Simulation and Optimization of Urban–Rural Settlement Development from the Perspective of Production–Life–Ecology Space: A Case Study for Aksu City

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Abstract: To explore the future development state of urban and rural settlements, we combined random forest algorithm (RFA) and cellular automata (CA) to simulate high precision in urban and rural settlements in Aksu city. The settlement distribution was predicted for the next 10 years, and suggestions for urban and rural settlements were proposed based on a “production–life–ecology” space. The results show the following: Transportation factors and administrative location have an important influence on the development of settlements, and infrastructure has a greater impact on the development of settlements. The overall accuracy of the 2019 settlement distribution obtained through the RFA–CA model simulation is 93.8%, with a G-mean coefficient of 0.815. The simulation accuracy is better and more suitable for the simulation and prediction of settlement expansion than the logistic-CA model. The forecasted settlement expansion in 2029 for Aksu city is 58.36 km² of settlement expansion compared to the 2019 settlement distribution, with an overall growth trend for sparse north-south and dense central areas. This study analyzed the causes of settlement expansion in 19 regions of Aksu city, explored the main function of “production–life–ecology” space in different areas, and proposed layout optimizations from the perspective of production, life, and ecology. The results of this study can provide a reference for the spatial planning and rural revitalization strategy of Aksu city.

Keywords: production–life–ecology space; RFA–CA model; urban and rural cluster; prediction

1. Introduction

Since the 21st century, China has made remarkable progress in urbanization [1], and the gap between urban and rural development has gradually widened, which in turn has led to vacant rural land, decreased agricultural production, older, weaker, and sicker people dominating rural society, and stunted rural development becoming urgent national problems [2,3]. The development of urban–rural integration has been inextricably linked since the 18th National Congress, but it is difficult to explore urban or rural areas alone to meet the demands of urban–rural integration development in China in the new era [4]. Urban and rural settlements face problems of ecology, environment, resources, population movement, land use, and regional spatial changes [5–10], which have led to the uneven development of urban and rural settlements. This requires people to explore ways to maintain good economic, ecological, and social development benefits between urban and rural areas. In fact, this is an important basis for the management of cities at all levels. The differences in industrial nature and scope have divided urban settlements and rural settlements. Compared to urban settlements with large scale and high building density, rural settlements are mostly distributed with scattered low-rise buildings, fewer roads, lower road quality, and agricultural production as the main mode of economic development.
In recent years, the study of urban and rural settlement development in the northwest arid zone has become a research topic for many scholars [11–14]. Simulating and predicting the future state of urban and rural settlement development in the oasis zone can provide a reference for urban and rural layout and planning and put regional urban and rural settlement development on a sustainable development path.

Cellular automata (CA) models are commonly used for the simulation of self-organized development processes because of their spatial operations and ability to invert complex system diffusion processes [15]. Since the 1980s, CA models have received attention from geographers and have been widely used in the fields of LUCC change simulation [16], geomorphological evolution, and urban diffusion [17–19]. Driven by foreign research, many domestic geographers have used CA combined with GIS applications in the study of future land development scenarios. Chenghu Zhou proposed the concept of geographic metacells and constructed the GeoCA-Urban model based on the DUEM model [20]; Xia Li et al. created the artificial neural network-CA(ANN-CA) model as applied to land use and cover change (LUCC) simulation [21]; and Ping Luo and Chunyang He [22] extended the urban CA model based on different perspectives. To adapt the simulation accuracy of CA in different land types, several models, such as the ANN-CA model [23], Logistic-CA [24], and decision tree-CA (DT-CA) model [25], were gradually refined in predicting future land types to build a good platform for urban and rural settlement evolution simulation. Among many models, the random forest algorithm (RFA) has excellent data mining ability and prediction accuracy and is suitable for solving problems such as the classification of multiple sites [26,27]. The RFA has high tolerance for outliers and noise and can artificially control the root nodes of decision trees, thus avoiding overfitting and obtaining high simulation accuracy [28]. The RFA can combine out-of-bag (OOB) data to calculate the importance of feature variables from a large dataset, thus revealing the complex relationships of various feature variables. Compared to other models, the RFA–CA model is easier to construct and allows individual spatial variables to be correlated [27].

Since the 19th National Congress, the state council has clearly put forward the basic requirements for the delineation of “three spatial zones”, and land use planning should gradually move from a production-oriented space to a comprehensive spatial development situation in which the “production–life–ecology” spaces are coupled and coordinated [29]. The expansion of urban and rural settlements is a very complex socioeconomic process, and production–living–ecological spaces are important vehicles for the development of urban and rural settlements [30]. Taking urban and rural settlements in Aksu city as the research target area and combining data such as urban and rural settlement data from 2009 and 2019, we explored the spatial expansion simulation of urban and rural settlements under the influence of the production–life–ecology spatial factors, and empirically prove the production–life–ecology spatial effects on settlement development research to provide a new research idea for the optimal layout of global settlement development.

