EVOLUTIONARY GAME ANALYSIS OF ECOLOGICAL COMPENSATION IN THE ECONOMIC TRANSITION OF STATE- OWNED FOREST AREAS

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Abstract. The excessive consumption of forest resources has severely challenged the sustainable development of society, economy and resources in state-owned forest areas, so it is urgent to explore the economic transformation of forest areas. In the process of economic transformation and development in forest areas, a large amount of social capital is needed to make up for the shortage of national financial investment. The implementation of an ecological compensation mechanism is of great significance to attract social capital to the economic transformation and development of forest areas and to realize the sustainable development of the ecological environment. However, ecological compensation involves the direct interests of many parties, and it is easy to form a game situation. The evolutionary game model between government's ecological compensation behavior and social capital's ecological protection behavior is constructed to study the selection strategies of ecological problems under different circumstances by both sides, obtaining stability strategy and evolution path of both sides within different range of parameters. The research shows that the necessary condition to realize the optimal and stable equilibrium strategy is that the project investment profit of social capital should be larger than speculative profit under the government's ecological non-compensation, and the supervision cost of government departments should be less than ecological profit.

Keywords: *ecological protection, ecological compensation, evolutionary strategy, evolutionary trend, ecological benefit*

Introduction

During the inspection of state-owned forest areas in China, some scholars have pointed out that new ways for industrial development should be explored after the commercial logging has been completely stopped in the state-owned forest areas. It is necessary to shift from the extensive strategy of resource development and economic development to the ecological development strategy of rational protection, intensive resource development and economic development. At this stage, the research achievements on the economic transformation of state-owned forest areas are as follows: the current situation of the transformation is analyzed, and the measures for the coordinated development of ecological construction and economic transformation are put forward (Li et al., 2019; Tong et al., 2018; Wen et al., 2017). Through the analysis of the interest game among the central government, local government and state-owned forestry enterprises in the process of the construction of the ecological function zones in the Daxiaoxingan Mountains, the strategies for improving the economic transformation in the state-owned forestry areas are put forward (Zhong et al., 2017). In the reform of the state-owned forest ownership, the game model of the stakeholders' responsibility of the government, forestry enterprises and workers is established, and the measures for the three parties to obtain reasonable interests according to their responsibilities are put

forward (Sun et al., 2018). To sum up, it is an arduous task to protect both ecology and the people's livelihoods in the transformation and development of forest areas. We should broaden our thinking and take multiple measures simultaneously. Therefore, finding a balance between ecological protection and economic transformation has become the key to the reform of state-owned forest areas in China. Introducing the mechanism of ecological compensation and adjusting the ecological interest relations among ecological stakeholders by economic means are of great significance for protecting the forest ecosystem and promoting the economic transformation and upgrading of forest areas.

The existing research on ecological compensation mainly includes two aspects: one is the construction of ecological compensation mechanism. On the basis of systematic analysis of the elements of ecological compensation for forest tourism, the specific mechanism of taking ecological protection and economic development into account simultaneously through ecological compensation is put forward (Fang et al., 2018; Liu et al., 2018). The other is that the evolutionary game theory is used to solve the problem of ecological compensation in many fields. In China's non-resident islands, the dynamic evolution process of the influence of various elements of the main stakeholders of ecological compensation on decision-making behavior is analyzed by using the evolutionary game theory (Liu et al., 2016). The strategic selection between ecological compensation of mineral resources development enterprises and government supervision is discussed from the perspective of evolutionary game theory (Zhang, 2016). The game behavior of upstream and downstream governments in the process of implementing ecological protection and compensation is analyzed, and the effective ways to protect the ecological environment of the basin is obtained (Zhou et al., 2018). The conflict of interest and game in ecological compensation for coal mining is analyzed, and some measures and suggestions for coordinating and balancing the interests of all parties in ecological compensation is put forward (Guo et al., 2018). In summary, no scholars have explored the ecological compensation problems for the economic transformation of the state-owned forest areas in China from the perspective of the Public-Private Partnership model and the evolutionary game. Therefore, this paper introduces evolutionary game theory to construct a game model between the social capital side's ecological protection behavior and government's ecological compensation behavior, which provides theoretical basis and decision support for the realization of high-quality coordinated development of ecological construction and economic transformation.

