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Research on the Impact of Agricultural Mechanization Service on Wheat Planting Cost: A Case Study of Henan Province

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Abstract
Given the different effects of agricultural mechanization on various stages of wheat planting in Henan, this article selects 78 observation samples from Henan, a major wheat-growing province. It uses different research methods (multiple linear regression, social network analysis model, multi-layer sensory nerves network) to conduct a comparative study, and the calculation results of the model show that the experimental results have a strong convergence and consistency. Agricultural mechanization services have significant effects on the three stages of wheat planting: harvesting, plowing and sowing. A higher degree of mechanized service in several stages can reduce the cost of growing wheat on family farms.

Keywords
Agricultural Mechanization Services, Family Farms, Wheat Planting Costs

1. Introduction and Literature Review

China is a large agricultural country with a sizeable rural population, and agriculture has entered a stage of rapid development. The most commonly used method of acquiring agricultural machinery is purchasing with own funds, followed by leasing, including direct financial leasing, sale, leaseback, manufacturer leasing, joint leasing, and entrusted leasing. These methods are suitable for new agricultural operations. The main body is also ideal for ordinary small farmers [1]. The promulgation of the "three rural" policies has contributed to the utilization rate of agricultural machinery. We should continue to explore more efficient agricultural machinery subsidy models, stimulate demand for agricultural machinery, and tilt agricultural machinery subsidy policies toward key agricultural machinery organizations. Additionally, we should promote the development and growth of agricultural machinery cooperatives to ensure agricultural machinery operators' ability and workload professionally [2].

The production efficiency of agricultural products plays a vital role in the yield and quality of food. Moreover, many scholars have discussed the impact of AMS on the production efficiency of agricultural products. With the gradual easing of China's preferential agricultural policies, agricultural machinery is used to produce and plant various agricultural products. This reduces the high labor costs in agricultural production, introduces advanced technology to a certain extent, increases and promotes product yields.

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The development of agriculture has validated the mechanization development policy in agriculture [3,4]. From the perspective of the impact of agricultural machinery services on the cultivation of the same agricultural products in different regions, the use of such machinery can generally improve the production efficiency of wheat. Agricultural machinery services play an important role in replacing labor, introducing planting technology and specialization of labor, and reducing the imbalance phenomenon between regions [5]. Additionally, for farmers, the high level of agricultural machinery services can make their employment more extensive, product cultivation more standardized, and increase the output rate of agricultural products [6,7].

With the gradual prevalence of family farming, traditional purely artificial planting can no longer meet the needs of farmers. Moreover, the problem of aging rural labor is becoming increasingly more prominent, severely impacting the production efficiency of crops. The introduction of agricultural machinery services in the planting process can improve the planting efficiency of elderly farmers to a certain extent as well as the quality of their crop output [8]. The increase in the use cost of agricultural machinery will reduce agricultural machinery services. For example, the maintenance of agricultural machinery and equipment requires a certain amount of capital. The land-labor ratio is positively correlated with the investment in per acre agricultural machinery services. Furthermore, non-agricultural employment status, cultivated land leveling degrees, and so on will also affect farmers' willingness to use agricultural machinery [9,10].

Most current research in China focus on the methods and processes of agricultural machinery services; why farmers choose them, and the factors influencing their choice; the output and loss rates between agricultural machinery services and different crops; the efficiencies; and effects, among others. This study analyzes the cost impact in Henan Province at various stages of wheat planting from a microscopic perspective and highlights the difference in the impact of agricultural machinery services on wheat at different stages of the plantation, and presents the best way to use agricultural machinery services to minimize farming costs.

2. Analysis of the Impact of Agricultural Mechanization Services on Wheat Planting Costs in Henan based on Regression Models

2.1 Analysis of the Correlation between Agricultural Mechanization Services and Wheat Costs

This study extensively discusses agricultural mechanization services. Additionally, it studies different agricultural mechanization services in different planting stages. Thus, in the questionnaire design, from the perspective of different wheat planting stages, agricultural mechanization services have different degrees of influence in their six stages and use the Richter scale seven sub-scale to measure the importance of cost reduction of the six wheat planting stages (Table 1).

