The Varying Roles of Ecosystem Services in Poverty Alleviation Among Rural Households in Urbanizing Watersheds

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Abstract

Context

Understanding the relationship between ecosystem services and human well-being in rural areas of rapidly urbanizing watersheds is one of the core research questions of landscape sustainability science. It is important for poverty alleviation and forming related policies. However, there is insufficient investigation on the impact of ecosystem services on poverty alleviation at the household level in such regions.

Objectives

This paper investigates whether household characteristics play an important role in connecting ecosystem services and poverty alleviation in a rapidly urbanizing landscape from the perspective of landscape sustainability science.

Methods

We use an urbanizing watershed with a large number of poor people, analyzing the impacts of ecosystem services on poverty alleviation among different types of rural households based on surveys, cluster analysis, and multinomial logit models.

Results

The results suggested that neither provisioning services nor cultural services that are received by the households were significantly associated with poverty alleviation ($p > 0.1$). However, the decline in one regulating service (natural disaster prevention) had a significant, negative impact on poverty alleviation ($p < 0.1$), and the probability for natural disaster-affected farmers to fall into poverty was approximately 32 times higher than that for those who were not.

Conclusions

Differences in household-level endowments largely explained the diverging roles of ecosystem services on poverty alleviation. Therefore, in urbanizing watersheds, pro-poor policies such as providing agricultural insurance and targeted support (e.g., interest-free microcredit) should be adopted to improve the ability of poverty-stricken households to cope with disasters and prevent them from returning to poverty.

1. Introduction

Poverty is defined as an extreme deprivation of human well-being (MA, 2005; Carpenter et al., 2009), including multiple dimensions such as food security, nutrition, health, income and assets, education, and skills (Suich et al., 2015). It can be measured in an absolute way, i.e., the severe deprivation of basic

human needs, and in a relative way, i.e., comparison with the economic status of other members of the society (United Nations, 2014), among which income is often used to measure absolute poverty (Barrett et al., 2011). For example, the World Bank established the international poverty baseline of US\$1.90 per day in 2015 (United Nations, 2015). Eradicating poverty is the first goal of the Sustainable Development Goals (SDGs) of the United Nations. Therefore, understanding the pathways to poverty alleviation is fundamental for sustainable development and landscape sustainability science.

Ecosystem Services (ESs) refer to the benefits that humans obtain from ecosystems (MA, 2005), which are strongly linked to poverty alleviation (Carpenter et al., 2009; Suich et al., 2015). Recently, the Millennium Ecosystem Assessment (MA) framework and the Ecosystem Services for Poverty Alleviation (ESPA) programme has maintained a strong attention to the wellbeing of the poor (i.e. income and employment) and the effect of ESs management on poverty alleviation (Schreckenberg et al., 2018). These studies have found that the relationships between ESs and human wellbeing were complex (Fisher et al., 2013; Liu and Wu, 2021). For example, the basic food and energy needs of rural residents in poor areas rely heavily on provisioning services (TEEB, 2010), and selling these natural products also generates income (MA, 2005). Regulating services have played an indispensable role in maintaining a safe and healthy environment for the poor (TEEB, 2010; Stringer et al., 2012). Meanwhile, the effect of cultural services on poor areas has been discussed (TEEB, 2010; Derkzen et al., 2017).

Although the importance of ES to the poor has been widely recognized, there were still at least three research gaps that deserve our attention. First, we still lack an understanding of the disaggregate benefits of ESs in poverty alleviation (Fedele et al., 2017; Suich et al., 2015), which hinders policymakers from targeted policies for improving ESs and alleviating poverty. Recently, the roles of individual ES in improving living conditions for the rural poor and creating pathways out of poverty were qualitatively discussed (Schreckenberg et al., 2018; Adams et al., 2020; Mandle et al., 2020), a quantitative analysis comparing the varying roles of multiple ESs in poverty alleviation was rare. In addition, previous studies mainly focused on the impacts of provisioning and supporting services in poverty alleviation, while the impacts of regulating and cultural services were less considered.

Second, although some researchers have examined the direct association between household characteristics and ES dependence, their relationship with poverty alleviation have not been quantitatively explored. For example, Robinson et al. (2019) found that ES dependence is related to socioeconomic factors, such as age composition, health, education and family assets. Chaigneau et al. (2019) implied that the ability of individuals to gain wellbeing through ESs depends not only on monetary mechanisms, but also on the use and experience mechanisms. Hua et al. (2017) found that the human, natural, and financial capital of watershed residents have significant impacts on livelihood strategies and poverty alleviation. Therefore, understanding the varying quantitative relationship between ESs and poverty reduction among different household types is imperative to forming targeted poverty alleviation policies.

Third, previous studies largely focus on sparsely populated regions, such as protected areas (Zheng et al., 2019) and remote mountainous areas (Sandhu et al., 2014). While generating valuable knowledge on

ecosystems such as forests (Von Maltitz et al., 2016), farmlands (Cruz Garcia et al., 2016) and wetlands (Verma and Negandhi, 2011), there is inadequate attention on the urbanizing areas (Marshall et al., 2018), especially the rural poor in these regions. Due to the rapid transformation of ecological land to urban land, the supply of ESs in urbanizing watersheds has decreased (Zhang et al., 2017; Huang et al., 2019). The income of a large number of people engaged in ES-related industries, such as crop cultivation and animal husbandry, has been negatively affected (TEEB, 2010). Conversely, the increase in land use intensification improves rural livelihoods by increasing rural income (Liao and Brown, 2018). In addition, due to the differences in economic status and social capitals between urban and rural residents, the rural-urban income gap has been widening alongside with urbanization, and poor rural residents are vulnerable to be trapped in poverty (Daw et al., 2011; Huang et al., 2020). Therefore, analyzing the relationship between ES and poverty alleviation in urbanizing watersheds can provide an important implication for the development of targeted poverty alleviation policies in the context of global urbanization.

