

Article

# The Influences of Livelihood and Land Use on the Variation of Forest Transition in a Typical Mountainous Area of China

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**Abstract:** As one of the countries which that has been experiencing a forest transition, China provides important insights into and theoretical and empirical knowledge of forest transition. In this study, through the framework of Sustainable Livelihood Analysis (SLA) and questionnaire surveys, we examined forest transition, farmers' land-use activities and livelihood changes in Chicheng county, a typical mountainous area in Northern China, during 1975–2018. Most villages of Chicheng county experienced forest transition during the period of 2003–2005, but some villages experienced forest transition in 2010–2015. Forest transition variation over time was influenced by land use and livelihood changes. Livelihood resources, policy and institutional constraints and livelihood strategies had significant influences on land use and then caused variation in forest transition characteristics. The process of “livelihood–land use–forest transition” was the key to achieving and maintaining forest transition, and the interaction between livelihood and land use was a negative feedback relationship between society and ecology. The dominant path of forest transition in Chicheng county was the “economic development path”. Moreover, the “intensive agriculture path of small-scale farmers” enhanced the “economic development path”, and the “forest scarcity path” promoted both of the above two paths. This implies that the feedback and interactions between society and ecology should be taken into account so as to achieve a sustainable human and environmental system.

**Keywords:** forest transition; land use; livelihood pattern; sustainable livelihood analysis; negative feedback

## 1. Introduction

Over the past three decades, reforestation has been observed in several countries, encompassing tropical and temperate countries, developed and developing countries [1–22]. Given that forests have critical environmental and ecological service functions [6], the phenomenon of forest increase has been of global concern to governments and various organizations (especially academic communities). Among the abundance of studies on reforestation, the theory of forest transition provides an explanation for the phenomenon of forest increase which suggests that, along with the development of the socio-economy from the primary stage to the advanced stage, the forest area of a country or region also correspondingly increases [1]. Forest transition theory brings hope for countries that seek sustainable social transformation when faced with the possible crisis of forest reduction [23].

From the proposal of forest transition in 1992 [1] to now, the theoretical content and frameworks have been constantly enriched and improved. The original theoretical explanation was “resource depletion–resource recovery” from the perspective of forest resource utilization [1]. Afterwards, the theory was further developed to include the transition of land use between agricultural land and forestry land [24,25], to the agricultural concentration on high-quality land [26] (the forestry concentration on high-quality land can also explain international forest transition, such as the leakage, spillover and replacement of forest products among countries [27]). The theory then shifted to the path hypothesis, mainly including the “economic development path” and “forest scarcity path” [28–31], and to an explanation based on Economics (such as Thünen location theory [32], the changes in the relative value of land use [33,34]), Social Ecology (the feedback between social dynamics and ecological dynamics [15,30,35]) and Ecology (the ecological threshold [36]).

Since Grainger proposed that the transition of land use (especially the transition of agricultural and forestry land use) was the cause of forest transition [24,25], land use has become the focus of forest transition as studied by geographers and economists. Forest transition focuses on the long-term model of land-use changes, which provides a unique perspective on land-use change science and is a theoretical tool to help us understand present and future long-term land-use changes [37]. Forest transition does not appear automatically; it can only take place when the land-use transition (the stage of forest reduction caused by agriculture and residential land occupation) is completed [24,25]. On the one hand, as agriculture and residential land continue to match the space with high-quality land, even if there is no agricultural intensification and technological improvement, the improvement of the level of agricultural productivity can be realized under the conditions of the reduced agricultural land area. The land released from the reduction of agricultural land can be used for forest restoration and artificial tree-planting, which leads to forest transition [26]. On the other hand, urbanization and industrialization bring about economic development, which causes the rural labor force to gradually change from agricultural to non-agricultural employment, so that the uneconomical nature of agriculture becomes apparent. After this, the low-quality and remote cultivated land and pasture are abandoned and transferred into forests [29]. Other economic analyses also focus on the changes in the relative value of agricultural land use [33,34]. In the social-ecological analysis of forest transition, land use is also studied as the core process of social-ecological interactions and feedback [15,30,35]. As the importance of livelihood in the research of land-use change science and environmental protection becomes increasingly clear [38–41], studies on forest transition are beginning to consider the livelihood changes of households as a causal and critical kind of progress which could lead to land-use changes and finally result in forest transition [42–44].

At present, researchers have reached a consensus that forest transition is the result of land-use change. Many studies have shown that farmers’ land-use activities and livelihood have an intimate relationship with forest transition [45–47]. At the same time, the Sustainable Livelihood Analysis (SLA) framework [48,49], as a popular livelihood analysis method [38,39], was developed to bring together the factors that impact people’s livelihood strategies by organizing the assets, activities and social and institutional relations that mediate access [49] and has been used in the research of forest transition [45]. However, previous research into forest transition in China paid little attention to the micro-relationship between livelihood and land use and their further influence on forest transition. They mainly focused on the Returning Farmland to Forest Program (RFFP) [46,50], economic growth and government policies [3,18,51–53], societal values about the forest resource [54] and natural disaster stimulation [55]. Moreover, questions regarding the time of forest transition in China and understanding of the process and mechanism of time and space variation of forest transition were not addressed adequately.

In this article, we seek to contribute to these ongoing effects in the forest transition literature by researching the case of a typical mountainous area, Chicheng county, located in Hebei province, China. Based on the field surveys and questionnaire data collected in Chicheng county, this paper aims to explore the spatio-temporal characteristic of forest transition at micro scales, examine the impact of livelihood and land-use changes on forest transition as well as the process and mechanism of the time

and space variation of forest transition affected by land use and livelihood. The third goal of the article is to determine whether the classical forest transition “path theory” can offer a conceptual framework to summarize and explain the forest transition based on the field surveys of our case study. Finally, we expect that the re-understanding, documentation and investigation of forest transition at micro scale can provide supports to the local government’s land-use policy and forest protection application.

The remaining sections of this paper describe the study area and the methodology used in our qualitative and comparative analysis, which draws on the questionnaire based on the land-use science and Sustainable Livelihoods Analysis (SLA) framework. The results and discussion sections subsequently examine the spatio-temporal variability and drivers of the forest transition in the study area, and interactions and feedbacks between land use and livelihoods under changing environmental, socio-economic and institutional factors, and the various pathways of forest transition in Chicheng County. The further purpose of the study is to understand the process and mechanism of the time and space variation of forest transition affected by land use and livelihood and to provide suggestions to the government about how to maintain a sound development of forest resources and how the local government makes choices in policy designs and management that promote a sustainable human and environmental system within the context of ever-changing socio-economic conditions of China.

