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A STUDY ON STRUCTURAL ANALYSIS OF SUBURBAN ECOLOGICAL AND ECONOMIC SYSTEM —Taking Tianjin Suburbs and Counties for Example

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ABSTRACT: Along with the development of urban economy, the growth of urban population and the increase of needs of urban society, the suburban ecological and economic system changes constantly and profoundly in its structure and function. Intensifying the research on structural analysis of suburban ecological and economic system is of great significance for grasping light the laws governing the development and evolution of the suburban ecological and economic system and leading this system onto a path of sound circle. By making comprehensive use of the cluster analysis and latent structural analysis the author attempts to explore a new avenue of revealing the structure of suburban ecological and economic system, taking Tianjin suburbs and counties as an example. The results obtained from the above-stated analyses show that it is entirely possible and extremely effective to study the structure and function of suburban ecological and economic system and provide scientific evidence for control of this system by using mathematical methods and statistical analyses.

KEY WORDS: suburban ecological and economic system, cluster analysis, latent structural analysis.

The suburban ecological and economic system is an ecological and economic system based on countryside, relying on city and being densely populated with worker-peasant integration, city-countryside combination and well-developed commodity economy. Along with the development of urban economy, the growth of urban population and the increase of needs of urban society, the suburban

ecological and economic system changes constantly and profoundly in its structure and function.

Intensifying the research on structural analysis of suburban ecological and economic system is of great significance for grasping the laws governing the development and evolution of the suburban ecological and economic system and leading the system onto a path of sound circle.

By making comprehensive use of the cluster analysis and latent structural analysis the author attempts to explore a new avenue of revealing the structure of suburban ecological and economic system, taking Tianjin suburbs and counties as an example.

I. BASIC DATA

Aimed to characterizing all-sidedly the structure of Tianjin suburban ecological and economic system on the basis of "The Statistical Data of Tianjin in 1993"[1], thirteen variables (indexes) representing the aspects of output level, plant structure and input level of energy are taken as original variables. The variables are labelled as:

1 (A). Farmland per capita (representing main condition)
2 (B). Grain yield per capita
3 (C). Pig on hand per capita (B and C represent output level)
4 (D). Area for planting rice/Area for grain crops
5. Area for planting wheat/Area for grain crops
6. Area for planting corn/Area for grain crops
7 (E). Area for planting sorghum/Area for grain crops
8. Area for planting soybean/Area for grain crops
9 (F). Area for planting cotton/Area of farmland
10 (G). Area for planting oil-bearing crops/Area of farmland
11 (H). Area for planting vegetables/Area of farmland (D-H represent plant structure)
12 (I). Input level of machinery/Area of farmland
13 (J). Input level of fertilizer (I and J represent input level of energy)

Among them the ten indexes (A-J) independent of each other are selected as initial data for exploring the structure of Tianjin agroecological and economic system.

II. NUMERICAL CLASSIFICATION OF REGIONAL STRUCTURE OF TIANJIN AGRO-ECOLOGICAL AND ECONOMIC SYSTEM

1. Procedure

To classify numerically the regional structure of Tianjin's agro-ecological and economic system the suburbs and counties of the whole city are taken as the classification units and above-mentioned ten indexes as the sample variables. We have in this case a total of twelve suburbs and counties (three coastal districts, four suburban districts and five suburban counties) in the whole city to be analysed taking each suburb or county for a sample which has ten variables. Being different in dimension from one another the above-mentioned ten variables have to be standardized by using Z-scores. In clustering process the correlation coefficient is selected as a statistic of similarity and the smallest distance method used. The whole classification procedure of suburbs and counties of the city may be depicted graphically in a two-dimensional linkage tree as shown in Fig. 1.

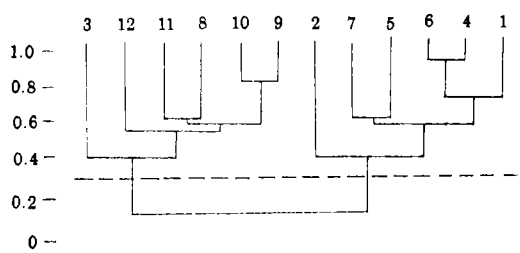


Fig. 1 Cluster hierarchy of agro-ecological system in Tianjin suburbs and counties

From Fig. 1, it is clear that the grouping produces two major types of suburbs and counties (numbered using Roman numerals) with respective districts attached: the type I which comprises five suburban counties including Ninghe (8), Wuqing (9), Jinghai (10), Baodi (11) and Jixian (12); the type II which comprises four suburban districts including the East Suburban District (4), the South Suburban District (6), the West Suburban District (5), the North Suburban District (7) and one coastal district—Tanggu (1). The two coastal districts—Dagang (3) and Hangu (2) attached to type I and type II respectively. The distribution of both types of suburbs and counties is shown in Fig. 2.