We used EXCEL to organize data from the 78 survey records of Henan Province, transpose the data, import the organized data into statistical analysis software, use the correlation test (Pearson correlation), and select the two-tailed test. Table 2 shows the relationship between the six different stages of agricultural mechanization service.

Table 2 is a schematic representation of the correlation test results of the importance and cost of agricultural mechanization services at different wheat planting stages in Henan. The importance of agricultural mechanization services in the cultivation stage V1 and the Pearson correlation coefficient of the sowing stage V2 are 1. Thus, the significance level of the two-tailed test is passed. This indicates that the farmers in the cultivation stage believe that the importance of agricultural mechanization services and the sowing stage are strongly correlated. The Pearson correlation coefficients of the cultivation stage V1, the sowing stage V2, the fertilization stage V5, the harvest stage V6, and the irrigation stage V4 are -0.035, -0.035, -0.035, and -0.035, respectively, indicating that the interviewed farmers believe that the degree of correlation with the importance of agricultural mechanization services in the irrigation stage is weak and negative. The two-tailed test probability value is greater than 0.05, failing the significance test. The correlation coefficients of the other planting stages are all concentrated in the range of 0.337–1.000. The interviewed farmers believe that the importance of agricultural mechanization services in these planting stages has a specific correlation.

Table 1. Basic characters of varieties

Variety	Stage	Meaning
V1	Cultivation stage	Agricultural mechanization services to reduce the influence of agricultural cost in the wheat cultivation stage
V2	Sowing stage	Agricultural mechanization services to reduce the influence of agricultural cost in the wheat sowing stage
V3	Plant protection stage	Agricultural mechanization services to reduce the influence of agricultural cost in the plant protection stage
V4	Irrigation stage	Agricultural mechanization services to reduce the influence of agricultural cost in the irrigation stage
V5	Fertilization stage	Agricultural mechanization services to reduce the influence of agricultural cost in the fertilization stage
V6	Harvest stage	Agricultural mechanization services to reduce the influence of agricultural cost in the harvest stage
V7	Total cost	Agricultural mechanization services to reduce the influence of the total agricultural cost

Table 2. Correlation test of Henan wheat cost

		V1	V2	V3	V4	V5	V6	V7
V1	Correlation	1	1.000**	0.337**	-0.035	0.288*	1.000**	1.000**
	Sig. (two-tailed)		0.000	0.003	0.758	0.010	0.000	0.000
V2	Correlation	1.000**	1	0.337**	-0.035	0.288*	1.000**	1.000**
	Sig. (two-tailed)	0.000		0.003	0.758	0.010	0.000	0.000
V3	Correlation	0.337**	0.337**	1	0.919**	0.056	0.337**	0.337**
	Sig. (two-tailed)	0.003	0.003		0.000	0.629	0.003	0.003
V4	Correlation	-0.035	-0.035	0.919**	1	-0.054	-0.035	-0.035
	Sig. (two-tailed)	0.758	0.758	0.000		0.640	0.758	0.758
V5	Correlation	0.288*	0.288*	0.056	-0.054	1	0.288*	0.288*
	Sig. (two-tailed)	0.010	0.010	0.629	0.640		0.010	0.010
V6	Correlation	1.000**	1.000**	0.337**	-0.035	0.288*	1	1.000**
	Sig. (two-tailed)	0.000	0.000	0.003	0.758	0.010		0.000
V7	Correlation	1.000**	1.000**	0.337**	-0.035	0.288*	1.000**	1
	Sig. (two-tailed)	0.000	0.000	0.003	0.758	0.010	0.000	

*Correlation is significant at the 0.05 level (two-tailed), **correlation is significant at the 0.01 level.

