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 impacts of ecosystem services on poverty alleviation on multiple scales in such region.

Objectives This paper investigates whether ecosystem services at the landscape level and household characteristics play important roles 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, nonparametric tests, and multinomial logit models.

Results The results suggested that differences in household-level endowments had significant impacts on poverty alleviation. In terms of ecosystem services, regional (village-level) food supply were significantly associated with poverty alleviation ($p < 0.1$); while household-level benefits from cultural services had a significant positive effect ($p < 0.01$) on households moving to the better-off group.

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Conclusions Differentiating the roles of ecosystem services on poverty alleviation between landscape level and household level is important for policy making. In urbanizing watersheds, offering ecological compensations, and providing trainings and financial supports for rural poor people should be adopted to help them get out of poverty.

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 cultural identity of poor people has been discussed, and a decline in natural habitats was associated with a deprivation of cultural services and possibility to express spiritual values of these services (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 forming 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 (Barrett et al. 2011; Daw et al. 2011; Sandhu et al. 2014; Zheng et al. 2019), 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 capitals 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 rural land (e.g., forest land, grassland, wetland) 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; Ye et al., 2020). 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 landscape, 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 Common International Classification for Ecosystem Services (CICES, Haines-Young and Potschin-Young, 2018) or the Millennium Ecosystem Assessment (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 paper 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 ES mapping, surveys and interviews. Then, we divided the sampled households into three groups based on their incomes. 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 strategies for achieving the broader poverty alleviation goal.

Study area and data

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. Fall is pleasant but short. The average annual water in the watershed is 3.12 billion m^3, and the per capita water is only 297m^3, which is far below the internationally recognized extreme water shortage line, i.e., 500 m^3 per capita (Baiyang et al. 2013). The total area of the watershed
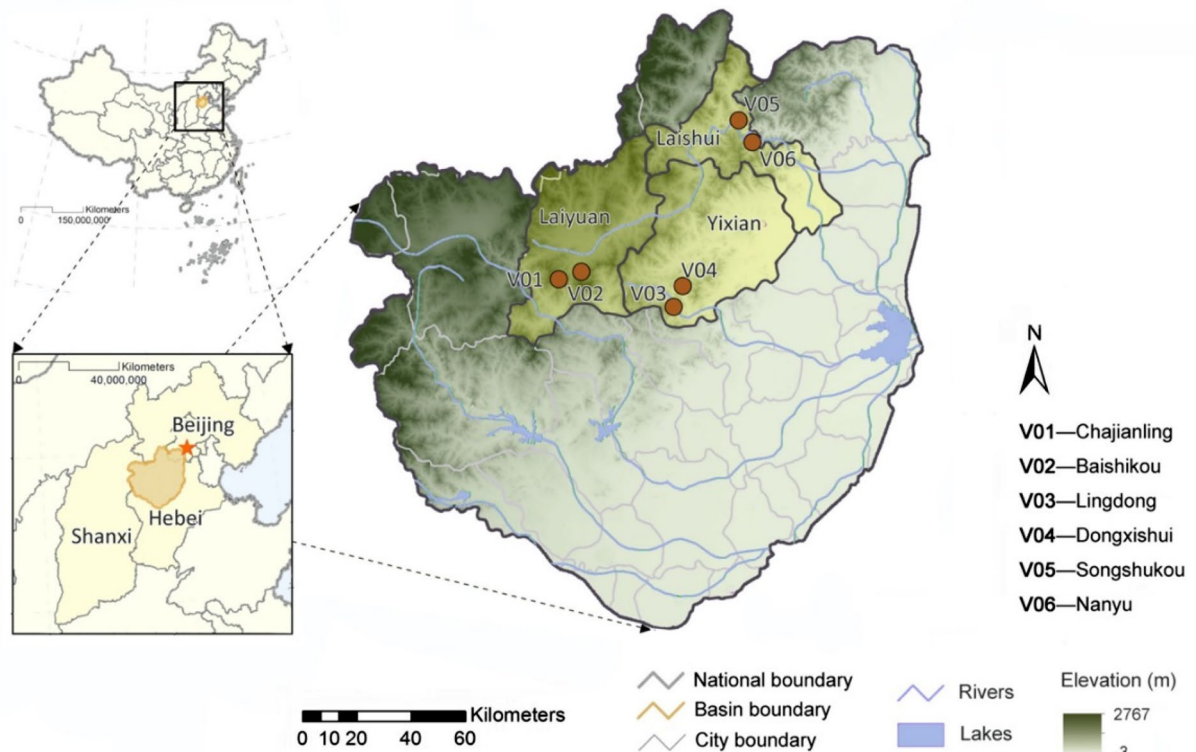
Fig. 1 The study area (the selected six counties for surveys was marked)

is approximately 31,200 km², and the elevation is high in the west and low in the east, forming mountains, plains and waterlogs (Fig. 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 3,941 US dollars at an exchange rate of 6.6899), 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 conservation (Frazier et al. 2019).

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.

Methods

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).

