Land Use Changes of an Aeolian-Loessial Soil Area in Northwest China: Implications for Ecological Restoration*1

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ABSTRACT

China has experienced dramatic land use changes over recent decades, with marked environmental and socio-economic consequences. Hengshan County, located in the aeolian-loessial area of Northwest China, was investigated to illustrate land use changes and their implications for environmental and long-term rural economic development. The farmland in Hengshan County significantly decreased during 1990–2003, whereas forest land and grassland increased. The conversion rates of farmland, orchard land, forest land and construction land varied markedly among different periods: 1990–1995, 1995–2000 and 2000–2003. Conversion of orchard land, grassland and construction land was dominant in 1990–1995, whereas the conversion of farmland to forest land mainly occurred in 2000–2003. The results suggested a profound transition in institutional policy and political economy of land management, including implementation of integrated soil erosion control projects, adoption of a market-oriented economy and the ‘Grain-for-Green’ policy, during this period in China. To achieve long-term sustainable land use in Hengshan County, efforts should aim at increasing off-farm income of rural families as well as establishing land-economizing mechanisms to promote land productivity, in addition to conservation measures.

Key Words: Hengshan County, land management, per capita land area, policy, sustainable land use


INTRODUCTION

China’s per capita land resources are extremely scarce compared to the world average, due to its huge population. With the third largest territory in the world, China’s per capita land area is only 0.777 ha, one-third of the world average. The cultivated land per capita was merely 0.094 ha in 2004, less than half the world average. Consequently, about 20% of the world’s population lives on < 10% of the world’s cultivated land (Lin and Ho, 2003). In the past, China has relied largely on relentless reclamation of marginal land to maintain its leadership in world grain production. However, land reclamation in these environmentally-fragile frontier regions has led to severe land degradation and other environmental disasters, such as dust storms and soil and water losses, which generated negative external constraints on regional economic development (Lin and Ho, 2003; Liu et al., 2003; Xie et al., 2005). At the same time, China’s rapid economic and population growth has brought some rapid changes in land use. One of the alarming consequences of land use changes is the loss of agricultural land, especially cropland. Before adjustments in land use policy are made, there is a pressing need to examine the current situation and recent trends in land use change. In this article, Hengshan County in Northwest China was selected as a case study to illustrate land use changes and their implications for the environment and long-term rural economic development.

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LAND USE CHANGE AND ECOLOGICAL RESTORATION

MATERIALS AND METHODS

Study area

Hengshan County of Shaanxi Province, Northwest China is located in the environmentally-fragile frontier region (Fig. 1) and covers 4288 km$^2$. It lies in the transitional area between the Loess Plateau and the Mu Us Sandy Land. Elevation rises from <900 m a.s.l. in the north-east to >1500 m in the south-west. Loess hills account for about 70% of the land area and aeolian sandy land for 30% (CCHCR, 1993). Consequently, loessial and aeolian soils (Fluvisols and Arenosols in FAO soil classification) are dominant in Hengshan. Both soil types are young with unstable properties that are vulnerable to water and wind erosion. The pedogenic rates are far slower compared with the erosion rates on poorly cultivated soils.

![Fig. 1 Geomorphology of the study area, Hengshan County in Shaanxi Province, Northwest China (cited from CCHCR, 1993).](image)

Hengshan County is dominated by a dry mid-latitude steppe climate: cold, dry and windy winters, and short and warm summers. The mean annual temperature is 8.8 °C. The mean annual precipitation is 380 mm; most rain falls in July–September, decreasing from south-east towards north-west with a large inter-annual variation (Wang et al., 2005). The Wuding River, a tributary of the Yellow River, traverses most of the county. The natural vegetation is semi-arid tufty grasses and shrubs dominated by *Stipa bungeana*, *Agropyron michnoi*, *Caragana korshinskii*, *Artemisia ordosica*, etc. (CCHCR, 1993).

Data

The land use data of Hengshan County from 1990–2003 were collected from the Land Resources Management Bureau of Hengshan County. The data were compiled from yearly change surveys by the Bureau. Land uses are classified into eight types as listed in Table I.

The demographic and socioeconomic data were collected from published statistical yearbooks (Statistical Bureau of Hengshan County, 1991, 1996, 2001, 2004).