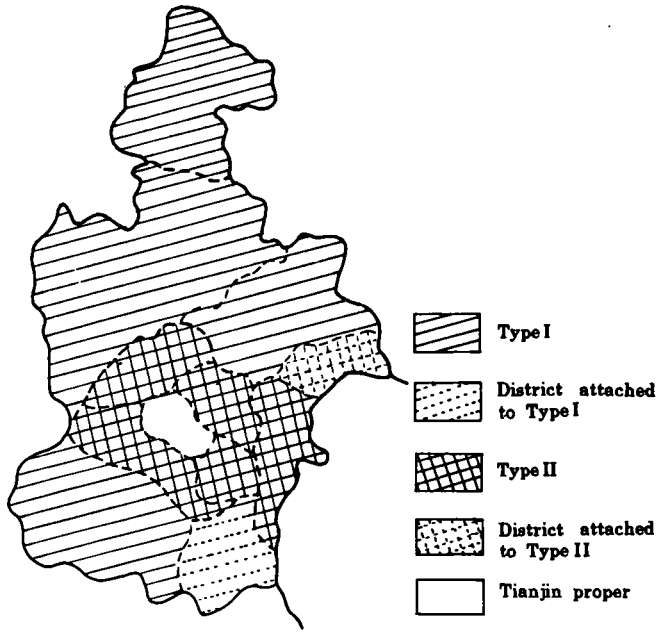


Fig. 2 The regional structure of agro-ecosystem in Tianjin suburbs and counties

2. **Result Analysis**

The law of spatial distribution of classification units can be revealed by cluster analysis. Because clustering means gradational generalization of attributes of classification units the higher the grade of classification units is, the less property in common the classification units have. For convenience sake first the average values and total standardized values of variables for both types of suburbs and counties and both districts are calculated respectively as shown in Table 1 and Table 2. The graphs by the vertical and horizontal axes with ten variables in both types and both districts respectively are then constructed as shown in Fig. 3. From Fig. 3 a, b, it is clear that the output level of grain is corresponding with the basic condition. For instance in type II of suburbs the farmland per capita is the least, so the level of grain yield is the lowest. The South Suburban District (6) can be taken as a representative. Its farmland and grain yield per capita are 0. 054 ha and 531kg respectively. The pig on hand per capita is corresponding to the input level of fertilizer on the whole (see Fig. 3c, j). There is a quite good correspondence in both types. The input level of fertilizer in both types is high, so the pig on hand per capita, as secondary production based on planting, is high too. This shows that the level of agriculture as a whole is quite high. However, in Dagang (3) the input

and output are both low. In Hangu (2) the input is high, but the output is low. This shows the relatively low level of agriculture as a whole.