## 2. Materials and Methods

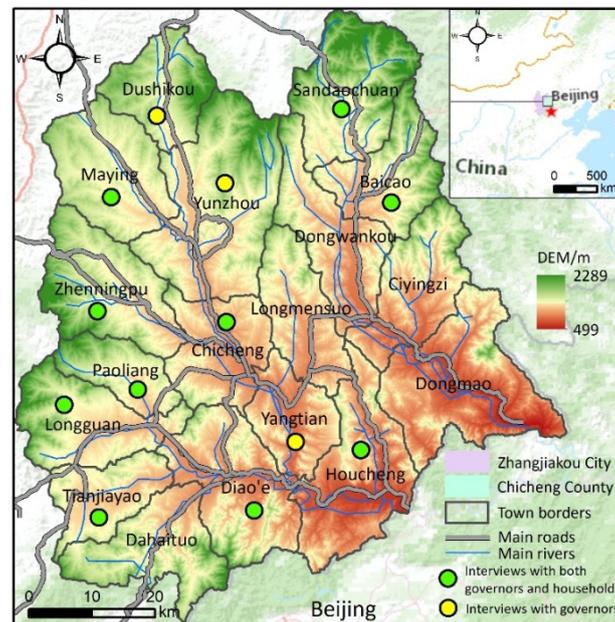
### 2.1. Study Area Boundaries

The study area (Chicheng County) covers 5238 km<sup>2</sup> in the eastern Zhangjiakou City of China (40°30′37″–41°23′26″ N, 115°25′18″–116°27′33″ E) (Figure 1). The Chicheng County, located in the northwestern Hebei Province, is situated at the junction of Beijing and Inner Mongolia and includes 18 towns, 440 villages with a population of about 295,000 people (2018). Chicheng County is a typical mountainous region which is a part of the western Yanshan Mountains and is bound on the south of a part of the Mongolia Plateau, the west of the mountainous area of Chengde City, and the north of the mountainous region of Beijing. The mountainous region accounts for 86% of the total county area, the arable lands account for 10%, and the rivers and villages (rural residences) and roads account for 4%. The average elevation of Chicheng County is 945 m above sea level (a.s.l.). While the northern and western regions reach up to 2289 m a.s.l., and the southeastern Chicheng County fall to 499 m a.s.l.. The region has a temperate continental monsoon climate with four distinct seasons. Spring is short, windy and dry, summer is warm and rainy, autumn is short, cool and dry, and winter is long, cold and dry.

Due to the high elevation in the northwest and low elevation in the southeast, the rivers in Chicheng County become the upstream of the White River, the main branch of the Chaobai River (one of the three rivers which flow through Beijing). The Black River in the east of the county and the Red River in the west converge into the White River in the middle of the county. The White River is Beijing’s main source of water for industrial, commercial, and residential uses. The three main valleys in Chicheng County, i.e., Black River valley, White River valley, Red River valley, account for a large proportion of cultivated land.

The diverse topography of Chicheng County contributes to the generation of a biodiversity-rich environment. Forests are mainly found in the high mountainous areas and foothills (Figure 2a,b). Trees located between 800 to 1800 m a.s.l. include Apricot, Birch, Aspen, Linden, Maple. Shrubs in locations between 1000 and 1500 m a.s.l. are mainly Hazelnut, Caragana microphylla and Thorns. Herbaceous vegetation is mostly distributed in foothills and lowlands (500–1300 m a.s.l.). After 2000, plane seeding, seedling cultivation, direct seeding and other plantation mechanisms were used to increase rapidly the area covered by Chinese pines, and Larch and Mongolian scotch pines. Farmers have contracts with the government to purchase barren mountain land and ditches, which made the shrubs well cultivated and protected. Shrubs play a critical role in soil and water conservation, windbreak and sand fixation, and slope protection. After 2000, the government developed mechanisms to protect herbaceous vegetation in the county. This included the promotion of cattle and sheep feeding through

drylot-fed and rearing, which contributed to the restoration of herbaceous vegetation. Forest cover in 2018 increased to 57.57% from 25.8% in 1991 and the vegetation cover rate raised to 83.11%.



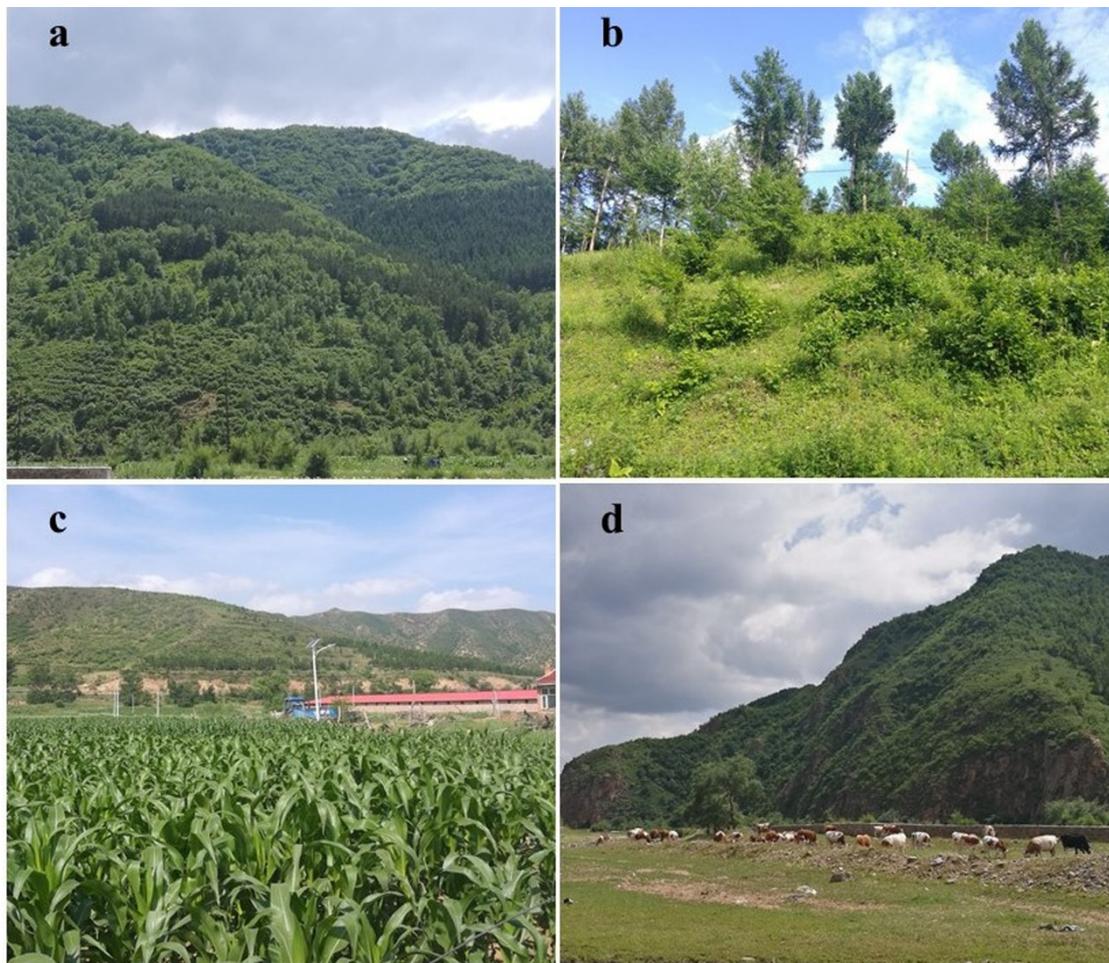
**Figure 1.** Map of Chicheng County indicating the extent of the study area, the elevation range generated with a Digital Elevation Model (DEM), and positions of interview plots. The background map is a colour map of China generated with Arcgis 10.3 software.