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. We used both regional ESs (see Sect. 3.3) and household-level ESs to represent natural characteristics. In the questionnaire, we collected three household-level ESs, i.e., 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). The three benefits from ESs were selected following three criteria. First, the selected ESs can be represented by monetary terms because our pre-survey found local poor people with low-level education have difficulty in expressing the non-financial benefits of ESs quantitatively. Second, the selected ESs can represent multiple categories of ESs, including provisioning, regulating and cultural services. Third, the sleeted ESs were found to be important drivers of local residents' wellbeing (Huang 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 km 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 (Appendix Table S6-S7). 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.

Classifying household type

To understand the differentiating roles of ES in poverty alleviation among rural households in the watershed, we classified the sampled households into three types. We divided the households into three types (i.e., households in poverty, household prone to fall into poverty, and better-off households) instead of two types (households in or out of poverty) because previous studies found that some rural households may fall back to poverty and need ecosystem service functioning as a safety net to prevent the poverty trap (TEEB, 2010; Stringer et al. 2012; Marshall et al. 2018).

The main criterion for the classification was household-level annual net income because income was the most commonly used indicator for measuring absolute poverty (United Nations, 2015). Type I households (referred as poverty-stricken households in this study) are registered poor households. China has created a national registration system (i.e., National Poverty Alleviation Information System of China) since 2014 (Liu et al. 2017). The registered poor households live under national poverty line (annual net income of 3747 RMB in 2019, or approximately 543 USD at the exchange rate of 6.899), and illness and chronic/serious diseases are the main reason for them living becoming impoverished (Liu and Idris, 2019). We collected 35 Type I households during the field trip. Type II households (referred as below-average households) are rural households with annual net income below the average value at the county scale (i.e., 9334 RMB or 1353 USD for Laishui County, 6863 RMB or 995 USD for Laiyuan County, and 8358 RMB or 1211 USD for Yi County in 2018). We collected 36 Type II households during the survey. Type III household (referred as better-off household) has an annual net income above its county's average income. There were 32 households belonging to this type.

To test whether the three types of households were statistically different, we further conducted non-parametric tests to compare the differences in the three types of households for their characteristics. Because most variables for these households neither fit the normal distribution, nor show heterogeneity of variance (Appendix Table S1), we used the non-parametric tests. To be specific, we used the Mann–Whitney U test to compare the household differences between a pair of household types (e.g., Type I households versus Type II households), and the Kurskal-Wallis H test to compare the differences among the three types of households.

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 and mutually exclusive, we tested whether the ordered logit model or the MNL should be used in this study. The test of parallel lines showed that the ordered logit model did not meet the proportional odds assumption (Appendix

Table S2), and therefore, we used 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).

For independent variables, we considered regional ESs (seven variables) and household-level characteristics (16 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. In terms of regional ESs, we calculated seven services at the village scale as previous studies found they were essential for this region's sustainability (Bai et al. 2013a, b; Meng et al. 2020). The seven services included two provisioning services, i.e., food supply (Xie et al. 2014), freshwater supply (Redhead et al. 2016), two regulating service, i.e., carbon storage (Sharp et al. 2015), water retention (Yang et al. 2015), one supporting service, i.e., habitat quality (Sharp et al. 2015), and two cultural services, i.e., recreational service (Meng et al. 2020) and aesthetic service (Nahuelhual et al. 2013). The methods and maps of the seven services are provided in the supplementary file (Appendix Table S3, Figure S1). Since quantifying most of these regional ESs used the land cover map as input, these regional ESs can reflect landscape pattern to some extent. For example, a high food supply value at the regional (village) scale suggests a cropland dominant landscape. In terms of household-level characteristics, we included three ES benefits,

four demographic features, seven economic variables, and two locational factors (Table 1). For the three household-level ES benefits, only monetary benefit from provisioning service (e.g. growing crops) was related to household-level landscape pattern. The two remaining benefits (i.e., the monetary loss from natural disaster and monetary benefit from participating tourism-related work) were not related to household-level landscape pattern.

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 among the pairs of independent variables could reach up to 0.99 (Appendix Table S4), the tolerance of five variables (carbon storage, water retention, habitat quality, recreational service and aesthetic service) were below 0.1. According to the above results, the five variables were excluded for multicollinearity. After the multicollinearity test, we conducted the likelihood ratio test to examine whether the remaining independent variables were associated with the dependent variable (household type). Only seven variables (i.e., regional food supply, household-level cultural service, the highest education level, medical expenditure portion, educational expenditure portion, loan, and travel time to local town center) passed the test and were included in the MNL analysis (Appendix Table S5). SPSS 20.0 and Stata13.0 were used for measurement and statistical analysis.

