

# Exploration of Land-Use Change and Drivers In Qixia City Based on Multi-Temporal Landsat8 Remote Sensing Image

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**Abstract.** The research results on land use and cover change (LUCC) are constantly updated, which is of great significance to correctly handle the relationship between human activities and ecological environment. In this article, Landsat8 remote sensing images, DEM data and statistical yearbook data of Qixia city in Shandong province are selected in 2013, 2018 and 2021 to explore the changes in this city's land use. Through supervised classification, land use dynamic degree (LUDD) and land use transfer matrix, LUCC has been analyzed, and through the CORREL and DEM slope analysis, the main driving force has been investigated. The results indicate that the area of orchards in Qixia city is showing an increasing trend and the area of farmland, water and residential land shows a decreasing trend. Single land use dynamic degree of industrial land is the largest. The main driving forces of the industrial land and the orchard area are the social economic factors, which are mainly manifested as the influence of the regional GDP, the gross product of primary and tertiary sectors as well as the gross value of agricultural produce. In addition, the population is what is causing changes in the amount of farmland and residential land, and the terrain slope also impact on the variation of land-use classification significantly.

**Keywords:** LUCC; LUDD; correlation coefficient; drivers; Qixia City.

## 1. Introduction

LUCC is an accessible way of expressing how human activity affects the ecosystem. It is one of the key components of the study of global environmental change and a significant component of the current study [1, 2]. Qixia City of Shandong Province is known as "Apple Capital of China" and "Ridge of Jiaodong". Hence, the exploration of LUCC and their motivating factors in this area are helpful for coordinating the growth of the forest and fruit industries in hilly areas and the wise use of land resources.

Current researchers mainly focus on the province, city, county, and key ecological reserve. With the help of remote sensing (RS) and geographic information system (GIS) technology, the combination of mathematical statistical analysis, land use variation, LUDD (including a single type and comprehensive type), land use transfer matrix, geographical detector, land use frequency changes etc., characteristics of the quantity, space and amplitude of land use cover change can be analyzed [3-5]. Liu Wenjuan et al. employed the LUDD and land use transfer matrix to examine the geographical and temporal changes in land use in the typical arid region of central Ningxia. They also utilized the land use transfer network to concentrate on the process and situation of land use change in the research area. According to the study, ecological projects have significantly enhanced the vegetation in the study area, and the land use pattern dominated by grassland has progressively developed [6]. In order to quantify the impact of human activities on land use change in the Tibet Autonomous Region, a thorough index model of land use degree was created by Chen Yiduo and colleagues. The overall level of the research region as well as the comprehensive change trend in land use can both be quantitatively described using this model. Their research demonstrates that the causes of LUCC in Tibet are highly complicated, and that human activity and climate change are major contributors to LUCC in the study region. [7]. A scientific foundation for land use planning and the prevention and control of soil erosion was provided by Yi Yanping et al., who used the hypothetical scenario method to construct the change scenario of land use overburden and analyze the impact of various scenarios on soil erosion using GIS and the soil and water assessment tool (SWAT). The findings of studies

looking at how changes in land use and cover affect geological disasters, water conservation, soil erosion, and other ecological environment changes are also being updated continuously [8-10]. New research findings on the alteration of land use and cover in Qixia City, Shandong Province, are, nevertheless, few.

Qixia city is located in the hinterland of Jiaodong Peninsula in Shandong Province. It is one of the county-level cities under the jurisdiction of Shandong Province and is managed by Yantai City. The geographic location is between north latitude 37°05'05" -37°29'46" and east longitude 120°32'45" -121°15'58", and the total area is 1,793 square kilometers. Located in hilly and mountainous areas, hilly lands make up 48.2% of the city's total area, while low mountainous parts make up 36.8%. Qixia has an East Asian continental monsoon semi-humid climate in a warm temperate zone, with distinct seasons and sufficient sunshine. The average annual temperature is 11.3 degrees Celsius and the average annual precipitation is 743.14 mm [11].

According to the RS image data of the years 2013, 2018, and 2021 from Landsat8, the land use status of Qixia city is categorized. Specifically, LUDD and transfer matrix are used to examine LUCC, distribution features, and drivers.