The Sustainable Livelihood (SL) framework provides a multidimensional perspective for analyzing the relationship between ESs and poverty alleviation in the context of landscape sustainability science. First of all, maintaining a benign relationship between ES and human well-being is rapidly urbanizing landscape is a key target of landscape sustainability science (Wu 2013); and understanding how socioeconomic processes and institutions affect the relationship among urbanizing, ES and human-well-being is one of the eight core research question of landscape sustainability science (Wu 2021). Second, the SL framework believes that natural, human, physical, financial, and social capital influenced by regional institutions and organizations together determine people's livelihood strategies and affect the sustainability outcomes (Scoones, 1998). This framework can not only be used to understand poverty alleviation at the household level, but is also compatible with or complementing other frameworks (Fisher et al., 2013). For example, natural capital in the SL framework includes most ESs categories in the CICES (Haines-Young and Potschin-Young, 2018) or MA framework (MA, 2015). Meanwhile, some important moderators (such as the differences in income, employment, and social differentiation) between ESs and poverty alleviation, which are not explicitly included in the MA, were also considered in the SL framework (Daw et al., 2011). Therefore, using the SL frameworks can help us address one core research question of landscape sustainability science and understand the varying roles of ES in poverty alleviation among different households in rapidly urbanizing landscapes.

This investigates whether household characteristics play an important role in connecting ESs and poverty alleviation in a rapidly urbanizing landscape from the perspective of landscape sustainability science. To this end, we first obtained the ESs characteristics and socioeconomic information of households in the Baiyangdian watershed according to surveys and interviews. Then, we conducted a cluster analysis to identify the types of rural households. Subsequently, a multinomial logit model (MNL) was constructed to analyze the factors that influence poverty alleviation across different types of rural households. Towards the end, we discussed the significance for understanding the relationship between ESs and the well-being of poor residents in urbanizing watersheds, as well as achieving the broader poverty alleviation goal.

2. Study Area And Data

2.1 Study area

The Baiyangdian watershed is located in northern Hebei Province, China (38°3'N–40°4'N and 113°39'E–116°12'E) and is part of the Daqing River system of the Haihe watershed. It is situated in continental monsoon climate zone with four distinct seasons. Spring and winter are dry and windy, whereas summer is hot and rainy. The average annual water in the watershed is 3.12 billion m³, and the per capita water is only 297m³, which is far below the internationally recognized extreme water shortage line, i.e., 500 m³ per capita (Baiyang et al., 2013). The total area of the watershed is approximately 31,200 km², and the elevation is high in the west and low in the east, forming mountains, plains and waterlogs (Figure 1). The main types of land use in the watershed include farmland, grassland and woodland, accounting for 90.2% of the total area. This watershed provides the region with a variety of ESs, such as flood control, recreation, aquatic products, raw material products, water resources, and carbon sequestration (Jiang et al., 2017). It covers 28 cities and counties in Hebei, Shanxi and Beijing. The total population of the watershed in 2018 was 9.6 million, of which urban population accounts for 52.9%.

We chose this watershed as a case to explore the relationship between ES and poverty alleviation for two reasons. This watershed is a typical rapid urbanizing watershed. Recently, the Baiyangdian watershed has experienced rapid urbanization. From 1990 to 2018, the area of urban land in the watershed expanded by 488.98 km², nearly five times as large as the area at the beginning of the period. The average annual growth rate of urban land reached 5.6%, which was 1.6 times the global annual growth rate of 3.5% (He et al., 2019). In addition, the urbanization of the watershed has led to increased human activity, resulting in environmental problems, such as surface runoff reductions and increased water and air pollution (Gao et al., 2009). In the future, the construction of Xiong'an New District, a national new district in China, will further promote the urbanization of the watershed.

More importantly, there are a large number of poor households living in the watershed. This watershed contained eight counties that were identified as China's contiguous poor areas by the national government (Zhao et al., 2014). The income gap between urban and rural residents is quite large. The per capita disposable income of urban residents in the watershed was 27,188 RMB yuan in 2018 (equivalent to 4,109 US dollars at an exchange rate of 6.617 in 2018), approximately 2.6 times that of rural residents (10,405 RMB yuan or US\$1,572). The Chinese government pays great attention to green and sustainable development of the Baiyangdian watershed, hoping to build it into a demonstration area of sustainable urbanization and ecological construction (Frazier et al., 2019).

2.2 Data

Two types of data were used in this study. The first one is the survey and interview data in Baiyangdian watershed from July to August 2019. The second one is socioeconomic statistics derived from *The China Rural Poverty Monitoring Report in 2019* and *The Hebei Rural Statistical Yearbook in*

2018, including population data and socioeconomic data for all rural areas in Laiyuan County, Laishui County, and Yi County in Baoding City, Hebei Province.

3. Method

Based on the SL and MA framework, we put the poor and marginalized households whose livelihoods are directly dependent on ESs at the center of our analysis, and examined the full chain connecting ESs, household differences, and final benefits for poverty alleviation.