2. Study Area Overview and Data Sources

2.1. Study Area Overview

Aksu city is located in the southwestern Xinjiang Uygur Autonomous Region, with typical warm temperate continental arid climate characteristics. The geographical coordinates are 39°30′ N~41°27′ N, 79°39′ E~82°01′ E. The average temperature throughout the year is 10.8 °C. The climate is dry, and the frost-free period is long because of scarce precipitation and high evaporation. The topography decreases from northwest to southeast, and its settlements are mainly distributed along the alluvial fan of the Aksu River. Aksu city has jurisdiction over a total area of 14,415 km², including 6 subdistricts, 2 towns, 4 townships, 6 township-level units and the regiments, with urban settlements covering 43.65 km² and rural settlements covering 43.83 km². The total population of the city has reached 551,000, among which the urban population is 341,500 and the rural population is 209,800. Aksu’s local GDP reached 204.291 billion yuan. Regarding industry, the added value of the primary industry reached 22.358 billion yuan, the secondary industry 60.285 billion
yuan, and the tertiary industry 121.647 billion yuan. Figure 1 shows, Since Aksu city is administratively divided into enclaves and the southern part is a desert area, which is not suitable for human habitation, it was not used as the object of this paper.

Figure 1. Aksu city overview map.

2.2. Data Source

This study extracted data of urban and rural settlement land, agricultural land, industrial and mining land, and commercial land. Combining the “Aksu Regional Town System Plan (2013–2030)” and “Restrictions on Construction and Mining along Roads and Railways”, we extracted all levels of roads, infrastructure land, squares and parks, township centers in the Aksu city land use data. According to the “Urban Land Vertical Planning Code (CJJ-83-99)”, “Regulations on the Protection of Basic Farmland”, and the relevant provisions in the “Thirteenth Five-Year Plan for Environmental Protection in Aksu District”, we extracted the data of the watershed protection zone and permanent basic protection farmland in the Aksu city land use data. The land use vector data could reduce the errors brought by supervised classification and visual interpretation. The land use vector data could reduce the errors caused by supervised classification and visual interpretation and have higher accuracy. Water system data and scenic tourist spots were extracted from Xinjiang vector data. The spatial variables for the simulation of urban and rural settlements were obtained by using the ArcGIS Euclidean distance function for each type of land. In addition, the altimetric data of Aksu city were obtained from the geospatial data cloud, and the slope was extracted as a natural environmental element using ArcGIS.

3. Research Methodology

3.1. RFA–CA Model

The RFA–CA model was used to simulate the changes in urban and rural settlements in Aksu city. This paper is divided into two steps: (1) training the RFA–CA transformation rules using the urban and rural settlement data and the “production–life–ecology” spatial characteristics variables in 2009; (2) using the 2019 settlement data as the initial data, the trained transformation rules and spatial variables are used to predict the distribution of urban and rural settlements in 2029, and the RFA integrates multiclass classifiers by training M-tree decision trees using the powerful processing power of RFA classification. The probability $P_{ij(t)}$ can be accurately calculated for tuple $j$ to become a colony site or a
non-colony site at moment $t$. $P_i$ is the probability that the data $\theta$ will be divided into colony sites or non-colony sites.

$$P_i(j, l, t, i) = \frac{I(h_i(\theta) = Y_i)}{M} \quad (1)$$

$$H(x) = \arg\max_{i=1}^M I(h_i(x) = Y_i) \quad (2)$$

In the formula, $H(x)$ is the classification result of the RFA model, $h(x)$ is the classified category of the single decision tree, and $I(*)$ is the indicator function of the classification result of the clusters.

The neighborhood effect was calculated. The transformation of a particular cell in the CA model into a colony land state is the result of the joint influence of the surrounding cell states, and the colony cell neighborhood function can be expressed as:

$$\Omega'_k = \sum_{n \times n} \text{con}(S'_k = \text{Landuse}_i)$$

$$n \times n - 1 \quad (3)$$

In the formula, $\Omega'_k$ denotes the value of the $n \times n$ neighborhood action of the tuple at moment $k$, $n > 3$; $\text{con}(*)$ is the conditional function; $S_{ti}$ represents the current state of the tuple; Landuse is the land use category, and in the simulation of colony expansion with the CA model, the value of 1 is assigned to the tuple transformed into colony land use; otherwise, it is 0.

