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The Study of Woodland Use Efficiency from the Perspective of Forest Resources Change

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Abstract From the perspective of forest resources change, this article uses comparative analysis and panel data regression to study the woodland use efficiency from forest resources quantity and quality change. The results show that although the forest coverage and forest stock volume per hectare show an overall upward trend, there are different change laws between the two; there are also differences in the influencing factors between forest coverage and forest stock volume per hectare (population density, rainfall and project having significant effect on forest coverage; population density, economic density and institution having significant effect on forest stock per hectare). Finally the recommendations are put forth for improving the woodland resources use efficiency: it is necessary to improve both the forest quantity and forest quality, focus on demand and supply, and pay equal attention to project promotion and property rights system reform.

Key words Woodland, Forest resources, Forest coverage, Forest stock

1 Introduction

Woodland is the important national natural resource and strategic resource, and the foundation for survival and development of forests. At present, there are the problems of insufficient total woodland quantity and low woodland quality in China. China's forest coverage is only 69% of the world average, ranked 139th in the world, using 5% of the world's forest area, 3% of the world's forest stock volume to support ecology and forest product needs of 20% of the total global population.; most of China's woodlands are located in the arid and semi-arid regions, with barren soil, poor water and fertilizer conditions and low woodland productivity. Researching the woodland use efficiency from the perspective of forest resources change can provide growth potential for the cultivation of forest resources, and provide intellectual support for the sustainable use of woodland, so it is of important practical and theoretical significance.

The scholars have carried out the studies of China's woodland use efficiency, and obtained a lot of useful findings. However, the majority of studies are at the policy level [1–10] (Yang Ping, 2000; Hong Jiafeng, 2001; Zhang Yongmin, 2005; Huang Heliang, 2005; Wan Zhifang, Geng Yude, 2005; Hua qiqing, Lin Qing, 2006; Su Zuyun, Fei Shimin, Li Yu, 2007; Xiao Ping, Zhang Minmin, 2010; Mu Dan, Chao Luomeng, 2010; Hong Mingyong, Wang Houjun, Chen Weihong, 2001), and the impact of social and economic systems on woodland use change is mainly expounded. The empirical studies are mainly based on the statistical description and analysis [11–14] (Zhang Kefeng, Zhang Junlian, Lu Shilei et al, 2002; Chen Guojian, 2006; Du Guoming, Zhang Shuwen, 2006; Hemmavanh Chanhda, Ye Yanmei, Yoshida A, 2010). There is also the regression analysis based on general mixed data [15–16] (Zhan Jinyan, Shi Nana, Yan Haiming et al, 2011; Wang Chengjun, He Xiurong, Xu Xiuying et al, 2010), and the time trend analysis [17–18] (CYJIM, HT LIU, 2001; Xu Xinliang, Liu Jiyuan, Zhuang Dafang et al, 2004). The empirical analysis data are mostly based on the national macro level, and the data are relatively simple.

Through the statistical description, this article analyzes the trend of changes in the woodland area, forest coverage, and stock volume change per hectare, and through the provincial panel data regression, this article studies the factors influencing forest coverage and stock volume per hectare, in order to explore the law of change and improvement of woodland resources change, and provide theoretical support for the optimal allocation of woodland resources. This article carries out studies from two aspects. First of all, it analyzes the historical changes in the woodland area, forest coverage and stock volume per hectare; secondly, it analyzes the factors influencing the forest coverage and stock volume per hectare. The methods used in this article include graphical description, correlation analysis, panel regression analysis. By Husman test, panel regression model compares the fixed effects and random effects, and repeatedly compare several forms of fixed effects to select the best.

2 Historical changes in the woodland and forest resources

In accordance with the information of the Seventh National Forest Inventory (2004 – 2008), the total national woodland area was 303.7819 million ha, accounting for 31.6% of the land area, and the forest coverage was 20.36%. China's closed forest land area was 120 million ha in 1949; it declined slightly in the 1960s (113.3556 million ha); during the First National Forest Inventory (1973 – 1976), it rose to 119.78 million ha; during the Second National Forest Inventory (1977 – 1981), it declined to a certain

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extent (114.0209 million ha); during the Third National Forest Inventory (1984 – 1988), it rebounded to 122.6833 ha; subsequently, there was no fluctuation and it showed a gradual rising trend; during the Seventh National Forest Inventory, it reached 181.3809 million ha; the per capita closed forest land area first declined, then climbed and fell, but then rose again. Overall, the national closed forest land area showed repeated fluctuations, and it seemed to have no fixed rules to follow, as shown in Table 1.