2.2 Regression Analysis of Agricultural Mechanization Service on Henan Wheat Cost

We transpose the original data of 78 visits and surveys in Henan Province in EXCEL, import the original data into SPSS software, and perform multiple linear regression analysis through SPSS software (IBM, Armonk, NY, USA). Therefore, the following analysis results are obtained.

Table 3 shows the linear regression analysis results of the importance and cost of agricultural mechanization services at different wheat planting stages in Henan Province. In the table, we can obtain an adjusted R^2 coefficient of 1, indicating that the agricultural mechanization service levels of planting stages of harvesting stage V6, irrigation stage V4, and plant protection stage V3 can fully explain the changes in wheat cost in Henan Province. The standard error of the dependent variable's predicted value is 0.04035, which indicates that the error between the actual observation and the regression estimate is minimal. Durbin-Watson is 1.855, close to about 2, indicating that the overall fit of the regression model is good.

Table 3. Fitness of fit of Henan wheat cost regression

Model summary[c,d]					
Model	**R**	**R2[b]**	**Adjusted R^2**	**SE of the estimate**	**Durbin-Watson**
1	1.000[a]	1.000	1.000	0.04035	1.855

[a] Predictors: VAR00006, VAR00004, VAR00003.
[b] For regression through the origin (the no-intercept model), R^2 measures the proportion of the variability in the dependent variable about the origin explained by regression. This CANNOT be compared to R^2 for models which include an intercept.
[c] Dependent variable: VAR00007.
[d] Linear regression through the origin.

Table 4 illustrates the importance of agricultural mechanization services and cost variance analysis at different wheat planting stages in Henan Province, as well as the mean square, degree of freedom, *F*-test, and significance level. The variance is 3797.878, the mean square 1265.959, the residual 0.122, and the associated probability Sig less than 0.05, indicating that the independent variable has a significant impact on the dependent variable. The importance of agricultural mechanization services at different wheat planting stages in Henan Province significantly impacts the cost.

Table 4. Analysis of variance analysis

ANOVA[c,d]						
Model		**Sum of squares**	**df**	**Mean square**	***F***	**Sig.**
1	Regression	3797.878	3	1265.959	777559.213	0.000[a]
	Residual	0.122	75	0.002		
	Total	3798.000[b]	78			

[a] Predictors: VAR00006, VAR00004, VAR00003.
[b] This total sum of squares is not corrected for the constant because the constant is zero for regression through the origin.
[c] Dependent variable: VAR00007.
[d] Linear regression through the origin.

Table 5 shows that in the collinearity test, the *t* value of the cultivation stage V1 and the seeding stage V2 is 1.744E9, and the associated probability is 0. Thus, there is a severe collinearity problem between the two independent variables, and the dependent variables V1 and V2 need to be excluded from the model.

Table 5. Variable exclusion analysis

Excluded variables[b,c]						
Model		Beta In	t	Sig.	Partial correlation	Collinearity statistics tolerance
1	V1	1.000[a]	1.744E9	0.000	1.000	3.215E-5
	V2	1.000[a]	1.744E9	0.000	1.000	3.215E-5

[a] Predictors in the model: VAR00006, VAR00004, VAR00003.
[b] Dependent variable: VAR00007.
[c] Linear regression through the origin.

Table 6. Multiple regression coefficients

Coefficients[a,b]						
Model		Standardized coefficients		Standardized coefficients	t	Sig.
		B	SE	Beta		
1	V3	0.302	0.013	0.293	22.807	.000
	V4	-0.273	0.012	-0.265	-22.411	.000
	V6	0.970	0.005	0.972	193.290	.000

[a] Dependent variable: VAR00007.
[b] Linear regression through the origin.