## 2. Data and Study Techniques

### 2.1. Data Source and Preprocessing

The Landsat8 OLI remote sensing image data in 2013, 2018 and 2021 and the 30 m resolution digital elevation model (DEM) data of Qixia City were all from the Geospatial Data Cloud (<https://www.gscloud.cn>). ENVI 5.3 was used for radiation calibration and FLAASH atmospheric calibration of the three-phase Landsat8 remote sensing images, and then the administrative boundary of Qixia City was used for image clip. The administrative boundary vector data was obtained from the Georemove Sensing Ecological Network (<http://www.gisrs.cn>). Slope analysis of the DEM was performed using ArcGIS. Data from the relevant Statistical Yearbook of Qixia City were also used in this study.

### 2.2. Classification of RS Images

Firstly, ISODATA method in ENVI 5.3 was used for unsupervised classification of RS images, roughly determining the categories of land classes. Secondly, the visual interpretation was used to select training sample, thus distinguishing 7 kinds of land use classes except the background (water, residential land, industrial land, farmland, orchard, arbor forest and other forest land), and calculating the separation of training sample was greater than 1.9, meeting the research requirements. The neural network method was used for the supervised classification. Combined with the comparison of high-resolution satellite maps such as Google Earth, the validation samples was selected to verify the accuracy of the results of supervised classification. The total precision was 97.51% and Kappa value was 0.97.

### 2.3. Analysis of LUDD

One technique for examining the magnitude and rate of acreage alternation of land-use in a given area over a specific period of time is the LUDD [12]. In this study, the magnitude and rate of quantitative changes of the primary land use categories in Qixia city between 2013-2018 and 2018-2021 were examined using LUDD single. Its expression formula is

$$K = \frac{U_b - U_a}{U_a} \times \frac{1}{T} \times 100\% \quad (1)$$

K denotes a land type's single dynamic land use degree over a given time span in the study area. T is the length of time used in this computation, and land use area change is represented by  $U_a$  and  $U_b$  in the initial and final phases, respectively.

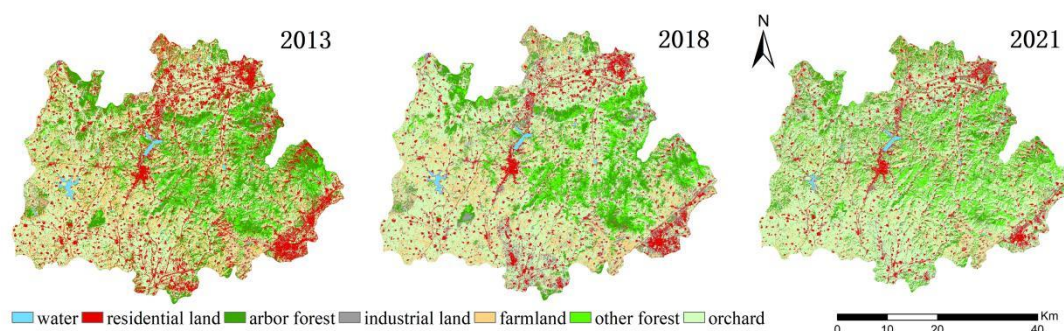
## 2.4. Land Use Transfer Matrix

The land use transfer matrix, which can clearly display the total area of land use types in different eras as well as the area alternation and transfer, is one of the prominent techniques to examine LUCC. In this research, the land use transfer matrices for the years 2013–2018 and 2018–2021 were also generated using ENVI 5.3, which was also used to construct the distribution map of land use classes.

## 3. Results

### 3.1. Classification Results

According to the supervised classification results, as can be seen from Figure 1, the main land use classes in Qixia city include water, residential land, industrial land, arbor forest, other forests, orchards and farmland. The orchard area was the largest and showed an increasing trend. Farmland, residential land, and arbor forest all saw significant decreases in area while industrial land saw a large increase.



**Fig. 1** Major Land Use Class Distribution Map for Qixia City in 2013, 2018, and 2021.

### 3.2. Analysis of the Land Use Transfer Matrix

Table 1 and Figure 2 demonstrate that residential property, arbor woodland, and farming accounted for the majority of the increase in orchard area. The orchards created from farmland were larger and more widely scattered, whereas those created from residential land were mostly located in the south and southeast. The increase of industrial land area mainly came from the residential land and orchards. The industrial land converted by residential land was distributed in the southeastern edge and southern and northern areas, while the industrial land converted by orchards was mainly concentrated in the south.

As can be seen from Table 2 and Figure 3, the increase in orchard area mainly originated from farmland, arbor forest and industrial land, and the orchard area reached 954.04 km<sup>2</sup> in 2021. The area of industrial land had been reduced, and the reduced industrial land was mainly converted into orchards and arbor forest. Orchards that were converted to industrial land were primarily dispersed in the south, and arbor forests that were converted to industrial land were primarily distributed in the north and northwest.