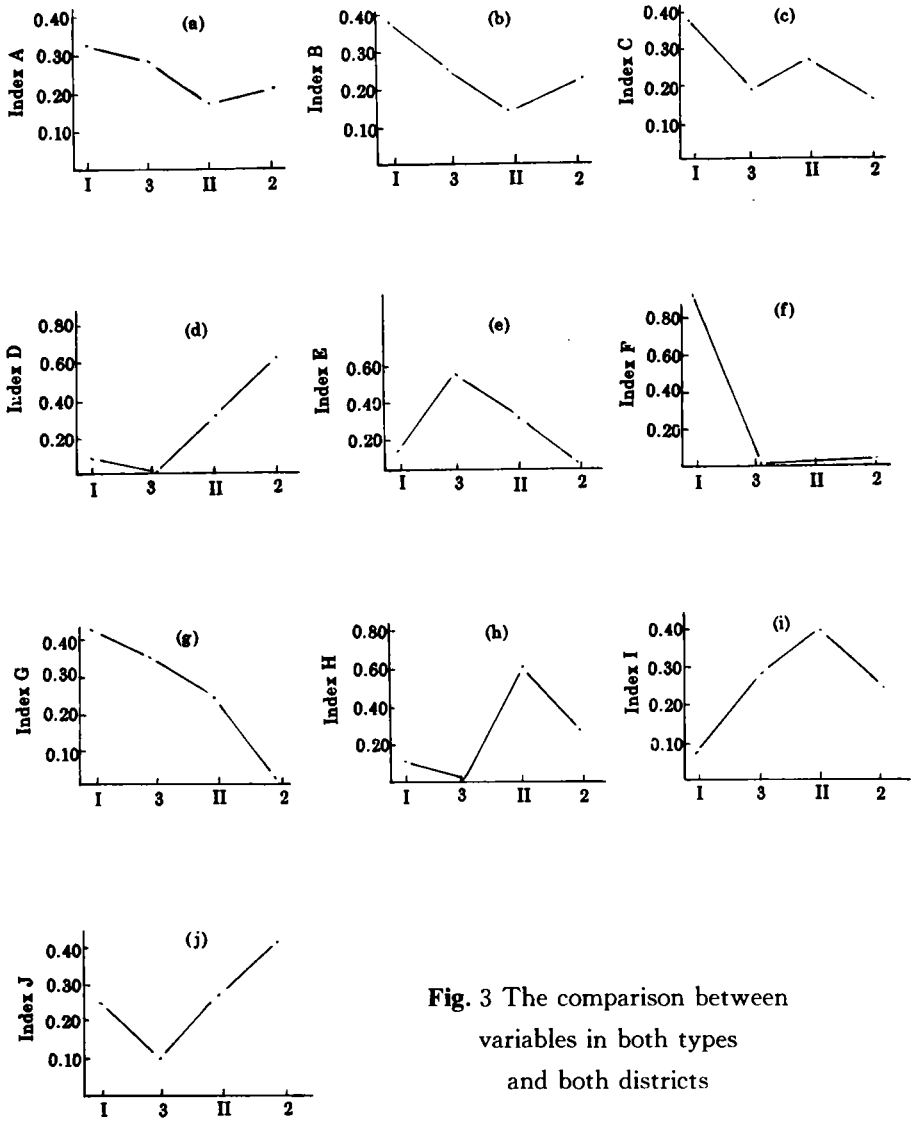


Fig. 3 The comparison between variables in both types and both districts

The characteristics of plant types in the suburban ecological and economic system are revealed (see Fig. 3 d, e, f, g, h). Main sorghum-producing area is in type II of suburbs and Dagang (3), and rice-producing area in type II of suburbs and Hangu (2), and cotton and oil-bearing crop-producing area in type I of counties, and vegetable-producing area in type II of suburbs.

The input of machinery reaches a peak value in type II of suburbs adjacent to the city proper and favorable to the introduction of supplementary energy (Fig. 3j).

Table 1 Average values of variables in both types and both districts

Index	Types and districts			
	Type I	District (3)	Type II	District (2)
A	2.01	1.73	1.05	1.38
B	2877	1894	1118	1712
C	0.22	0.11	0.16	0.10
D	10.00	0.26	33.11	70.36
E	6.72	34.63	19.96	2.25
F	5.41	0.10	0.09	0.29
G	6.64	5.29	3.86	—
H	7.93	1.76	35.39	14.26
I	0.04	0.15	0.21	0.13
J	48.6	19	51	78

Table 2 Total standardized values of variables in both types and both districts

Index	Types and districts			
	Type I	District (3)	Type II	District (2)
A	0.326	0.280	0.170	0.224
B	0.379	0.249	0.147	0.225
C	0.373	0.186	0.271	0.169
D	0.088	0.002	0.291	0.619
E	0.106	0.545	0.314	0.035
F	0.919	0.017	0.015	0.049
G	0.421	0.335	0.244	—
H	0.134	0.030	0.596	0.240
I	0.075	0.283	0.396	0.245
J	0.247	0.097	0.259	0.397