In this study, we used the SL framework to explore the impacts of ESs on poverty alleviation. Following the SL framework, households make livelihood activity choices based on their assets, access, and capabilities, and the ecosystem endowments they get from the local ecosystem. The household's benefits from the ecosystems can be seen as two parts, natural resources that do not combine human labor (that is, direct ESs, such as non-material benefits and aesthetic values), and the benefits or abilities through a combination of ecosystem entities and anthropogenic assets (including human capital, social capital, and financial capital) as well as human labor (Robinson et al., 2019). Despite current research indicates both the material benefits and non-material benefits provided by ecosystems are important for poverty alleviation (Chaigneau et al., 2019), this study mainly focused on the material benefits because they are fundamental and critical to improving the livelihood of rural poor, particularly the financial dimension of poverty alleviation (de Koning et al., 2011).

3.1 Sampling and semi-structured interview

Built on SL framework's assumption that natural, human, physical, financial, and social capital determine the livelihood of households (Scoones, 1998), and the livelihood of rural poor households is closely related to their material well-being (Soltani et al., 2012). The questionnaire was designed to collect information including natural characteristics, basic household information, household economic characteristics and locational context. Among them, natural characteristics refer to the assessment of multiple ESs. We selected three ESs in this study for three criteria. First, the selected ESs can be represented by monetary terms because our pre-survey found local poor people with low-level education cannot understand the non-financial benefits of ESs. Second, the selected ESs can represent multiple categories of ESs, including provisioning, regulating and cultural services. Third, the selected ESs were found to be important drivers of local residents' wellbeing (Huang et al., 2020). Following these criteria, we used household income from farming and tourism to represent realized provisioning and cultural services, respectively. In addition, whether the households were financially protected from natural disasters was used to represent the realization of regulating services, because exposure to natural disasters (e.g., drought) is closely related to household poverty alleviation (Adams et al., 2020).

Basic household information include household labor availability (Soltani et al., 2012), age of household head (Nguyen et al., 2015), highest education level in a household (Fang et al., 2014), and proportion of employed individuals. In addition, household economic characteristics were collected to represent material and financial capital, which are also important for livelihood and poverty alleviation (Fisher et al.,

2014). Specifically, we obtained area of land (Soltani et al., 2012), household expenditures (total expenditures and medical, education, and operating expenditures), loans (Jiao et al., 2017), and the proportion of durable goods at the household level (Qian et al., 2017). Household locational context refers to the ability to obtain resources and enhance livelihood security, which is important for overcoming a range of dilemmas and collective-action problems surrounding natural resources (Ostrom, 2001). We use the travel time to the local town center (Soltani et al., 2012) and the frequency of visiting market fairs to demonstrate locational context.

Since this watershed has eight national-level poor counties and many national attractions/ historical sites, we selected three counties which has at least one national-level tourist attraction. To analyze the roles of cultural services in poverty alleviation, we further selected a pair of villages in each chosen county. One is adjacent to the tourist attraction and the other is slightly away, about 15 kilometers away from it. Then, households were randomly sampled according to the amount of total households and the official records of poor households (i.e., poor people with official poverty cards). The number of sampled households was determined following the formula proposed by Yamane (1967). Finally, a total of 110 households were selected from 1,477 rural households for interviews (see Appendix 3, 4). After eliminating incomplete answers, our sample included 103 valid surveys, with a response rate of 93.6%.

We used semi-structured interviews to collect information from the sampled households. This method was based on the preset theme and outline of the interview, and interviewers recorded the whole process. We conducted a one-week pre-survey in July 2019. In the pre-survey, we mainly interviewed local government officials (county poverty alleviation officials), and revised the questionnaire based on their feedback. After that, we conducted formal surveys from July to August in 2019. Each household interview lasted about one hour.

3.2 Classifying household type

To understand the differentiating roles of ES in poverty alleviation among rural households in the watershed, we classified the sampled households using cluster analysis (Table 1). Specifically, we chose four key factors. Among them, three (household head occupation, total expenditure, and the proportion of non-agricultural income) represent economic factors that affect poverty, and one (whether the tourist attractions affect the lives of residents) represents the social factor. To be specific, household head occupation represents the main livelihood activities of a poor family (Walelign, 2015). The total expenditure is a good representation of living conditions and consumption capacity (You and Zhang, 2017). The proportion of non-agricultural income reflects the economic structure of a household (Walelign and Nielsen, 2013). Due to the abundant tourism resources in the selected counties, the nearby tourist attractions may change the livelihood choices of households and engage in rural tourism (Mbaiwa and Stronza, 2010).

Following the study by Wang et al. (2019), we applied a two-step clustering to classify the sample households. Compared with the hierarchical clustering method, the two-step clustering method uses the

log-likelihood distance as a criterion to automatically define the optimal number of clusters, which is less arbitrary and can deal with both categorical and continuous variables (Hua et al., 2017).

Table 1 Description of the variables used for dividing household groups

Variable	Description
The occupation of the household head	The main occupations of the head of household were divided into six categories (farmer =1, businessman =2, employee =3, wage laborer =4, unemployment =5, others =6)
Total expenditures	The total expenditures of a household in the past year (RMB yuan)
Proportion of non-agricultural income	Non-agricultural income/total income (%)
Whether the tourist attractions affect the lives of residents	Respondents claim whether the surrounding tourism has an influence on any aspects of their lives, 3 categories (strongly influential = 1, somewhat influential = 2, no influence = 3)

Note: Employee refers to a person who has a stable position in an enterprise or company. Wage laborer refers to a person who earns salary through various temporary jobs.