The population of Chicheng County in 2017 was 295,089, and the number of households was 135,518. Among the total population and households, the rural population and households were 217,484 (73.7%), and 89,054 (65.7%), respectively. Rural households in Chicheng County had larger families in 2017 (average household size was 2.44) than urban households (average household size was 1.67). Most of the rural population in this county depends on agricultural activities. Croplands are mainly located in the lowlands of the valleys in Chicheng County, and cattle grazing lands are mainly in the foothills and half-hillsides of the study area (Figure 2c,d). Farmers primarily grow grains (51.4% by 2018) and vegetables (32.1% by 2018). Grains production in 2018 was mostly concentrated on maize (35.7%), potatoes (35.7%) and millet (28.6%). The proportion of production for different types of vegetables varies according to expected local market demand. Production of traditional Chinese medicine and forage green maize accounts for 12.8% and 3.6% of total croplands, respectively. As a result of geological processes associated with mountain formation (the Yanshan Movement which occurred from the Jurassic period to the Cretaceous period), Chicheng County is rich in iron, magnetite, zeolite and other minerals. Consequently, the mining industry is also a relevant contributor to the livelihood of people in the region. Geothermal resources (e.g., hot springs) and picturesque mountainous landscapes in the county also contribute to the presence of tourism enterprises. Due to its proximity to Beijing, a significant proportion of the county's population relies on low-skilled jobs in Beijing, especially farmers. Income from work in Beijing has become a critical livelihood-source to improve the living standards of the local population.

## 2.2. Methodology

For this study, background information about household composition, livelihood characteristics related to the Sustainable Livelihoods Analysis framework and land-use activities was obtained through a comprehensive household questionnaire survey (Table 1). Interviews and questionnaires were the primary source of forest transition, land-use and livelihood data for Chicheng County. This information was used in the analysis of the spatiotemporal variability of forest transition, the impact of

livelihood and land-use changes on forest transition and in the investigation of mechanisms through which forest transition impacted land-use and livelihoods in the study area.



**Figure 2.** Examples of landscapes and vegetation observed in the study area. (a) The forest vegetation in the high mountainous areas; (b) The forest vegetation in the foothills; (c) The croplands in the lowlands; (d) The cattle grazing.

The study draws upon historical forest cover, land-use, and livelihood data and other related information from detailed field research conducted in Chicheng County in April 2018 and July 2019. The main methods used, the survey distribution, the main topics covered, and the data collection locations are presented in Table 1. Semi-structured interviews were carried out at three government departments involved in agriculture, forest and developing investments at the county level, and three villages (Beishagou village, Dushikou village, Shuimoyao village) in 2018. The earlier primary semi-structured interviews provided basic insights about the livelihood, land-use and forest transition in Chicheng County for the study and guided the follow-up fieldwork in 2019. Continuous informal interviews and observations derived from long stays in some villages also enabled building up a rapport with the villagers and create the trust for discussions of sensitive topics, which contributed to obtaining relevant information about the socio-economic and environmental characteristics of the villages. In 2019, fieldwork was conducted to apply semi-structured interviews to 13 government village officials, and questionnaire surveys to 120 households (heads of households and/or their wives, randomly sampled from all village households) in 10 villages (Table 1). The informal interviews carried out in our analysis supplemented the insights gained through formal interviews.

**Table 1.** The representation of the methods used, topic covered, data acquisition time and locations and the quantitative density.

Data Collected Locations	Inventory Density	Method	Data Collected Time	Main Topics
Agricultural government departments, Forest government departments, Development and Reform departments	Government officials of county level	Semi-structured interviews	April 2018	Basic natural and geographic condition of county Basic social and economic condition of the village Agricultural and grazing activities The regrowth of forest Main livelihood types
Chicheng town (Haomenling village) Sandaochuan town (Sandaochuan village) Baicao town (Sidao village) Maying town (Houcungou village) Zhenningpu town (Yangjia village) Houcheng town (Xishan village) Diao'e town (Xiahu village) Longguan town (Balizhuang village) Paoliang town (Hanzhuang village) Tianjiayao town (Jiangjiazhai village) Yunzhou town (Beishagou Village) Dushikou town (Dushikou village) Yangtian town (Shuimoyao village)	13 government officials of village level and 3 government official of town level	Semi-structured interviews	April 2018 July 2019	Basic natural and geographic condition of village Basic social and economic condition of the village Main land resources of the village Main land-use types of the village Main crop types and livestock types of the village Basic livelihood of the village in the history Forest cover changes in the history Main land-use policies in the history Main forestry projects in the history Other related policies in the history Ecological payment policies in the history
	120 households interviews	Household questionnaire survey	July 2019	Family structure Education level of the whole family Main livelihood strategies of the family in history Main land use of the family in the history Human livelihood resources Natural livelihood resources Economic livelihood resources Social livelihood resources Produced livelihood resources Livelihood outcomes Sustainable livelihood outcomes Related policies influenced the livelihood in history
	Continuously	Informal interviews	April 2018 July 2019	Perception of future livelihood opportunities Perception of future agricultural development Environmental awareness
	Continous residence in the village	Participant observation	April 2018 July 2019	Agricultural and grazing activities Main labor types Main daily life in the village The regrowth of forest

The identification of forest transition in the county was based on historical changes in the rate of forest cover from 1975 to 2018 (see in Table 1). Interviews with elderly villagers and documentation provided by other villagers were used to estimate changes in forest cover. Land-use change associated with forest cover change (e.g., forest regrowth in livestock grazing areas) was also validated through interviews and questionnaires. Land-use variables investigated include, but are not limited to, the following indicators: main land resources, main land-use types, main crop and livestock activities, predominant land-use of the households' agricultural land area and grazing land area, main labor types (see in Table 1).

We used the Sustainable Livelihoods Analysis (SLA) framework to guide our fieldwork, the implementation of questionnaires and interviews, and to analyze livelihood resources and strategies within the study area. The SLA framework relies on a conceptual assessment of factors that influence the livelihood strategies of people [48]. The SLA framework has been used extensively to analyze the impacts on livelihoods of environmental and land-use management changes through the analysis of not only livelihood assets and activities but also social and institutional relations [45]. The SLA framework considers that the basic livelihood assets of people include natural assets (e.g., land, water), economic assets (e.g., credit, income), human assets (e.g., labor skills), social asset (e.g., social relationship) and produced asset (e.g., roads, energy). The SLA framework also considers that livelihood strategies are shaped by a range of related policies, institutions and processes [48,49]. Changes in livelihoods during periods of significant forest cover change in each village, and each household were identified through interviews and questionnaires. Specifically, we collected information about the following indicators (see in Table 1): the primary livelihood in the village, main livelihood types, main livelihood strategies, human livelihood resources(HLR), natural livelihood resources(NLR), economic livelihood resources(ELR), social livelihood resources(SLR), produced livelihood resources(PLR), livelihood outcomes, perception of future livelihood opportunities.