Analysis


\[
R_c = \left( 1 - \frac{A_1 - A_2}{A_1} \right)^{\frac{1}{n}} - 1 \times 100\% \tag{1}
\]
TABLE I
Classification of land use of Hengshan County in Shaanxi Province, Northwest China

<table>
<thead>
<tr>
<th>Land use type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmland</td>
<td>Grain crops, vegetable and annual cash crops</td>
</tr>
<tr>
<td>Orchard land</td>
<td>Fruit, mulberry, tea and other perennial crops</td>
</tr>
<tr>
<td>Forest land</td>
<td>Forest, shrub and bamboo</td>
</tr>
<tr>
<td>Grassland</td>
<td>Herbaceous plants for livestock husbandry</td>
</tr>
<tr>
<td>Construction land</td>
<td>Settlements, industrial and mining sites</td>
</tr>
<tr>
<td>Transportation land</td>
<td>Railways, roads, airports and ports</td>
</tr>
<tr>
<td>Water area</td>
<td>Water area and land used for irrigation works</td>
</tr>
<tr>
<td>Unmanaged land</td>
<td>Wasteland, desert, salinized land, swamp, bare land, etc.</td>
</tr>
</tbody>
</table>

where $R_c$ is the conversion rate of a land use type, $A_1$ and $A_2$ are the areas of a land use type in years $t_1$ and $t_2$, and $n$ is the difference in years between the two dates, equal to $t_2 - t_1$.

RESULTS AND DISCUSSION

Land use change in Hengshan County

Areas and changes of land use types in Hengshan County between the years 1990–1995, 1995–2000, 2000–2003 and 1990–2003, are listed in Table II. There were distinct differences in the conversion rates for most land use types for different periods. The farmland area decreased annually with the annual conversion rate during 2000–2003 being 3.1 and 2.6 times those during 1990–1995 and 1995–2000, respectively. The decrease trend in water area during 1990–2003 was opposite to that of farmland. Orchard land increased at a higher rate during 1990–1995 than during 1995–2000 and 2000–2003; the same trend was observed for construction land. Conversely, forest land and transportation land experienced a different trend; their biggest increases occurred during 2000–2003. The largest increase in grassland was observed during 1995–2000. In terms of absolute values of land area decrease, farmland decreased 22 884 ha during 1990–2003, which represented 95% of the total decrease. Forest land and grassland were the two largest beneficiaries of the farmland loss (Table II). The orchard was another beneficiary of the farmland loss.

TABLE II

<table>
<thead>
<tr>
<th>Land use type</th>
<th>1990</th>
<th>1995</th>
<th>2000</th>
<th>2003</th>
<th>Annual conversion rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmland</td>
<td>130 497</td>
<td>124 491</td>
<td>117 668</td>
<td>107 613</td>
<td>-1.47</td>
</tr>
<tr>
<td>Orchard land</td>
<td>724</td>
<td>2 352</td>
<td>2 553</td>
<td>2 565</td>
<td>10.22</td>
</tr>
<tr>
<td>Forest land</td>
<td>98 245</td>
<td>98 970</td>
<td>100 349</td>
<td>109 209</td>
<td>0.82</td>
</tr>
<tr>
<td>Grassland</td>
<td>176 732</td>
<td>180 375</td>
<td>185 509</td>
<td>186 652</td>
<td>0.42</td>
</tr>
<tr>
<td>Construction land</td>
<td>9 281</td>
<td>10 119</td>
<td>10 180</td>
<td>10 255</td>
<td>0.77</td>
</tr>
<tr>
<td>Transportation land</td>
<td>894</td>
<td>896</td>
<td>1 011</td>
<td>1 250</td>
<td>2.61</td>
</tr>
<tr>
<td>Water area</td>
<td>6 281</td>
<td>5 663</td>
<td>5 656</td>
<td>5 655</td>
<td>-0.80</td>
</tr>
<tr>
<td>Unused land</td>
<td>6 112</td>
<td>5 902</td>
<td>5 841</td>
<td>5 568</td>
<td>-0.71</td>
</tr>
</tbody>
</table>