Table 1 The changes in the national woodland in different periods

National Forest Inventory//year	1973 – 1976	1977 – 1981	1984 – 1988	1989 – 1993	1994 – 1998	1999 – 2003	2004 – 2008
Woodland area//10^4 ha	25 509	26 688.57	25 969.28	25 677.4	25 704.73	28 280.34	30 378.19
Closed forest land area//10^4 ha	11 978	11 402.09	12 268.33	12 852.23	15 363.23	16 901.93	18 138.09
Per capita closed forest land area//ha	0.13	0.12	0.12	0.11	0.12	0.13	0.14

Data source: National Forest Inventory and the authors' processing.

The forest coverage was 12.5% in 1949; it declined to 11.81% in the early 1960s; during the First National Forest Inventory, it was 12.7%; during the Second National Forest Inventory, it dropped to 12%; during the Third National Forest Inventory, it rebounded to 12.98%, and continued to rise subsequently; during the Seventh National Forest Inventory, it reached 20.36%, as shown in Fig. 1.

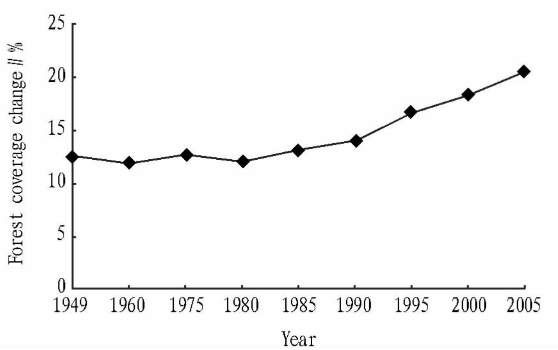

Fig. 1 Forest coverage change

The trend of change in China's forest stock volume per hectare is different from the trend of change in the forest coverage, showing repeated fluctuations. It was 90 m3 per hectare in 1949; it was 95.37 m3 per hectare in the 1960s; during the First National Forest Inventory, it was 79 m3 per hectare; subsequently, there were repeated fluctuations; during the Seventh National Forest Inventory, it reached 85.88 m3 per hectare, as shown in Fig. 2.

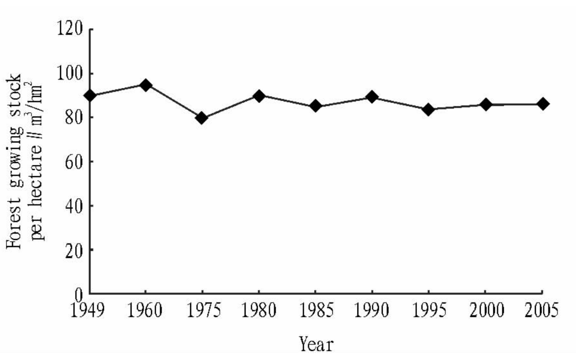

Fig. 2 The change in the forest stock volume per hectarestock volume

The trend of change in the forest coverage is different from the trend of change in the forest stock volume per hectare. The change in the forest coverage does not bring the corresponding change in the forest stock volume per hectare. There is no significant correlation between the change laws of both, which may be due to different influencing factors. This article will make further empirical analysis.

3 Analysis of the factors influencing forest coverage and stock volume per hectare

3.1 Data sources and variable selection

3.1.1 Data sources. This article is based on the forest survey data in 1949 and the early 1960s, and the National Forest Inventory (1st – 7th) data. The forest data in 1949 are from the system database of the Chinese Academy of Sciences; the forest data in the early 1960s are from the statistical work of national forest resources carried out by the Ministry of Forestry in 1962, and the subsequent statistical summary; the National Forest Inventory data are from the national forest survey results released by the State Forestry Administration. The forest coverage in this article is directly given from the above data sources; the forest stock volume per hectare is indirectly given from the above data sources, and the forest stock volume per hectare equals to the standing forest stock volume of stand per hectare. The data on system (forestry property rights change) and project (ten forestry projects) mainly come from Forestry Statistical Yearbook; the data on population, economy, sunshine, temperature and rainfall are from China Statistical Yearbook.

