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Analysis

Effect of agricultural economic growth on sandy desertification in Horqin Sandy Land

Xiaodong Ge [a,*], Yaoguang Li [a], Albert E. Luloff [b], Kaikai Dong [a], Jun Xiao [a]

[a] College of Resources and Environment, Huazhong Agricultural University, Wuhan, China
[b] Department of Agricultural Economics, Sociology, and Education, The Pennsylvania State University, University Park, PA, USA

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ABSTRACT

Using traditional methods, this paper gave assessment to the extent of sandy desertification and the changes of land use in eight counties in Horqin Sandy Land over the period 1980–2010. A coupling model was established on the base of general Environmental Kuznets Curve (EKC) model to better understand the roles of economic growth and other factors to sandy desertification in an integrated framework. To avoid the bias owing to the data discordance and the autocorrelation in time series data, Unit Root Test was applied and an ARDL model was established to improve the EKC model. The results showed that there was a positive linear correlation between the extremely severe sandy desertification per capita and the real agricultural GDP per capita in the short run, while there was a Kuznets Curve in the long run, showing the effect of economic growth as both the pressure on land and the capability to alleviate the risk of sandy desertification in different phases. The effect of economic growth on sandy desertification was greatly influenced by exogenous factors, including strategy factors, climatic factors and the extent of sandy desertification itself.

1. Introduction

As the definition given by the United Nations Convention to Combat Desertification (UNCCD), desertification refers to the land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors including climatic variations and human activities (UNCCD, 2004). Because of the complexity of the mechanism of desertification, it is quite difficult to identify the exact role of specific variable in the context of the synergistic effect of various driving factors of desertification. In particular, the interaction between economic factors and desertification is still far from being fully understood. As the population increases steadily and the economy continues to grow, the earth's capacity of supporting human beings is diminished (Skonhoft and Solem, 2001). Many projects have been designed and implemented to better understand the roles of economic factors and to prevent the deterioration of ecological systems (Abdelgalil and Cohen, 2007). For instance, the project MEDALUS developed physically-based models to describe environmental processes and land use changes in different scenarios of socio economic development (European Commission, 2001b). Another example, the project DESERTLINKS searched for a common methodology with social-economic indicators for desertification monitoring and management (European Commission, 2001a). Different aspects of social-economic activities in various regions were discussed in these projects, like land use, water utility, grazing culture and etc. However, the interaction between specific economic factor and desertification remained unclear especially in temporal and spatial dimensions (Hillel and Rosenzweig, 2002; Mohamed, 2011; Sánchez-Arcilla et al., 2011; Salvati et al., 2013b; Sun et al., 2006).

Sandy desertification is the most severe issue among all types of desertification in Northern China where the fragility of the ecosystems is predetermined by inherently harsh physical conditions, such as sparse vegetation, continental climate, sandy soils and water deficiency (Chen and Tang, 2005; Wang et al., 2002, 2004, 2008). Under the special ecological conditions, grazing and cultivation are the traditional ways of agricultural production in Northern China, which provide the family income to meet the basic needs for the survival of local people (Démurger and Fournier, 2011). Because the ecological systems are vulnerable and the technologies for agricultural production are backward, many people are very poor in these regions (Fu and An, 2002; Jiang, 1999). The inner demand of increasing family income may lead to excessive human activities, resulting in the frequent rapid expansion of sandy desertification (Blazey, 2012; CCICCD, 2002; Ci and Yang, 2010; Démurger and Fournier, 2011; Huang et al., 2009; Liu, 2012; Sjögersten et al., 2013; Sun et al., 2006; UNCCD, 2004; Wang et al., 2008).

Obviously, economic growth is one of the most important anthropogenic driving factors of sandy desertification (Salvati et al., 2011; Skonhoft and Solem, 2001; Zilio and Recalde, 2011). For decades, researchers made efforts to explore the mechanism of sandy desertification with the economic driving factors, such as land use, etc. (Wang et al.,

* Corresponding author at: Department of Environmental Sciences and Engineering, Huazhong Agricultural University, China.
E-mail address: gexd@mail.hzau.edu.cn (X. Ge).

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2002, 2006, 2008). Some researches claimed that sandy desertification was largely attributed to a range of agricultural production factors mainly, including over-grazing, over-reclamation, and extensive cutting (Hai et al., 2002, 2003; Yu-Zhu and Han-Min, 2007; Zhao et al., 2005). The reclamation would destruct the original ground vegetation and deteriorate the chemical or physical properties of soil. The grazing would destroy the vegetation coverage of grassland and destruct the soil's crust layer through livestock's crunching and trampling. The urgent demand for increasing family income would violently change the land cover in the desertified regions in Northern China.

However, as the driving mechanism of sandy desertification is so complex that it is very difficult to assess the relative role of specific factor under an independent condition, plenty of researchers would not accept the economic factors as main cause of sandy desertification. They claimed that historical records and archaeological evidence indicated sandy desertification in Northern China was likely influenced by climate change and geomorphological processes with specific trends in temperature, drought and wind regime (Hillel and Rosenzweig, 2002; Peters et al., 2012; Salvati et al., 2013a; Turkes, 1999; Wang et al., 2006; Yang et al., 2005; Zhu and Chen, 1994). The divergence of different disciplines lead to the long time dispute about the main cause of sandy desertification (Sun et al., 2006). The focus on this debate detracted much needed attention from studies of specific factor in the context of a combined effect of all kinds of factors (Ge et al., 2006; Wang et al., 2008).