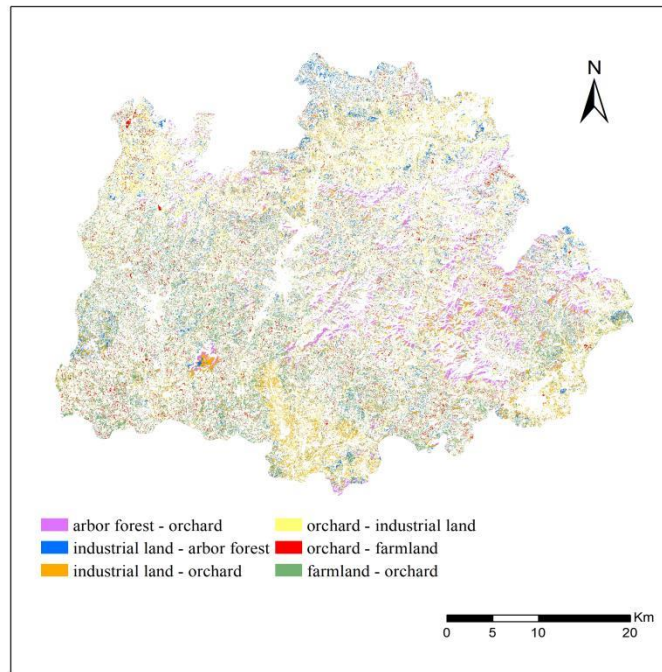
Tables 1 and 2 show that the area of farms and villages continued to shrink, and it did so significantly. The majority of the cropland that was reduced was turned into orchards, while the majority of the residential land that was reduced was turned into industrial land.

**Table 1.** Major LUCC Transfer Matrix in Qixia City from 2013 to 2018.

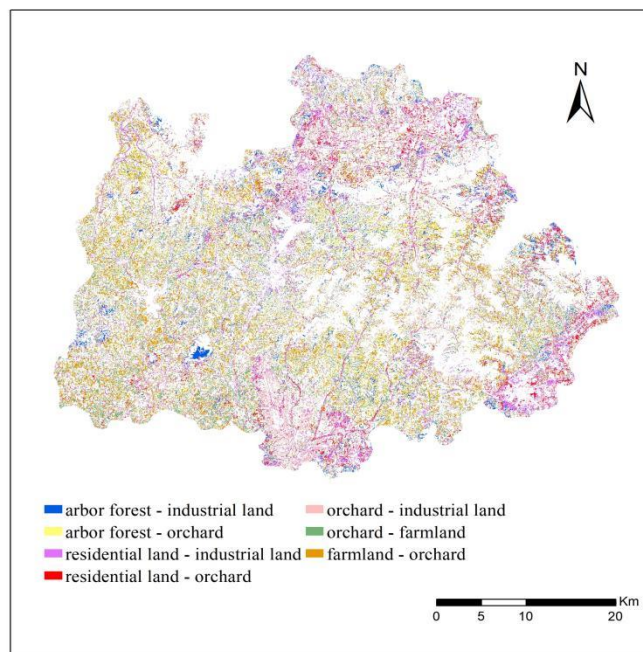
	Water	Other Forests	Residential Land	Arbor Forest	Industrial Land	Farmland	Orchard	In Total
Water	14.87	0.03	0.72	0.31	0.03	0.04	0.08	16.08
Other Forests	0.05	73.87	1.72	57.79	0.01	0.04	13.76	149.23
Residential Land	4.67	73.87	129.4	14.84	6.35	3.77	12.17	171.92
Arbor Forest	0.05	9.18	5.57	190.47	0.06	1.46	25.83	232.63
Industrial Land	0.71	2.62	119.49	75.28	22.85	25.91	95.07	341.93
Farmland	0.05	0.20	25.41	20.91	9.97	130.34	93.43	280.31
Orchard	0.14	0.80	76.00	83.23	8.58	126.41	528.87	824.03
In Total	20.54	87.43	358.31	444.83	47.85	287.97	769.20	