Stochastic factor part: In addition to the influence of the spatial elements of the “three lives”, the change in the settlement is also due to policy changes, economic development and other factors that are difficult to quantify, and to reflect these uncertain random factors, the model introduces random factors.

$$RA = 1 + (\ln \gamma)^\alpha \quad (4)$$

$RA$ is a random factor, $\gamma$ is a random number in the range of $(0, 1)$, $\alpha$ is an integer taking the value of $(1, 10)$, and $\alpha$ takes the value of 2 to minimize the influence of uncertainties on the change of clusters.

The simulation of settlement change must consider objective spatial constraints [27] such as basic farmland protection zones, ecological protection zones, surface water control construction zones, and other restricted development units. The spatial constraint interval for colony simulation can be expressed as:

$$\text{con}(S'_{ij}) = \begin{cases} 0 & \text{Metacells are prohibited from developing into settlement} \\ 1 & \text{Metacell development as a settlement} \end{cases} \quad (5)$$

where $\text{con}(S'_{ij})$ represents whether the metacell at moment $t$ can be developed into a settlement site, with a predetermined value of 0 for the restricted development zone $S'_{ij}$.

$$P_{ij}^{t+1} = RA \times P_{ij} \times \text{con}(S'_{ij}) \times \Omega'_{ij} = (1 + (\ln \gamma)^\alpha) \times P_{ij} \times \text{con}(S'_{ij}) \times \Omega'_{ij} \quad (6)$$

Whether a metacell transforms into a colony is determined by the following conditions:

$$\begin{cases} P_{ij}^t \geq P_{\text{threshold}} & \text{Conversion of settlement sites} \\ P_{ij}^t \leq P_{\text{threshold}} & \text{Non – conversion of settlement sites} \end{cases} \quad (7)$$

In the formula, $P_{\text{threshold}}$ is the threshold value for conversion to settlement. When it is greater than the set threshold, the location cell is transformed into a colony.
3.2. Production–Life–Ecology Spatial Variable Construction

The change in land use in settlements is affected by the interaction of living, production, and ecological space and presents different development scales and states. Living space refers to the place used for people’s daily living activities; production space mainly refers to the regional space where production and operation activities provide services. Ecological space refers to the natural environment and the area with ecological protection. The spatial framework of “production–life–ecology” space is used to construct the driving factors of urban and rural settlement development, and the five functional dimensions of accessibility, convenience of living, industrial category, location, and natural environment are used as the spatial variables of urban and rural settlement land development.

As shown in the Figure 2, seven impact factors were selected in the living space considering the convenience of living and transportation for the settlement residents. For convenience of life, distance to squares and parks, distance to infrastructure land, distance to town center were selected; for convenience of transportation, distance to national and provincial roads, distance to highways, distance to general roads, and distance to railroads were selected. In the production space, five impact factors were selected from three industries: the distance from the first industry to the agricultural land, the distance from second industry to the industrial land and mining land, and the distance from the third industry to commercial and service land and scenic spots. Restricted development zones were set in the ecological space, including permanent basic farmland, wetlands, and ecological reserves in Aksu city, and the expansion of settlements was simulated according to the natural environmental conditions of the study area according to local conditions.

Figure 2. Simulated spatial variables of urban and rural settlements in Aksu city.
4. Analysis of Results

4.1. RFA Model Training and Parameter Calibration

The urban and rural settlements vector data were converted to raster data with a resolution of 10 m as the metacell size. The urban and rural settlements in Aksu city in 2009 were used as the training set to construct the RFA–CA model. Random stratified sampling was used to extract 30,000 points from the settlement land and non-settlement land, and the spatial variable values of each point were obtained to obtain the original training set X.

The Scikit-learn toolkit in MATLAB was used to generate the RFA model from the training set X. Next, two important parameters in RFA needed to be defined: the number of decision trees available, ntree, and the number of spatial variables, mtry. As seen in Figure 3a, the training accuracy reached 93.75% when mtry = 10 for a certain control decision tree (ntree = 1000), specifying a predictor variable parameter of 10. Similarily, by controlling the mtry constant (mtry = 10), the training accuracy increased as ntree increased. As shown in Figure 3b, when ntree was 1, the classification accuracy was only 59.72%, and when ntree reached 400, the accuracy reached 93.21%. Then, the classification accuracy had limited growth, and the decision tree ntree was set to 400 considering that the increase in ntree would make the model operation redundant.

![Figure 3](image)

**Figure 3.** The relationship between classification accuracy (a) the number of predictor variables; (b) the number of decision trees.