Materials and methods

Research subject

This paper takes Lutou forest farm in Pingjiang County, Yueyang City, Hunan Province, China, as a specific research object. The construction of Lutou forest farm needs a large amount of financial support. The Public-Private Partnership model should be adopted to encourage and guide the participation of social capital, which is conducive to promoting the economic transformation of the forest farm. However, in the process of cooperation, there is a certain conflict between the social capital's goal of maximizing economic benefits and the government's goal of pursuing environmental benefits, which leads to the game between them in the process of ecological protection implementation. In the process of game, when the investment income of the social

capital side decreases due to the protection of the ecological environment, they tend to prefer not to protect the ecological environment. For this kind of behavior of the social capital side, when the government takes incentive measures to compensate for the ecological expenditure of enterprises, they will restore the ecological environment; and when the government relaxes the incentive of their ecological protection behavior, the social capital side will produce acts of destroying the environment. In this way, the social capital side and governments play games according to their respective goals until they reach equilibrium.

Therefore, the main stakeholders involved in the evolutionary game model of the ecological compensation are the social capital side and government departments. The social capital side and government departments conduct strategy selection for ecological protection. The strategic space for social capital side is ecological protection and non-ecological protection, and the strategic space for government departments is ecological compensation and non-ecological compensation. During the whole process of cooperation, the two sides are bounded rationality and they constantly adjust their own decision-making according to their own benefits and strategies of the other side.

Basic assumptions

The following assumptions are made on the evolutionary game model of ecological compensation:

(1) Benefits and cost of social capital side: I is the project investment; R is the benchmark rate of return; b_s is the for the distribution rate of benefits; L_l is the environmental benefits obtained by carrying out the ecological protection measures; e is the extra benefits by pursuing the pure economic interests but failing to implement the ecological protection measures, which is related to the degree of speculation of the social capital side. c_1 is the cost paid by social capital to achieve the project economic and environmental benefits; K is the ecological compensation given by government departments when social capital side performs ecological protection measures; S is the punishment imposed by government departments on the social capital side which does not perform ecological protection measures.

(2) P_1 ($0 \leq P_1 \leq 1$) is the ecological protection level of the social capital side. In the case of ecological protection measures in place, $P_1 = 1$; the smaller the value of P_1 , the weaker the ecological protection, which is reflected in the decline in ecological protection costs, increase in the extra benefits and punishment cost.

(3) Benefits and cost of government departments: the benefits of government departments come from the distribution of the income of the social capital side and punishment imposed on the social capital side. The cost includes the cost c_2 of supervising whether the social capital side implement ecological protection measures and the incentive cost of ecological subsidy for the social capital side.

(4) P_2 ($0 \leq P_2 \leq 1$) is the ecological compensation level of government departments. The smaller the value of P_2 , the less the compensation, which is reflected in the decline of supervision cost and punishment cost.

Establishment of evolutionary game model

The evolutionary game is based on bounded rationality, which assumes that due to the bounded rationality of the economic subjects, it is impossible for the economic

subjects to clearly understand their own state and thus they will follow the most favorable strategy to imitate until reaching the equilibrium.

Based on the above assumptions, the income matrix of the ecological compensation can be obtained, as is shown in *Table 1*.