**Table 2.** Transfer Matrix of Main LUCC in Qixia City from 2018 to 2021

	Water	Other Forests	Residential Land	Arbor Forest	Industrial Land	Farmland	Orchard	In Total
Water	10.71	0	0.58	0	0.06	0.01	0.02	11.37
Other Forests	0.01	88.95	0.80	44.62	0.01	0.04	13.76	139.49
Residential Land	3.09	0.34	113.20	0.83	25.18	1.93	4.07	148.64
Arbor Forest	0.90	24.94	9.37	103.65	63.32	17.78	76.68	296.63
Industrial Land	0.92	8.49	29.05	20.81	101.15	24.25	95.62	280.28
Farmland	0.10	0.15	6.69	3.46	24.13	98.22	52.92	185.68
Orchard	0.36	26.35	12.23	59.27	124.18	138.11	593.54	954.04
In Total	16.08	149.23	171.92	232.63	341.93	280.31	824.03	



**Fig. 2** Distribution Map of Main Land Use Classes in Qixia City from 2013 to 2018



**Fig. 3** Distribution Map of Main Land Use Classes in Qixia City from 2018 to 2021

### 3.3. Analysis of LUDD Single

According to the LUDD single equation, Table 3 shows the change and area dynamic degree of the key LUCC in the two study periods.

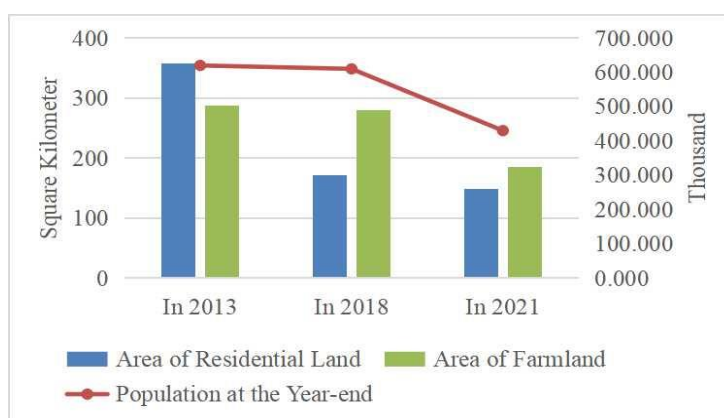
**Table 3.** Area Changes and LUDD in Qixia City between 2013 and 2021

	2013-2018		2018-2021	
	Area change/Km <sup>2</sup>	Single Land Class Dynamic Degree/%	Area change/Km <sup>2</sup>	Single Land Class Dynamic Degree/%
Residential Land	-186.39	-0.104	-23.28	-0.0451
Industrial Land	294.08	1.2292	-61.65	-0.0601
Farmland	-7.66	-0.0053	-94.63	-0.1125
Orchard	54.83	0.0143	130.01	0.0526
Arbor Forest	-212.20	-0.0954	64.00	0.0917
Other Forest	61.80	0.1414	-9.74	-0.0218
Water	-4.46	-0.0434	-4.71	-0.0976

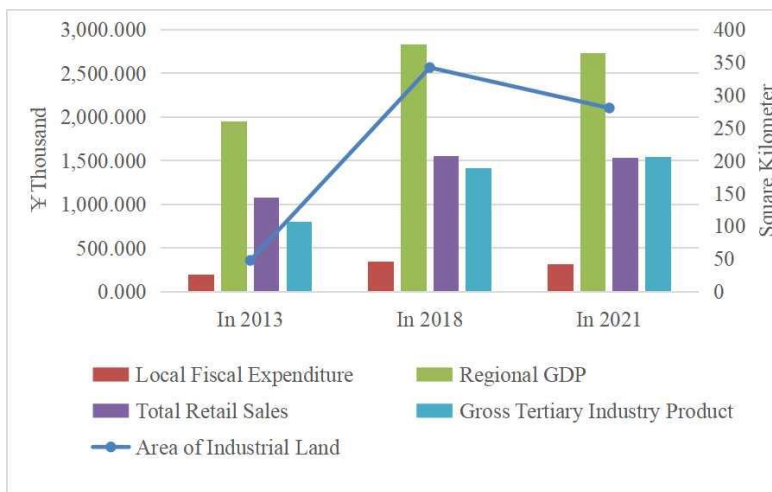
Between 2013 and 2018, industrial land experienced the greatest change (an increase of 294.08 Km<sup>2</sup>), and its single land class dynamic degree was also the largest. Between 2018 and 2021, the orchard region experienced the most change, while the farmland's single land class dynamic degree underwent the most change. In contrast to the water, farmland, and residential land, the orchard area expanded while changing more gradually during both periods. Residential land area sharply decreased during the first period, while cultivated land and water bodies sharply decreased during the second.

### 3.4. Exploration of Motivating Factors in LUCC

The correlation coefficient was computed (Table 4) using the pertinent information from the Qixia City Statistical Yearbook and the variable-area of land-use in 2013, 2018, and 2021, and the drivers was examined in conjunction with the change in terrain slope.



