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Designing afforestation subsidies that account for the benefits of carbon sequestration: A case study using data from China's Loess Plateau

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ABSTRACT

This paper presents a method for determining the subsidy required to motivate farmers to participate in timber afforestation programs designed to maximize social well-being. The method incorporates a carbon sequestration benefit function into the land expected value model in order to quantify the social benefit arising from carbon sequestration by the planted trees. This is used to calculate the optimal rotation age for newly planted forests that maximizes social utility. The minimum subsidy required to motivate farmers to participate in the afforestation program was calculated using a modified decision model that accounts for the subsidy's impact. The maximum subsidy offered by the government was taken to be the NPV of the carbon sequestration achieved by afforestation. Data on *Robinia pseudoacacia* L. trees planted on the Loess Plateau were used in an empirical test of the model, which in this case predicts an optimal subsidy of 254.38 yuan/ha over 40 years. This would guarantee the maintenance of forest on land designated for afforestation until they reached the socially optimal rotation age. The method presented herein offers a new framework for designing afforestation subsidy programs that account for the environmental service (specially, the carbon sequestration) provided by forests.

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Introduction

The purpose of this study was to develop a method for calculating the optimal subsidy to encourage the planting of timber trees in China in a way that accounts for the benefits of the resulting carbon sequestration and can be used in the design of new policies relating to forest carbon sequestration.

Climate change is a global issue of great significance and has been the focus of considerable international attention. China attaches great importance to this problem and began implementing the *National Climate Change Program* in 2007. At the 2009 Summit on Climate Change, President Hu Jintao (2009) promised that China would spare no efforts to increase forest carbon sequestration and would endeavor to increase the country's forest cover by 40 million ha and forest stock volume by 1.3 billion m^3 by 2020, relative to the situation in 2005. To achieve these goals, it will be necessary to promote sustainable forest management and to improve the existing forest subsidy policy. Consequently, the establishment of a science-based afforestation subsidy that will achieve substantial carbon sequestration and the country's ability to manage climate change has become a key goal of China's forest development policies (Tang, 2010).

The Chinese government has undertaken several major ecological restoration programs (ERPs), including the Sloping Land Conversion Program (SLCP), Natural Forest Protection Program (NFPP), and the Desertification Combating Program around Beijing and Tianjin (Yin and Yin, 2010). These ERPs all offer subsidies to individuals or organizations performing afforestation activities. However, program management costs and the opportunity cost of afforestation were not considered when these programs were established. They provide a single uniform subsidy covering activities in large areas, without regard for regional and economic differences. This ultimately had a negative impact on participants' enthusiasm for afforestation. In 2010, the central government launched a pilot afforestation program that also subsidizes afforestation. It remains to be seen whether this new program will provide incentive that are sufficient to influence individuals' or organizations' afforestation behaviors, and whether it will be for the good of society as a whole or will primarily benefit planters alone. Overall, the issues encountered with the first generation of afforestation subsidy programs clearly demonstrate the need for a theoretically grounded and practical method of determining appropriate subsidies for afforestation programs.

Carbon sequestration in forests has been put forward as a process that could slow or reverse the ongoing increase in the atmosphere carbon dioxide levels (Asante et al., 2011). Concerns about this increase in greenhouse gas levels and the resulting global warming have led to the recognition of carbon sequestration as an important ecosystem service provided by forests (Asante and Armstrong, 2012). Forests are carbon stores, acting as carbon dioxide sinks as their density or area increases (CFS, 2007). Therefore, the planting of trees on marginal agricultural land could be a useful method of carbon sequestration (Noss, 2001). From 1990 to 2009, the annual net CO_2 flux of forestland accounted for more than 81.99% of the total net CO_2 flux in the US (EPA, 2010). Notably, in 2009 forests (including vegetation, soils, and harvested wood) accounted for approximately 85% of the United States' total net CO_2 flux. Ten percent of the United States' total annual carbon emissions are absorbed by its forests (Dickinson, 2010), and enhanced carbon sequestration by forests could play an important role in offsetting carbon emissions (Dickinson et al., 2012). The net sequestration by forests is dependent on net forest growth, changes in forest area, and the net accumulation of carbon stocks in harvested wood pools. Increasing the size of forested areas thus greatly enhances the scope for alleviating the greenhouse effect. Afforestation is the replanting of trees on marginal crop- and pasturelands to incorporate carbon from atmospheric CO_2 into biomass (McDermott, 2008). Fang et al. (2001) claim that ongoing nationwide reforestation can contribute significantly to global C sinks. Both afforestation and reforestation involve the planting of trees, and so afforestation can also significantly increase a region's carbon sinking capacity. Consequently, many countries have adopted policies with the aim of increasing the amount of land available for afforestation as a relatively inexpensive way of addressing climate by mitigating their CO_2 emissions (Kula, 2010). Afforestation has thereby become an important ecological tool, especially in the context of global warming.

In order to calculate a forest's positive externalities with respect to carbon sequestration, one must understand the relationships between the forest's growth period, its forest stock volume and its sequestration capacity. It is also important to compensate the tree planter with cash in recognition of

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