4.2. Calculation of Importance of Production–Life–Ecology Spatial Variables

The importance of spatial variables is an important assessment criterion for studying the degree of influence on urban and rural settlement development, and in this paper, OOB (out-of-bag) estimation was chosen to measure the importance of spatial variables. As shown in Figure 4, the drivers of settlement changes in Aksu city are complex, and there is no single dominant driving factor. Among the living space factors, the distance to the general road factor is the strongest driver for the settlements because the high accessibility of the general road facilitates the circulation of goods, information, and capital with other areas and provides a good channel for exchange between the residents of the settlements. Next is the distance to the town center, which is due to the radiation effect of the township center, because the town center is a comprehensive area of living services and economic development, which can attract settlement development as a gathering place. Next is the distance from national and provincial roads, highways, and railroads, which shows that the transportation factor has a very important impact on the settlement change, and the distance from instruction is also important, which shows that education, culture, and medical infrastructure has a greater influence on the development of settlements. In ecological space, the distance from water systems has a greater influence on the change in settlements, which is because settlements gather in areas with sufficient water resources. For production space factors, the importance of distance from commercial and service facilities is above
0.08, which indicates that areas with good infrastructure, such as commercial development, can promote the development of nearby unsettled land to settlement land; the distance from scenic attractions, the distance from mining land, and distance from industrial land have less influence on settlement development. Considering the computing efficiency and accuracy of the model, general roads, national and provincial roads, highways, railroads, town centers, and land for science and infrastructure are selected as feature variables in production space; agricultural land and commercial and service land are selected as feature variables in production space; and water systems and elevation are selected as feature variables in ecological space.

![Figure 4. Importance measure of spatial variables.](image)

4.3. Dynamic Simulation of Aksu City Settlements

4.3.1. RFA–CA Simulation Accuracy

Before the simulation of settlement development in Aksu city, the transfer probability of each tuple under the action of spatial variables was calculated by the RFA model, and the transfer probability of the base period tuple was obtained by combining the neighborhood effect and random factors in CA. In the simulation process, the Pthreshold setting for settlement development affected the accuracy of the simulation: if the Pthreshold was set too large, the cluster expansion would be too dense, and vice versa. As shown in Table 1, the model settlement simulation threshold Pthreshold = 0.7 was determined. Colony development changes were influenced not only by production–life–ecology space but also by policy and economy, so they were stochastic in nature. To highlight that the RFA–CA model received less influence from external factors in the simulation, the stochastic factor parameter α was set to 2.

![Table 1. Simulation accuracy of urban and rural settlements in Aksu city in 2019 under threshold.](table)

4.3.2. Analysis of Simulation Results

After the simulation of the RFA–CA model to obtain the urban and rural settlement distribution map of Aksu city in 2019. Figure 5a,b shows the actual distribution of urban and rural settlements in Aksu City in 2009 and 2019, covering an area of 32.86 and 97.48 km², respectively. The settlements grew significantly in this period, and the settlement area
increased by 64.54 km². To prove the simulation effect of the RFA–CA model, the simulation results were compared with the real distribution of urban and rural settlements in Aksu city in 2019 and the logistic regression CA model. As shown in Figure 5c,d, the simulation results of urban and rural settlements in Aksu city in 2019 were obtained by using RFA–CA and logistic regression CA, respectively. Comparing Figure 5b–d, it can be seen that the RFA–CA model was more detailed and accurate in the simulation of urban centers and urban–rural intersection zones compared to the logistic regression CA model, and is therefore more suitable for the simulation and prediction of settlement expansion.

![Figure 5](image-url)

**Figure 5.** The simulation results of Aksu city settlement were compared with the actual settlements. (a) shows the actual distribution of urban and rural settlements in Aksu City in 2009 and 2019; (b) shows the actual distribution of urban and rural settlements in Aksu City in 2009 and 2019; (c) shows the simulation results of urban and rural settlements in Aksu city in 2019 were obtained by using RFA–CA and logistic regression CA; (d) shows the simulation results of urban and rural settlements in Aksu city in 2019 were obtained by using RFA–CA and logistic regression CA.

To quantitatively evaluate the effect of the RFA–CA simulation and compare it with the logistic-CA simulation accuracy with geometric mean (G-mean) coefficients, the entire agglomeration tuple sample was evaluated for classification accuracy in the study. The urban and rural agglomerations of Aksu city were evaluated for accuracy with non-agglomerated cells, and the actual agglomeration points of Aksu in 2019 were compared with the simulated agglomeration points correspondingly one by one to obtain a confusion matrix for simulation accuracy evaluation. As in Table 2, the RFA–CA model had a settlement simulation accuracy of 68.9%, an overall accuracy of 93.8%, and a G-mean coefficient of 0.815, while the logistic regression model had a settlement simulation accuracy of 60.9%, an overall accuracy of 89.4%, and a G-mean coefficient of 0.751. The quantitative analysis showed that for the development of settlements with very uneven sample sizes, the RFA–CA model was much more accurate than the logistic regression CA model in terms of both cluster simulation accuracy and overall. The accuracy of RFA–CA model was much higher than that of logistic regression CA model.
### Table 2. RFA–CA and logistic-CA simulation accuracy confusion matrix.

