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Indirect Economic Losses Associated with Alien Invasive Species to Forest Ecological System in China

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Abstract

Indirect economic losses associated with alien invasive species to forest ecological system are mainly caused by the decrease of commonweal function. The indirect economic losses are in proportion to the decrease of forest volume growth caused by alien invasive species. Based on the data from forest inventory and typical case studies, indirect economic losses caused by alien invasive species to forest ecological system in 2000 are figured out. Indirect economic losses are ¥15443.43 million. Losses caused by alien conifer insects, such as *Bursaphelenchus xylophilus, Hemiberlesia pitysophila, Oracella acutus, Dendroctonus valens* and *Matsucoccus matsumur* are ¥13264.07 million, comprising 85.89 percent of the total losses, while losses caused by alien broad-leaved insects such as *Hyphantria cunea* are ¥742.90 million, comprising 4.81 percent. Losses caused by alien pathogens and other alien insects are ¥1436.46 million, comprising 9.30 percent of total losses.

Keywords: Alien invasive species; Forest ecological system; Indirect economic losses

1. Introduction

Alien species invasion is the phenomenon that harmful non-native species are introduced into new habitats and threaten the health of local ecosystems, species and human beings. Because of having unprecedented environmental and economic effects, alien species invasions now have become a global problem and China is one of the most seriously damaged countries by alien invasive species in the world. Since the foundation of P.R.C, many harmful species, such as *Bursaphelenchus xylophilus*, *Dendroctonus valen, Hyphantria cunea*, *Hemiberlesia pitysophila*, *Oracella acutus*, *Matsucoccus matsumura*, *Opogona sacchari, Eupatorium adenophorum, Mikania micrantha* have been introduced into China intentionally or unintentionally. Alien invasion is one of the most severe factors which threaten the existence of forest ecosystem. After alien invasive species have established in a forest stand, the values of timber products and tour sightseeing of forest ecosystem are decreased drastically. At the same time, many commonweal service functions of the forest ecosystem, such as regulating of climate, hydrological cycle including flood control and water supply, waste assimilation, recycling of nutrients, conservation and regeneration of soils, are greatly impaired. Because the indirect economic losses caused by the alien invasive species to the forest ecosystem are much greater than the direct losses, the valuation of the indirect losses in 2000 is carried on in order to increase the understanding of the damages deriving from alien invasive species and to supply the theoretical basis for the making of the control strategies.

2. Ecological and economic theories for evaluation of indirect losses

After the alien invasive species have established in local forest ecosystem, the structure of the system is badly damaged, the recovery ability and stability are decreased. Because of the complexity of forest ecosystem, until now, the researches on the economic evaluation of the structure and flexibility of forest ecosystem have not made breakthrough yet. On the contrary, the researches on the theory and methodology of evaluation on the service function have been conducted extensively since the conference on the economic value of biodiversity organized by SCOPE in 1991. Therefore, the emphasis of the research on the evaluation of indirect economic losses should be put on the service function of the forest ecosystem.

The functions of forest ecosystem are classified into four kinds: regulation, production, carrier and information. According to the viewpoints of the environmental economist, ecological damages are divided into three categories: direct economic losses, indirect economic losses, and recovery expenses. The direct losses are caused by the decrease of the output and quality of forest products. Indirect losses are induced by the

decrease of the commonweal service function. The direct economic losses can be calculated directly with the market prices, while the indirect economic losses can only be estimated with the opportunity costs, the shadow prices.

3. Theoretical models of indirect economic losses

The biomass is the basis of the function and process of ecosystem and is usually be used by many ecologists as a clue to evaluate the service function of ecosystems. So the indirect economic losses can be calculated by evaluating the extent of the decrease of the biomass of forest ecosystem. Because there is a close relationship between forest volume growth and forest biomass, an assumption can be made that the indirect economic losses are proportional to the decrease of forest volume growth. Indirect economic losses can be estimated by taking following steps. First, the data of forest areas attacked by alien invasive species are gathered. Secondly, the economic values of commonweal service function of forest ecosystem are estimated. Thirdly, the relationship between the attack and the loss of commonweal service function is established. Theoretical models of indirect economic losses are set up as following:

$$L = L(cpest) \times L(bpest) + L(others) \quad (1)$$

$$L(cpest) = S(cpest) \times F(conifer) \times K \quad (2)$$

$$L(cpest) = S(bpest) \times F(broad) \times K \quad (3)$$

$$L(others) = S(others) \times F(average) \times K \quad (4)$$

Among the above models, *L*(*cpest*), *L*(*bpest*) and *L*(*others*) stand for the indirect losses caused by the major conifer forest pests, major broad-leaved forest pests, other pests and pathogens respectively. *S*(*cpest*), *S*(*bpest*) and *S*(*others*) mean the areas of forests which were invaded by alien conifer forest pests, broad-leaved forest pests, other pests and pathogens. *F*(*conifer*), *F*(*broad*) and *F*(*average*) are the economic values of the commonweal service function of conifer forest, broad-leaved forest, the mean value of the conifer and the broad-leaved forest. *K* is the degree of the decrease of forest commonweal service function caused by the alien species.