3.3 Analyzing the roles of ES in poverty alleviation among households

As the dependent variables (e.g., the type of household) in this study are discrete, disordered, and mutually exclusive, we selected the MNL to understand the roles of ESs in poverty alleviation among different types of households following a previous study by Wang et al. (2019). The establishment of the MNL model requires setting a reference group and then compares the reference groups with other groups to figure out the factors that affect poverty alleviation among different types of households. The MNL model based on different household types can be expressed as,

$$\text{logit}(y) = \ln \left[\frac{P(y = k)}{P(y = 1)} \right] = \alpha_k + \sum_{n=1}^N \beta_{kn} x_n$$

Where k is the type of households, x_n is the factor influencing household type, α_k is a constant, and β_{kn} is the estimated coefficient corresponding to n kinds of influential factors of k households. By calculating relative risk ratio (RRR), the model can quantify the ratio of the probability of the result (dependent variable) caused by exposure to a certain risks (independent variable) in the reference group (Eltinge and Sribey, 1997). We used the household-level ESs and endowments as independent variables to explore which combination of household characteristics and ES is more likely to increase the probability of farmers falling into poverty, and quantify the degree of such risk (Table 2).

In addition, we used the Pearson Correlation Coefficient (PCC) and Tolerance and Variance Inflation Factor (VIF) to test for multicollinearity. The results showed that the PCC between the travel time to the local town center and the frequency of going to market fairs was the highest, at -0.664 ($0.664 < 0.8$), the

tolerance of operating expenditures was the lowest at 0.190 ($0.190 > 0.1$), and the highest VIF was 5.257 ($5.257 < 10$). According to the above results, there was no multicollinearity between the independent variables. SPSS 20.0 and Stata13.0 were used for measurement and statistical analysis.

Table 2 Characteristics of variables used for the multinomial logit model (N=103)

Type	Variable	Description	Mean	Standard deviation	Min.	Max.
Dependent variable	Household type	type I=1, type II=2, type III=3	1.99	0.82	1	3
Ecosystem services	Provisioning services	Income from growing crops or cash crops in the past year (RMB yuan)	1149.81	2526.92	0.00	15000.00
	Regulating services	The impact of drought, hail, extreme precipitation, and sandstorms on households (have no impact = 0; have impact = 1)	0.65	0.48	0.00	1.00
	Cultural services	Income earned from tourism-related work in the past year, such as operating shops and selling specialty products (RMB yuan)	24182.04	57866.89	0.00	400000.00
Demographic	Household labor availability	The number of persons in the household over the age of 16	2.88	1.50	1.00	8.00
	Proportion of employed individuals	Number of people working/total household labor availability (%)	0.52	0.40	0.00	1.00
	Age of household head	The age of the head of the household (years)	56.96	14.25	29.00	91.00
	The highest education level in the household	The highest level of education among family members (uneducated = 1; primary school = 2; junior high school = 3; senior high school = 4;	3.43	1.30	1.00	5.00

		college and above = 5)				
Economic	Area of land	The total area of cropland and forestland owned by the household, excluding leased and abandoned land (m ²)	1446.67	2126.67	0.00	20000.00
	Medical expenditures	Expenditures of the household on medical treatment and medicine in the past year (RMB yuan)	5396.12	11274.33	0.00	60000.00
	Operating expenditures	Expenditures of the household on operations and investments in the past year (RMB yuan)	5029.13	19138.02	0.00	100000.00
	Education expenditures	Expenditures of the household on education in the past year (RMB yuan)	8378.64	13437.67	0.00	70000.00
	Total expenditures	Total expenditures of the household in the past year (RMB yuan)	28359.22	28787.95	2000.00	175000.00
	Loans	Has the family had any loans in the past year, including marketing cooperative loans, short-term agricultural loans, commercial housing loans, and private loans, etc. (no loan =0; have a loan =1)	0.26	0.44	0.00	1.00
	Proportion of durable goods	Number of durable goods owned by the household/Total	0.17	0.37	0.00	1.00

		of 12 assets from list (see Appendix 3, %)				
Locational context	Travel time to local town center	Average travel time from home to local town center (min)	22.15	11.90	5.00	35.00
	Frequency of going to market fairs	Frequency of family members attending market fairs in the local town center each month (times)	3.10	5.08	0.00	30.00

4. Results

4.1 Characteristics of respondents and residents in the watershed

The characteristics of respondents were generally consistent with the overall demographic features of residents in the watershed (Table 3). According to the survey data, the average labor availability (over 16 years old) in the surveyed households was 2.88, which was close to the average number (2.72) in the watershed. Most of the sampled households (68.9% of total samples) had an education background of primary and junior high school, which was slightly below than that (80.1% of total population) in the study area. The proportion of employed individuals in a household, land area, per capita net income, per capita consumption and per capita medical expenditures of the surveyed households were also consistent with the overall values of residents in the watershed. The education expenditures in the sampled households were higher than the regional average, probably because respondents added living expenses such as boarding and lodging costs into the education expenses of their children during the interview.

Table 3 Characteristics of the respondents and residents in the watershed

Type	Characteristics of respondents	Characteristics of residents [#]
Number (proportion)	Number (proportion)	
Mean household labor availability	2.88	2.72
Mean proportion of employed individuals	52.56%	53.37%
The education level of the household		
Uneducated	15 (14.56%)	9.36×10 ⁴ (7.8%)
Primary school	37 (35.92%)	42.35×10 ⁴ (35.3%)
Junior high school	34 (33.01%)	53.74×10 ⁴ (44.8%)
Senior high school	15 (14.56%)	10.32×10 ⁴ (8.6%)
College and above	2 (1.94%)	4.20×10 ⁴ (3.5%)
Average area of land (m ²)	1446.67	1360.00
Per capita income (RMB yuan)	14553.20	15121.94
Per capita consumption expenditures (RMB yuan)	7502.44	9798.28
Per capita education expenditures (RMB yuan)	2216.57	1014.12
Per capita medical expenditures (RMB yuan)	1427.54	1257

[#] Data on characteristics of residents were collected from the China Rural Poverty Monitoring Report in 2019 and the Hebei Rural Statistical Yearbook in 2018, including all rural residents in Laiyuan County, Laishui County and Yi County. Among them, the mean household labor availability in the watershed is calculated according to the total number of household members and the dependency ratio.