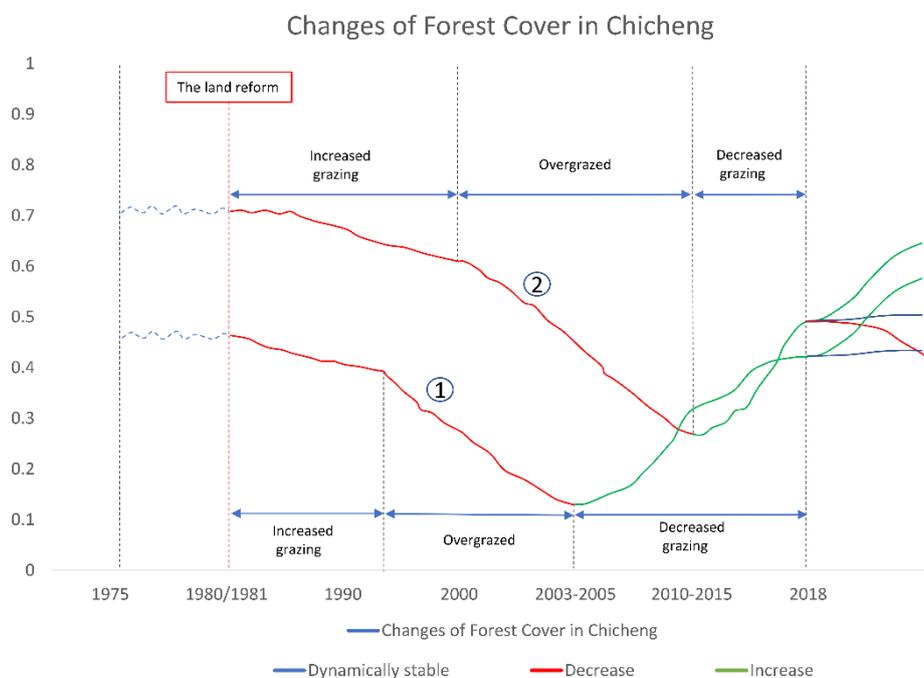
### 3. Results

#### 3.1. Forest Transition Variety

Changes in the proportion of forest cover in Chicheng County from 1975 to 2018 are shown in Figure 3, which illustrates two different forest transition periods. Between 1975 and 2018, all surveyed villages experienced forest transition, i.e., net forest cover decreased first and then increased. However, the timing of forest transitions in the surveyed villages was asynchronous. Some villages experienced a forest transition between 2003 and 2005 (Figure 3, curve 1) while others reached such a transition between 2010 and 2015 (Figure 3, curve 2). Villages with fewer forest resources experienced earlier a forest transition than villages with large forest cover (Figure 3).

Although forest transition in the surveyed villages occurred in different periods, there are some consistent patterns about the drivers of such transition. From 1975 to 2018, forest cover change in Chicheng County showed four critical time points. Between 1975 and early 1980s, China's rural regions were under a planned economy system under the control of the People's Commune socio-economic institutions [56]. In that period, the incentives for farmers to expand their agricultural production were not large. Therefore, forest cover was generally not affected by changes in agricultural production. Forest cover rates during such a period were mainly at a stable level, although slight annual changes were observed. From the early 1980s to 2003–2005 or 2010–2015, the rates of forest cover significantly decreased in all surveyed villages due to the expansion of the agricultural frontier, mainly due to the cultivation of hillside lands and free grazing activities. Such an expansion was incentivized by market economic reforms that started around 1978. The decreasing rates of forest cover were slower for the period 1980–1990 and accelerated after 1990. After the period 2003–2005 or 2010–2015, the rates of forest cover in the study area began to increase, mainly due to the reduction of agricultural areas and the implementation of a grazing prohibition policy. However, increases in the rates of forest cover were not linear (Figure 3), the increasing forest cover trends were shaped by changes in forest

policies and forest restoration projects implemented in Chicheng County. Villages with earlier forest transition maintained or increased existing rates of forest cover due to more effective forest protection and restoration and a large proportion of farmers involved in industry and service work, and fruit-tree planting. On the other hand, most of the villages with late forest transition registered decreasing forest cover rates after 2018, due to increasing agricultural production and increasing livestock grazing.



**Figure 3.** Changes in forest cover rate in surveyed villages of Chicheng County. Villages with forest transition between 2003 and 2005 (curve 1), and villages with forest transition between 2010 and 2015 (curve 2).

### 3.2. The Changes in Land Use

Chicheng County is an agricultural county, and its main land-use activities are crop cultivation and livestock grazing. According to our field surveys, the cultivated land area in the surveyed villages remained stable between 1975 and 2000. Therefore, we investigated changes in cultivated land area between 2000 and 2018 (Table 2). The results show that cultivated land area reduced significantly after 2000, mostly due to natural vegetation regrowth on abandoned hillside cultivated land, fruit-tree plantings and reforestation, especially after the implementation of the policy and subsidy of “Farmland to Forestland Program” in 2002. On average, the proportion of converted hillside cultivated land accounted for one-third of the total previously cultivated land.

**Table 2.** The changes of cultivated land area, large-scale planting and abandoned cultivated land in surveyed villages of Chicheng County.

Time of Forest Transition	Village	Area of Cultivated Land (ha)		Area of Large-Scale Planting (ha)		Cultivated Land Abandonment (ha)	
		2000	2018	2000	2018	2000	2018
2003–2005	Yangjia	30	10	none	few	none	none
	Hanzhuang	263	143	none	60 (mainly planted trees by Forest Burea, partly planted maize by farmers)	none	none
	Jiangjiazhai	126	93	none	20 (mainly planted vegetable)	none	6
	Xiahu	245	153	none	57 (mainly planted vegetable, partly planted maize)	none	13
2010	Xishan	200–267	125	seldom	38 (planted vegetable)	none	few
2015	Haomenling	127	127	none	100 (planted aronia melanocarpa after 2015)	seldom	small area (after 2012)
	Houcungou	187	92	none	33 (planted vegetable)	none	none
	Balizhuang	397	312	none	66.7 (mainly planted maize)	none	16.7
	Sandaochuan	153	80	none	60 (planted mushroom after 2012)	none	none
	Sidao	300	200	Few	33–40 (mainly planted maize)	Few (less than 20)	more than 20

The phenomenon of large-scale plantings or centralized planting by renting cultivated land was rare before 2000. However, a considerable number of farmers' cultivated land had been rented to large agricultural planters to plant vegetables, maize or fruit-trees by 2018. The highest rent rate of cultivated land was 80%, and the average rent rate was 20% within the surveyed villages. This phenomenon of large-scale rental showed that many farmers stopped cultivating their land to engage in manual or service work in nearby cities. The trend towards an increasing proportion of rented cultivated land area was also influenced by the low returns from farming in the region observed during the study period. The large availability of cultivated land for rent resulted in low rental prices in the surveyed villages. Generally, rented cultivated land had high soil quality, irrigation infrastructure, low slopes and access to transportation networks. Low-quality land, such as hillside land, was not in high demand in the rental market and was usually withdrawn from cultivation. Cultivated land abandonment by 2018 increased significantly relative to 2000. Before 2000, land abandonment of cultivated land only existed in individual villages due to the "cultivated land protection" policy of the Chinese government.