Results

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 2). 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

Table 1 Variables used for the multinomial logit model (N = 103)

Type	Variable	Description	Mean	Standard deviation	Min	Max
Regional ecosystem service[a]	Food supply	Food provided by cropland, grassland and water area together	0.64	0.07	0.73	0.56
	Freshwater supply	Precipitation minus water retention by vegetation and soil	0.61	0.02	0.65	0.58
	Carbon storage	Carbon stored in aboveground and belowground vegetation, as well as in soil and organic litter	0.68	0.05	0.72	0.61
	Water retention	Water intercepted by different land use types by precipitation and soil infiltration	0.29	0.06	0.37	0.23
	Habitat quality	Ability of ecosystem to provide habitats for various species	0.58	0.02	0.61	0.56
	Recreational service	Kernel density of the points of interests including parks, green spaces, and playgrounds	0.02	0.00	0.02	0.01
	Aesthetic service	Road accessibility to points of interests including parks, green spaces, and playgrounds	0.29	0.16	0.41	0.08
Household-level ecosystem service	Provisioning services	Income from growing crops or cash crops in the past year (RMB yuan)	1149.81	2526.92	0.00	15,000.00
	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)	24,182.04	57,866.89	0.00	400,000.00

Table 1 (continued)

Type	Variable	Description	Mean	Standard deviation	Min	Max
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; college and above = 5)	3.43	1.30	1.00	5.00
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	20,000.00
	Medical expenditure portion	Proportion of medical expenditures to total expenditures in the past year	0.45	0.44	0.00	1.00
	Operating expenditure portion	Proportion of operating expenditures to total expenditures in the past year	0.42	0.46	0.00	0.99
	Education expenditure portion	Proportion of educational expenditures to total expenditures in the past year	0.08	0.27	0.00	1.00
	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 of 12 assets from list (see Appendix Table S6, %)	0.17	0.37	0.00	1.00

Table 1 (continued)

Type	Variable	Description	Mean	Standard deviation	Min	Max
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

[a]Regional ecosystem services are normalized by the maximum and minimum values of this basin, therefore, the values are between 0 and 1 and unitless

Table 2 Characteristics of the respondents and residents in the watershed

Type	Characteristics of respondents Number (proportion)	Characteristics of residents[a] Number (proportion)
Mean household labor availability	2.88	2.72
Mean proportion of employed individuals	52.6%	53.4%
The education level of the household		
Uneducated	15 (14.6%)	9.36×10^4 (7.8%)
Primary school	37 (35.9%)	42.35×10^4 (35.3%)
Junior high school	34 (33.0%)	53.74×10^4 (44.8%)
Senior high school	15 (14.6%)	10.32×10^4 (8.6%)
College and above	2 (1.9%)	4.20×10^4 (3.5%)
Average area of land (m²)	1446.67	1360.00
Per capita income (RMB yuan)	14,553.20	15,121.94
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

[a]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

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.

Different groups of households in the watershed

The three groups of households exhibited clear differences in household-level ES, demographic, and socioeconomic characteristics (Fig. 2). In terms of

household ES, provisioning services and cultural services increased sequentially from Type I to Type III households, while regulating services were the highest in the Type II households and the lowest in the Type III households (Fig. 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 (Fig. 2b). The Type I households had the lowest level of education, and the Type II households had a slight lower
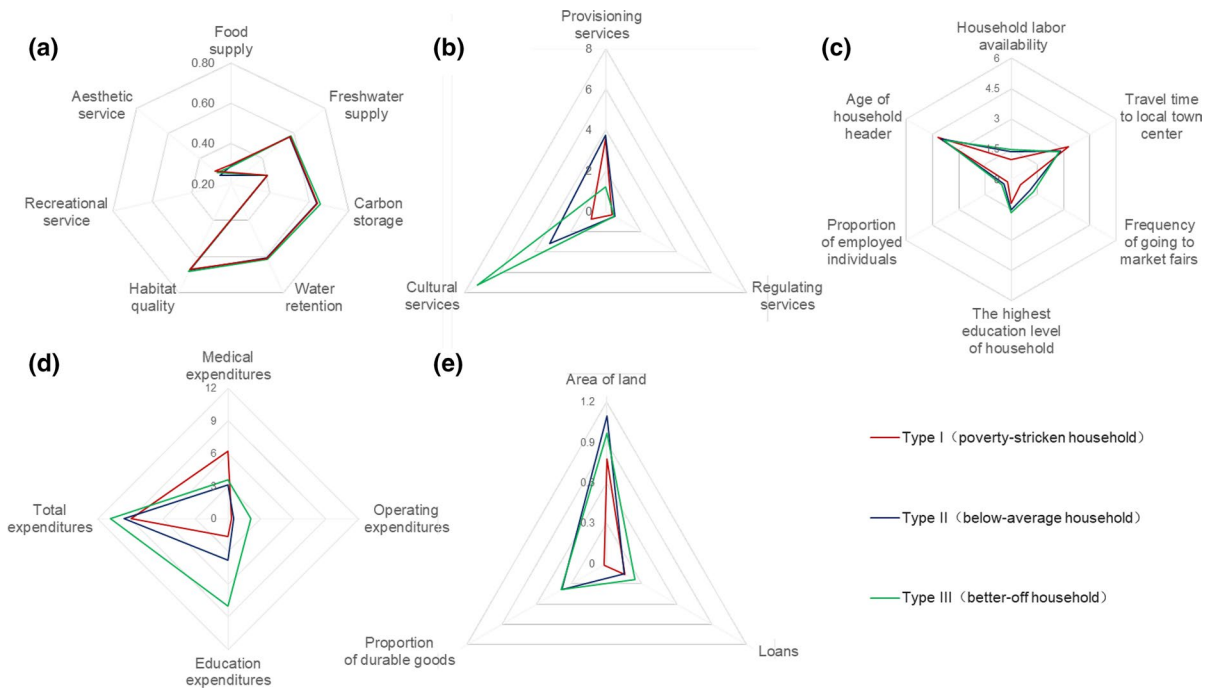
Fig. 2 The characteristic of the three types of households. **a** Ecosystem services; **b** demographic and locational features; **c** expenditure status; (d) non-expenditure status