4.2 Different groups of households in the watershed

The clustering results showed that the sampled households can be divided into three groups: poverty-stricken (Type I) households, average (Type II) households and better-off (Type III) households (Table 4). Among them, the heads of poverty-stricken households were mainly unemployed and farmers (82.9%) who claimed that they were barely affected by tourist attractions and had the lowest total expenditures. The average per capita income of the poverty-stricken households was 3696.2 RMB yuan (equivalent to 535 US dollars at the exchange rate of 6.899 in 2019), which was below China's rural poverty line of 3747 RMB yuan (US\$543) in 2019. The heads of average households were mainly farmers and wage laborer (61.7%) who claimed that they were moderately affected by tourist attractions. The per capita income of the average households was 8279.3 RMB yuan (US\$1,200), which exceeded the 2019 rural poverty line.

The heads of better-off households were mainly businessmen and farmers (94.2%) who claimed that they were greatly affected by tourist attractions. The total expenditure and the proportion of non-agricultural income in better-off households were substantially higher than the amounts in the other two groups of households. The per capita income of the better-off households was 30,867.2 RMB yuan (US\$4,474).

Table 4 Characteristics of the three groups of households clustered

Variable	Type I Poverty-stricken household (35, 34%)	Type II Average household (34, 33%)	Type III Better-off household (34, 33%)
Occupation of household head	Unemployment (48.6%); Farmer (34.3%)	Farmer (44.1%) Wage laborer (17.6%) Businessman (14.7%)	Businessman (82.4%) Farmer (11.8%)
Whether the tourist attractions affect the lives of residents	Strongly influential (5.7%) Somewhat influential (14.3%) No influence (80.0%)	Strongly influential (0.0%) Somewhat influential (32.4%) No influence (67.6%)	Strongly influential (64.7%) Somewhat influential (35.3%) No influence (0.0%)
Proportion of non-agricultural income [#]	0.76	0.62	0.98
Total expenditures (yuan)	13605.71	22582.35	49323.53

[#] This income includes annual living allowances, government subsidies and land transfer payments for households.

The three groups of households exhibited clear differences in ES, demographic, and socioeconomic characteristics (Figure 2). In terms of ES, regulating services and cultural services increased sequentially from Type I to Type III households, while provisioning services were the highest in the Type II households and the lowest in the Type III households (Figure 2a). Although both the Type I and Type II households were dominated by farmers, Type II households had higher income from provisioning services. In terms of household demographic, the labor availability and proportion of employed individuals in a household increased sequentially from the Type I to Type III households, while the age of household head declined (Figure 2b). The Type I households had the lowest level of education, and the Type II households had a similar level of education to that of the Type III households. In terms of locational context, the Type II and

Type III households were closer to the town center than the Type I households, which was conducive to activities other than farming (Figure 2b). In terms of economic characteristics, total expenditures, education expenditures and operating expenditures increased sequentially from the Type I to Type III households, whereas medical expenditures were reversed (Figure 2c). It can be seen from the absolute amounts and proportions of medical expenditures that there was a certain proportion of households in poverty due to diseases. In addition, the land area increased sequentially from the Type I to Type III households. Among them, because the management of cropland and forestland asks for a certain amount of household labor, the poor households who did not have enough labor often chose to transfer or rent the land at a low price. The proportion of households with loans was the highest for the Type III households and lowest for the Type II households (Figure 2d).

4.3 Results of the multinomial logit model

4.3.1 Factors affecting households out of poverty

In terms of ES, natural disasters had a significant negative impact on the transition from Type I (poverty-stricken) households to Type II (average) households, which was significant at the 0.1 level (Table 5, Appendix 2). The regression coefficient for the impact of natural disasters on household type was -3.37, and the relative risk ratio was 0.03. It indicated that the probability of the households who were not affected by disasters falling into poverty was approximately 0.03 times that of households affected by disasters. In the survey, we also found that threats from wildlife (such as wild boar damaging crops), summer hail and landslides commonly occurred in this watershed. However, local poor households had very limited means to cope with these disasters. In addition, the decrease in stream water in summer also had a negative impact on available domestic and irrigation water, which could exacerbate water scarcity and affect agricultural income for poor households in the watershed (Sandhu et al., 2014).

For household demographic features, the labor availability and the highest level of education significantly affected poverty alleviation (Table 5). Among them, the increase in labor availability had a significant negative impact on poverty alleviation for Type I households ($p < 0.1$), and the probability of falling into poverty for households with more labor availability increased approximately 70 times compared to households with less labor availability. In the interview, we also found that the effective labor force in Type I households decreased severely, and most of the labor force in these households worked in nearby cities. The remaining labor force were mainly "old or sick" and usually lacked the ability to work. In addition, increasing the education level had a significant positive effect on poverty alleviation ($p < 0.01$). Specifically, it would be the most difficult to get out of poverty when the household's highest education was primary school or below (see Appendix 2).