The results show that the type of cultivation activity, cultivated area, and land abandonment, might not be relevant drivers of the dissimilarity in forest transition periods in the surveyed villages. However, changes in cultivated land had critical impacts on the forest transition in Chicheng, which provided institutional and policy guarantees and economic incentives for the recovery of forest vegetation on hillside land.

Changes in livestock grazing from 1975 to 2018 in the surveyed villages of Chicheng County are shown in Table 3. In general, the results show that livestock numbers (including free-grazing cattle and sheep) increased gradually from 1975 to 2000, and peaked during the period 1990–2000. Afterwards, the livestock numbers decreased, especially after the implementation of the "Farmland to Forestland Programme" and policies limiting free-grazing.

The gradual improvement of farmers' economic capacity after China's market economy reform, made more affordable the initial investment need for livestock husbandry. Such an activity gradually became an important part of households' livelihoods. Farmers were encouraged to invest in livestock husbandry since the income of such activity was higher than the income from planting grains. Meanwhile, the government also adopted policies encouraging livestock husbandry as an option to increase farmers' income. Consequently, livestock numbers increased significantly. The largest number of grazing sheep was observed in Hanzhuang village, between 2000 to 3000 sheep before the year 2000, and the average amount was about 1000 in most villages. In regions where livestock numbers had exceeded the carrying capacity of grasslands, livestock grazing limits were applied, and captive breeding and feeding operations were encouraged. The government also limited livestock activities in regions where land and environmental conditions generated low grass production or contributed to serious environmental issues (e.g., mudslides, floods). Farmers in impacted regions gradually transitioned to off-farm work (urbanization development generated high labor demand), and livestock numbers gradually decreased (especially sheep numbers). Livestock production decreased earlier in villages with forest transition between 2003 and 2005 than in villages transitioning afterwards.

Sheep production was the primary livestock type impacting forest transition processes in Chicheng. Chicheng County is dominated by mountainous terrain and large livestock, such as donkeys and cattle, cannot climb to grazing areas with a steep slope. Therefore, large livestock was mainly free-grazed on lowland grasslands or feed and breed in barns. In contrast, sheep grazing was suitable for steep hillsides. Since free-grazing on natural grasslands is cheaper than captive breeding and feeding livestock production, sheep production became the main livestock type for regions where grazing was feasible. Free-grazing on hillsides not only seriously damaged fragile hillside grasslands but also caused severe damage to tree seedlings in those areas. According to the survey results, there was a significant negative relationship between the number of sheep and the quality of vegetation on hillsides. Almost all the villages with more than 500 sheep (historical average) experienced soil erosion and floods risks. Once sheep grazing reduced, the vegetation on hillsides recovered significantly.

**Table 3.** The changes of livestock in Chicheng County from 1975 to 2018.

Time of Forest Transition	Village	Livestock Amount		
		1975	1990–2000	2018
2003–2005	Yangjia	few	more than 1500 sheep	few (after 2005)
	Hanzhuang	2000–3000 sheep, 3000 pigs, 150 cattle	about 2000–3000 sheep, 3000 pigs	200 sheep, 60–70 pigs (after 2003–2004)
	Jiangjiazhai	much more than 1000 sheep	more than 1000 sheep	230–240 sheep (after 2003–2004)
	Xiahu	few	much more than 300–400 sheep	300–400 sheep, seldom cattle (after 2005), 1000 pigs (after 2018)
2010	Xishan	few	much more than 300 sheep	300 sheep, 30 donkey (after 2010)
2015	Haomenling	less than 1200	about 1200 (sheep were main)	seldom (after 2015)
	Houcungou	about 100 sheep	about 100 sheep	100 cattles, 300–400 sheep
	Balizhuang	not so much	more than 1000 sheep	300–400 sheep (after 2015)
	Sandaochuan	500 cattle, 300 sheep	500 cattle, 300 sheep	800 cattle, 300 sheep
	Sidao	less than 100 cattle	700–800 cattle, 200 sheep (more than 200 households)	1500 cattle

### 3.3. The Changes of Livelihood

Following the Sustainable Livelihood Framework, a comparative analysis of the state of livelihood resources, strategies, and outcomes was conducted for villages experiencing forest transition during the study period (Table 4). Those villages had two primary types of livelihood resources, HLR and NLR. Villages that experienced earlier forest transition, such as Yangjia, Hanzhou, Jiangjiazhai, Xiahu, were relatively rich in economic and social livelihood resources. This could be explained by the proximity of those villages to mining operations which had positive economic and social spillover effects (see the introduction of the Study Area). Social livelihood resources in Xishan, Haomenling, Houcungou, Balizhuang were also significant, mainly due to their proximity to Beijing or the county center which allowed villagers to work in Zhangjiakou or Beijing and develop large social networks. Social relationships based on interactions with village leaders were also relevant. Villages with late forest transition generally depended on human and natural livelihood resources. Those villages were usually located in remote areas with high transportation costs but with relatively rich forest resources that were easier to regrow. In terms of livelihood strategies, there were similarities and differences within the study area. All the villages with forest transition adopted a livelihood strategy based on livelihood diversification. This was motivated by increasing off-farm work opportunities which consequently improved the livelihood diversity of villagers. In addition, Jiangjiazai, Xiahu, Xishan, Haomenling, Houcungou adopted the livelihood strategy of agricultural intensification. The main reasons were that these villages had better agricultural land resources and extensive social networks. The Sidao village also adopted the livelihood strategy of migration which was supported by the government's "Poverty Alleviation Policy". In terms of livelihood outcomes, all villages increased average income and well-being levels, which showed that socio-economic development improved the living conditions of villagers.

**Table 4.** The main characteristic of livelihood in the village which experienced the forest transition in Chicheng County.

Time of Forest Transition	Village	Livelihood Resources	Livelihood Strategies	Livelihood Outcomes
2003–2005	Yangjia	HLR,NLR,ELR,SLR	Livelihood diversification	More income Increased well-being
	Hanzhuang	HLR,NLR,ELR,SLR	Livelihood diversification	More income Increased well-being
	Jiangjiazhai	HLR,NLR,ELR,SLR	Agricultural intensification Livelihood diversification	More income Increased well-being
	Xiahu	HLR,NLR,ELR,SLR	Agricultural intensification Livelihood diversification	More income Increased well-being
2010	Xishan	HLR,NLR,SLR	Agricultural intensification Livelihood diversification	More income Increased well-being

Table 4. Cont.

