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Eco-environment contribution of agroforestry to agriculture development in the plain area of China—Huai'an Prefecture, Jiangsu Province as the case study area

REN Hong-chang[1,2], LU Yong-long[1,*], LIU Can[3], MENG Qing-hua[2], SHI Ya-juan[1]

(1. Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, Beijing 100085, China. E-mail: score@mail.rcees.ac.cn; 2. Academy of Forest Inventory and Planning, State Forestry Administration, Beijing 100714, China; 3. China National Forestry Economics and Development Research Center, Beijing 100714, China)

Abstract: For improving the environmental quality and ensuring supply of wood and non-timber forest products, many forests have been planted in plain areas of China. Scientists have studied their benefits, almost all of the approaches were based on fixed-point data, and few was considered on the non-efficient factors and temporal scale effects. This paper studies the positive and negative benefits at a large temporal scale, and the effects of plain afforestation on stockbreeding and rural economy. The benefits of plain afforestation, correlation coefficiency of agroforestry and production factors are analyzed via stochastic frontier modeling in Huanghuaihai Plain Area of China; elastic coefficient of agroforestry, husbandry, farming, and total output of agricultural sector are calculated through adopting partial differential equation. Some conclusions can be drawn that, plain forests have an important effect on the development of plain agriculture. But shelterbelts and small-scale forests have different effect on the development of agricultural economy. Shelterbelts have negative effect on the industries, but small-scale forest has positive effect. On the whole, contribution of forest resource to value of animal husbandry and gross production value of agriculture is positive, and to the value of farming is negative.

Keywords: plain afforestation; agricultural development; agroforestry; plain area of China

Introduction

Since the 1950s, many forests have been planted in the plain areas of China for the improvement of the environmental quality and ensuring the supply of wood and non-timber forest products. Forestry development has played an important role in adjusting the rural economic structure, increasing farmers' income, and accelerating local economic development.

The benefits of plain afforestation include timber and non-timber production, ecological and social contributions (Pang, 1997; Li, 1999; Xu, 1999; Wu, 2001). Many researchers have studied the benefits of plain afforestation (Tao, 1995; Zhang, 1996a; 1996b; Zhao, 1996; Liu, 1997; Wu, 1997; Yin, 1997; 2000; Wang, 1999; Wan, 1999; Fan, 2001; Li, 2002; Zeng, 2002), but almost all of the researches have adopted fixed-point data, and few considered the non-efficient factors and temporal scale effects, therefore, it is necessary to study the positive and negative benefits at a large temporal scale, and the effects of plain afforestation on stockbreeding and rural economy.

The case study is designed to analyze the benefits of plain afforestation in Huanghuaihai Plain Area, with a time span from 1991 to 2001. Stochastic frontier analysis and transcendental logarithmic production function were adopted to analyze the correlation coefficiency of agroforestry and production factors; and partial differential equation is adopted to calculate the elastic coefficiency of agroforestry in the plain area, husbandry, farming, and total output of agricultural sector.

1 Data collection and methodology

The case site is located in the Huai'an Prefecture, Jiangsu Province (32°43′—34°06′N, 118°12′—119°36′E), with 2 districts and 4 counties. The population was 5.14 million in 2001. It covers from the middle-latitude warm temperate zone to the north subtropical temperate zone. Forest coverage ratio was 17.2% in 2001, and forest types include boarded-deciduous-forests and deciduous-evergreen-mixed forests.

From 1991 to 2001, labor forces in the study area have increased 157900 persons. The total output of agriculture has increased with 169%, and the production value of farming, forestry, husbandry and fishery has increased 116%, 266%, 119% and 396% respectively, which shows the high increase rate of forestry and fishery output value. Total power of agricultural machinery and consumption of rural electricity and chemical fertilizer also increased in terms of absolute values, which shows the level of farm mechanization increasing.