3.1.2 Variable selection. Forest coverage (FGL) and stock volume per hectare (GQXJ) are selected as the dependent variables in this article. The following variables are selected as the independent variables: population density (RKMD), economic density (JJMD), sunshine (RZ), temperature (WD), rainfall (JY), system (ZD, nominal variable, namely the change in the forestry property rights system), and project (GC, ordinal variable, mainly referring to the "Ten Key Forestry Projects" implemented under the guidance of the State Forestry Administration). It should be noted that the study designed for woodland use efficiency in this article regards forest coverage and stock volume per hectare as the dependent variables, and selects independent variables to analyze for their influencing factors, which is merely the choice under limited rationality and practical conditions. The design of equation variables is not entirely satisfactory.

On the one hand, as for the natural factors selected as independent variables, except sunshine, temperature and rainfall, soil conditions and other site conditions may also be the important influencing factors. Under normal circumstances, soil and other site factors are spatially and temporally consistent with the above climate variables (sunshine, temperature, rainfall). Due to the availability of data and complexity of land distribution, it is omitted here for simplification, and the correlation variables are regarded as the substitute variables. In addition, the total land area may also be an important factor, because the dependent variables of forest coverage and stock volume per hectare are the ratio form containing the land area information, and omitting the variable of total land area can even avoid the equation endogencity problem.

On the other hand, as for the economic and social factors selected as the independent variables, except forestry projects and systems, the external economic and social environments, such as the market, the relevant state laws and regulations and local leaders' decisions, will also have a significant impact on the dependent variables. It is believed in this article that the above external environments of various regions during the same period are approximately the same, without adding too many variables for simplification. When processing the provincial panel data, due to the changes and adjustments from the large span of time, in order to unify statistical standards, the Chongqing data are included in Sichuan data, the Hainan data are included in Guangdong data through contrast and corresponding calculation, and measurement regression does not include Taiwan and Hong Kong data.

3.2 Analysis of the factors influencing forest coverage

Based on the above analysis and the results of previous research, the research equation is designed as follows:

$$FGL = \beta_0 + \beta_i RKMD + \beta_2 JJMD + \beta_3 ZD + \beta_4 GC + \beta_5 WD + \beta_6 JY + \beta_7 RZ + uit.$$

Firstly, in order to make the equation smooth and eliminate the adverse effects of heteroscedasticity, the log – linear regression equation form is used for regression, and the dependent variable of forest coverage is in the ratio form itself. The logarithm of independent variables of population density, economic density, sunshine, temperature and rainfall is taken, respectively; the logarithm of independent variables of system and project (nominal variables) is not taken.

Secondly, by comparing the fixed effects and random effects, it is found that the fixed effects are more effective (R^2 is significantly improved, and other indicators are also improved).

Thirdly, the unit root test is carried out, and the results show that there is autocorrelation between population density and economic density, so EGLS method is used to correct the individual fixed effects model, as shown in Table 2. Finally, the final equation model of fixed effects is tested, as shown in Table 3.

Table 2 Fixed effects test of forest coverage (EGLS)

Cross – section fixed effects estimate				
Variables	Coefficient	Standard deviation	*t* statistic	*P* value
C	5.323 9	13.006 3	0.409 3	0.682 7
Population density	1.476 4	0.577 1	2.558 0	0.011 2
Economic density	0.187 2	0.135 5	1.381 3	0.168 5
Sunshine	0.464 2	1.150 5	0.403 5	0.687 0
Temperature	0.719 0	2.646 6	0.271 6	0.786 1
Rainfall	2.067 3	0.686 7	3.010 4	0.002 9
System	0.396 3	0.304 1	1.303 0	0.193 9
Project	2.363 2	0.143 6	16.447 5	0.000 0
The weighted evaluation statistic				
R^2	0.974 7	Mean of the dependent variable	25.844 2	
Corrected R^2	0.970 8	Standard deviation of the dependent variable	21.866 7	
Regression standard errors	3.911 8	Residual sum of squares	3 442.996 0	
F value	248.202 0	D – W value	1.153 4	
P value	0.000 0			
The evaluation statistic without being weighted				
R^2	0.938 7	Mean of the dependent variable	20.482 8	
Residual sum of squares	3 759.586 0	D – W value	0.880 7	