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 (Fig. 2b). In terms of economic characteristics, total expenditures, education expenditures and operating expenditures increased sequentially from the Type I to Type III households, whereas Type III households' medical expenditures were highest (Fig. 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, Type I households had the least amount of land area. Among the three types of households, 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 (Fig. 2d).

The Mann–Whitney U and the Kruskal–Wallis H tests confirmed that the differences among the three sampled households (Type I: poverty-stricken households; Type II: below-average households; and Type III: better-off households) were statistically significant. The differences for household-level cultural services, demographic features, and total expenditures are statistically significant between each pair of household types, as well as the three types of households (Table 3). It indicates that it is appropriate to divide the sampled households into these three groups and explore the varying roles of ESs on poverty alleviations among the three groups of households.

Among them, the heads of poverty-stricken households were mainly unemployed and farmers (82.9% of households) 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 RMB yuan (equivalent to 535 USD), which was below China's rural poverty line of 3747 RMB yuan in 2019. The heads of below-average households were mainly farmers and wage laborer (52.8%) who claimed that they were moderately affected by tourist attractions. The per capita income of the below-average households was 9327.8 RMB yuan (US$1,352), which exceeded the 2019 rural poverty line. The heads of

Table 3 Difference tests for the characteristics of the three types of households

Variables		Type I vs. Type II	Type I vs. Type III	Type II vs. Type III	Type I vs. Type II vs. Type III
Household-level ecosystem services	Provisioning services	0.617	0.006**	0.006**	0.010*
	Regulating services	0.041*	0.152	0.569	0.102
	Cultural services	0.022*	0.000**	0.001**	0.000**
Demographic	Household labor availability	0.000**	0.000**	0.232	0.000**
	Proportion of employed individuals	0.003**	0.000**	0.028*	0.000**
	Age of household head	0.006**	0.000**	0.008**	0.000**
	The highest education level in the household	0.000**	0.000**	0.041*	0.000**
Economic	Area of land	0.059	0.083	0.506	0.101
	Medical expenditure portion	0.007**	0.008**	0.932	0.006**
	Operating expenditure portion	0.553	0.030*	0.079	0.040*
	Education expenditure portion	0.015*	0.000**	0.012*	0.000**
	Loans	0.949	0.300	0.268	0.452
Locational context	Proportion of durable goods	0.002**	0.001**	0.777	0.001**
	Travel time to local town center	0.009**	0.004**	0.382	0.006**

The Mann–Whitney U test was conducted for each pair of household types; and the Kruskal–Wallis H test was conducted among the three household types. * and ** denote the significance level at 0.05 and 0.01, respectively

better-off households were mainly businessmen and farmers (90.7%) 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 31,099.4 RMB yuan (US$4,508).

Results of the multinomial logit model

Factors associated with households out of poverty

In terms of ES, only one regional ecosystem service, food supply had a significant positive impact on the transition from Type I (poverty-stricken) households to Type II (below-average) households, which was significant at the 0.1 level (Table 4). The regression coefficient for the impact of food supply on household type was 14.19, and the relative risk ratio was larger than 1. It indicated that the probability of the households who live in a village with a higher level of food supply falling into poverty was substantially greater that of households living in other counties. In the survey, we also found that households living in counties

which highly depend on primary industry (i.e., agricultural products) for income expressed their frustrations in increasing their income by selling agricultural products. This is also in line with previous findings in China that rural households were prone to fall into poverty if they strongly relied on agricultural income and lacked off-farm income for livelihood diversification (Démurger et al. 2010; Liu and Lan, 2015). For household-level ES, we did not find the selected three ESs were associated with household out of poverty.

For household demographic features, the education level significantly affected poverty alleviation (Table 4). Among the five education levels, we found that it would be the most difficult to get out of poverty when the household's highest education was primary school or below. The relative risk ratio for a household with an education level of primary school or below was more than 37 times greater than that for a household with an education level of junior high middle school and above. These households with a low education level do not possess the ability to engage in jobs which require professional knowledge and techniques, and have limited means to increase their incomes.

