location. PFFVs show a directionality to water resources. IFFAVs show a directionality to plain areas. IFFAVs show a directionality to mineral resources and mountains. FGVs with wood production and ecological conservation as the main function show a directionality to mountains and cities. The study makes up for the shortcomings of a large number of existing studies that have taken counties as the smallest unit to explore urban-rural relationships and provides a reference for scientific guidance on differentiated village development.

5.4. The Spatial Distribution of Administrative Village Multifunctional Types Has a Significant Layer Structure

The paper not only explores the influence of urban-rural relationships on the formation of administrative village multifunctional types, but also makes conclusions by calculating the distances of each type of village to different levels of central cities and towns and by drawing three circular structure maps. The ranks of each village type in each circle are different in terms of the different hierarchies of central cities or towns. The overall structure of the circle shows an expansion pattern of "non-agricultural production to agricultural production", which indicates that in the rapidly urbanizing China, the rapid spillover of urban development has caused the near-urban villages to take up part of the non-agricultural production functions, resulting in a change in the internal production structure of villages. This has led to a restructuring of village functions, rather than a complete change. On the other hand, centered on townships, county built-up areas, and cities respectively, the main circle and agglomeration belt of each type of village exhibit a spacing pattern of 1.20 km, 3.30 km, and 7.00km, indicating that the degree of siphoning and spillover effects of different levels of cities or towns on rural areas varies.

6. Conclusions

The study of rural territorial multifunction is a hot research topic in rural geography. In China, which is undergoing rapid urbanization and implementation of rural revitalization strategy, the thesis takes administrative villages as the research object and land plaques as regional function carriers and innovatively constructs the mapping relationship between land use types and the rural territorial sub-function system. By measuring the interactions among sub-functions, the structure of administrative village multifunctional types, which are a representation of functional externalities, is identified. This is also taken as the starting point of the study, focusing on the mechanism of urban-rural relations on the role and spatial distribution characteristics with different levels of central cities and towns.

This study, focusing more on small-scale units, is significantly different from existing studies in China and is closer to international studies, especially to European studies. However, compared to European studies, this paper has several differences and advances. First, the intensity measurement of sub-function uses the comparative index of location entropy, which is more favorable to measure the externality of sub-function compared with the indexes of evaluation index system, land size, and population density [24,34,36].

Second, on the basis of type division, this paper discusses the spatial distribution pattern of each type from the perspective of geography, especially through the circle structure composed of different levels of central cities and towns. Compared with discussion only on the characteristics of type division or singular circle structure centered only on one central city [72,73], this paper helps to revisit the compositeness and complexity of urban-rural relations. To put village studies in the bigger picture of urban-rural relations makes the understanding of village multifunctions more systematic. Third, this thesis allows deeper study on urban-rural relations. It quantitatively measures the impact of the urban-rural relationship on village functional types and verifies that the causes of rural territorial multifunctional types are more closely related to the rural participation in urban-rural labor division. In this connection, this thesis also provides an empirical supplement to the rural restructuring mechanism [19,20].

Therefore, this study opens up a perspective of urban-rural relations for the study of rural territorial multifunction. When formulating guidelines for rural regional development or laying out the elements of urban-rural development, the contents of urban-rural customs and the natural condition suitability system of rural land use should be considered, and rural development should not be explored separately from the comprehensive role of urban-rural regional systems.

Author Contributions: Conceptualization, X.Y. and M.W.; methodology, X.Y.; software, X.Y.; validation, X.Y. and M.W.; formal analysis, X.Y. and M.W.; investigation, X.Y. and M.W.; resources, M.W.; data curation, X.Y. and M.W.; writing—original draft preparation, X.Y.; writing—review and editing, X.Y. and M.W.; visualization, X.Y.; supervision, M.W.; project administration, M.W.; funding acquisition, M.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Key Research and Development Program of China (2018YFD1100803).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Land use data used in the paper were obtained from the local land management authority and are not publicly available. Geographic data, such as the data of terrain and rivers, was taken from Geospatial Data Cloud (http://www.gscloud.cn) on 10 May 2021. Vector data, such as administrative divisions and roads, was taken from the National Catalogue Service for Geographic Information (http://www.webmap.cn) on 10 May 2021.

Conflicts of Interest: The authors declare no conflict of interest.

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