Table 1. Income matrix of the evolutionary game model of ecological compensation

Social capital side	Government departments	
	Ecological compensation	Non-ecological compensation
Ecological protection	$(b_s IR + L_1 - C_1 + K,$ $(1 - b_s) IR + L_1 - C_2 - K)$	$(b_s IR + P_2 L_1 - C_1 + P_2 K,$ $(1 - b_s) IR + P_2 L_1 - P_2 C_2 - P_2 K)$
Non-ecological protection	$b_s IR P_1 + P_1 L_1 + e(1 - P_1) -$ $P_1 C_1 + K - (1 - P_1) S,$ $(1 - b_s) IR P_1 + P_1 L_1 -$ $C_2 - K + (1 - P_1) S$	$b_s IR P_1 + P_1 P_2 L_1 + e(1 - P_1) -$ $P_1 C_1 + P_2 K - (1 - P_1) S,$ $(1 - b_s) IR P_1 + P_1 P_2 L_1 -$ $P_2 C_2 - P_2 K + (1 - P_1) S$

Assuming that ratio of adopting “ecological protection” by the social capital side is x and the ratio of adopting “non- ecological protection” is $1 - x$ ($0 \leq x \leq 1$); the ratio of adopting “ecological compensation” by government departments is y and the ratio of adopting “non-ecological compensation” is $1 - y$ ($0 \leq y \leq 1$). In this way, the benefits θ_{11} and θ_{12} when adopting “ecological protection” and “non-ecological protection” and the group average benefit $\bar{\theta}_1$ are showed in *Equations 1–3*:

$$\theta_{11} = y(b_s IR - C_1 + K) + (1 - y)(b_s IR - C_1 + P_2 K) \quad (\text{Eq.1})$$

$$\theta_{12} = y(b_s IR P_1 + e(1 - P_1) - P_1 C_1 + K - (1 - P_1) S) + (1 - y)(b_s IR P_1 + e(1 - P_1) - P_1 C_1 + P_2 K - (1 - P_1) S) \quad (\text{Eq.2})$$

$$\bar{\theta}_1 = x\theta_{11} + (1 - x)\theta_{12} \quad (\text{Eq.3})$$

The replicated dynamic equation of the social capital side is showed in *Equations 4* and *5*:

$$G(x) = \frac{dx}{dt} = x(\theta_{11} - \bar{\theta}_1) = x(1 - x) \left(\frac{(b_s IR - e - C_1 + S + L_1 P_2)(1 - P_1)}{+ L_1 y(1 - P_1)(1 - P_2)} \right) \quad (\text{Eq.4})$$

$$G'(x) = (1 - 2x) \left(\frac{(b_s IR - e - C_1 + S + L_1 P_2)(1 - P_1)}{+ L_1 y(1 - P_1)(1 - P_2)} \right) \quad (\text{Eq.5})$$

In the same way, the replicated dynamic equation of local government department is showed in *Equations 6* and *7*:

$$G(y) = \frac{dy}{dt} = y(\theta_{21} - \bar{\theta}_2) = y(1-y) \left(\frac{(-C_2 - K + L_1 P_1)(1-P_2)}{+L_1 x(1-P_2)(1-P_1)} \right) \quad (\text{Eq.6})$$

$$G'(y) = (1-2y) \left(\frac{(-C_2 - K + L_1 P_1)(1-P_2)}{+L_1 x(1-P_2)(1-P_1)} \right) \quad (\text{Eq.7})$$

Make $G(x) = 0$, $G(y) = 0$, and obtain the five local equilibrium points in this evolutionary game system is $A(0,0)$, $B(1,0)$, $C(0,1)$, $D(1,1)$. When $0 \leq x^* \leq 1$ and $0 \leq y^* \leq 1$, the $E(x^*, y^*)$ is also the local equilibrium point in this evolutionary game system. In *Equations 8 and 9*:

$$x^* = \frac{C_2 + K - L_1 P_1}{L_1(1-P_1)} \quad (\text{Eq.8})$$

$$y^* = -\frac{b_s IR - e - C_1 + S + L_1 P_2}{L_1(1-P_2)} \quad (\text{Eq.9})$$

The Jacobian matrix corresponded to *Equations 4 and 6* is shown in *Equation 10*:

$$J = \begin{bmatrix} \frac{\partial G(x)}{\partial x} & \frac{\partial G(x)}{\partial y} \\ \frac{\partial G(y)}{\partial x} & \frac{\partial G(y)}{\partial y} \end{bmatrix} = \begin{bmatrix} (1-2x) \left(\frac{(b_s IR - e - C_1 + S + L_1 P_2)(1-P_1)}{+L_1 y(1-P_1)(1-P_2)} \right) & x(1-x)L_1(1-P_1) \\ y(1-y)L_1(1-P_2) & (1-2y) \left(\frac{(-C_2 - K + L_1 P_1)(1-P_2)}{+L_1 x(1-P_2)(1-P_1)} \right) \end{bmatrix} \quad (\text{Eq.10})$$