Table 4 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)
Ecosystem services				
Food supply (regional)	14.193[+] (7.344)	1,459,279.489	− 3.627 (5.790)	0.027
Cultural services (household-level)	− 0.110 (0.106)	0.896	0.189** (0.065)	1.208
Demographic				
The highest education level in the household	_	_	_	_
Uneducated	4.210** (1.563)	67.332	_	_
Primary school	3.636** (1.288)	37.933	− 17.215 (7626.348)	_
Junior high school	1.629 (1.148)	5.098	− 0.806 (0.767)	0.446
Senior high school	− 0.930 (1.165)	0.395	− 0.226 (0.744)	0.798
College and above	_	_	_	_
Economic				
Medical expenditure portion	1.933* (0.903)	6.910	1.594[+] (0.871)	4.921
Educational expenditure portion	0.514 (1.065)	1.671	2.227** (0.832)	9.269
Loans	_	_	_	_
No loans	− 2.076* (0.944)	0.125	− 0.425 (0.676)	0.654
Having loans	_	_	_	_
Locational context				
Travel time to local town center	1.789* (0.792)	5984	− 0.146 (0.474)	0.864

**, *, [+] 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, $\chi^2(20)$ 97.015, $P > \chi^2 = 0.0000$

For economic characteristics, an increase in proportion of medical expenditure to total expenditures was positively related to remaining in poverty ($p < 0.05$). In addition, not 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 without loans was only 0.13 times that of those with loans. In other words, poor households having chronic diseases and a loan were harder to get out of poverty than those without loans. For locational context features, the increase in travel time to the local town center had a significant positive association with falling into poverty ($p < 0.05$).

Among them, the probability of falling into poverty for households living far away from the local town center was nearly 6 times higher than those who live close to the local town center.

Factors associated with households becoming better-off

In terms of ESs, an increase in household-level benefits from cultural services had a significant positive effect on households moving to the better-off group, which was significant at the 0.01 level (Table 4). The regression coefficient of the impact of cultural services on household type was 0.19, and the relative

risk ratio was 1.21. In other words, compared to households with low monetary benefits from cultural services, households with high monetary benefits from cultural services were more 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. In terms of regional ESs, food supply was not significantly associated with the transition from Type II to Type III households statistically.

For household economic characteristics, an increase in proportion of educational expenditures to total expenditures had a significant positive effect on the transition of households from Type II to Type III ($p < 0.01$). The probability of further improvement in well-being for Type II households with high level of educational expenditures increased by more than 9 times. In other words, households spent a large portion of total expenditures on education were less likely to fall back to poverty than their counterparts. No statistically significant association was established between education levels and household becoming better-off. For locational context characteristics, an increase in travel time to local town center would not have a significant impact on the transition of households from Type II to Type III ($p > 0.1$).

Discussion

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). These studies have provided increasing evidence that ES contributes to human well-being, and poor people with a single source of livelihood are strongly dependent on ES. However, the effects of ES on poverty alleviation vary across scales, and such multiscale effects have not been fully understood, especially via quantitatively empirical studies. In this study, we included both regional

ESs and household-level benefits from ESs to examine the varying roles of ESs on poverty alleviation, and we also considered the differences in household endowments in investigating such nuanced linkages. Some of our findings are in line with previous conclusions, while others contribute new knowledge on the relationships between ES and poverty alleviation in urbanizing watersheds (Table 5).

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). Previous studies believed that household-level provisioning services were conductive 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, household-level provisioning services did not have significant effects on reducing poverty for poor households. This is partly due to our definition of poverty-stricken households (i.e., registered poor household living under the poverty line), because most of these households have chronic/serious diseases or physical/mental disabilities, and therefore, live on government subsidies and cannot engage in agricultural and off-farm work. An alternative explanation is that household-level 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, poor households usually only use the monetary benefit from provisioning services to maintain their original consumption levels (WRI, 2005), and have less access to cash crop or need to invest more time in food crops than the households living above the poverty line. Household-level food supply for these registered poor households are less for markets and more for subsistence purposes. In addition, we found that regional food supply had a negative impact on poverty alleviation. That is because those registered poor households were living in counties in the upstream of the basin, which largely depended on the primary industry for livelihood. The poor households neither possessed the endowments to conduct alternative non-agricultural livelihood nor mastered the skills to diversify their incomes (Démurger et al. 2010; Liu and Lan, 2015). Therefore, the village-level food supply is negatively associated with poverty alleviation.

Table 5 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)	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) 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)	**Household-level 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 **Regional (village-level) food supply was negatively associated with poverty alleviation.** Poor households did not have the assets and skills to diversify their livelihood strategies
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

Such findings contribute to our understanding and practice of landscape sustainability science at least in three ways. First, our findings can help answer one of the core research questions of landscape sustainability science, i.e., how socioeconomic processes and institutions affect the landscape pattern-ecosystem services-human wellbeing relationship (Wu 2021). We found that cropland dominant landscape at the village level (landscape pattern) and related food supply (ecosystem service) were not beneficial for poverty alleviation (human well-being), because the poor households living in these villages usually could not get access to other forms of income. Second, we argued that confirming there was no relationship between landscape pattern (and related ecosystem service) and poverty status at household level would also contribute to the above core research question

of landscape sustainability science. We found at the household level, income for growing cropland was not associated with poverty alleviation in a statistically significant way. Regardless of how rural households changes their landscape pattern for growing crop, the income from cropland did not play a key role in poverty alleviation. In other words, changing household-level landscape pattern would not be a priority for forming targeted poverty alleviation in this studied area. Third, our findings also confirmed the importance of differentiating the impacts of regional ESs and household-level ESs on poverty alleviation when exploring the connections between ESs and human well-beings. It echoes with the principle of landscape sustainability science that the complex linkages of landscape pattern-ecosystem service-human welling should be explored in a specific environmental and

socioeconomic context (Forman 2008; Liao et al. 2020; Wu 2021).