| Type                  | RFA–CA Model | Logistic-CA Model |
|----------------------|--------------|-------------------|
|                      | Settlement   | Non-Settlement   | Accuracy% | Settlement | Non-Settlement | Accuracy% |
| Settlement           | 200,089      | 90,316           | 68.9      | 176,857    | 113,548        | 60.9     |
| Non-settlement       | 90,284       | 2,509,329        | 95.8      | 192,371    | 2,407,242      | 92.6     |
| Total accuracy       |              |                   | 93.8      | 194,228    | 2,599,569      | 92.4     |
| G-mean               | 0.815        | 0.751             |           |            |                |          |

Table 2 Confusion matrix of the RFA–CA model and logistic-CA model simulation.

4.4. Analysis of Prediction Results

4.4.1. Analysis of Prediction Results

The RFA–CA model predicted the expansion of settlements in Aksu city in 2029. Compared with the distribution of settlements in 2019, the area of settlements will expand by 58.36 km² by 2029, and it can be seen in Figure 6 that the expansion of cluster size will be obvious over the next ten years, and the overall growth trend is sparse in the north and south and dense in the middle. Among them, the south city street, the south of Kekeya street, the new city street, the column street, and the central and north parts of the Iganqi township are clustered expansion trends, and the settlement development is rapid. The economic development zone, the eastern plain area, and the southern part of the Yingbazar street settlement expansion are more significant. The Ayikul township, Kumubashi township, and Topruk township settlements near the main road expansion are significant, and the rest of the region expansion is scattered. In Baishi Tugman township and Kartal township, the settlements expand sporadically along the Aksu River basin; the settlements in the northwestern part of Keqia street, Hongqipo farm, and the eastern part of Ayikul township expand in a band. On the whole, settlements expand and cluster in urban areas and town centers, while in rural areas, settlements expand more sporadically.

Figure 6. Aksu city 2029 urban and rural settlement distribution.

Aksu city is divided into 19 areas by street and township, and the different types of expansion are listed in Table 3. As the streets in the center of the city are more developed in terms of infrastructure and transportation networks, urban settlements are concentrated in the form of expansion, especially in the vicinity of infrastructure and commercial services, making urban settlements too dense. The expansion of rural settlements is mainly divided...
into two forms: one is the township and the central village as the core to the surrounding scattered expansion. The reason is that the rural settlement infrastructure services are poor, the industry is mainly agriculture, and road access is poor; thus, the settlement expands to an area closer to agricultural land development. The other reason is that along the edge of agricultural land and road expansion is in the form of a belt, so that the degree of fragmentation of agricultural land becomes high, resulting in low land use efficiency.

Table 3. 2029 Aksu city street township settlement development pattern.

| Type of Expansion | Region |
|-------------------|--------|
| Agglomeration expansion | Hongqiao street, Yinghazar street, new town street, Langan street, Nancheng street, economic and technological development zone |
| Sporadic expansion | Topruk township, Iganiq township, Baishi Tugman township, Kartal township, seed farm, textile industrial city, special industrial park, first and second regiment |
| Band expansion | Kekeya street, Hongqipo farm, Ayikul township, Kumubashi township |

4.4.2. Analysis of the Spatial Functions of Production-Life-Ecology Space of Urban and Rural Settlements in Aksu City

(1) Living Space

The expansion of agglomeration of settlements within the urban area of Aksu is mainly due to the dense road network and robust infrastructure, and the development of surrounding rural settlements gradually tends toward the central city, so that the development of settlements in the downtown area is under great pressure. In contrast, the expansion of rural settlements with low road network density and far from township centers is small and scattered, which makes it more difficult to accommodate the centralized allocation of living space resources. As seen in Figure 7, the road network in Aksu urban areas is dense, with abundant infrastructure, and though the economic and technological development zones, textile industrial cities, special industrial parks, and Iganiq township have a high road network density, the infrastructure space needs to be improved. Ayikul town, Topruk township, and Baishi Tugman township are near the urban center, but the road network and infrastructure are concentrated in the town centers. At Hongqipo farm, Kumubashi township, the road network structure is relatively simple, infrastructure and land density are low, and other areas need to drive the development. The simple function of the living space of the region and Kartal township and the distance from the urban area lead to a high degree of fragmentation in the distribution of rural settlements.