In order to reveal the relationship between both types and both districts the standarized average values of variables are changed into the form of bisection, i. e. given index is taken as 1, if it is more than average value in suburbs and counties of the whole city; or as O, if the former is less than the latter. The results indicate that for type I of counties and type II of suburbs the grade of amalgamation is relatively low, and the degree of similarity is relatively high. For type I of counties the five indexes—farmland per capita, grain yield per capita, pig on hand per capita, area for cotton/area of farmland and area for oil-bearing crops/area of farmland are more than the average level in suburbs and counties of the whole city, but the rest indexes area for rice/area for grain crops, area for sorghum/area for grain crops area for vegetables/area of farmland, input level of machinery/area of

farmland and input level of fertilizer/area of farmland are less than the average level of the whole city. In contrast to type I and type II of counties the first five indexes are less than the average level of the whole city, but the last five indexes are more than the average level of the city. The grades of amalgamation of district (3) with type I of counties and district (2) with type II of suburbs are relatively high. The property to the former is reflected in the two indexes—farmland per capita and area for oil bearing crops/area of farmland. The property common to the latter in the two indexes—area for rice/area for grain crops and input level of fertilizer.

If the total standardized values of variables in both types and both districts (see Table 2) are interpreted as location quotients of these variables, the order of location quotients of each variable in both types and both districts can be defined and the average order of location quotients of all variables then calculated. For type I of counties and type II of suburbs it is equal to 2. 1 and 2. 5 respectively. For district (3) and district (2) it is equal to 2. 7.

The type I of suburban counties situated in the periphery of suburban districts of the city and bounded by rural hinterland has considerable supremacy in ecological respect, occupying the optimal location in the suburban ecological and economic system as whole and reflecting the features of this system on the basis of the countryside. The type II of suburban districts situated a round the city proper between the latter and the type I of suburban counties is strongly influenced by the city, its location quotient being slightly lower than the type I of suburban counties. The coastal districts of Dagang (3) and Hangu (2) situated in coastal plain region and abounding in salt and oil resources are marine-chemical and petrochemical bases respectively, thus causing the lowest location quotient.

III. ANALYSIS OF LATENT STRUCTURE OF TIANJIN AGRO-ECOLOGICAL AND ECONOMIC SYSTEM

1. Essence and Procedure[2]

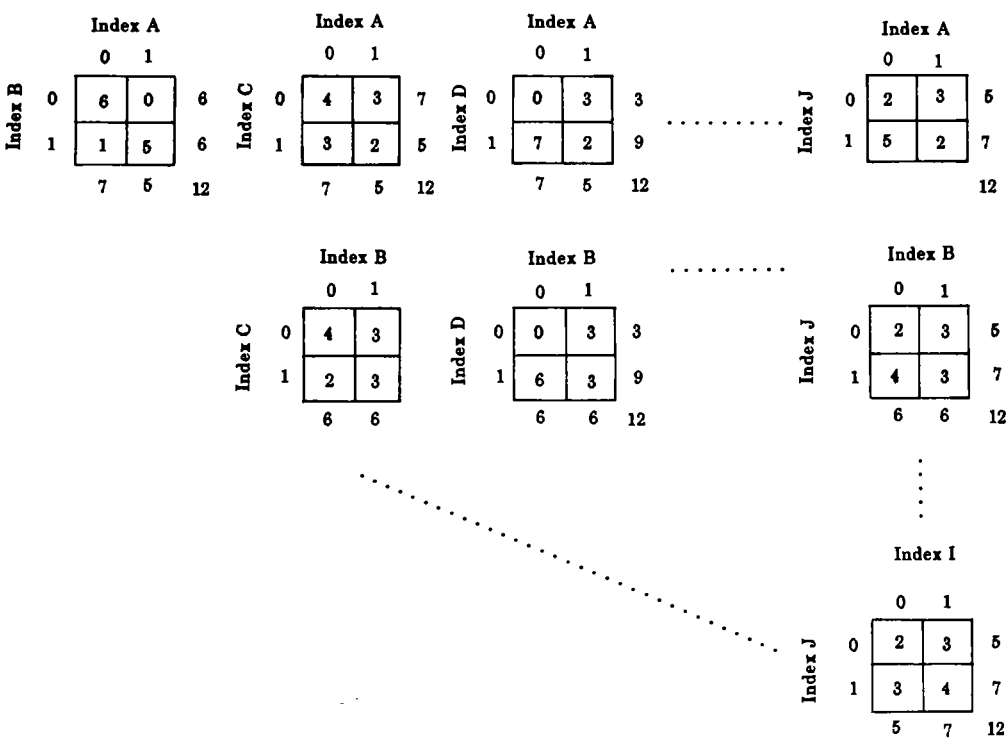
The latent structural analysis is a mathematical method for revealing th latent structure or directly unobservable structure of an object of study. In order to use the method the two permissible approximate conditions must be introduced as follows: (1) a set of observable properties might be expressed in the form of bisection; (2) the latent structure in an one-dimensional structure using a