Table 6 shows that the t values of the multiple linear regression equations for the plant protection stage V3, irrigation stage V4, and harvest stage V6 of Henan wheat are 22.807, -22.411, and 193.290, respectively. Additionally, the associated probability is 0, less than 0.05, indicating linearity. After the regression equation is tested, the following regression equation models are obtained.

Eqs. (1) and (2) show that after the standardized coefficient, the mechanization of harvest stage V6 has the greatest impact on the cost of planting wheat, with a coefficient of 0.972. It has a significant positive impact on reducing planting costs, followed by plant protection stage V3 with a coefficient of 0.293, and then irrigation and drainage. The mechanization of stage V4 impacts planting costs, with a coefficient of -0.265, indicating that mechanized services in the irrigation and drainage stage may increase planting costs. But in general, the mechanized services in these three stages impact the cost of wheat cultivation in Henan Province.

Regression model of non-standardized coefficients:

$$Y=0.302X1-0.273X2+0.97X3 \tag{1}$$

Standardized regression model:

$$\begin{gathered} Y=0.293X1-0.265X2+0.972X3 \\ (22.807)\ \ (-22.411)\ \ (193.290) \end{gathered} \tag{2}$$

3. Social Network Analysis of the Six Planting Stages of "The Cost of Wheat in Henan" based on SNA Model

The social network analysis model (SNA) is a common social network analysis paradigm, describing the distance between the various related factors or stages and the clan relationship. In this study, UCINET 6.0 is used to complete the visual processing of social network phase relevance, visual processing of branch blocks, and centrality analysis of each phase, phase block cluster and phase block density analyses.

We choose SNA software (UCINET 6.0) for data entry, then use NETDRAW for visualization processing and obtain the following diagram.

Spring embedding displays a strong correlation among tillage, sowing, plant protection, irrigation and drainage, fertilization, and harvesting (Fig. 1). The correlation coefficients are 1.000, 1.000, 1.000, 1.000, and 1.000, respectively. The cost of wheat has a similar effect. On this basis, we further analyze the centrality measures, using OutDegree and InDegree to characterize, we obtain the following data.

From the degree measures and centrality measurement in Table 7, it can be seen that the centrality of drainage and irrigation stage V4, fertilization stage V5, harvesting stage V6, tillage stage V1, sowing stage V2, OutDegree, and InDegree are all 4.107. The agricultural mechanization service cost of these five stages has an equally significant impact on the cost of the entire planting stage, while that of the plant protection stage V3 has a negligible effect. The OutDegree and InDegree centrality points are 0.535.

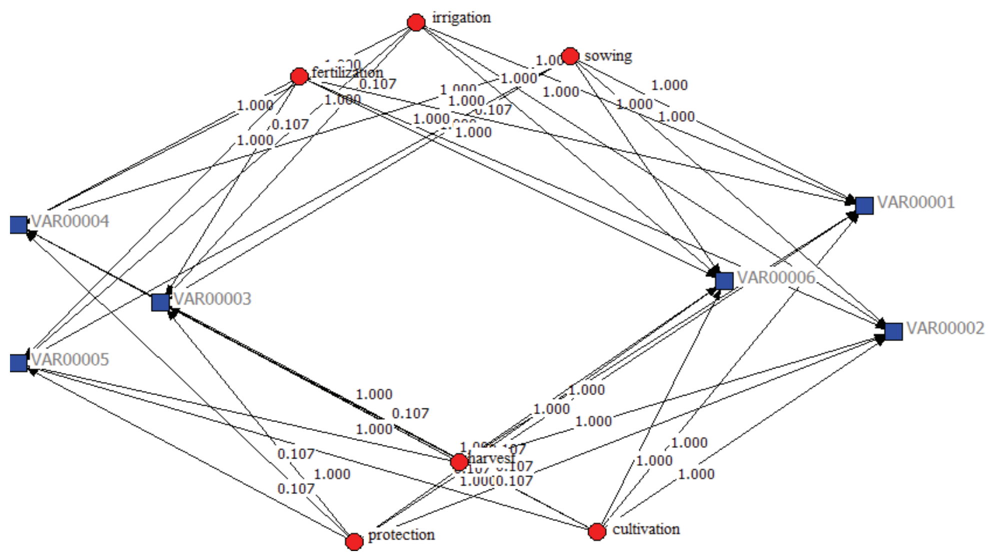

Fig. 1. Empowered two-node spring embedding display diagram.