The determinant and trace of this Jacobian matrix can be obtained from *Equation 10*, see *Equations 11 and 12*:

$$\det J (\det e \min ant. Jacobian, \det J) = \frac{\partial F(x)}{\partial x} \square \frac{\partial F(y)}{\partial y} - \frac{\partial F(y)}{\partial x} \square \frac{\partial F(x)}{\partial y} \quad (\text{Eq.11})$$

$$\text{tr} J (\text{trace Jacobian}, \text{tr} J) = \frac{\partial F(x)}{\partial x} + \frac{\partial F(y)}{\partial y} \quad (\text{Eq.12})$$

If $\det J > 0$ and $\text{tr} J < 0$ are satisfied, then the equilibrium point of the replicated dynamic equation is evolutionary stable strategy.

Results

Make $\pi_1 = (b_s IR - e - c_1 + S + L_1)(1 - P_1)$ as the net income of social capital side who implement the ecological protection measures under the ecological compensation of government departments, $\pi_2 = (b_s IR - e - c_1 + S + L_1 P_2)(1 - P_1)$

as net income of social capital side who implement the ecological protection measures under the non- ecological compensation of government departments, $\pi_3 = (-c_2 - K + L_1)(1 - P_2)$ as the net income of government departments who perform ecological compensation when social capital side implement the ecological protection measures, and $\pi_4 = (-c_2 - K + L_1 P_1)(1 - P_2)$ as the net income of government departments who perform ecological compensation when social capital side fails to implement the ecological protection measures. From the formulas, $\pi_1 > \pi_2$ and $\pi_3 > \pi_4$.

The local equilibrium point stability of the Jacobian matrix of the system in Case (1) ($\pi_1 < 0, \pi_3 < 0$) were analyzed as shown in *Table 2*. Similarly, the evolutionary stable strategy of the system with different parameter value ranges, as shown in *Table 3*.

Table 2. Analysis of equilibrium point stability in case (1)

Equilibrium point	det. J	tr J	$\pi_1 < 0, \pi_4 < 0$		
			det. J	tr J	Stability
$A(0,0)$	$\pi_2 \cdot \pi_4$	$\pi_2 + \pi_4$	+	-	ESS (evolutionary stable strategy, ESS)
$B(1,0)$	$-\pi_2 \cdot \pi_3$	$-\pi_2 + \pi_3$	-	$\pm$	Saddle point
$C(0,1)$	$-\pi_1 \cdot \pi_4$	$\pi_1 - \pi_4$	-	$\pm$	Saddle point
$D(1,1)$	$\pi_1 \cdot \pi_3$	$-\pi_1 - \pi_3$	+	+	Instability

Table 3. Analysis of equilibrium point stability with different parameter values

	Parameter value range		Evolutionary stability strategy
(1)	$\pi_1 < 0, \pi_3 < 0$	$A(0,0)$	{no protection, no compensation}
(2)	$\pi_1 < 0, \pi_3 > 0, \pi_4 < 0$	$A(0,0)$	{no protection, no compensation}
(3)	$\pi_1 < 0, \pi_3 > 0, \pi_4 > 0$	$C(0,1)$	{no protection, compensation }
(4)	$\pi_1 > 0, \pi_2 < 0, \pi_3 < 0$	$A(0,0)$	{no protection, no compensation}
(5)	$\pi_1 > 0, \pi_2 > 0, \pi_3 < 0$	$B(1,0)$	{protection, no compensation}
(6)	$\pi_1 > 0, \pi_2 > 0, \pi_3 > 0, \pi_4 < 0$	$D(1,1)$	{protection, compensation}
(7)	$\pi_1 > 0, \pi_2 > 0, \pi_3 > 0, \pi_4 > 0$	$D(1,1)$	{protection, compensation}
(8)	$\pi_1 > 0, \pi_2 < 0, \pi_3 > 0, \pi_4 > 0$	$D(1,1)$	{protection, compensation}
(9)	$\pi_1 > 0, \pi_2 < 0, \pi_3 > 0, \pi_4 < 0$	$D(1,1)$	{protection, compensation}