Table 3 Fixed effects equation test of forest coverage

Test effects	statistic	DOF	*P* value
Cross – section *F* value	125.316 6	(28, 225)	0.000 0

The results in Table 2 show that the population density, rainfall and project have a significant impact on forest coverage (0.05 significance level); through standardized correction, the goodness of fittest and various test standards are optimized, and R^2 reaches as high as 97%. The results in Table 3 show that the likelihood ratio (LR) test is significant, indicating It is incorrect that the fixed effects in the null hypothesis are redundant, and fixed effects model passes the test.

Population density has a significant impact on forest coverage, indicating that with the increase in population density, people have a growing demand for forest products and forests' unique social and ecological functions, thus improving the investment in forestry project and directly enhancing the forest coverage.

Economic density has a significant impact on forest coverage, indicating that the investment used for forest resource construction and protection does not increase with the growth of GDP.

Rainfall has a significant impact on forest coverage, while other natural conditions such as temperature and sunshine have not a significant impact on forest coverage. Relatively speaking, the effect of rainfall on tree growth is more direct.

Due the principles of the survival of the fittest and matching species with the site, trees have been selective and adaptive towards temperature and sunshine, while rainfall is more random, so it may have a greater impact on the growth of trees.

The system has no significant impact on forest coverage, and the possible reasons are as follows:

(i) The impact of system is indirect, and in order to play a role, the system needs to be combined with factors of production such as capital and technology.

(ii) In view of the unique system and system change path in China, the impact of system change in forest property rights on the forest growth can be considered to be synchronous and similar.

3.3 Analysis of the factors influencing the forest stock volume per hectare Based on the above analysis and the results of previous research, the research equation is designed as follows:

$$GQXJ = \beta 0 + \beta iRKMD + \beta 2JJMD + \beta 3ZD + \beta 4GC + \beta 5WD + \beta 6JY + \beta 7RZ + uit.$$

Firstly, in order to make the equation smooth and eliminate the adverse effects of heteroscedasticity, the log – log regression equation form is used for regression.

Secondly, by comparing the fixed effects and random effects, it is found that the fixed effects are more effective.

Thirdly, the unit root test is carried out, and the results show that there is autocorrelation between population density and economic density, so EGLS method is used to correct the individual fixed effects model, as shown in Table 4.

Finally, the final equation model of fixed effects is tested, as shown in Table 5.

Table 4 Fixed effects test of forest growing stock per hectare (EGLS)

Cross – section fixed effects estimate				
Variables	Coefficient	Standard deviation	t statistic	*P* value
C	5.265 4	1.033 6	5.093 8	0.000 0
Population density	0.126 4	0.050 5	2.500 8	0.013 1
Economic density	0.046 8	0.013 3	3.518 0	0.000 5
Sunshine	–0.060 3	0.087 5	–0.689 4	0.491 2
Temperature	–0.015 4	0.200 2	–0.077 1	0.938 6
Rainfall	–0.006 8	0.047 2	–0.143 9	0.885 7
System	0.058 5	0.028 9	2.025 2	0.044 0
Project	–0.009 6	0.011 8	–0.809 1	0.419 3
The weighted evaluation statistic				
R^2	0.948 4	Mean of the dependent variable	8.278 4	
Corrected R^2	0.940 4	Standard deviation of the dependent variable	5.319 8	
Regression standard errors	0.413 5	Residual sum of squares	38.485 1	
F value	118.396 3	D – W value	1.447 0	
P value	0.000 0			
The evaluation statistic without being weighted				
R^2	0.727 5	Mean of the dependent variable	3.928 3	
Residual sum of squares	46.500 3	D – W value	1.070 6	

Table 5 Fixed effects equation test of forest growing stock per hectare

Test effects	statistic	DOF	*P* value
Cross – section *F* value	23.883 7	(28, 225)	0.000 0

The results in Table 4 show that population density, economic density and system have a significant impact on the forest stock volume per hectare (0.05 significance level), and through standardized correction, the goodness of fittest and various test standards are optimized, and R^2 reaches as high as 94%.

The results in Table 5 show that the likelihood ratio (LR) test is significant, indicating that the fixed effects in the null hypothesis are redundant, and fixed effects model passes the test.