Table 7. Centrality analysis of planting stage

Order	Stage	1	2	3	4
		OutDegree	InDegree	NrmOutDeg	NrmInDeg
4	V4	4.107	4.107	82.140	82.140
5	V5	4.107	4.107	82.140	82.140
6	V6	4.107	4.107	82.140	82.140
1	V1	4.107	4.107	82.140	82.140
2	V2	4.107	4.107	82.140	82.140
3	V3	0.535	0.535	10.700	10.700

Table 8 reveals that wheat agricultural mechanization service cost is the relationship connection diagram and matrix. It can be divided into four blocks. The first block element is the cultivation stage

V1, sowing stage V2, harvest stage V6, and drainage and irrigation stage V4. The second block element is the plant protection stage V3 and the fertilization stage V5. The interaction relationship between the first and the second block elements comprise the third and fourth blocks. The maximum value in the block is one, and the minimum 0.107.

Table 8. Divide blocks of different stages

Order	Stage	1	2	6	4	5	3
1	V1	1.000	1.000	1.000	1.000	1.000	0.107
2	V2	1.000	1.000	1.000	1.000	1.000	0.107
6	V6	1.000	1.000	1.000	1.000	1.000	0.107
4	V4	1.000	1.000	1.000	1.000	1.000	0.107
5	V5	1.000	1.000	1.000	1.000	1.000	0.107
3	V3	0.107	0.107	0.107	0.107	0.107	1.000

Table 9 shows that the maximum value is 1 among the four blocks. The density coefficient between the first and the second blocks indicates that the relationship between the two blocks is strong. The minimum value of the density coefficient between the first and the second blocks is 0.107, which weakens the relationship between the two.

Table 9. Wheat planting block density matrix

	1	2
1	1	0.554
2	0.553	0.107

4. Relationship Network Analysis of the Six Planting Stages of "the Cost of Wheat" based on the RBF Neural Network Model

Radial basis function (RBF) neural network is also called the local receptive field neural network. The principle is to use the RBF to perform interpolation operations in high-dimensional space, the RBF network model, and the backpropagation (BP) neural network. Both are multi-layered feed-forward BP networks. However, the RBF neural network is more accurate than the BP neural network. Therefore, it can overcome the slow process of BP network global approximation and accommodate more time-efficient models. RBF can detect the nonlinear and complex relationship between the input and the output layers to intuitively understand the six stages: cultivation stage V1, sowing stage V2, plant protection stage V3, drainage, and irrigation stage V4, fertilization stage V5, harvest stage V6, affecting the "cost of wheat in Henan." We selected 78 data points (shown in Table 10) from Chongqing, Shaanxi, Henan, Liaoning, and other provinces and cities for model analysis on the complex influence of the relationship between the fertilization stage V5 and the harvest stage V6 on the total cost V7.

Table 10 shows that a total of 78 samples were selected, 5 of which were eliminated during the calculation process. The number of model training samples was 55, the test support samples 18, and the effective rate 100%. Training is terminated when the error cannot be further reduced. Thus, the training effect is good and meets the standard requirements.