(2) Production space

In terms of production space, commercial and service land has a greater impact on settlement development, followed by agricultural, industrial, mining, and tourism land. Settlement development needs to be judged according to its regional industrial characteristics. As seen in the figure, the main production space land in each region varies, and resources need to be allocated according to their industrial characteristics. The city center is well developed with various types of land space and has a strong transportation hub. The economic and technological development zone, the textile industry city, and the special industrial park are industrial development areas. The town of Kartal is mainly focused on agriculture and tourism, while the regional field in the south, Kumubashi township, and the Red Flag Slope farm in the north are mainly focused on the development of agriculture. Western Iganiq township and Ayikul township have rich tourism resources and railroads and highways running through both areas, while Baishi Tugman has rich tourism resources and a highway. In the west, Iganchi township and Ayikul township have rich tourism resources and railroads and highways running through them, while Baishi Tugman township has folklore tourist attractions and is close to the textile industry city.
Figure 7. Production–life–ecology spatial function zoning of Aksu city.

(3) Ecological space

Water systems are an important factor affecting the development of urban and rural settlements in Aksu city. In the figure, we can see that the rivers are mainly distributed in the area with the Aksu river and Dolang river as the main streams, running through most of the area from north to south and part of Western Aikul town. From the simulation results of urban and rural settlements in 2029, there is a clear trend of settlement growth near rivers and wetlands, which will lead to a rapid decline in water resources in the concentrated areas of settlements in the long term. Therefore, the protection of water resources is required for the sustainable development of urban and rural settlements.

5. Optimization Suggestions

The optimization of urban and rural settlement space requires the rational allocation of town and countryside resources. Based on the basic conditions for the optimization of settlement space in Aksu city, the optimization of settlement space is driven by the development of life–production–ecology. With ecological protection as the premise, social and economic development as the guide, and people’s living standard improvement as the purpose, we promoted the efficient development of urban and rural settlement spaces.

5.1. Living Space Layout

To increase the scale of urban and rural settlements, improve living service facilities, and strengthen the integration of urban and rural living spaces, the layout of urban and rural settlements was optimized, and the living service system was improved based on the current development status of urban and rural settlements, combined with factors such as transportation and infrastructure. As shown in Table 4, the urban and rural settlements in Aksu city are divided into four development areas: a high-speed development area with the urban area as the core, a key development area near the industrial park, a coordinated development area with more scattered settlements and a stable development area with lower infrastructure services.
Table 4. Aksu city urban and rural settlements: living space development type.

| Development Type            | Region                                                   | Development Direction                                                                 |
|-----------------------------|----------------------------------------------------------|----------------------------------------------------------------------------------------|
| High growth zone            | Downtown streets, Iganqi township, economic and technological development zone, special industrial park, textile industrial city | Further upgrading of the infrastructure will allow the settlement to expand towards its center of concentration. |
| Key growth zone             | Ayikul township, Topruk township, Baishi Tugman township | Strengthening the density of the road network with the township center makes the settlement expand towards it. |
| Coordinated growth zone     | Hongqipo farm, Kumubashi township                        | The development of clusters in the surrounding townships drives the growth of clusters from fragmentation to aggregation. |
| Stable growth zone          | First region, Second region, Khartal town                | Strengthen the construction of infrastructure such as science, education, culture and health and road access to enable the stable development of the settlement. |

To relieve the pressure of dense settlement development within the urban area of Aksu city, subcenters are set up around the city center. Taking into account the complete road network structure of the western economic and technological development zone, the western subcenter should be set up as a core to attract settlements by developing science and technology industries, while the northern part should strengthen the road network connection with Wensu county to form a joint development of sharing and building infrastructure with the advantage of its proximity to the city to attract settlements around the city and Wensu county to develop there. The southern subcenter should be set up in the southeast to increase infrastructure land with the light textile city as its core. The central urban area is dominated by modern service industries and high-tech industries, and its infrastructure capacity and layout should be given due consideration to the construction needs of the secondary urban area. Topluk township and Baishi Tugman township should take advantage of the proximity to the urban area, gradually urbanize and set up a new township, strengthen the construction of township center facilities, and promote the central area of the settlement township as a gathering place. With the main urban area and the suburban area as the core, five development axes are drawn out to enhance the density of the traffic road network on the axes so that the rural settlements are strongly expanded along the axes and the intensive use of land in the rural settlements is enhanced. Hongqipo farm settlements rely on the central city infrastructure advantage to the south, Ayikul town settlements rely on the west city economic development advantages to the northwest to expand. The Kumubashi township cluster development center of gravity gradually moves toward Topluk township and Baishi Tugman township to take advantage of infrastructure and transportation to complement their own loose cluster development advantages, and the second region groups common infrastructure and natural resources to share and strengthen the regional cluster. The formation of four linked development circles create the formation of resource sharing and the agglomerated development of spatial distribution. The infrastructure construction of education and scientific research, medical and health care, culture, and entertainment in each township center should be strengthened so that rural agglomerations can gather internally and change the spatial distribution of fragmented expansion. The overall spatial layout of urban and rural settlements in Aksu City forms a coordinated model of “one main center joining three subcenters, three districts and five axes, with multiregional association”.