4. Calculation of the parameters in the models

4.1 Forest areas invaded by alien species

The forest areas that were invaded by several major invasive pests in 2000 are 1,498,200hm^2 in which the areas of conifer forest and broad-leaved forest are 1,392,900hm^2 and 105,300hm^2 respectively [1]. As for the areas of forest invaded by minor pests and alien pathogens, Ding H. et al. [2] from Nanjing Institute of Environmental Sciences estimated the areas to be 265,100hm^2 with the data from various resources, such as statistic report of related government departments, periodicals, information on official websites. Therefore, *S*(*cpest*), *S*(*bpest*), *S*(*others*) are 1,392,900hm^2, 105,300hm^2, 267,100 hm^2 respectively. Adding up these three figures, the total forest areas invaded by alien species in 2000 are 1,765,300hm^2.

4.2 Economic values of commonweal function of forest ecosystem

Based on the data from the third forest resources inventory between 1984 and 1988 by State Forestry Bureau, using the method of Costanza et al. [3], Jiang and Zhou [4] calculated the service function of Chinese 38 typical forest ecosystems in 1999. The total economic value of forest service function is $11740.1million, averaging ¥952.42/hm^2·a. While Chen and Zhang's calculation in 2000 is ¥11953.42/hm^2·a [5]. With the help of the data and the method in the article of Ouyang et al. [6], the average commonweal service function is figured out to be ¥12931.152/hm^2·a. The result is within the range of ¥11,606 to ¥16,580 which was estimated by international environmental economists when they evaluated the service function of Chinese forest ecosystems. The results of Jiang and Zhou [4] and Chen and Zhang [5] are calculated with the method suggested by Costanza et al. [3]. Whether the results are suitable to Chinese forest ecosystems needs further study. While the estimation by Ouyang et al. [6] is based on the plenty of data from Chinese located research. So, in this article we calculate the commonweal service function based on the materials used in Ouyang et al.'s article [6]. The *F*(*conifer*), *F*(*broad*) and *F*(*average*) are ¥14855.897/hm^2·a, ¥11006.407/hm^2·a and ¥12931.152/hm^2·a respectively.

4.3 Extent damaged by alien species

According to the results of the fifth forest resources inventory organized by State Forestry Bureau, the annual timber volume growth is 3.36m^3/hm^2. In 2000, the total forest areas infected with pests and pathogens are 7,892,200hm^2 [1]. Under the normal condition, the annual gross volume growth of the uninfected forest with the same area is 26,517,800m^3. It was reported by Zhang M. [7] that the annual gross volume growth has been decreased by 17millionm^3 in recent years because of attack from forest pests and pathogens, which is equal to the 64.1 per cent of the total gross volume growth of the forest of 7,892,200hm^2. Under the assumption that the extent damaged by alien species is equal to that of common pests and pathogens, we can suppose that the extent of commonweal service function of forest ecosystem damaged by alien species is proportional to the decrease of forest gross volume growth. Then a conclusion can be drawn that *K* equals to 64.10 per

cent. That is to say, 64.1 percent of commonweal service function of forest ecosystem is lost because of alien invasive species. Parameters of the models, their values and data sources are shown in Table 1.

Table 1. Values of the parameters in evaluation models of indirect economic losses

Parameter	Value	Unit	Data source
F(*conifer*)	14855.897	¥/hm^2·a	[6]
F(*broad*)	11006.407		
F(*average*)	12931.152		
S(*cpest*)	1392900	hm^2	[1, 2]
S(*bpest*)	105300		
S(*others*)	267100		
K	64.10	%	[7]

5. Conclusion and comments

In 2000, indirect economic losses associated with alien invasive species to Chinese forest ecosystem are ¥15443.43million. Losses caused by alien conifer insects, such as *Bursaphelenchus xylophilus, Hemiberlesia pitysophila, Oracella acutus, Dendroctonus valens* and *Matsucoccus matsumur* are ¥13264.07million, comprising 85.89 percent of the total losses, while losses caused by alien broad-leaved insects such as *Hyphantria cunea* are ¥742.90million, comprising 4.81 percent. Losses caused by alien pathogens and other alien insects are ¥1436.46million, comprising 9.30 percent of total losses.

The object of this paper is to improve the people's awareness of the damages caused by alien invasive species to forest ecosystem. Until now, there have been no practical theories and methodologies for reference to evaluate the indirect economic losses caused by alien species to natural ecosystems on state scale in China and abroad. It is easier to estimate the direct economic losses then the indirect losses when a forest stand is attacked by an alien pest. However, when we make an evaluation of indirect economic losses on the state scale, three questions must be answered firstly: economic value of commonweal function of forest ecosystem, forest areas attacked by alien species, the relationship between the attack and the loss of commonweal function. It was just a few years ago since the concept of alien invasive species has been aware by Chinese people. Apart from only a handful alien species which have brought huge damages to Chinese economics and human's health, little research has been done on the relationship between the attack of alien invasive species and the environmental influence on ecosystems on the national scale. Besides, there is no an authorized method to evaluate the commonweal service function of forest ecosystem. Therefore, the theories and methodology in the article are only set up to provide a rough study frame which needs to be further modified jointly by forest ecologist, forestry economist and forest protection scientists. The conclusion of this article is not a precise result but just an overall estimation to supply the theoretical basis for the making of the control strategies.

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