Table 10. Data selection of the model of wheat planting

Case processing summary	N (%)
Sample	
Training	55 (75.3)
Testing	18 (24.7)
Valid	73 (100)
Excluded	5
Total	78

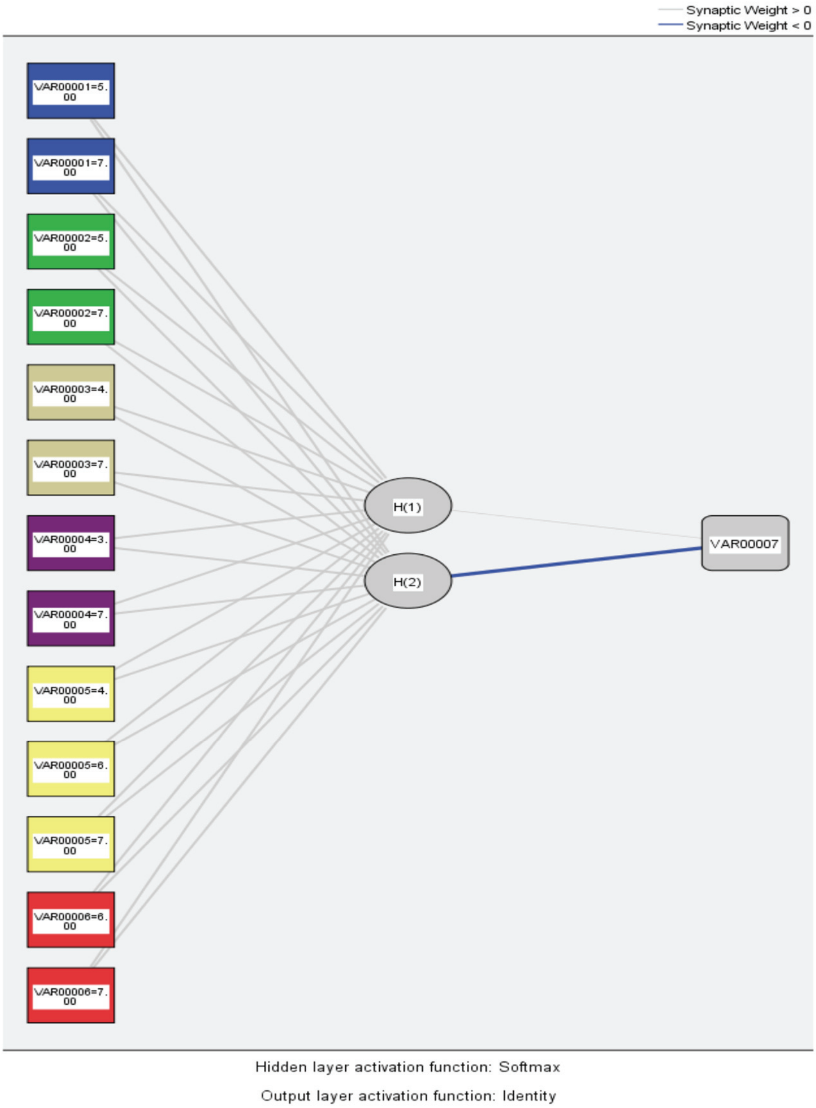

Fig. 2. Radial basis function network.

The nonlinear and complex relationship diagram of the RBF network of the six planting stages of the "cost of wheat in Henan" (Fig. 2) shows that the model contains a hidden layer (Hidden-Layer) of four neural units (Units), an input layer (Input-Layer), and an output layer (Output-Layer). There are several lines mapped from the input layer to the hidden layer. The gray lines represent the positive weight relationships, and the blue line the negative weight relationships. Similarly, the mapping from the hidden layer to the output layer is the same. Again, the blue line represents a negative weight relationship, and the gray lines a positive weight relationship.

Fig. 3 shows that the independent variable is sorted by V1 at the tillage stage, with a coefficient of 0.222. The importance after standardization treatment is 100%; V2 at the sowing stage, with a coefficient of 0.199, standardized. The importance after treatment is 89.8%; V4 in the irrigation stage, the coefficient is 0.178, and the importance after standardization treatment is 80.2%; V6 in the harvest stage, the coefficient is 0.163, and the importance after standardization treatment is 73.4.%; V3 in the plant protection stage, the coefficient is 0.131, and the importance after standardized treatment is 59.1%; V5 in the fertilization stage, the coefficient is 0.106, and the importance after standardization is 47.5%.