According to the change in agricultural structure from 1991 to 2001, as seen in Fig.1, the ratio of farming industry decreased from over 50% in 1991 to about 40% in 2001; the proportion of husbandry has almost no changes in the same period, and accounted for one third; while the percentage of forestry and fishery industry has increased rapidly. As the base value of forestry industry in 1991 was small, its proportion was not high yet in 2001.

Data were collected in the six counties of Huai'an Prefecture. It comprises three parts: (1) production values, including gross output value of agriculture, production values of forestry, husbandry, and farming etc.; (2) production factors, including labor, total power of agricultural machinery, amount of rural electricity and fertilizer, and the land area each year etc.; (3) forest resource data, including

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* Corresponding author

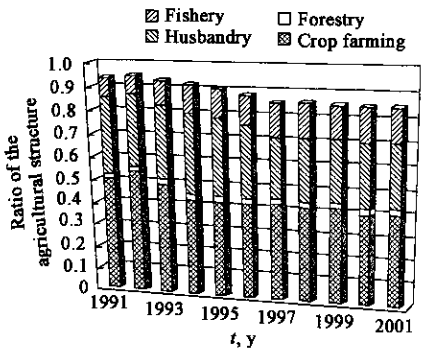

Fig.1 Agricultural structure of case site between 1991—2001

area and standing value of wood and shelterbelt, forest age structure, and so on. According to the real price index of 1990 in Huai'an, data of value index were deflated so that the true condition of input-output would be more comparable, and the results could be more rational.

The stochastic frontier production function, proposed by Aigner *et al*. (Algner, 1977) and Meeusen and Van den Broeck (Meeusen, 1977), has become popular with the increasing availability of firm-level data, for evaluating efficiency of individual firms and industries. Both economists and policy makers have made use of this trend as the notion of frontier which is consistent with the theory of optimization for identifying factors that can explain relative efficiencies of economic units (Kumbhakar, 1995; 1987; 1988; Battese, 1992; Bauer, 1990; Dhawan, 1997).

This function considers the error or disturbance term which consists of two components (U_{it} and V_{it}). V_{it} is the disturbance term with a zero mean. The disturbance term reflects random effects outside the control of production processes, including statistical noises, measurement errors, topography, and the effects of weather, and so on. The inefficiency part (U_{it}) has a one-sided distribution which is a non-negative truncation of the ~ $N(0, \sigma_u^2)$. The component U_{it} is independent of V_{it} (Aigner, 1977; Meeusen, 1977; Hartono, 2002).

The frontier production concept can be distinguished from the regression function concept, which provides the mean output for a given set of inputs (Hartono, 2002). Given the factor input values, inefficiency exists if the level of production or output is less than what must be the case of a fully technically efficient productive system (Pitt, 1981; Battese, 1993). The technical efficiency of an individual productive system is defined as the ratio of observed output to the attainable frontier output, given the level of input used by the productive system (Hartono, 2002).

A number of studies have explored the determination of technical efficiency using a two-step procedure (Battese, 1995). We can use this function to study the eco-contribution of agroforestry to agricultural development via the software FRONTER, which utilizes a Davidon-Fletcher-Powel maximization routine to produce the value of log likelihood at the maximum value (Coelli, 1998).

According to the social-economic conditions of the case site, models of stochastic frontier analysis (Hartono, 2002) and trans-log production function were adopted. The structure of model was as follows:

$$\ln(ao \text{ or } ho \text{ or } tpv)_{it} = \beta_0 + \beta_1\ln(lb)_{it} + \beta_2\ln(fl)_{it} + \beta_3\ln(fm)_{it} + \beta_4\ln(ff)_{it} + \beta_5\ln(fe)_{it} + \beta_6\ln(lw)_{it} + \beta_7\ln(yl)_{it} + \beta_8\ln(lw_{it})\ln(lb_{it}) + \beta_9\ln(lw_{it})\ln(fl_{it}) + \beta_{10}\ln(lw_{it})\ln(fm_{it}) + \beta_{11}\ln(lw_{it})\ln(ff_{it}) + \beta_{12}\ln(lw_{it})\ln(fe_{it}) + \beta_{13}\ln(yl_{it})\ln(lb_{it}) + \beta_{14}\ln(yl)_{it}\ln(fl)_{it} + \beta_{15}\ln(yl)_{it}\ln(fe)_{it} + \beta_{16}\ln(yl)_{it}\ln(ff)_{it} + \beta_{17}\ln(yl)_{it}\ln(fe)_{it} + \beta_{18}t + \beta_{19}t^2 + v_{it} + u_{it}. \quad (1)$$