5.2. Production Space Layout

By combining the industrial advantages of urban and rural settlements, promoting the upgrading and optimization of industrial structure, and advancing the development of each regional characteristic industry in Aksu city, the industrial development of urban and rural areas in Aksu city is divided into six types: comprehensive, agrotourism, agritrade,
trade-tourism, trade industry, and tourism industry, as shown in Table 5. The spatial layout of production drives the development of surrounding settlements and thus improves the economic and social development of urban and rural settlements in Aksu city.

Table 5. Aksu city urban and rural settlement industry development type.

| Industry Type | Region | Main Functions and Industrial Development Direction |
|---------------|--------|------------------------------------------------------|
| Comprehensive| Downtown streets | Transportation hub and commercial service distribution center. The eastern part of the development of light textile industry, the southern part of the main agricultural and sideline product processing, the western part of the strengthening of heavy chemical industry, advanced manufacturing industry as the leading secondary industry; the center to enhance the service industry and modern commerce, tourism hubs, and other tertiary industries. Agriculture as the main industry, with a unique natural scenic area. Relying on the proximity of urban areas to develop high-quality fruits and vegetables and other suburban-type special agricultural products, the development of agritourism and leisure tourism industry; relying on the advantages of natural scenic areas to develop scenic agricultural products. |
| Agrotourism | Eganchi township, Ayikul township | Place agriculture as the leading industry. Develop all kinds of fruits, red dates, walnuts, and other special agricultural products according to local planting characteristics, strengthen modern agriculture, create special agricultural and sideline products, and strengthen agricultural commerce. Folklore and cultural scenic spots and agricultural communities. Development focus on folklore tourism and processing of special agricultural products, vigorously promote special tourism agricultural products; develop desert tourism, special B&B tourism, and create a cultural tourism line from the northwest to the south. |
| Agritrade | Hongqipo farm, Kumubashi township, Good seed farm, first regiment, second regiment | Place agriculture as the leading industry. Develop all kinds of fruits, red dates, walnuts, and other special agricultural products according to local planting characteristics, strengthen modern agriculture, create special agricultural and sideline products, and strengthen agricultural commerce. Folklore and cultural scenic spots and agricultural communities. Development focus on folklore tourism and processing of special agricultural products, vigorously promote special tourism agricultural products; develop desert tourism, special B&B tourism, and create a cultural tourism line from the northwest to the south. |
| Trade-tourism | Kartal town | Aksu City key industrial park. The three districts focus on the development of modern industry, textile industry, and product processing, respectively, and large logistics parks are planned in the three districts. North adjacent to the textile industry city, joint light textile city to create the development direction of the combination of special textile and folk culture tourism. From the south to the north along the eastern tourism line development characteristics of the style park, become the eastern tourism development folklore station. |
| Trade industry | Economic and technological development zone, light textile city, special industrial park | Aksu City key industrial park. The three districts focus on the development of modern industry, textile industry, and product processing, respectively, and large logistics parks are planned in the three districts. North adjacent to the textile industry city, joint light textile city to create the development direction of the combination of special textile and folk culture tourism. From the south to the north along the eastern tourism line development characteristics of the style park, become the eastern tourism development folklore station. |
| Tourism industry | Baishi Tugman township | Aksu city is an important transportation and logistics center in the Aksu region, as well as the core area of the textile industry, heavy industry, and technology industry. To strengthen the construction of Aksu city’s technology industrial park and special industrial park, enhance the development mode of industrial clustering, and then better attract the surrounding settlements to it, the industrial park is considered an axis to enhance logistics and transportation and drive the development of settlements near the axis, as shown in Figures 8 and 9. To upgrade and transform the development of commerce and service industries in township settlements, the construction of central village markets, community chain supermarkets and rural e-commerce services is the focus, along with building a rural commerce service network with two-way circulation of industrial products and daily necessities into villages and agricultural products into cities and homes. This form will connect Aksu city’s town economy with the economies of the rural settlements; rural industries can break through the development limitations of township settlements; and urban and rural economies will grow together. Based on the regional tourism resources,
a tourism reception center can be built in the urban area, driving the development of the Kokoya ecological tourism park in the north and the ecological agricultural park in the south, forming a central tourism development circle. Using the West Lake scenic area as a hub, Yi Gaoqiu town can radiate to create leisure resorts and the formation of a western tourism development circle. Southwest of Aishman lake can become a hub to create a leisure and health area, driving the development of the tourism economy of the Ayikul town settlement, and the southeast unique desert and folk culture of Kartal town can become a special agricultural experience area. From the city center to the southwest and southeast, respectively, two tourism lines are created, forming a southwest leisure and health tourism line and a southeast folk culture tourism line, driving the economic development of the township settlements along the line. In the development of business services and tourism, the development of modern agriculture should be strengthened mainly in the agricultural development of Hongqipo farm, the mission, Kumubashi township, and Kartal township to form a large agricultural area.