For economic characteristics, total expenditures, medical expenditures and education expenditures had a significant association with poverty alleviation ($p < 0.01$). An increase in total expenditures had a significant positive effect on poverty alleviation. By contrast, increasing medical and educational expenditures had a significant negative association with poverty alleviation. Among them, the probability of falling into poverty for households with higher medical expenditures increased by 1.5 times compared

to households with lower medical expenditures. We also found that the lack of medical resources in rural areas made it difficult for the elderly to get medical treatment in the context of an aging rural population. According to the statistical records, approximately 70% of the rural population in Hebei Province had only 20% of total medical resources in 2015, and it was common for the rural elderly to suffer from poverty due to extensive medical expenditures (Duan et al., 2018). Having a loan had a significant negative impact on the transition of households from type I to type II ($p<0.05$), and the probability of falling into poverty for households with loans was 5.5 times that of those without loans (see Appendix 2).

For locational context features, the increase in travel time to the local town center and the frequency of going to market fairs had a significant negative association with the transition from Type I households to Type II households ($p<0.05$). Among them, the probability of falling into poverty for households living far away from the local town center was 33.4 times higher than those who live close to the local town center. The probability of households with a high frequency of going to market fairs also had a higher chance (10.6 times) of falling into poverty than those with low frequency of going to market fairs.

Table 5 Factors influencing different types of households in Baiyangdian watershed

Variable	Between type II and type I		Between type II and type III	
	Coefficient	Relative risk ratio (RRR)	Coefficient	Relative risk ratio (RRR)
<i>Ecosystem services</i>				
Provisioning services	0.1067 (0.1465)	1.1126	0.0093 (0.2373)	1.0094
Regulating services	2.4017 ⁺ (1.8559)	0.034 [#]	2.5117 (2.8144)	0.011 [#]
Cultural services	-0.1077 (0.1400)	0.8979	0.6937 ^{**} (0.2267)	2.0012
<i>Demographic</i>				
Household labor availability	4.2631 ⁺ (2.4905)	71.0290	6.6163 [*] (3.1033)	747.1881
Proportion of employed individuals	1.3570 (2.3258)	3.8843	8.1812 [*] (4.0813)	3573.097
Age of household head	-0.2769 (3.8662)	0.7581	10.4792 ⁺ (5.6923)	0.00003
The highest education level in the household	-9.5653 ^{**} (3.3385)	–	5.0817 (4.7894)	–
<i>Economic</i>				
Area of land	-0.9698 (1.3105)	0.3792	0.5660 (1.1750)	1.7612
Medical expenditures	0.9190 ^{**} (0.2983)	2.5067	0.5699 [*] (0.2617)	1.7682
Operating expenditures	2.6597 (183.8198)	14.2926	1.8777 (183.8196)	6.5384
Education expenditures	0.7525 ^{**} (0.2825)	2.1223	0.1299 (0.2074)	1.1387

Total expenditures	-3.7638** (1.3313)	0.0232	0.3038 (1.1711)	1.3550
Loans	5.6963* (2.4943)	6.503 [#]	2.6729 (2.2310)	0.053 [#]
Proportion of durable goods	-24.4776+ (14.5145)	2.34×10 ⁻¹¹	-2.7843 (12.2632)	0.0618
<i>Locational context</i>				
Travel time to local town center	3.5380* (1.5824)	34.3973	0.0412 (1.3743)	1.0420
Frequency of going to market fairs	2.4516* (1.1128)	11.6074	0.1412 (1.1231)	1.1517

Note: **, *, + denote the statistical significance levels of 0.01, 0.05 and 0.1 respectively; Values in the brackets represent the robust standard error. Likelihood ratio test for model significance, $\chi^2(32) = 158.77$ $Prob > \chi^2 = 0$.

[#]The values of the relative risk ratio were calculated as a categorical variable, see Appendix 2 for details.

4.3.2 Factors affecting households becoming better-off

In terms of ESs, an increase in cultural services had a significant positive effect on households moving to the better-off group, which was significant at the 0.01 level (Table 5). The regression coefficient of the impact of cultural services on household type was 0.69, and the relative risk ratio was 2.00. In other words, compared to households with low monetary benefits from cultural services, households with high monetary benefits from cultural services were twice as likely to be Type III households. For poor local households, tourism is a cultural service that can increase their income and help them meet their basic material needs (Daw et al., 2011). For example, we found in interviews that gains from tourism not only predicted an increase in monetary income but also potentially provide employment opportunities, reduced environmental impacts (e.g., logging) and improved infrastructure.

For the demographic characteristics, an increase in labor availability and the proportion of employed individuals had a significant positive effect on the transition of households to the better-off group ($p < 0.05$). For households with more labor availability and a higher proportion of employed individuals, the probability of further improvement in their well-being was greatly increased. Conversely, the higher the age of the household head, the less likely it was for a household to change from Type II to Type III ($p < 0.1$). In terms of household economic characteristics, an increase in medical expenditures had a significant

positive effect on the transition of households from Type II to Type III ($p < 0.05$). Unlike the increase in medical expenditures that was not conducive to poverty alleviation of Type I households, the probability of further improvement in well-being for Type II households with high medical expenditures increased by 0.77 times. In addition, all the variables for locational context characteristics had no significant effect on the transition of households from Type II to Type III and were not significant ($p > 0.1$).