Where:
i is the ith county; ao_{it} is the output of planting for ith county at the tth time; ho_{it} is the output of animal husbandry for ith county at the tth time*; tpv_{it} is the gross output of agriculture for ith county at the tth time*; lb_{it} is the number of laborers for ith county at the tth time; fl_{it} is the area of farmland for ith county at the tth time; fm_{it} is the total power of agriculture machinery for ith county at the tth time; ff_{it} is the amount of fertilizer for ith county at the tth time; fe_{it} is the amount of electricity for ith county at the tth time; lw_{it} is the area of shelterbelt for ith county at the tth time; yl_{it} is the area of small scale forest for ith county at the tth time; t is the time factor, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000 and 2001 were assigned as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11 individually; v_{it} is error. It is assumed as 0 of expectations, and its variance is σ_v^2 with normal distribution. β_0, β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8, β_9, β_{10}, β_{11}, β_{12}, β_{13}, β_{14}, β_{15}, β_{16}, β_{17}, β_{18}, β_{19} are estimated parameters.

Theoretically required regularity conditions for this function include homogeneity of degree one in output and symmetry (Lovell, 1990). Where: $u_{it} = u_i\exp(-\eta(t-T))$, u_i is a non-negative random error term, independently and identically distributed as $N^+(\mu\sigma_u^2)$, intended to capture time-invariant technical efficiency in outputs; μ, η parameters to be estimated.

According to the assumption of constant scale return and producer equilibrium, contribution of the area of shelterbelt to husbandry, farming, and gross output of agriculture can be difined by this formula:

$$\alpha_{it}^{lb} = \beta_6 + \beta_8\ln(lb_{it}) + \beta_9\ln(fl_{it}) + \beta_{10}\ln(fm_{it}) + \beta_{11}\ln(ff_{it}) + \beta_{12}\ln(fe_{it}). \quad (2)$$

The contribution of shelterbelt to the development of farming, husbandry, and agriculture was estimated as follows:

$$\alpha_{it}^{yl} = \beta_7 + \beta_{13}\ln(lb_{it}) + \beta_{14}\ln(fl)_{it} + \beta_{15}\ln(fe)_{it} + \beta_{16}\ln(ff)_{it} + \beta_{17}\ln(fm)_{it}. \quad (3)$$

The gross contribution of forest resources was:

$$\alpha_{it} = \alpha_{it}^{lw} + \alpha_{it}^{yl}. \quad (4)$$

2 Results and discussion

According to model (1), the gross production value of agriculture, production value of husbandry and farming were adopted as dependent variable, results of regression analysis are presented in Table 1.

Major factors were significant at 1% and 5% level. Through one-side check (Jondrow, 1982), the value is 100.62, higher than the critical value. So the model has the technical efficiency effect. The regression results can be used for correlation analysis.