**Fig. 4** Relationship between the Changes of Population at the end of the year and the Area of Residential Land or the Farmland in Qixia City from 2013 to 2021



**Fig. 5** The relationship chart between industrial area and local fiscal expenditure, regional GDP, total retail sales and regional GDP of tertiary industry in Qixia City from 2013 to 2021

Figure 4 exhibited the alternation in the city of Qixia's overall population at the end of the year was favorably connected with the variation in settlement area and farmland (the correlation coefficient was 0.6148 and 0.9995).

As can be seen from Figure 4, the alteration of the total population at the end of the year of Qixia city was positively correlated with the variation of settlement area and farmland (the correlation coefficient was 0.6148 and 0.9995). The correlation coefficient (Table 4) demonstrated that the acreage of industrial area was positively correlated with the GDP of the tertiary industry, local fiscal expenditure, regional GDP and retail sales of consumer goods with the correlation coefficient close to 1, while it was negatively correlated with total population at the end of the year. It can be intuitively seen from Figure 5 that the acreage of industrial land first rose substantially and then declined slightly, which was consistent with the change trend of local fiscal expenditure, regional GDP and total retail sales. Consequently, it can be concluded that these three variables are the primary forces behind the modification of the industrial land area.

The acreage of farmland was positively correlated with the total population at the end of the year, grain yield, the oil crop yield and the total power of agricultural machinery. The decrease of farmland area affected grain yield to some extent, and it had the greatest impact on oil crop yield. The positive correlation coefficient between total population at the end of the year and the farmland area was close to 1, indicating that the population change in these years was the main driving force in social economy aspect for the decrease of the farmland area in Qixia City. As can be seen from Figure 6, the slope of most areas in Qixia city was greater than 6.8, so the area suitable for farmland was small. Therefore, the terrain slope was the main driving force of the natural factors for the change of farmland area while demographic change is the main social driving force.

The gross value of agricultural output and the gross product of the primary industry were positively correlated with the orchard area (the correlation coefficient was greater than 0.94), and the population change showed an obvious negative correlation with orchard area. It can be intuitively seen from Figure 7 that the gross value of agricultural output and the gross product of primary industry have the same change trend as the orchard area. From the social and economic perspective, the gross value of agricultural output and the gross product of the primary industry are the main driving forces for the increase of the orchard area. Figure 5 and Figure 2 and Figure 3 indicate that the area of farmland, residential land, industrial land having changed into orchard mainly distributed in the slope area of 6.8-16.7. The places where arbor forest converted to orchards was mainly distributed in areas with slopes of 16.7-20.6. Therefore, from the perspective of natural conditions, the terrain slope was the driving force of orchard area.

**Table 4.** LUCC Correlation Coefficients in Qixia City from 2013 to 2021

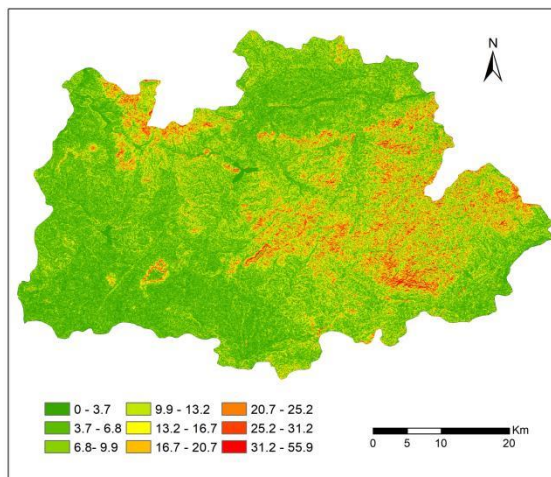
Correlation Coefficients				
	Area of Industrial Land		Area of Farmland	Area of Orchard
Regional GDP of the Tertiary Industry	0.93	Grain Yield	0.6152	-0.776
Local Fiscal Expenditure	0.9999	Oil Crop yield	0.9005	-0.9749
Regional GDP	0.9958	Gross Value of Agricultural Output	-0.8467	0.9443
Total Volume of Retail Sales of Consumer Items	0.9853	Total Output of Agricultural Machinery	0.5772	-0.7453
Gross Value of Industrial Output	0.2971	Regional GDP of the Primary Industry	-0.8539	0.9487
Regional GDP of the Secondary Industry	0.3399	Fruit Yield	-0.7052	0.8460
Total Foreign Trade Value	0.3859	Regional GDP	-0.4635	0.6500
Population at the end of the Year	-0.3528	Annual Mean Rainfall	-0.7248	0.8606
Regional GDP of the Primary Industry	0.8064	Population at the end of the Year	0.9995	-0.9674