The changes in per capita land area during 1990–2003 showed an increasingly tensiional relationship between population and land in Hengshan County (Figs. 2 and 3). The per capita areas under both farmland and grassland declined throughout the period 1990–2003. Forest land area per capita declined during 1990–2000, but increased in 2000–2003 (Fig. 2). Construction land area per capita increased from 1990 to 1995, decreased after 1995, and declined to 312 m² in 2003 (Fig. 3).
A series of land policy reforms launched after 1978 led to both positive and negative socio-economic consequences (Ding, 2003). Farmland protection policy was initiated in the mid-1990s to control the increase of construction land and to reduce farmland loss (Ding, 2003; Xie et al., 2005). This policy significantly slowed down the increase in land used for construction, whereas it did not slow down the rate of decrease in farmland in Hengshan County. This situation was totally different from the counties in eastern China, where much agricultural land was lost due to rapid industrialization and urbanization (Xie et al., 2005; Long et al., 2007a, b). Hengshan County is identified as a national poverty county in western China and its industrialization and urbanization processes lag far behind the counties in eastern China. Historically, a large area of marginal land was reclaimed to meet increasing food demands. Hengshan County is located in a semi-arid area and agro-pastoral zone, which is characterized by an erratic climate and fragile soil. The most pressing tasks for Hengshan are to restore the damaged ecosystem and the environment and to rebuild the foundation of urban and rural development, a common issue confronting western China (Liu et al., 2004). The Mu Us Sandy Land and Loess Plateau are the two areas seriously affected by desertification and soil erosion in China (Fu, 1989; Chen and Tang, 2005). A key way to reverse these processes is to stimulate the recovery of vegetation (Mitchell et al., 1998; Chen et al., 2002). The Chinese government has paid increasing attention to control desertification and soil erosion since the 1980s. Until 2000, following Western Development Policy in China, the Western Ecological Environment Construction Project has been initiated with “convert farmland into forest or grassland” (or ‘Grain-for-Green’) as the main activity. As a consequence, the desertification and soil erosion controls in China reached an unparalleled size (Zhang et al., 2004; Gao et al., 2006; Sun et al., 2006). These policy shifts brought about the slight positive conversion of forest land in 1990–2000 and high positive conversion rate after 2000. The policy of ‘Grain-for-Green’ became the primary driving force causing farmland loss and increase of forest land since 2000. In fact, the motivation for this policy was to clean up the ecological debts historically left behind by adjusting land use to more ecologically and economically suitable utilization types.

The purpose of land use policy is to promote use of land suitable to its properties. The potential and original vegetation would be temperate steppe and trees and shrubs in hilly and gully areas (Ren, 2004; Nan et al., 2007). Nevertheless, land use suitability is site-dependent and whether land use policy of recent past is proper and rational should be the focus of further studies.

The increase in orchard land during 1990–1995 has been caused by the effect of policy on land use change. Although rural economic reform was initiated in 1978 and featured the ‘Household Responsibility System’, the plan-directed economic system was still followed until a market-directed economic system was adopted in 1992. The market-directed economic system released the vigor of the rural eco-
nomy, diversified agricultural products and caused a great alternation in agricultural land use.

Implication of land use change

The land use change has been dramatic in Hengshan County over the past 13 years. It reveals a profound transition in institutional structure and political economy of land management in China. Land use change from 1990 to 1995 reflected the outcome of agricultural restructuring. Increased industrialization and urbanization resulted from the gradually relaxed state control over the rural economy in China that has taken place since 1978. A considerable amount of cultivated land was reallocated from food grain production to horticulture for better profits. The conversion of farmland to forest land constituted the main event of land use change in 2000–2003 due to the ‘Grain-for-Green’ policy in China. The farmland area of Hengshan County decreased by 18% and per capita farmland decreased by 30% between 1990 and 2003. Fortunately, its total grain yield increased by 62% and per capita grain increased from 237 to 328 kg during this period, as a result of the implementation of an integrated soil and water conservation project. Besides adoption of conservation techniques to promote land productivity, however, it is critical for long-term sustainable land use to enhance off-farm incomes of rural families.

The change of construction land during the period reveals the low intensity and productivity of construction land use in Hengshan County. Although per capita construction land area declined from 1990 to 2003, it was still very high, more than twice the national average for the same period. This situation was manifested by the lack of a healthy land market and of mechanisms for efficient allocation of land in the study area. It is crucial for the Chinese government to encourage more efficient and effective land use for the sake of sustainable socio-economic development.

CONCLUSIONS

The recent history of land use in Hengshan County reveals a decreasing trend in farmland and an increasing trend in forest land and grassland throughout 1990–2003. Distinct differences in the conversion rates of farmland, orchard land, forest land and construction land were observed in 1990–1995, 1995–2000 and 2000–2003, respectively. This corresponded to the profound transition in the institutional setting and political economy of land management in China. From the view of encouraging long-term sustainable land use, besides conservation measures to promote land productivity, enhancement of off-farm income of rural families as well as mechanisms for efficient allocation of land are highly recommended.

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REFERENCES