Time of Forest Transition	Village	Livelihood Resources	Livelihood Strategies	Livelihood Outcomes
2015	Haomenling	HLR,NLR,SLR	Agricultural intensification Livelihood diversification	More income Increased well-being
	Houcungou	HLR,NLR,SLR	Agricultural intensification Livelihood diversification	More income Increased well-being
	Balizhuang	HLR,NLR,SLR	Livelihood diversification	More income Increased well-being
	Sandaochuan	HLR,NLR	Livelihood diversification	More income Increased well-being
	Sidao	HLR,NLR	Livelihood diversification Migration	More income Increased well-being

Notes: HLR = Human Livelihood Resources; NLR = Natural Livelihood Resources; ELR = Economic Livelihood Resources; SLR = Social Livelihood Resources.

Land-use activities (planting and grazing) are closely related to livelihood patterns [45]. It will be helpful to understand the relationship between historical changes in land-use activities, livelihoods and forest transition in Chicheng County (Table 5, data for 1975 were incomplete). On aggregate, relative to total household income, the proportion of income from livestock and migrant part-time work gradually increased from 1975 to 2018. Furthermore, the income from migrant part-time work slowly exceeded livestock income after 2000 because employment opportunities and wages for migrant part-time work increased. However, the variety existed between the villages experienced the earlier forest transition and those with the later forest transition. Villages that experienced earlier forest transition had higher income from migrant part-time work than from livestock production around 2000. This shift in the relative importance of those income sources occurred after 2000 for other villages. This suggests that early reduction in livestock numbers was associated with increased opportunities for off-farm work that occurred first in regions that experienced forest transition between 2003 and 2005.

**Table 5.** The changes of livelihoods in Chicheng County.

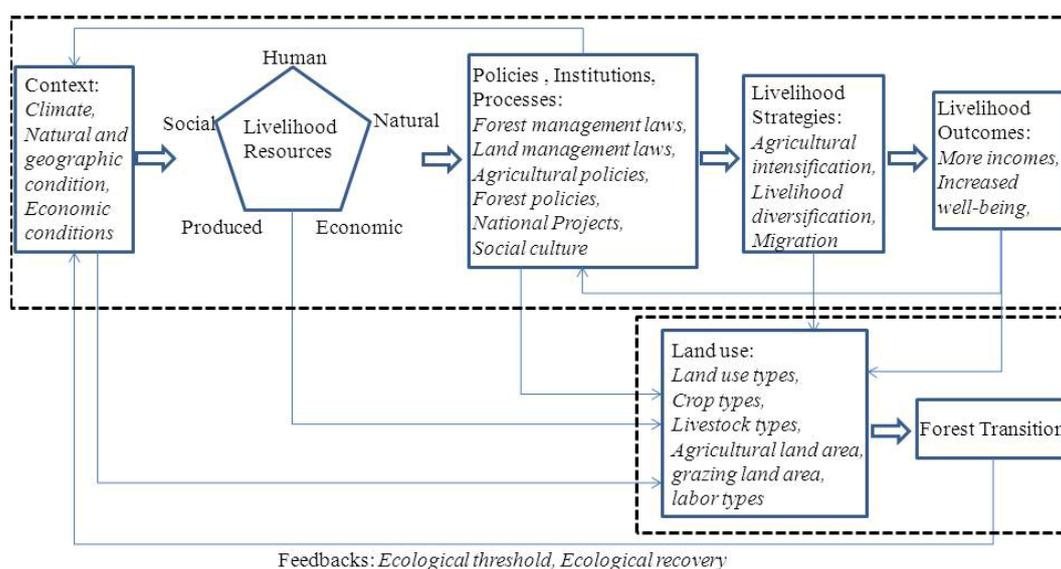
Time of Forest Transition	Village	Grazing Work Income			Part-Time Work Income		
		1990	2000	2018	1990	2000	2018
2003–2005	Yangjia	40% of income	40% of income	few	40% of income	40% of income	60% of income
	Hanzhuang	30% of income	30% of income	10% of income	50% of income	50% of income	60% of income
	Jiangjiazhai	30% of income	30% of income	10% of income	50% of income	50% of income	60% of income
	Xiahu	40% of income	30% of income	10% of income	10% of income	30% of income	50% of income
2010	Xishan	30% of income	30% of income	10% of income	40% of income	50% of income	60% of income
2015	Haomenling	half of income	1/3 of income	few	few	1/3 of income	2/3 of income
	Houcungou	30% of income	20% of income	10% of income	10% of income	20% of income	50% of income
	Balizhuang	20% of income	20% of income	10% of income	50% of income	50% of income	60% of income
	Sandaochuan	15% of income	20% of income	25% of income	15% of income	15% of income	20% of income
	Sidao	10% of income	40% of income	40% of income	40% of income	30% of income	40% of income

Although the proportion of total family income generated by livestock production decreased, there was an increase in livestock numbers in some villages, especially in villages experiencing forest transition after 2005. In some cases, savings from migrant part-time work enabled farmers to invest more in livestock husbandry. Since large-scale forest planting had not occurred in villages with late forest transition, migrant workers needed to return to their villages during the crop growing season. This partial dependence on cultivated land also became an important reason for villagers to increase livestock numbers as a way to diversify and increase their income. Such dependence also explains why households did not transition entirely to off-farm work even when there were financial incentives to do so.

#### 4. Discussion

##### 4.1. Interactions and Feedbacks of Land Use, Livelihood and Forest Transition

Based on land-use analysis and SLA analysis framework, we investigated the relationship between livelihood strategies, land-use and forest transition in villages which experienced shifts to net forest cover gains in Chicheng County (Figure 4). Differences in forest transition periods were a result of land-use changes driven by multiple socio-economic, environmental and institutional processes. The livelihood resources of each village in the study area were determined by their environmental, topographic, and socio-economic characteristics. Differences in livelihood resources and strategies were also influenced by policy and institutional changes (e.g., changes in forest and land management laws, agricultural policies, forest policies, national projects, social culture). Therefore, villagers adopted different livelihood strategies depending on their livelihood conditions. (agricultural intensification, livelihood diversification, migration). The impact of changing livelihood resources and strategies, policies and institutional constraints on land-use (land-use types, crop types, livestock types, agricultural land area, grazing land area, labor types, etc.) explains the difference in forest transition periods in the study area. Forest transition outcomes also provided feedback to some conditions related to livelihood resources, particularly by promoting ecological recovery and distancing from ecological thresholds.



**Figure 4.** Conceptual generalization of the relationship between livelihood resources and strategies, land-use and forest transition.