standarized measure and endowed with a number axis (scale) on which the numerical values are lineally correlative to a set of observable properties M, i. e. for each of these properties the following equation is valid:

$$M_I = a_i + b_i x$$

The essence of the latent structural analysis lies in constructing an equation or a system of equations in which the constant a shows the degree of distribution of a certain property and the coefficient b the role of a certain property in formation of latent structure.

The procedure in exploring the degree of differentiation of above-mentioned ten indexes with respect to the agro-ecological and economic system of the whole city and revealing the latent structure of this system on the basis of these ten indexes is as follows. First the above-mentioned indexes are characterized by bisection as dual data; "0" shows that given index is less than average level in the whole city; "1" shows that the former is more than the latter. Thus a number of characteristic conjugate matrixes of order 2×2 can be constructed as follows.



For each of indexes the constant a is then calculated as follows.

$a_A = 5/12 = 0.417$; $a_B = 6/12 = 0.500$; ....•••....; $a_J = 7/12 = 0.583$

To calculate the coefficient b the coefficient k must be determined by formula

$$k = (ad-bc)/n^2$$

where n is the number of suburban districts and counties and a, b, c, d are the signs of the numbers in corresponding squares of conjugate matrix respectively shown as

	0	1
0	a	b
1	c	d

With the aid of above-mentioned conjugate matrixes the coefficients k can be then calculated as

$$k_{AB} = 0.28,\ k_{AC} = 0.007,\ k_{AD} = 0.146,\ \cdots\cdots\ k_{AI} = 0.160,\ k_{AJ} = 0.076$$
$$k_{BC} = 0.042,\ k_{BD} = 0.125,\ \cdots\cdots\ k_{BI} = 0.208,\ k_{AC} = 0.042$$
$$\vdots$$
$$k_{IJ} = 0.007$$

Lastly, as a result of calculating the value of b for each of indexes in terms of different combination from the formula is as

$$b_1 = (k_{AB} \cdot k_{AC}/k_{BC})^{0.5}$$
$$b_2 = (k_{AB} \cdot k_{AD}/k_{BD})^{0.5}$$
$$\vdots$$

The average value of these coefficients of b for each index is taken as the coefficient b of X

Thus the equations for the above-mentioned ten indexes are obtained as

$$M_A = 0.417 + 0.395X \quad (1)$$
$$M_B = 0.500 + 0.538X \quad (2)$$
$$M_C = 0.417 + 0.083X \quad (3)$$
$$M_D = 0.750 + 0.267X \quad (4)$$
$$M_E = 0.500 + 0.325X \quad (5)$$

$$M_F = 0.538 + 0.260X \quad (6)$$

$$M_G = 0.667 + 0.545X \quad (7)$$

$$M_H = 0.583 + 0.363X \quad (8)$$

$$M_I = 0.583 + 0.477X \quad (9)$$

$$M_J = 0.583 + 0.147X \quad (10)$$

2. **Result Analysis**

In the equations constructed for each of indexes in the latent structural analysis the constant a shows the frequency of each index in the whole agro-ecological and economic system of the city, i. e. shows the degree of distribution of each index. The coefficient b shows the degree of differentiation of each of indexes for the whole system, i. e. shows the role of each index in formation of latent structure of agro-ecological and economic system. If the value of b is less than 0. 3. this shows that the index plays in fact no role in formation of latent structure.

In respect of the structure of planting types in the Equation for rice (4) the frequency of suburbs and counties where rice is grown is the highest (75%, $a=0.75$). but the coefficient b is less than 0. 3. This shows that rice (wheat, because both are correlated negatively to each other) plays no role in formation of latent structure of suburban ecological and economic system. Nevertheless, in the Equations (5), (7) and (8) for sorghum (corn), oil-bearing crops and vegetables values of a are less than the Equation for rice (4), i. e. the distribution of the former is more extensive than the latter. But the b values of the former are more than 0. 3. This shows that oil-bearing crops, vegetables and sorghum (corn) participate in formation of latent stru cture of suburban ecological and economic system of Tianjin City. The b value of b of cotton in the equation (6) is less than 0. 3 too as rice. This indicates that degree of differentiation of cotton with respect to the suburbs and counties is not so high as sorghum (corn) and vegetables and oil-bearing crops particularly. It might be indicated incidentally that the place of cotton ($a = 0.583$), oil-bearing crops and vegetables in planting structure of Tianjin suburbs and counties has become more important than grain crops.