Table 1 Regression results of the case site

Factors	Coefficient		
	Gross production value of agriculture	Production value of animal husbandry	Production value of farming
Invariable	9.1624***	10.0747***	6.5983***
Number of rural labors(ten thousand people)	-0.6703	-1.6610	-1.2056***
Farmland area(ten thousand mu, 1 hm^2 = 15 mu)	2.2403***	12.3932***	0.9858
Total power of agricultural machinery(ten thousand kilowatt)	5.2773***	1.1803	2.3535
Amount of fertilizer(ten thousand tons)	-0.8497	-5.7492***	0.4823
Amount of rural electricity(ten thousand kilowatts)	2.9240***	4.0556***	-3.5452***
Shelterbelts	0.19520*	-0.7340***	0.3693***
Forest area	-0.0184*	0.2046***	0.0466*
Shelterbelts × number of rural labors	1.0351***	-0.8782	-0.2452
Shelterbelts × farmland area	-4.5577***	-7.0878***	-0.3166
Shelterbelts × total power of agricultural machinery	0.1128	-0.1405	-0.7098
Shelterbelts × number of fertilizer	-0.1846	3.5916***	1.1597***
Shelterbelts × number of rural electricity	-2.5453***	-1.8007***	-1.2014*
Forest area × number of rural labors	-2.2169**	4.2467***	1.7005
Forest area × farmland area	11.2982***	11.7411***	0.3347
Forest area × total power of agricultural machinery	-3.5843***	-0.3120	0.5769
Forest area × amount of fertilizer	1.3761	-5.9414***	-3.5747***
Forest area × amount of rural electricity	5.2784***	2.5656*	5.5734***
Time	0.1306***	0.0521***	0.0678***
Time × time	-0.0052***	-0.0023	-0.0015

Notes: *** significant at 1% level; ** significant at 5% level; * significant at 10% level

For the case study area, frontier production model, by the null hypothesis that there are no technical efficiency effects in the model, can be conducted by the testing the null and alternative hypotheses of H_0: $\gamma = 0$ versus H_1: $\gamma > 0$. Coelli(Coelli, 1998) suggested that the one-sided generalized likelihood-ratio should be performed when maximum likelihood estimation is involved because the test has the correct size. The calculation of the critical value for this one-sided generalized likelihood-ratio test of H_0: $\gamma = 0$ versus H_1: $\gamma > 0$ is equal to $\chi_1^2(2\alpha)$. The critical value for our test of a size $\alpha = 5\%$ is 100.62, the *LR* test of the one-sided error with institutional arrangement and without institutional arrangement are 292 and 287808 respectively, which exceed $\chi_1^2(2\alpha)$, thus, we can reject H_0: $\gamma = 0$ in favor of H_1: $\gamma > 0$. There are technical inefficiency effects in the model.

2.1 The contribution analysis

According to model 2 and 3, the contribution of protection forest shelters and small scale forest areas to husbandry, farming, and gross output of agriculture is listed in Table 2.

Table 2 shows that the contributions of shelterbelts to husbandry, farming, and gross production value of agriculture are negative, but that of small-scale forest are positive. It means that, from 1991 to 2001, shelterbelts had negative effects on husbandry, farming, and gross production value of agriculture, and small-scale forests had positive effect on them. Shelterbelts had the largest passive effects on husbandry, then gross production value of agriculture, and then farming; small-scale forests had the highest positive effect on the production value of agriculture, husbandry, and then farming.

If data of shelterbelts and small-scale forests were combined for analyis, the contribution of forest resources was negative on farming, and positive on husbandry and gross production value of agriculture. That is, from 1991 to 2001, enlargement of forests in the case site had negative effect on farming development, and had positive effects on husbandry development of the agricultural output.

Table 2 The contribution of shelterbelts and small-scale forests to husbandry, farming, and gross production value of agriculture

Year	Husbandry			Farming			Gross production value of agriculture		
	Protection forest shelterbelt	Small-scale forest	Total	Protection forest shelterbelt	Small-scale forest	Total	Protection forest shelterbelt	Small-scale forest	Total
1991	-59.08	104.44	45.36	-15.53	8.73	-6.80	-49.96	118.61	68.65
1992	-59.13	104.79	45.66	-15.59	8.80	-6.79	-49.97	118.96	68.99
1993	-59.02	104.44	45.42	-15.60	8.64	-6.96	-50.08	118.93	68.85
1994	-58.88	104.13	45.25	-15.68	8.29	-7.39	-50.44	119.65	69.21
1995	-59.02	104.32	45.30	-15.85	8.09	-7.76	-50.93	120.74	69.81
1996	-59.02	104.30	45.28	-15.92	8.12	-7.80	-50.93	120.49	69.56
1997	-60.84	107.27	46.43	-16.13	8.07	-8.06	-52.39	123.86	71.47
1998	-59.38	104.84	45.46	-16.09	7.95	-8.14	-51.52	121.66	70.14
1999	-59.26	104.62	45.36	-16.09	7.90	-8.19	-51.48	121.41	69.93
2000	-59.16	104.50	45.34	-16.09	7.88	-8.21	-51.41	121.20	69.79
2001	-59.02	104.24	45.22	-16.08	7.81	-8.27	-51.37	120.96	69.59