Discussion

Analysis of the system stability strategy

In line with comparison and analysis of the data in *Table 3*:

(1) It can be concluded from Cases (1), (2) and (4) that only when $\pi_2 < 0$ and $\pi_4 < 0$, namely $b_s IR - c_1 + L_1 P_2 < e - S$ and $c_2 > L_1 P_1 - K$, the point $A(0,0)$ refers to the evolution stable strategy of the system, namely non- ecological protection by social capital side and non-ecological compensation by government departments. And the rest of the points are in a temporarily stable state, which means that once affected by factors, they will deviate from this state.

(2) It can be concluded from Cases (3) that only when $\pi_1 < 0$ and $\pi_4 > 0$, namely $b_s IR - c_1 + L_1 < e - S$ and $c_2 < L_1 P_1 - K$, ESS is $C(0,1)$, referring to non-ecological

protection by social capital side and ecological compensation by government departments.

(3) From Cases (5), it can be concluded that only when $\pi_2 > 0$ and $\pi_3 < 0$, namely $b_s IR - c_1 + L_1 P_2 > e - S$ and $c_2 > L_1 - K$, ESS is $B(1,0)$, indicating ecological protection by social capital side and non-ecological compensation by government departments.

(4) From Cases (6), (7), (8) and (9), it can be told that only when $\pi_1 > 0$ and $\pi_3 > 0$, namely $b_s IR - c_1 + L_1 > e - S$ and $c_2 < L_1 - K$, ESS is $D(1,1)$, referring to ecological protection by social capital side and ecological compensation by government departments.

Analysis of the system evolutionary trend

In line with the stability theorem of the differential equation and the nature of the evolutionary stable strategy, the value of y under $G'(x) < 0$ and the value of x under $G'(y) < 0$ can constitute the evolutionary stable strategy. Therefore, if $G(x) = 0$, $x_1 = 0$ and $x_2 = 1$ are the two stable state points of the dynamic equation of the social capital side. When $y = y^*$, $G(x) \equiv 0$, indicating all x refer to the stable state of the social capital side. When $y > y^*$, $G'(x) < 0$ shall be met. As $G'(1) < 0$, $x_2 = 1$ is the evolution stable strategy, when government departments choose “ecological compensation” strategy with the $y > y^*$ level, the social capital side tends to choose the strategy of ecological protection. When $y < y^*$, $G'(x) < 0$ shall be met. As $G'(0) < 0$, $x_1 = 0$ is the evolution stable strategy, when government departments choose “ecological compensation” strategy with the $y < y^*$ level, the social capital side tends to not choose the strategy of ecological protection.

If $G(y) = 0$, $y_1 = 0$ and $y_2 = 1$ are the two stable state points of the dynamic equation of government departments. When $x = x^*$, $G(y) \equiv 0$, indicating all y are in the stable state. When $x > x^*$, $G'(y) < 0$ shall be met. As $G'(1) < 0$, $y_2 = 1$ is the evolution stable strategy, when the social capital side choose “ecological protection” strategy at the $x > x^*$ level, the government departments tends to choose the strategy of ecological compensation. When $x < x^*$, $G'(y) < 0$ shall be met. As $G'(0) < 0$, $y_1 = 0$ is the evolution stable strategy, when the social capital side choose “ecological protection” strategy with the $x < x^*$ level, the government departments tends not to choose the strategy of ecological compensation.