Recently, the scientists realized that it was much more important to identify the roles of specific factors in a coupling context before comparing the contribution of different types of factors to sandy desertification (Wang et al., 2006, 2012; Xiaodong et al., 2013; Xu et al., 2011). To achieve this goal, coupling quantitative methods should be developed to combine the dynamics of ecological processes and the effect of economic growth (Wang et al., 2005, 2006; Xu et al., 2009, 2010). Statistic models, such as linear regression models and principal component analysis models, were frequently used in recent studies (Xu et al., 2011). For instance, Salvati et al. (2011) investigated the correlation between the vulnerability to land degradation and some socioeconomic indicators with regression models separately. These quantitative methods were widely questioned. Some researchers believed that the role of the driving factors should not be tested individually and separately (Bagliani et al., 2008; Saboori et al., 2012). They also believed that there could be inevitable biases in these models due to the dissonance of the different sources of data, especially when the spatial or temporal effect of the factors were considered (Khan and Khan, 2009; Wang et al., 2012; Xu et al., 2009, 2011).

The absence of coupling methods contributed to the confusion about the exact role of economic growth to sandy desertification. As Environmental Kuznets Curve (EKC) models were widely used to uncover the relationship between environmental degradation and economic growth (Agras and Chapman, 1999; Ahmed and Long, 2012; Bagliani et al., 2008; Grossman and Krueger, 1991, 1995; Stern, 2004), they might be used as references to improve the coupling methods in sandy desertification researches. As initially proposed by Simon Kuznets, the EKC concept was portrayed as an inverted U shaped relationship between income and income inequality (Ahmed and Long, 2012; Kuznets and Simon, 1995). This finding attracted global interest (Bulte and van Soest, 2001). Since the early 1990s, the EKC has been applied to a range of studies examining economic growth and environmental degradation (Bowman, 1997; Dinda, 2004; Farshad and Zinck, 1993; Glomm and Ravikumar, 1998; Grossman and Krueger, 1995; Stern et al., 1996; Zaki, 1997). In these EKC models, the quadratic item even cubic item of economic factor was included to better describe the non-linear change of the effect of economic factor (Cox et al., 2012; David, 2004; Stern et al., 1996). And also, several types of EKC models were developed to give specific explanation to the correlation between various variables, including square form model, cubic form model, logarithm form model and etc. (Bulte and van Soest, 2001; Dinda, 2001; John and Pecchenino, 1994; Kadekodi and Agarwal, 1999). Hence, EKC models could help to establish the coupling models for identifying the relative roles of economic growth to sandy desertification (Arrow et al., 1995).

Of course, the EKC models were criticized by many researchers. They claimed that many attempts failed to find an inversed-U shaped curve or other specific shaped curves (Choumert et al., 2013). The results in different cases could vary widely (Choumert et al., 2013; de Freitas and Kaneko, 2012; Yang et al., 2015). Too much enthusiasm was engaged in interpreting the existence or non-existence of the inversed-U shaped curve, while the real interaction between economic growth and environmental degradation was insufficiently explained. Furthermore, most of the EKC models were applied to the issues of pollution, and only a few of them were applied to the ecological issues (Ahmed and Long, 2012; Bagliani et al., 2008; Caviglia-Harris et al., 2009; Chiu, 2012; Culas, 2007; Damette and Delacote, 2012; Huang et al., 2009; Mills and Waite, 2009). In ecological issues, the interaction between different types of factors was more complex. The results of EKC models could still be biased owing to the existence of the autocorrelation in temporal or spatial dimension (Dinda, 2003; Ekins, 1998; Zang, 1998). For instance, current economic growth could be influenced by that in the last year, and local policy factors, climatic elements and geomorphological variables could be greatly influenced by those in neighboring regions. Further theoretical studies should be conducted to improve the EKC models to solve the problems (Dinda et al., 2000; Liu, 2012; Panayotou, 1997). To date, such attempt was seldom found in sandy desertification related researches (Rozelle et al., 1997).

It was much more important to give assessment on the exact role of economic growth on sandy desertification than to argue for the existence or non-existence of a specific shaped curve. A time series analysis would provide better framework to study the relationship between economic growth and sandy desertification. Autoregressive distributed lag (ARDL) model was regarded as a preferential technique for cointegration analysis in datasets with limited number of observations (de Freitas and Kaneko, 2012). It was first introduced by Pesaran and Shin (1999). Based on the general-to-specific modelling technique, the ARDL model took sufficient number of lags to capture the data generating process in a dynamic framework to avoid the bias of the autocorrelation (Kanjilal and Ghosh, 2014; Rushdi et al., 2012). It could provide both the short-run and the long-run information from a small sample collection.

This paper aims to analyze the interaction between sandy desertification and economic growth in Horqin Sandy Land in both the short run and the long run, in the context of synergistic effect of climatic variables and policy factors. Therefore, the main objectives of this paper are to (1) establish an integrated coupling model based on EKC model, incorporate the data of different sources into the same analysis framework, including economic indicators and ecological indicators; (2) extract ecological indicators from satellite images with traditional methods of sandy desertification assessment and land use analysis; and (3) improve the EKC model with Unit Root Test and *ARDL* techniques to eliminate the influence of the non-stationarity that is caused by time series data.

2. Method

2.1. Study Area

Horqin Sandy Land (118°35′-123°30′E; 42°21′-45°15′N) is located in the east of Inner Mongolia of China, as shown in Fig. 1. As one of the four largest sandy lands in China, Horqin Sandy Land has an average annual precipitation of 360–500 mm which varies widely in spatial and temporal dimensions. It belongs to the agro-pastoral region in Northern China. Grazing and cultivation are the two main types of human activities in this region. Due to the fragile ecological system and improper management of natural resources, Horqin Sandy Land has been seriously desertified, particularly since over-grazing and over-cultivation occurred in different historical periods. To bring desertification under