In terms of cultural services, we found that poverty-stricken households could hardly rely on them to escape 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 1.2 times those with low cultural services. It suggested that financial assets played an important role in escaping the poverty trap. In our interview, we found that some registered poor failed to benefit from local tourism-based poverty alleviation policies as they did not possess the financial and demographic advantages to realize the ES. Engaging in rural tourism or selling local specialties requires the household to invest in assets at an early stage, but poor households usually lived 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. Therefore, providing financial supports (Zhao and Xia, 2020) and education chances (Knight et al. 2009) for these poor household would be crucial for them accumulating assets and skills to escape the poverty trap.

Our study also emphasized that the process of urbanization plays an unique role in the relationship between ecosystem services and poverty alleviation. First, some households living close to nearby cities (e.g., Baoding) rented out the farmland and started to do off-farm jobs (e.g., couriers) in the cities. In other words, urbanization provides opportunities for rural residents to work in cities and diversify their income composition. Such trend was also widely found in other places of China (Liu and Liu, 2016). Second, a few households in our study area were used to be migrant workers in cities of the east coast of China. After accumulating the initial capital to start their own businesses, they went back to the hometown to started *Nongjiale* (i.e., a form of rural tourism providing rustic food and lodging for visitors, see Su 2013) hosting urbanite guests who wanted to experience countryside or visit local attractions (e.g., Yeshanpo Mountain and Langya Mountain). Urbanization enables these households to convert cultural services provided by local attractions to monetary benefits. However, they also expressed their concerns on the pandemics and its impacts on tourism.

Third, urbanization also attracted private enterprises to invest in tourism. When we conducted the survey in Yixian county (Fig. 1), we found that a private enterprise, Zhongkai Group, has constructed a four-star hotel, as well as a flower industrial park in the Langya Mountain Scenery Area, which offer various job opportunities for local rural households. The investment brought by urbanization could help rural households to get a stable income from provisioning and cultural services.

Policy implications

Considering the variations in 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, Grain-for-Green Program 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 contribute to 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 under 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, preferential policies can be designed for households just above the poverty line to encourage them to diversify livelihoods and stabilize household income that is likely to be affected by pandemics. Through strategies such as risk aversion and risk sharing, various types of households can improve their ability to cope with pandemics and reduce the risk of returning to poverty. In addition, because the selected three counties are located on the upper reaches of the basin, the rural households living therefore had to restrict the anthropogenic pressures exerted on this region. Consequently, some households further lost certain means diversifying livelihoods. From the perspective of watershed management, payments for ecological conservation or ESs from urban dwellers living in the lower reaches of this basin could be adopted to guarantee the well-beings of the rural households living in the upper reaches (Bulte et al. 2008; Tang et al. 2012).

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, for example, medical expenditure due to the prevalence of respiratory diseases. 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).

Conclusions

Unique linkages between ESs and poverty alleviation can be found in rapidly urbanizing watersheds. The case study in the Baiyangdian watershed found that household-level provisioning services and cultural services did not have a significant effect on poverty alleviation for rural households, while regional (village-level) food supply was negatively associated with poverty alleviation. Our findings reveal that rural poor householding living in cropland dominant landscape should find alternative ways other than crop cultivation to increase their income and escape poverty. It also indicates that it is crucial to differentiate the impacts of ES on poverty alleviation between landscape level and household level.

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 1.2 times that of average households.

Our findings higlight 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 provide financial support and skill training to poverty-stricken households to escape poverty. On the other hand, preferential policies toward poor

households should be designed when allocating the benefits of cultural services.

Data availability Included in supplementary files.

Code availability Not applicable.

Declarations

Conflict of interest None.