Based on the above analysis, the evolution trends of the system under different parameter values are as shown in *Figure 1* (value ranges).

The strategic choice of the social capital side

Define $b_s IR - c_1 + L_1$ and $b_s IR - c_1 + L_1 P_2$ as the project investment profits of the social capital side under the ecological compensation and non- ecological compensation strategy of government departments, with $b_s IR - c_1 + L_1 > b_s IR - c_1 + L_1 P_2$. $e - S$ are defined as the speculative profits of the social capital side. For the social capital side, when $y^* > 1$ (the value range in cases (1) (2) (3)), $b_s IR - c_1 + L_1 < e - S$. The trend of evolution is that as long as the project investment profit is less than the speculative profit under the ecological compensation by the government, no matter what kind of strategy the government department adopts, the social capital side will tend to adopt the non- ecological protection strategy. When $y^* < 0$ (the value range in cases (5) (6) (7)), $b_s IR - c_1 + L_1 P_2 > e - S$. And the evolution trend is that as long as the

investment profit of the project is greater than the speculative profit under the non-ecological compensation of the government, the social capital side will tend to adopt the strategy of ecological protection regardless of the strategy adopted by the government. When $0 < y^* < 1$ (the value range in cases (4) (8) (9)), $b_s IR - c_1 + L_1 P_2 < e - S < b_s IR - c_1 + L_1$, and the strategy choice of the social capital side is related to the selection of government departments. When the proportion of government departments adopting the strategy of “ecological compensation” is large enough ($y > y^*$), the social capital side will eventually choose to implement the ecological protection strategy after evolution. However, if the government at this time fails to strengthen compensation ($y < y^*$), then the social capital side will be more likely to choose not to implement the ecological protection strategy.

Figure 1. Game evolution phase diagram of ecological compensation

The strategic choice of government departments

Define $L_1 - K$ and $L_1 P_1 - K$ as the ecological benefits of government departments under the ecological protection and non-ecological protection strategy of the social capital side. For the government, when $x^* > 1$ (the value range in cases (1) (4) (5)), $c_2 > L_1 - K$. In this case, the evolution trend is that as long as the supervision cost is greater than the ecological benefits, the government department will tend to adopt the non-ecological compensation strategy regardless of the strategy adopted by the social capital side. When $x^* < 0$ (the value range in cases (3) (7) (8)), $c_2 < L_1 P_1 - K$, and the evolution trend is that as long as the supervision cost is less than the ecological benefits,

the government departments will tend to adopt the ecological compensation strategy regardless of the strategy adopted by the social capital side. When $0 < x^* < 1$ (the value range in cases (2) (6) (9), $L_1P_1 - K < c_2 < L_1 - K$, and the government departments' strategy choice is related to the selection of the social capital side. As long as the social capital party increases the proportion of the strategy of "ecological protection" ($x > x^*$), the government department will eventually choose ecological compensation strategy after evolution. However, if the ratio is lowered in this case ($x < x^*$), government departments are more likely to choose non-ecological compensation strategy.

The evolutionary game characteristics of ecological compensation in state-owned forest areas

The evolutionary game analysis of ecological compensation in state-owned forest areas is different from that in other fields. This paper is based on the Public-Private Partnership model. The role of the government is no longer a supervisor, but a cooperator. In the process of setting model parameters, three characteristics of Public-Private Partnership model should be embodied: partnership, benefit sharing and risk sharing. Therefore, in the process of the economic transformation of state-owned forest areas, the government departments and the social capital side can actively use the results of this study to achieve the consistency of project objectives. At the same time, the model construction in this paper is a theoretical analysis under a series of basic assumptions, but the reality is more complex. For example, the dishonest behavior of the government, the high financing cost of the social capital, and the complexity of the transaction structure, and so on. All of these have a certain impact on the strategic choice of the government departments and the social capital side on ecological protection.