From 1991 to 2001, effects of shelterbelts and small-scale forest had little changes on farming, husbandry and gross production value of agriculture. The contribution of forest resources to the production values of farming, husbandry, and gross production value of agriculture undulated around 45%, 8%, and 70% respectively.

Effects of forest resource had great differences among counties in the case site. Lianshui County had the highest effect, and Chuzhou County had the lowest effect. In other words, effects of forest resource are relevant to the local economic structure. Local economic development of Lianshui County is farming and husbandry orientation, and the formidable natural conditions for agricultural, therefore, the ecological effect of forest resources was more significant. Chuzhou County is industry orientation, and more-developed economy, with its smooth relief, so the ecological effect of forest resource was less significant.

According to model (1), the total factor productivity from 1991 to 2001 in the case site is presented in Table 3.

Table 3 Total factor productivity from 1991 to 2001 at case site

Year	Gross production value of agriculture	Production value of husbandry	Production value of farming	Year	Gross production value of agriculture	production value of husbandry	Production value of farming
1991	0.999052	0.654785	0.815854	1997	0.999043	0.664145	0.947796
1992	0.999047	0.656358	0.922044	1998	0.999046	0.665686	0.982105
1993	0.999051	0.657925	0.971282	1999	0.999049	0.667223	0.994782
1994	0.999052	0.659488	0.880881	2000	0.999044	0.668754	0.952698
1995	0.99906	0.661045	0.948667	2001	0.999054	0.670281	0.979639
1996	0.999058	0.662598	0.902118				

For gross production value of agriculture, its total factor productivity was >0.99, much higher than that of farming and husbandry. This meant plain afforestation could make rural production factors utilized sufficiently. According to the trend of efficiency, we can say that there are combined production effects among rural production factors. And for the level of total factor productivity, there are positive combined production effects among husbandry, forestry, and farming.

With regard to time span, the total factor productivity was relatively stabled not only for gross production value of agriculture, but also for production values of husbandry and farming, which meant that the results were reasonable.

2.2 Regional efficiency analysis

From this case study, the Chuzhou District has the lowest efficiency of husbandry, farming, and in terms of gross production value of agriculture, and this was coincident with the prevision conclusion that industry was more developed in Chuzhou County; Lianshui County has the highest efficiency of husbandry, farming, and gross production value of agriculture, and this was coincident with the forgoing conclusion that industry was less developed in Lianshui County.

2.3 Genetic analysis

It is reported in literature that shelterbelts accelerate farming, husbandry and agricultural developments, but the results of the case study indicated that shelterbelts in the plain areas constrain farming, husbandry and agricultural developments.