5. Discussion

5.1 Unique linkages between ES and poverty alleviation in urbanizing watersheds

Current research on ES and poverty mainly focus on provisioning services and their impacts on two dimensions of poverty: income/assets, and food/nutrition (Fisher et al., 2013). Although these studies have provided increasing evidence that ES contributes to human well-being, and poor people with a single source of livelihood and strongly dependent on ES, the differences in socioeconomic background at the household level, and their complex interactions with ES that contribute to poverty alleviation, have not been fully understood, especially for households in poverty (Suich et al., 2015). In fact, the household characteristics (such as the number in the labor force, the financial status, and the household composition) could affect households' ability to convert the potential supply of ES to realized ES. On the one hand, such nuanced linkages between ES and poverty alleviation cannot be obtained by regional analysis without considering household heterogeneity. On the other hand, identifying the linkage at the household level is important for formulating targeted policies to achieve poverty alleviation and regional sustainable development.

For the linkage between the provisioning services and poverty alleviation, we found a unique linkage, which is different from previous findings conducted in areas with few human activities (e.g., protected areas and remote areas). The previous studies believed that provisioning services are conducive to reducing poverty and improving the well-being of the poor (Sandhu et al., 2014; Zheng et al., 2019). However, we found that in the urbanizing Baiyangdian watershed, provisioning services did not have significant effects on reducing poverty for poor households. An alternative explanation is that provisioning services can only help poor households maintain their livelihoods or prevent them from sliding further into poverty (Barrett et al. 2011). In other words, provisioning services were conducive for reducing the vulnerability of poor households to disturbances rather than reducing poverty (Daw et al., 2011). In urbanizing watersheds, the monetary benefits from provisioning services were usually driven by markets (Schreckenberg et al., 2018), and poor households usually do not possess the ability to use provisioning services as a way out of poverty. These households neither possess the endowments to conduct alternative non-agricultural livelihood in urbanizing region. Instead, these households in poverty can only use provisioning services to maintain their original consumption levels (WRI, 2005). Such findings also support that the complex nexus of landscape pattern-ecosystem service-human well-being should be explored in a specific environmental and socioeconomic context (Forman 2008; Liao et al., 2020; Wu 2021).

Second, we found that in urbanizing watersheds, the decline in one regulating service (natural disaster prevention) had a significant negative impact on poverty alleviation ($p<0.1$), and the probability of falling into poverty for households affected by natural disasters were approximately 32 times higher than those not affected by natural disasters. Unlike the direct linkage between provisioning services and income/nutrition for human well-being, regulating services (such as filtering clean water, controlling disease, and regulating floods) rely on a series of complex biophysical processes and their interactions with human influence (Fisher et al., 2013). Unprecedented human activities in urbanizing areas can seriously threaten the livelihoods and safety of poor people who were highly dependent on ES, especially in the context of increasingly frequent extreme climate events and concomitant natural disasters. Rural households with diversified livelihood choices (e.g., alternative income from working in urban areas) can use alternative livelihood strategies to mitigate the impact of the decline in regulating services on their well-beings (Liebenow et al., 2012). However, poor and marginalized households usually could not find alternative livelihood strategies when natural disaster strikes and would suffer from declining regulating services. Therefore, ensuring sufficient supply of regulating services is particularly important for poverty-stricken households who fail to meet the basic needs of life.

In terms of cultural services, we found that poverty-stricken households can hardly rely on them to get out of poverty. Nevertheless, the increase in cultural services was conducive to further improving the well-being of households who are above the poverty line. Our results showed that the probability of further improving the well-being of households with high cultural services was twice those with low cultural services. Since the Baiyangdian watershed has various natural landscapes and is adjacent to Beijing, the local government already formed some tourism-based poverty alleviation projects in the watershed (National Development and Reform Commission, 2012). For example, Laishui County has implemented tourism-based poverty alleviation projects in nearly 30 villages around the Yesanpo Mountain. Although these projects have had an overall impact on poverty alleviation at the watershed scale, it is worth noting that some poor households identified by the local government failed to benefit from these policies as they did not possess the financial and demographic advantages to realize the ES. For example, promoting rural tourism or selling local specialties requires the household to invest in assets and labor at an early stage, but poor households usually live far from local markets and their low level of education would lead to a less competitive position propagating and selling goods compared to affluent households.

Table 6 Comparison of the relationship between ecosystem services and poverty alleviation in the studied urbanizing watershed and previous studies

Ecosystem services	Previous findings on the relationship between ecosystem services and the poor	Previous findings on the effect of ecosystem services on poverty alleviation	Findings in the urbanizing watershed of this study
Provisioning services	The supply of natural products is important in helping poor rural households meet their cash needs (Fisher, 2004).	1) The supply of natural products can improve the livelihoods and incomes of the poor and prevent them from falling into poverty (Scherr et al., 2004). 2) Provisioning services had little effect on reducing poverty, and reliance on provisioning services has reduced the possibility of asset accumulation and livelihood diversification, forming a "poverty trap" (Barrett et al., 2011).	Provisioning services did not have a significant effect on poverty alleviation. The lack of human, economic and social capital in poverty-stricken households prevented them from using provisioning services as a means to increase income and get out of poverty (e.g., poverty-stricken households have the least land area among the three types of households).
Regulating services	The poor suffer more from the degradation in regulating services and are more vulnerable to natural disasters than others (MA, 2005; TEEB, 2010).	Rural households have high exposure and sensitivity to natural disasters, and the resilience of the poor is highly dependent on regulating services (Adger et al., 2005).	Guaranteeing and improving regulating services have promoted poverty alleviation. Poverty-stricken households lack the capacity to mitigate the negative impact of the declines in regulating services through alternative livelihood strategies (e.g., poverty-stricken households lack irrigation or drainage facilities and were unable to reduce their property losses when facing drought and flood).
Cultural services	Agricultural and forest landscapes can be a sanctuary for biological and cultural diversity for poor people (Barthel et al., 2013).	The privatization of public resources deprives the poor's access to ecosystem cultural services (WRI, 2005). Ignoring the differences in the impact of cultural services on different households may further fuel poverty (Lade et al., 2017).	Cultural services did not show a significant effect on poverty alleviation but can improve the well-being of better-off households. The inability of households to benefit from cultural services is related to the lack of human, economic and social capital (e.g., inadequate manpower and savings, too far from the local town center), and these households lost investment opportunities and locational advantages.