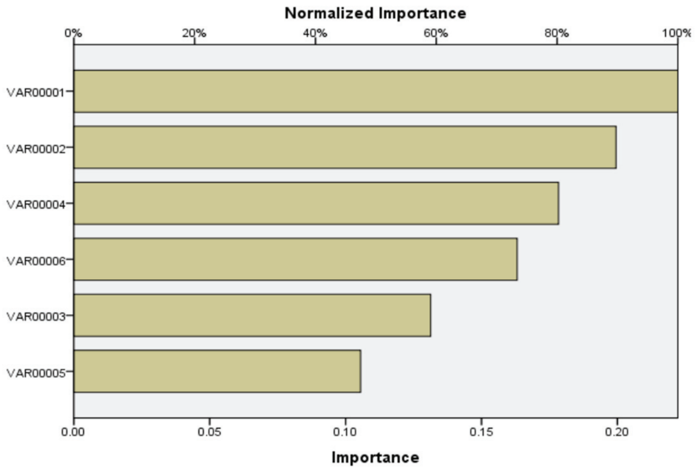

Fig. 3. Bar graph of the standardized measure of the importance of independent variables.

5. Comparative Analysis of Factor Ranking based on Linear and Nonlinear Research Methods

As the characteristics of each research method are different, the calculation results of may be different as well. Therefore, we further analyze the calculation results of the three methods, multiple linear regression, SNA and RBF neural network, as shown in Table 11.

Table 11. Factor ranking of various research methods

Importance	Multiple regression	SNA	RBF neural network
1	cultivation stage V1	cultivation stage V1	cultivation stage V1
2	sowing stage V2	sowing stage V2	sowing stage V2
3	harvest stage V6	harvest stage V6	irrigation stage V4
4	protection stage V3	irrigation stage V4	harvest stage V6
5	irrigation stage V4	fertilization stage V5	protection stage V3
6	-	protection stage V3	fertilization stage V5

Table 11 shows the phased impact of agricultural mechanization services on wheat planting costs. From the perspective of multiple linear regression analysis, the dependent and independent variables of the cultivation stage V1 and the sowing stage V2 are completely collinear. The correlation coefficient between them indicates that the two independent variables have the most significant impact on the dependent variable. The most important result of the SNA is in the cultivation stage V1, followed by the sowing stage V2 and the harvest stage V6. The three stages are consistent with the multiple linear regression analysis results; the most important calculation result of the RBF neural network is also in the tillage stage V1, followed by the sowing stage V2.

However, overall, the first few results calculated by the three methods are the same: in the cultivation stage V1, the sowing stage V2, and the harvest stage V6. This indicates that the agricultural mechanization services have the most significant impact on the cost of wheat cultivation. This is the experimental result confirmed by research methods, original data, and test data.

6. Conclusion

Based on previous studies, this article analyzes the effect of agricultural mechanization on the cost of wheat in different planting stages by decomposing the wheat planting stages in Henan. First, we obtained the agricultural mechanization service cost as the dependent variable using the multiple linear regression model. Then, we obtained the linear equation with the cost of different planting stages as the independent variable to analyze the importance of mechanization services at different stages. Second, SNA was used to analyze the relationship between the impact of agricultural mechanization services and the cost of wheat planting at different stages, the results of visualization processing, centralization analysis, and density coefficient model analysis. Third, we analyzed the six planting stages of the “cost of wheat” through the RBF neural network model. We obtained the weight chart of the nonlinear complex mapping relationship among the input, the hidden, and the output layers. Finally, we compared and analyzed the factor importance ranking results of the three models of multiple linear regression, SNA, and RBF neural network, indicating that different research methods have different calculation results. Nonetheless, their factor ranking calculation results have convergence.

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