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References

Adams H, Adger WN, Ahmad S, Ahmed A, Begum D, Matthews Z (2020) Multi-dimensional well-being associated with economic dependence on ecosystem services in deltaic social-ecological systems of Bangladesh. Reg Environ Change 20(2):1–16

Bai Y, Zheng H, Zhuang C, Ouyang Z, Xu W (2013a) Ecosystem services valuation and its regulation in Baiyangdian baisn: based on InVEST model. Acta Ecol Sin 33(3):0711–0717 (**in Chinese**)

Bai Y, Zheng H, Ouyang Z, Zhuang C, Jiang B (2013b) Modeling hydrological ecosystem services and tradeoffs: a case study in Baiyangdian watershed, China. Environ Earth Sci 70(2):709–718

Barrett CB, Travis AJ, Dasgupta P (2011) On biodiversity conservation and poverty traps. Proc Natl Acad Sci USA 108:13907–13912

Barthel S, Crumley C, Svedin U (2013) Bio-cultural refugia-safeguarding diversity of practices for food security and biodiversity. Glob Environ Chang 23(5):1142–1152

Bulte EH, Lipper L, Stringer R, Zilberman D (2008) Payments for ecosystem services and poverty reduction: concepts, issues, and empirical perspectives. Environ Dev Econ 13(3):245–254

Carpenter SR, Mooney HA, Agard J, Capistrano D, DeFries RS et al (2009) Science for managing ecosystem services: beyond the Millennium Ecosystem Assessment. Proc Natl Acad Sci USA 106(5):1305–1312

Chaigneau T, Coulthard S, Brown K, Daw TM, Schulte-Herbrüggen B (2019) Incorporating basic needs to reconcile poverty and ecosystem services. Conserv Biol 33(3):655–664

Cruz-Garcia GS, Sachet E, Vanegas M, Piispanen K (2016) Are the major imperatives of food securitymissing in ecosystem services research? Ecosys Ser 19:19-31

Daw T, Brown K, Rosendo S, Pomeroy R (2011) Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. Environ Conserv 38(4):370–379

De Koning F, Aguiñaga M, Bravo M, Chiu M, Lascano M, Lozada T, Suarez L (2011) Bridging the gap between forest conservation and poverty alleviation: the Ecuadorian Socio Bosque program. Environ Sci Policy 14(5):531–542

Derkzen ML, Nagendra H, Teeffelen V, Astrid JA, Purushotham A, Verburg PH (2017) Shifts in ecosystem services in deprived urban areas: understanding people's responses and consequences for well-being. Ecol Soc 22(1):51

Démurger S, Fournier M, Yang W (2010) Rural households' decisions towards income diversification: evidence from a township in northern China. China Econ Rev 21:S32–S44

Duan HB, Wu Z (2018) The study on the poverty of the aging population in Hebei Province: A field survey based on 14 counties of Hebei Province. J Heibei Univ 43(1):112–119 (**in Chinese**)

Eltinge J, Sribey W (1997) Versions of mlogit, ologit, and oprobit for survey data. Stata Stat Bull 40:39–42

Fang YP, Fan J, Shen MY, Song MQ (2014) Sensitivity of livelihood strategy to livelihood capital in mountain areas: empirical analysis based on different settlements in the upper reaches of the Minjiang River. China Ecol Indic 38:225–235

Fedele G, Locatelli B, Djoudi H (2017) Mechanisms mediating the contribution of ecosystem services to human well-being and resilience. Ecosyst Serv 28:43–54

Fisher M (2004) Household welfare and forest dependence in Southern Malawi. Environ Dev Econ 9:135–154

Fisher J, Patenaude G, Meir P, Nightingale A, Rounsevell M, Williams M et al (2013) Strengthening conceptual foundations: analysing frameworks for ecosystem services and poverty alleviation research. Glob Environ Chang 23(5):1098–1111

Fisher J, Patenaude G, Giri K, Lewis K, Meir P, Pinho P et al (2014) Understanding the relationships between ecosystem services and poverty alleviation: a conceptual framework. Ecosyst Serv 7:34–45

Forman RTT (2008) Urban regions: ecology and planning beyond the city. Cambridge University Press, Cambridge

Frazier A, Bryan B, Buyantuev A, Chen L, Echeverria C, Jia P et al (2019) Ecological civilization: perspectives from Landsc Ecology and landscape sustainability science. Landsc Ecol 34:1–8

Gao Y, Wang H, Long D (2009) Changes in hydrological conditions and the eco-environmental problems in Baiyangdian watershed. Resour Sci 31(9):1506–1513 (**in Chinese**)

Haines-Young R, Potschin-Young M (2018) Revision of the common international classification for ecosystem

services (CICES V5. 1): a policy brief. One Ecosyst 3:e27108

He C, Liu Z, Gou S, Zhang Q, Zhang J, Xu L (2019) Detecting global urban expansion over the last three decades using a fully convolutional network. Environ Res Lett 14:034008

Hua X, Yan J, Zhang Y (2017) Evaluating the role of livelihood assets in suitable livelihood strategies: protocol for anti-poverty policy in the Eastern Tibetan Plateau, China. Ecol Indic 78:62–74

Huang Q, Zhao X, He C, Yin D, Meng S (2019) Impacts of urban expansion on wetland ecosystem services in the context of hosting the Winter Olympics: a scenario simulation in the Guanting reservoir basin, China. Region Environ Change 19(8):2365–2379

Huang Q, Yin D, He C, Yan J, Liu Z, Meng S et al (2020) Linking ecosystem services and subjective well-being in rapidly urbanizing watersheds: Insights from a multilevel linear model. Ecosyst Serv 43:101106