Forest transition in Chicheng County was primarily driven by a reduction of the relative importance of agricultural activities as a source of household income, off-farm work gradually became more

important. On the one hand, the reduced importance of agriculture relative to other income sources (especially the planting industry) motivated the abandonment of low-quality cultivated land (mainly hillside cultivated land). This facilitated the acceptance and implementation of the “Farmland to Forestland Programme” policy, which resulted in large scale tree planting in previously cultivated land. On the other hand, the reduction of the economic importance of livestock husbandry and increasing production costs caused by governmental restrictions to free-grazing gradually reduced sheep numbers, which lead to the restoration of forest vegetation. Therefore, interactions between climate, institutional and policy changes occurring at a macro scale, with land-use choices determined by livelihood conditions and strategies at micro scales determined the processes and pathways to forest transition.

The effectiveness of institutional and policy changes was also related to the local socio-economic and environmental context. Crop planting, livestock husbandry, forestry and permanent residence in rural villages were core components of the Chinese rural land-use system. The gradual shift in livelihood resources and strategies generated changes in income sources, investment strategies, and place of residence which reconfigured rural land-use systems in the study area. Such reconfiguration contributed to achieving net forest cover expansion. Our results indicate feedbacks between land-use change and changes in forest cover. Socio-economic development has modified livelihood patterns of farmers in Chicheng County, resulting in a reconfiguration of land-use activities, which eventually lead to forest transition. When livelihood strategies (e.g., extensive grazing) resulted in excessive environmental degradation, the government, farmers, and related social sectors adjusted their behaviors to promote the restoration of environmental assets. It could be argued that there was a process of adaptation between a need to consume environmental resources to fulfill household needs and the development of alternative livelihood opportunities. In this type of socio-ecological process, livelihood strategies based on land-use choices had first a negative impact on ecological systems (i.e., large rates of deforestation) but shifted to ecological gains when alternative livelihoods were accessible. This pathway to forest transition could be regarded as derived from socio-ecological system interactions with foundations on social ecology theory [30,57].

#### *4.2. The Key Factors Affecting Forest Transition in Land Use and Livelihoods*

Our results also provide information about key drivers of land-use and livelihood patterns (Table 6). Migrant part-time work had a significant impact on land-use change and the diversification of livelihoods in all surveyed villages. With the development of the market economy reform in China from 1978, income sources for farmers in Chicheng County changed significantly. The economic development observed in Beijing had significant spillover effects in the economy of Chicheng County. Farmers with off-farm work opportunities improved their economic conditions increased their savings and invested in livestock husbandry. This was a common strategy before the implementation of the “Farmland to Forestland Programme” and the free-grazing ban. Once those governmental policies were implemented, livestock production decreased, and migrant work became key for rural households. This process gradually reduced grazing pressures on forest and grass vegetation.

Proximity to mining operations appears to be also a significant factor to explain observed forest transition paths in the study area. Farmers close to mining sites had access to employment opportunities in the sector which allowed them to generate the resources needed to increase their livestock inventories. Such an increase in livestock numbers resulted in environmental degradation, that triggered policy responses and behavioral changes that at the end resulted in forest and grassland restoration. Large-scale plantations were also key to achieving forest transition. The combination of land rental for large-scale plantations and the increasing opportunities for migrant work made more farmers rent their cultivated land. On the other hand, large-scale plantations prioritized rental of high-quality cultivated land, which lowered rental returns from low-quality land and indirectly promoted the abandonment of such low-quality land, especially around hillsides.

**Table 6.** The main factors affecting land use and livelihoods in Chicheng County.

Time of Forest Transition	Village	Near to Mining Stope	Part-Time Work	Large-Scale Plantation		Ecological Threshold
				Vegetable	Fruit Trees	
2003–2005	Yangjia	Y	Y			Y
	Hanzhuang	Y	Y			Y
	Jiangjiazhai	Y	Y	Y		Y
	Xiahu	Y	Y	Y		Y
2010	Xishan		Y	Y		Y
2015	Haomenling		Y		Y	Y
	Houcungou		Y	Y		
	Balizhuang	Y	Y			Y
	Sandaochuan		Y			
	Sidao		Y			

#### 4.3. The Various Pathways of Forest Transition in Chicheng County

Rudel proposed a “pathway framework” to summarize various ways to achieving forest transitions which include the “economic development path” and the “forest scarcity path” [28,29]. The “economic development path” indicates that urbanization and industrialization processes associated with economic development, shift rural labor markets from an agricultural focus to off-farm options. Shortages in agricultural labor resulted in increases in wages which further reduced the profitability of agricultural activities. This could generate abandonment of low-quality and remote agricultural and grazing lands where forests could gradually regrow. The “forest scarcity path” suggests that deforestation reduces the supply of forest ecosystem services, increasing the price of forest products which then incentivize tree plantings. Under this path, governments tend to implement tree-planting projects in response to floods or other disasters caused by the loss of ecosystem services. The “intensive agriculture path of small-scale farmers” indicates that small-scale farmers would gradually stop cultivating low-productivity land (e.g., high altitude land) due to improvements in agricultural productivity in other lands under their management (e.g., through intensive cultivation in valleys) [31]. Forest vegetation in abandoned land could be naturally restored through land improvement (such as terraces).

Previous studies have shown that China had a forest transition as early as the 1980s–1990s with the main driving force being tree-planting promoted by the government [3,7,18,19,55]. However, this study shows that Chicheng county, a unique mountainous area of Yanshan Mountain in northern China, experienced forest transition at a later period than the whole country. This delay was linked to the heterogeneous topographic, environmental and socio-economic characteristics of Chicheng County. Compared with southern China, rainfall in northern China, especially in the mountainous area, was less and more unstable. Soil thickness and nutrient content in Chicheng County were not enough to generate the rapid growth of arbor forests. Most afforestation sites had poor natural conditions (such as occasional geological hazards and difficult conditions for road construction) and poor climate profiles (such as uneven rainfall, and frequent high winds). Those sites were significantly affected by drought, which required additional replanting and reforestation costs to ensure the preservation rate of new forests.

Chicheng is a poor county, a typical mountainous farming-pastoral zone, with backward economic development. In the past, people’s livelihoods mainly relied on agricultural outputs on steep slopes and overgrazing. With the development of urbanization, more people migrated to work in cities, which decreased pressure on cultivated land and grassland. This was one of the key reasons for the observed forest transition. Therefore, the rapid achievement of forest restoration by large scale tree planting could not be achieved in this county. Our results show that urbanization and industrialization processes in Beijing reduced livestock husbandry (especially sheep breeding) and contributed to the abandonment

of marginal land. Concurrently, labor for agricultural and livestock production gradually reduced, which contributed to the implementation of the “Farmland to Forestland Programme” (returning cultivated land to forests or native vegetation) in the county. Lack of enough agricultural workers, even made more cultivated land to return to natural vegetation without subsidies. Furthermore, the development of livestock husbandry directly determined the speed and time of the natural restoration of forest vegetation. Especially reductions of sheep numbers were directly related to the timing of forest transition. Therefore, the forest transition of Chicheng County mainly depended on natural forest regrowth, and the condition, process and timing of natural forest restoration were largely determined by socio-economic development processes.