#### 4. Discussion

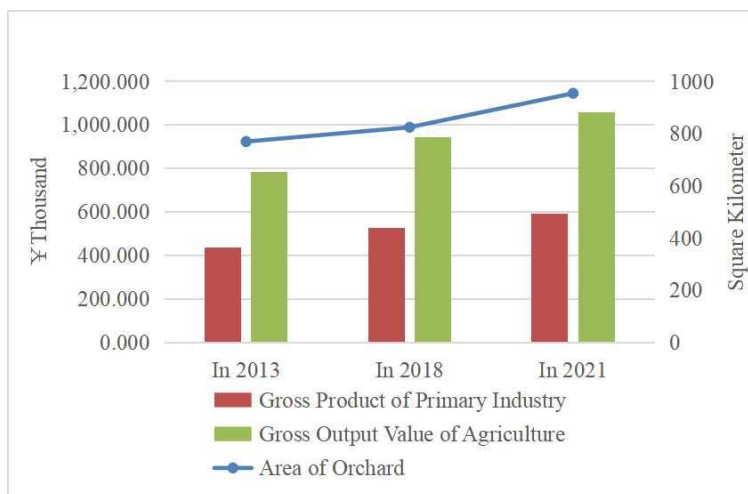
Social and economic factors, which are primarily expressed in the impact of the regional GDP, the gross value of agricultural output, and the gross product of the primary and tertiary industries, are the major driving forces behind the industrial land and orchard area in Qixia City.

From the perspective of the social economy, the increase of industrial land area is partially financed by the rise in the regional GDP and the expansion of local budgetary spending. Expanding the industrial land area can raise scale efficiency and boost output volume. To some extent, this can accelerate the regional GDP and the total retail sales, driving the development of regional industry and commerce, and further lead to the increase of the gross tertiary industry product. The increase of orchard area greatly accelerated the gross product of the primary industry in Qixia. The development of the fruit industry in Qixia focused on the deep integration of fruit deep processing and the whole industry chain, which required more mechanical processing factories to assist in the deep processing of fruit, which also drove the increase of the industrial land area.

From the perspective of natural conditions, because Qixia is mountainous and hilly, and not adjacent to the sea, the traffic conditions are limited, and the economic development is also affected to a certain extent, which lead to the serious population outflow in the region. At the same time, the terrain slope also has an impact on the orchard area and the farmland area. According to Figure 5, it can be seen that the areas with slope less than 3.7 are scattered, which is not suitable for large-scale mechanized farming, while the gentle slope area with slope of 3-15 is concentrated. Therefore, most areas of Qixia City are suitable for mechanized planting orchards. Because of that, the orchard area remained increasing in the case of the population decline. According to the plan formulated by the People's Government of Qixia City, returning farmland to forestry/grassland can be gradually realized in the areas with a slope above 25 degrees. Therefore, it can be simply predicted that the forest area of Qixia City will increase, and the orchard planting industry will develop further in the future.



**Fig. 6** Distribution Map of the Topographic Slope Change of Qixia City



**Fig. 7** The relationship chart between orchard area and regional GDP of primary industry and total value of agricultural output in Qixia City from 2013 to 2021

## 5. Conclusion

The orchard area was the biggest and showed an increasing trend year over year among the major land uses in Qixia City during the study period, while the farmland and residential land area were relatively small and showed a decreasing trend. Industrial land saw the greatest alteration between 2013 and 2018, and farmland and water saw relatively significant variation in land utilization from 2018 to 2021. The principal shifts in land use were a reduction in cultivated land and domestic land area and an increase in orchards and industrial land. While the expanded orchard area mainly from farmland, and the expanded industrial land area mainly from residential land and orchards.

The main drivers of the industrial land and orchard area in Qixia City were the social and economic factors, which were mainly manifested as the influence of the regional GDP, gross value of agricultural output and the gross products of the primary and tertiary industries. In terms of natural factors, the geographical location and topographic factors of Qixia City restrict the transportation the economic development to a certain extent, resulting in the serious population outflow. The region of farmland and orchards is also somewhat influenced by the topographic slope.

This research only looked at one aspect of the terrain when analyzing how natural conditions affected how land use changed in Qixia City. This needs to be expanded upon and improved.

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