From 1991 to 2001, the forest area in the case study area accounted for 20.20% of total farmland areas. The middle-age forest area decreased from 10.6×10^4 hm^2 in 1991 to 9.13×10^4 hm^2 in 2001, or 13.84% of the total forest area. Half-mature forest area had increased 0.67×10^4 hm^2 and the area of near-mature and mature had increased 0.45×10^4 hm^2 and 9.17×10^4 hm^2 respectively. Half-mature forests had maximal ecological benefits for farming, husbandry, and agricultural production, and ecological benefits of mature forest and overmature forest decreased seriously, therefore, the contribution of shelterbelts in the case study area was negative. At the same time, the pattern of plain afforestation also had effect on its ecological benefits. The standard of plain afforestation in Huai'an City was 200 m × 300 m. Shelterbelts with smaller ordinance had higher density and significant menace on crops, and it also affected herding in forests and collecting folds for husbandry development, therefore, the negative effect of shelterbelts on husbandry increased with its area. The proportion of husbandry and planting was high in the gross output of local agriculture, and the development of shelterbelts also competed with other industry for land, so the contribution of shelterbelts was negative. When the household responsibility system was introduced, farmland had been divided into small parts for different farmers. Forests had negative effect on the small farmland at the edge of forest network. In order to reduce the negative effect, farmers would disafforest or inhibit the cultural operations. And this also had a bad effect on the benefits of shelterbelts.

From 1991 to 2001, the area of small-scale forests had increased by 298%, and poplar was the major species, rotation of which is usually 10—15 years, and the distribution of forest age was more rational; area of economic forest had decreased 20.9%; area of protective forest had increased 1.19×10^4 hm^2; and area of special-purpose forests had little changes. As viewed from the whole, small forest in Huai'an City has increased. Area of small forest was 4.85×10^4 hm^2 and 6.82×10^4 hm^2 in 1991 and 2001 respectively, and the average increasing speed was about 0.20×10^4 hm^2 per year. With the area of small forest increasing, it could protect farmlands more effectively, improve the micro-climate, and accelerate the increase of grain and other crops. Small forest also provides location for herding and collecting feed. When the household responsibility system was carried out, small-scale forest also contracted by farmers, thus, it could be protected carefully, and the forest form was good. With increasing price of poplar wood, value of poplar wood also provided good excitation mechanism for farmers, and small forest resource was cultivated and managed primly. Another point is that, with the adjustment of agriculture framework, poplar forest with low density could provide land for intercropping hay crop and herding, and poplar forest in farmlands also provided good ecological protection for crops. So the contribution of small forest was positive.

To the value of animal husbandry and gross output of agriculture, contribution of small-scale forest could offset the negative effect of shelterbelts on corresponding industries. Generally, forest resource could accelerate the development of farming, husbandry, and agricultural development. In Huai' an Prefecture, production value of husbandry and gross production value could increase by 45% and 70% respectively, while the forest resource increased by 1%, but the production value of farming would decrease 8%. It was impossible for the forest resource to increase by 1% in the short time, it need a long process. Total land area of case site was 10072 km^2, according to the increasing rate of forest land from 1991 to 2001, there about 6 years for the forest resource increase 1%. If the contradiction of farmland and other land uses, time would be longer. According to six years, the growth rate per year of planting value and gross output of agriculture was about 6.39% and 9.25% respectively. If the technical progress were considered, the rate would be high than this. Actually, from 1991 to 2001, the growth rate per year of planting value and gross output of agriculture in Huai' an City was about 6.76% and 8.63% respectively. Changes of the rate were related to technical progress and production factor redundancy.

3 Conclusions

Plain forests had an important effect on the development of plain agriculture. But shelterbelts and small-scale forests had different effect on the development of agricultural economy. Shelterbelts had negative effect on the industries, but small-scale forest had positive effect. As a condusion, contribution of forest resource to the value of animal husbandry and gross value of agriculture production was positive, and was negative to the value of farming. From 1991 to 2001, the contribution had little changes, but it had great changes among different counties of the case area. And this was closely related to local industry structure and natural geographic conditions.

In order to improve the effect of forest resource on animal husbandry and the whole agriculture fully, the structure of plain afforestation should be adjusted and optimized, using the following measures: (1) Enlarge the standard of plain afforestation to reduce the negative impact effect on farmlands; (2) increase the proportion of small-scale forest, and intercrop with hay grazing to adjust the structure of agriculture; (3) update shelterbelts timely, decrease the proportion of mature forest and increase the proportion of half-mature forest; (4) innovate the management system and introduce compensation system.

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