Conclusions

(1) In this paper, evolutionary game tools were used to study the decision-making of ecological compensation strategies by government departments and the social capital side in the process of economic transformation of Lutou forest farm. The motivation and interaction between the two sides are emphasized. The government's guidance and support and the leading and coordinating role of the social capital side are used to protect the ecological environment, improve economic, social and ecological benefits, and realize the sustainable development of forestry.

(2) The income matrix of different selection of ecological compensation strategies by government departments and the social capital side was established through introducing social capital's ecological protection strength and cost, government's ecological compensation strength and supervision cost, opportunity benefit, penalty quota, ecological subsidy and profit distribution ratio.

(3) In order to achieve the coordinated development of ecological construction and economic transformation, the ecological protection by social capital and the ecological compensation by government departments were the best strategies. Only when the investment profit of the project was greater than the speculative profit under the non-ecological compensation of the government departments and the supervision cost of

government departments is less its ecological profit, the optimal strategy could be achieved in the game evolution.

(4) Through the analysis of the evolvement trend of government departments and social capital side, we could draw that: reducing the ratio threshold y^* of ecological compensation by government departments, it is conducive for the social capital side to select the ecological protection strategy; reducing the ratio threshold x^* of ecological protection strategy by the social capital side, it is conducive for government departments to select the ecological compensation strategy.

(5) In order to make the ecological compensation strategies of government departments and the social capital side evolve smoothly to a satisfactory state, we should clarify the dominant position of the government, actively promote the ecological compensation systems and reward and punishment restraint mechanisms, Give full play to the key role of the social capital side, coordinate their interests distribution and conflict, build the reasonable mechanism of cost sharing and benefit sharing, improve their initiative to protect the ecological environment, and reduce the risk of participating in the economic transformation of the state-owned forest areas.

REFERENCES

- [1] Fang, S. Q., Ma, H. Y., Xu, S. G. (2018): Analysis on ecological compensation mechanism of the forest tourism and its countermeasures. – *Ecological Economy* 34(5): 207-211.
- [2] Guo, B., Hou, D. (2018): Study of ecological compensation of coal enterprises based on evolutionary game theory. – *Coal Technology* 37(5): 333-334.
- [3] Li, C. H., Zhao, X. H. (2019): Study on the coordinated development of ecological construction and economic transformation in state-owned forest region of forest industry in Heilongjiang Province. – *Journal of Nanjing Forestry University (Natural Sciences Edition)* 43(2): 144-147.
- [4] Liu, C., Cui, W. L. (2016): On ecological compensation mechanism of evolutionary game-based uninhabited islands. – *Journal of Zhejiang Ocean University (Humanities Science)* 33(4): 24-30.
- [5] Liu, M. M., Lu, Q. Q., Yang, J. C. (2018): Problems and improvement of compensation system for forest ecological benefits in China. – *Issues of Forestry Economic* 38(5): 1-7.
- [6] Sun, W. Q., Sun, L. (2018): A study on the responsibility game of the interest subject in the reform of state-owned forest right from the perspective of the new development concepts. – *Ecological Economy* 34(6): 139-143.
- [7] Tong, G. J., Geng, X. X. (2018): A survey and analysis on economic transformation in state-owned forest regions-taking Yichun city as an example. – *Forestry Economics* (2): 19-20.
- [8] Wen, W., Tian, G. S. (2017): Research on the inter-regional ecological compensation coordination path of ecological function region in Heilongjiang province from the perspective of the game theory. – *Forestry Economics* (2): 16-20.
- [9] Zhang, Q. (2016): Research on ecological compensation of mineral resources exploitation based evolutionary game theory. – *Resource Development & Market* 32(2): 165-169.
- [10] Zhong, W. W., Zhang, B., Zhang, H. R. (2017): The game analysis on the economic transition in state-owned forest regions-based on the construction of Daxiaoxingan mountains ecological function districts. – *Forestry Economics* (12): 46-49.
- [11] Zhou, C. F., Zhang, X., Liu, B. (2018): Research on basin ecological compensation based on evolutionary game theory: case of Chishui River Basin in Guizhou Province. – *Yangtze River* 49(23): 38-41.