This study shows that there were various paths to forest transition in Chicheng County (Table 7). In all the surveyed villages, the “economic development path” and “forest scarcity path” were observed. On the other hand, some villages experienced the “intensive agriculture path of small-scale farmers” to net forest cover gains. The “economic development path” was driven by urbanization and industrialization processes that shifted regional labor markets away from agricultural employment and caused the abandonment of low-quality cultivated lands (especially hillside cultivated land) and the natural regrowth of forest in those lands. The “forest scarcity path” was observed since the government implemented tree-planting projects in response to floods, sandstorms and other disasters caused by the loss of forest ecosystem services. The “intensive agriculture path of small-scale farmers” was also present in the study area since some farmers abandoned high-altitude cultivated lands and increased the intensity of cultivation in the valley. Such activity also contributed to the restoration of forest vegetation on hillsides. The relevance of the observed forest transition paths was different. The dominant path of forest transition in Chicheng County was the “economic development path”. The “intensive agriculture path of small-scale farmers” enhanced the “economic development path”, and the “forest scarcity path” reinforced a shift to net forest cover gains. The results of this study prove that the interaction of multiple paths promoted the occurrence of forest transition as proposed by Meyfroid [31].

**Table 7.** The various forest transition paths in surveyed villages.

Time of Forest Transition	Village	Forest Transition Paths		
		Economic Development Pathway	Forest Scarcity Pathway	Intensive Land-Use Pathway
2003–2005	Yangjia	Y	Y	
	Hanzhuang	Y	Y	
	Jiangjiazhai	Y	Y	Y
	Xiahu	Y	Y	Y
2010	Xishan	Y	Y	Y
	Haomenling	Y	Y	Y
2015	Houcungou	Y	Y	Y
	Balizhuang	Y	Y	
	Sandaochuan	Y	Y	
	Sidao	Y	Y	

It was worth noting that although all the villages in our study area experienced forest cover gains as the regional economy developed, villagers only reduced livestock husbandry when environmental degradation reached ecological thresholds. Forest recovery policies occurred once the government realized that environmental degradation could no longer be ignored or it would lead to an unsustainable and hopeless loss of key forest ecosystem services. In this context, the theoretical framework associated with the “forest scarcity path” to forest transition can explain the role of policy changes that contributed

to net forest cover gains. Within the coexisting drivers of forest transition in Chicheng County, changes in livestock production were critical determinants of the timing of the shift to net forest cover expansion.

#### 4.4. Policy Suggestions

Chicheng County experienced forest transition due to socio-economic development and government-lead forest restoration. The remarkable improvement in forest cover shows that human and environmental systems could achieve sustainable development goals in rural settings. However, forest transition is not a linear, unidirectional process. The transition observed in villages in our study area, highlight that multiple factors interact in the generation of trends towards forest cover gains. If some of those factors are not adequately considered in policy design (e.g., incentives for livestock production), forest cover gains could reverse. Some forest areas in Chicheng County were under potential deforestation threats. In two villages (Sandaochuan and Sidao), forest resources were abundant and not significantly impacted by livestock grazing. The “Farmland to Forestland Programme” promoted afforestation in barren lands, in those regions so that existing forest resources were well preserved. However, the socio-economic development observed in China has not resulted in the diversification of livelihood options in these two villages, mainly due to their location at high altitude and poor transportation infrastructure. Villagers in these regions could not get enough income by simply relying on plantations, and living costs were higher than before. Therefore, livestock husbandry became a relevant livelihood option again, and forests in those villages could be negatively impacted.

Forest transition is a result of long-term land-use change processes driven by interactions across socio-economic, institutional and environmental systems. A better understanding of those interactions is essential for land-use policy and regional ecological environment protection and restoration strategies. The study of forest transition involves a series of questions, such as whether a region has undergone a forest transition, how to realize forest transition as soon as possible, how to maintain the sound development of forest transitions, how to reduce environmental degradation before forest transition occurs, and how the local government makes choices in policy design and management. In the context of a series of emerging socio-economic and ecological policies in China, research about spatiotemporal drivers of “forest transition” are valuable from scientific and policy perspectives.

As a result of changes in socio-economic, institutional and environmental systems, the future trend of forest cover change will depend on the evolution of changing external socio-economic conditions. Our study suggests that if we want to achieve stable forest transitions, it will not be enough to rely only on afforestation projects, e.g., the subsidy of “Farmland to Forestland Programme” and the free-grazing prohibition policy of the government. This study found that livelihood strategies are key to maintaining forest transitions. In this context, improving farmers’ non-agricultural income, increasing alternative livelihood options for livestock husbandry, and improving agricultural productivity is critical for the protection of natural vegetation in rural areas. This study found that increases in household income can reduce cultivation in marginal lands and deforestation. By increasing employment opportunities in remote mountainous villages, improving road networks, and enhancing farmers’ education levels, the trend to environmental recovery could be sustained. Furthermore, incentives to intensive livestock production could reduce pressures from remaining free grazing activities. Intensive agriculture and large-scale plantings could also result in land sparing and forest regrowth. Improvements to working conditions of forestry workers could also prevent personnel losses, and the implementation of regular maintenance and irrigation activities could improve the survival rate and efficiency of tree-planting. In addition, incentives to alternative environmentally-friendly livelihood options such as eco-tourism enterprises could further reduce the pressure over forest resources. Sustainable conditions across human and environmental systems can be realized and maintained only by formulating policies that have a positive impact on the livelihoods of rural villagers.

## 5. Conclusions

In recent years, China has made remarkable achievements towards the protection and restoration of critical environmental assets. However, China's environmental success is often considered as policy-led. For instance, the forest transition observed in China is generally only attributed to national forest planting and restoration projects. In this study, using land-use analysis, the Sustainable Livelihood Analysis framework, and sociological survey methods, we investigated the drivers of forest transition at a micro-scale (i.e., within urban villages). Our analysis accounted for changes in farmers' livelihood options, land-use choices, forest vegetation and other factors related to forest transition pathways observed from 1975 to 2018 in Chicheng County, a typical mountainous area in northern China. This study found that forest transition in Chicheng County occurred after the period 2003–2005, with villages shifting to net forest cover gains during different years. Differences in livelihood resources, urbanization and industrialization processes in nearby cities, and agricultural constraints generated by certain policies and institutions led villagers to adopt different livelihood strategies that resulted in heterogeneous paths to forest transition. In addition to the impact of climate change, and institutional and policy changes at macro scales, livelihood conditions and environmental and topographic characteristics at micro scales were crucial determinants of local land-use change patterns. The identification of interactions and dependencies between livelihood strategies and forest cover change is key for achieving and maintaining forest transition. Overall, the dominant path of forest transition in Chicheng County was the “economic development path”. However, the “intensive agriculture path of small-scale farmers” enhanced the “economic development path”, and the “forest scarcity path” further contributed to achieving net forest cover gains. Only by comprehensively considering the tradeoffs and benefits of ecological restoration and socio-economic development is it feasible to achieve and maintain sustainable human and environmental systems.

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