Figure 8. Aksu city urban and rural settlement living space distribution.

Figure 9. Aksu city urban and rural settlement production space distribution.
5.3. Ecological Space Layout

As shown in the Figure 10, the Hongqipo Shengguo reservoir, west bridge regulating reservoir, Aksu river water source, Dolang reservoir, Lake Aishiman, Aksu river, and Dolang river are important water sources for the production and livelihood of the settlement residents. The settlement expansion did not encroach on the reservoir land, there is a certain distance buffer distance from the reservoir, and its predicted results are the same as those in the “Aksu District Town System Plan (2013–2030)”. The results of the delineation of the guided construction areas under the key management of Aksu region are the same. These areas belong to the key controlled construction areas in Aksu city, so it is necessary to be strict with any kind of development and construction behavior in these areas to guarantee the normal operation of residential life and production in the settlements. Basic farmland is the lifeline; according to the requirements of general agricultural land protection in the Aksu area, the scope of the 591.58 km$^2$ basic farmland protection zone in Aksu city is strictly delineated, and it is prohibited for any construction land to encroach on the basic farmland protection zone. It is forbidden to open up land on the periphery of the agricultural land protection zone, and the red line of arable land is strictly guarded.

![Figure 10. Aksu city urban and rural settlement ecological space distribution.](image)

6. Conclusions and Discussion

The acquisition of conversion rules of CA models has been the focus of CA research in recent years, and machine learning methods have been used to obtain CA model conversion rules to simulate multiclass land use change problems with better results [21]. In this paper, a RFA–CA model is constructed to calculate the conversion probability of a settlement metacell to obtain the conversion rules of the CA model and simulate the settlement distribution state of Aksu city in 2029 with high accuracy. Combined with the requirements of the general planning of Aksu city, layout optimization suggestions for urban and rural settlements are proposed from production, living, and ecological perspectives, which provide a basis for realizing the rural revitalization and urban-rural integration development of Aksu city. The following conclusions were obtained from the study.

(1) In constructing the RFA–CA model, the best training effect on the clusters was achieved when the predictor variables were 10 and the decision tree was 400 trees. The importance measure of spatial variables found that the drivers of cluster change in Aksu city are complex, and no single driver dominates. Among the spatial factors of life, the distance
from general roads has the strongest driving force for cluster change, followed by the distance from town centers and the distance from national and provincial roads, highways, and railroads, indicating that transportation factors and administrative district location have a very important influence on cluster development. Areas with good infrastructure, such as science, education, culture, and health facilities, also play an important role in the development of urban and rural settlements. Among the ecological spatial factors, the distance from water systems has a greater impact on the change in settlements; among the production spatial factors, areas with good infrastructure, such as commercial service development, can promote the development of undeveloped land around developed land.

(2) The simulation obtained the distribution of settlements in 2019 and compared the actual results. The simulation results were very close to the actual situation in the overall spatial distribution, and the settlement grew by 64.54 km$^2$ in this period, with an obvious growth trend. The overall accuracy of the model was 93.8% with a G-mean coefficient of 0.815. The simulation accuracy was good, and the consistency of the simulation was stronger than that of logistic regression CA for urban and rural settlements in Aksu city.

(3) Compared with the distribution of settlements in 2019, the area of settlements in 2029 will be expanded by 58.36 km$^2$, with an overall growth trend that is sparse in the north and south and dense in the middle. The spatial expansion of 19 regions in Aksu city is calculated, the main functions of the “three living” space in different regions are discussed, and layout optimization suggestions are made from the perspective of the “three living” space.

Urban and rural settlement expansion is a complex nonlinear change that is influenced not only by factors such as transportation, location, and natural environment but also by policies and economic factors. Its prediction was only obtained by training historical data to transform the rules, and the future settlement expansion results were somewhat different from the past, so it was necessary to make an optimal layout for future urban and rural settlement development further according to the local urban master plan as a reference system and seek a policy-oriented blueprint for settlement development combined with data.

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