Economic density has a significant impact on the forest stock volume per hectare, while there is no significant impact on forest coverage. The possible reasons are as follows:

(i) With the improvement of people's purchasing power, there is a greater demand for forest products, and people pay more attention to the growth of forest stock volume, thereby increasing supply in order to achieve balance.

(ii) With the enhancement of economic strength, people pay more attention to improving the quality of forest resources, rather than simply pursuing the quantity increase.

Rainfall has a significant impact on forest coverage, but has no significant impact on forest stock volume per hectare, perhaps because in order to increase the forest stock volume, it urgently needs the synergy of natural climate and site conditions.

The impact of single factor is limited, and the explanation of the impact of population density and system is the same as previous analysis.

4 Conclusions and recommendations

4.1 Conclusions The improvement of woodland resources includes forest quantity increase and forest quality improvement. The forest quantity increase is mainly manifested in the growth of forest coverage, while the forest quality improvement is mainly manifested in the increase in the forest stock volume per hectare. This article carries out study of woodland use efficiency from the perspective of forest resources change. Based on the historical comparison and statistical description of woodland area and forest resources, as well as the econometric model analysis of the factors influencing forest coverage and forest stock volume per hectare, this article draws the following conclusions:

(i) Since the founding of New China, the woodland use efficiency has showed an overall upward trend except for slight fluctuations in the early period of New China. The closed forest land area, forest coverage and forest stock volume per hectare have different trends of change in the same period; the forest stock volume per hectare and forest coverage change have different trends of change, the change in the forest coverage does not bring the corresponding change in the forest stock volume per hectare, and there is no significant correlation between the change laws of both, which may be due to different influencing factors. In the 1960s, the closed forest land area and forest coverage declined to a certain extent, while the forest stock volume per hectare increased; after the 1970s, the three showed a steady upward trend.

(ii) The woodland use efficiency is analyzed from the perspective of forest coverage and forest stock volume per hectare. Through the panel data empirical analysis of the factors influencing forest coverage and forest stock volume per hectare, it is found that the population density, economic density, rainfall, project and system all have an impact on woodland use efficiency, but the impact is different. In terms of forest coverage, population density, rainfall and project have a significant impact, and the equation fitting degree is as high as 97%; in terms of forest stock volume per hectare, population density, economic density and system have a significant impact, and the equation fitting degree is 94%.

(iii) There are differences and also similarities in the equation regression results of the factors influencing forest coverage and forest stock volume per hectare. The population density has a positive impact on forest coverage and forest stock volume per hectare. The natural factors such as rainfall have a significant impact on the growth of forest quantity (forest coverage). The economic conditions such as economic density have a significant impact on the growth of forest quality (forest stock volume per hectare). The social environmental conditions such as project and system have different impact on both, that is, project has a significant positive impact on forest coverage while system (property rights system change) has a significant positive impact on forest stock volume per hectare.

4.2 Recommendations

(i) Based on the woodland use reality, two dimensions (forest quantity growth and forest quality improvement) should be considered for the cultivation of forest resources. Under the same external conditions, the trend of change in both may be different, and the increase in the forest coverage does not necessarily bring the corresponding increase in the forest stock volume per hectare. In the forestry planning and actual management, it is necessary to strengthen the guidance to different types of areas and scientific operation.

(ii) For the optimization of woodland resources use efficiency and the realization of multi-function forestry, it is necessary to pay attention to demand and supply. The population growth will bring many social and environmental problems, and increase people's overall demand for forest (quantity and quality). Economic growth will improve the supply capacity of forest resources, and with the increase in people's income, their consumer attitudes will accordingly change, and people will pay more attention to the improvement of forest quality. The forest quantity can be promoted by the forestry projects, and forest quality improvement needs a long-term effective mechanism. Based on the needs of people, it is necessary to timely adjust the forest management strategies, to improve the woodland use efficiency and continuously meet the needs of the people for a variety of functions of forest.

(iii) The forestry projects play an important role in improving the woodland resources use efficiency and enhance modern forestry development. In addition to the projects, it is also necessary to attach great importance to forestry property rights reform and other system factors, in order to improve woodland use efficiency and maintain comprehensive, balanced and sustainable forestry development.

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