5.2 Policy implications

Considering inequity of household characteristics and their impacts on poverty alleviation in the decision-making process can help policymakers form place-based and context-specific solutions (Wu 2021) to avoid unintended consequences and further marginalization of poor households. Since 2000, a series of policies, such as the Natural Forest Conservation Program (NFCP), Grain-for-Green Program (GFGP) and tourism development, have brought increasing non-agricultural income to households in relatively poor areas of urbanizing watersheds. However, the total amount of income varies greatly at the household level. It is imperative to adjust policies based on increasing understandings on linkages between ES and poverty alleviation.

First, incorporating differences among households into policy-making and forming policies favorable for households in poverty is important for promoting sustainable development (Walelign, 2015). In a typical urbanizing watershed with rich tourism resources, the unequal distribution of the benefits of ecosystem cultural services between poor and better-off households may further increase their socioeconomic gaps through tourism-based poverty alleviation policies. While retaining the development of tourism could increase the regional economy and employment in the watershed, the differences in benefits to various local households should also be considered. For example, providing favorable policies for households just above the poverty line could help them overcome their limitations in labor availability, economic status, and social status to participate in tourism and promote environmental justice in watershed development. Specifically, favorable policies should be designed to encourage them to relocate closer to tourist facilities and provide free training or microcredit to increase their involvement in tourism.

Second, more attention should be paid to regulating services to understand the linkages between ESs and poverty alleviation in urbanizing watersheds. Our study found that reducing the impacts of natural disasters is beneficial for poverty-stricken households and reducing poverty in urbanizing watersheds. Therefore, targeted policies such as agricultural insurance and agricultural credit for poverty-stricken households can be adopted to improve their ability to resist natural disasters (e.g., droughts, floods and pests) (Eakin et al., 2016; Zhang et al., 2020). In addition, preferential policies can be designed for households just above the poverty line to encourage them to diversify livelihoods and smooth household income that is likely to be affected by agricultural seasonality and natural disasters. Through strategies such as risk aversion and risk sharing, various types of households can improve their ability to cope with disasters and reduce the risk of returning to poverty.

5.3 Future prospects

In the context of landscape sustainability science, this paper adopted a multinomial logit model to investigate the roles of multiple ESs in poverty alleviation among different groups of households in urbanizing watersheds. The results would be beneficial for targeted policies to reduce poverty, but this study still has some limitations. First, we were not able to collect the realized benefits of some ecosystem services that were also important for local environmental condition (such as water and air pollution), because local residents cannot report them as a momentary unit. Therefore, some nonmaterial or nonmarket benefits derived from certain ESs should be included in the future. Second, we only considered

the impact of natural disasters as a proxy for regulating services. Other regulating service indicators (e.g., soil erosion, water quality regulation, and carbon storage) that are difficult to quantify and differentiate via questionnaire were not included in the analysis. Therefore, the established linkages between regulating service and poverty alleviation may not be comparable to other studies using alternative proxies for regulating services.

In the future, our research can be improved in the following ways. For example, mixed methods can be used to qualitatively and quantitatively evaluate the material and nonmaterial values of ESs. In addition, high-resolution remote sensing data can be used to quantify a range of ES indicators at the household level, which is helpful for linking the relationship between various ESs and poverty alleviation at the fine spatial scale (Watmough et al., 2019).

6. Conclusions

Unique linkages between ESs and poverty alleviation can be found in rapidly urbanizing watersheds. The case study in the Baiyangdian watershed found that provisioning services and cultural services did not have a significant effect on poverty alleviation for rural households, while the decline in one regulating service (natural disaster prevention) had a significant negative impact on poverty alleviation. Households affected by natural disasters were approximately 32 times more likely to fall into poverty than those not affected.

Differences in household endowments can largely explain the divergent linkage between ESs and poverty alleviation in urbanizing watersheds. As the poor households were disadvantaged in terms of labor availability and socioeconomic status, most of them cannot rely on income from provisioning services and cultural services to reduce poverty but only to maintain their basic living needs. In contrast, the better-off households had additional labor forces and financial support to transfer cultural services to their incomes. The probability of further improving their well-being was approximately twice that of average households.

Our findings suggest that differences in household characteristics and the varying roles of ESs in poverty alleviation among different types of households should be considered when formulating targeted poverty alleviation policies. On the one hand, it is imperative to reduce the losses suffered by poverty-stricken households from declines in regulating services, and improving their resilience to natural disaster shocks through agricultural insurance can reduce their risk of returning to poverty. On the other hand, preferential policies toward poverty households should be designed when allocating the benefits of cultural services.

Declarations

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Authors' contributions: YD and QH conceived the study, designed the framework, and wrote the paper. CH, XH, CL, LI, LZ and YB reviewed and edited the manuscript.

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Figures

Figure 1

The study area (the selected six counties for surveys was marked)

Figure 2

The characteristic of the three types of households. (a) ecosystem services; (b) demographic and locational features; (c) expenditure status; (d) non-expenditure status.

Supplementary Files

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