Although the a value in the equation for farmland as a basic condition of suburban ecological and economic system is the least among ten indexes, i. e. the degree of its distribution is the lowest, but the b value is more than 0. 3. This shows that farmland means to suburban ecological and economic system. The b

value in the Equation for grain yield per capita reflecting output level is the most in ten indexes. This indicates that the degree of differentiation of grain yield level with respect to the whole system is highest, its role in formation of latent structure of system is the most important and it is the most important sign of suburban ecological and economic system.

As to input of energy, the b value in the equation for machinery (9) is more and the b value in the equation for fertilizer (10) is less. Thus the former participates in formation of latent structure, but the latter pays in fact no role.

On the basis of above-mentioned analyses the main conclusions are obtained as follows:

1) The agricultural land is a foundation of the suburban ecological and economic system. The flatland of Tianjin is vast. The area of the farmland forms a comparatively large proportion. Agricultural land is bound to decrease and the area of non-agricultural land to increase year by year along with the spread of urban population and industry, the development of economic construction and population growth in suburbs and counties. As a basic condition of suburban ecological and economic system, the farmland plays undoubtedly an important role in formation of latent structure of Tianjin's agro-ecological and economic system ($b_A = 0.395$). In order to strengthen the foundation of macrosystem and promote its sound circle it is imperative to take effective measures to strictly control the decrease of agricultural land and the growth of population on one hand and raise the per unit area yield and transform the low-lying saline-alkali and waterlogging lands in particular.

2) To optimize the distribution of agricultural production and fully utilize the agricultural natural resources is a vital foundation of controlling Tianjin suburban ecological and economic system. The grain production occupies an extremely important position in the strategy of developing Tianjin' s agricultural economy. It must not only ensure the rural growing population their basic needs in food grain but also provide forage grain for developing non-staple food production in order to suit the growing needs of the urban society, especially the needs of urban residents in food. Though the planting production is composed mainly of grain crops such as wheat, corn, rice and sorghum, the last two ($b_E = 0.325$) play an even more important role in the whole city as compared with the first two. Corn is the most important of the coarse food grains in Tianjin. It occupies the first place in sown area among the others. Its yield accounts for more than 50 per cent of the total grain output. Sorghum is one of the grain crops with larger area in Tianjin.

Because of the strong adaptability and calamity-resistant sorghum planting is considerably widespread though it occupies the third place in sown area. Besides, sorghum planting has close relation to comprehensive exploitation of the low-lying, saline-alkali and waterlogging regions covering considerable area. Therefore expansion of area sown to sorghum and increase of sorghum yield is to some extent and an important sign of transforming the above-mentioned regions and taping the potential of production of land. In view of the above-stated in the process of expanded reproduction of food grain a particular attention must be paid to corn and sorghum production, especially in considering the adoption of intercropping, interplanting and multiple cropping.

3) In recent years there has been a rapid development to diversify economy in agriculture, so that the proportion of forestry , animal husbandry, side-occupations and fishery increased by a big margin. Even within the framework of farming, crop patterns have greatly varied and the situation in which only grain crops were grown has given way to greater production of cotton, oil-bearing crops and vegetables. With the total grain output guaranteed, areas for planting grain crops were reduced, while areas for oil-bearing crops increased and areas for cotton were also extended. The role of production of oil-bearing crops and vegetables ($b_G = 0.545$, $b_H = 0.363$) in the whole ecological and economic system is much more important than grain crops ($b_E = 0.325$). This shows that the structure and function of suburban ecological and economic system in Tianjin are steadily growing and changing into a commodity agro-economy suiting the needs of urban market and society and meeting the needs of urban residents in farm and sideline products and needs of industrial production in raw materials.

The results obtained from the aforementioned analyses show that it is entirely possible and extremely effective to study the structure and function of suburban ecological and economic system and provide scientific evidence for control of this system by using mathematical methods and statistical analyses.

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