Jiang B, Chen Y, Xiao Y, Zhao J, Ouyang Z (2017) Evaluation of the economic value of final ecosystem services from the Baiyangdian wetland. Acta Ecol Sin 37(8):2497–2505 (**in Chinese**)

Jiao X, Pouliot M, Walelign S (2017) Livelihood strategies and dynamics in rural Cambodia. World Dev 97:266–278

Knight J, Shi L, Quheng D (2009) Education and the poverty trap in rural China: setting the trap. Oxf Dev Stud 37(4):311–332

Lade S, Haider L, Engström G, Schlüter M (2017) Resilience offers escape from trapped thinking on poverty alleviation. Sci Adv 3(5):e1603043

Liao C, Brown DG (2018) Assessments of synergistic outcomes from sustainable intensification of agriculture need to include smallholder livelihoods with food production and ecosystem services. Curr Opin Environ Sustain 32:53–59

Liao C, Qiu J, Chen B, Chen D, Fu B, Georgescu M et al (2020) Advancing landscape sustainability science: theoretical foundation and synergies with innovations in methodology, design, and application. Landsc Ecol 35:1–9

Liu B, Idris SD (2004) China's anti-poverty endeavor: A unique model of communitarianism. 2019–11–04. https://news.cgtn.com/news/2019-11-04/China-s-anti-poverty-endeavor-A-unique-model-of-communitarianism-Llyur RYS7C/index.html

Liu Z, Lan J (2015) The sloping land conversion program in China: effect on the livelihood diversification of rural households. World Dev 70:147–161

Liu Z, Liu L (2016) Characteristics and driving factors of rural livelihood transition in the east coastal region of China: a case study of suburban Shanghai. J Rural Stud 43:145–158

Liu L, Wu J (2021) Ecosystem services-human wellbeing relationships vary with spatial scales and indicators: the case of China. Resour Conserv Recycl 172:105662

Liu Y, Liu J, Zhou Y (2017) Spatio-temporal patterns of rural poverty in China and targeted poverty alleviation strategies. J Rural Stu 52:66–75

Mandle L, Shields-Estrada A, Chaplin-Kramer R, Mitchell MGE, Bremer LL et al (2020) Increasing decision relevance of ecosystem service science. Nat Sustain 4:61

Marshall F, Dolley J, Bisht R, Priya R, Waldman L, Amerasinghe P, Randhawa P (2018) Ecosystem services and poverty alleviation in urbanising contexts. Ecosystem services and poverty alleviationpp. Routledge, London, pp 111–125

Mbaiwa J, Stronza A (2010) The effects of tourism development on rural livelihoods in the Okavango Delta, Botswana. J Sustain Tour 18(5):635–656

Meng S, Huang Q, Zhang L, He C, Inostroza L, Bai Y, Yin D (2020) Matches and mismatches between the supply of and demand for cultural ecosystem services in rapidly urbanizing watersheds: A case study in the Guanting Reservoir basin, China, Ecosystem Services, 45: 101156

Millennium Ecosystem Assessment (MA) (2005) Ecosystems and human well-being: synthesis. Island Press, Washington, DC

Nahuelhual L, Carmona A, Lozada P, Jaramillo A, Aguayo M (2013) Mapping recreation and ecotourism as a cultural ecosystem service: an application at the local level in Southern Chile. Appl Geogr 40:71–82

Nguyen T, Do T, Bühler D, Hartje R, Grote U (2015) Rural livelihoods and environmental resource dependence in Cambodia. Ecol Econ 120:282–295

Ostrom E (2001) Social capital: a fad or a fundamental concept? In: Serageldin I, Dasgupta P (eds) Social Capital: a Multifaceted Perspective. World Bank, Washington DC

Qian C, Sasaki N, Jourdain D, Kim S, Shivakoti P (2017) Local livelihood under different governances of tourism development in China—a case study of Huangshan mountain area. Tour Manag 61:221–233

Redhead JW, Stratford C, Sharps K, Jones L, Ziv G, Clarke D, Oliver TH, Bullock JM (2016) Empirical validation of the InVEST water yield ecosystem service model at a national scale. Sci Total Environ 569:1418–1426

Robinson BE, Zheng H, Peng W (2019) Disaggregating livelihood dependence on ecosystem services to inform land management. Ecosyst Serv 36:100902

Sandhu H, Sandhu S (2014) Linking ecosystem services with the constituents of human well-being for poverty alleviation in eastern Himalayas. Ecol Econ 107:65–75

Scherr S, White A, Kaimowitz D (2004) A new agenda for forest conservation and poverty reduction. Making markets work for low income producers. Forest Trends and Centre for International Forestry Research (CIFOR), Washington, DC

Schreckenberg K, Mace G, Poudyal M (2018) Ecosystem services and poverty alleviation: trade-offs and governance (OPEN ACCESS) Routledge Studies in Ecosystem Services. Routledge, London, pp 111–125

Scoones I (1998) Sustainable rural livelihoods: a framework for analysis. IDS Working Paper 72:1–22

Sharp R, Tallis HT, Ricketts T, Guerry AD, Wood SA, Chaplin-Kramer R et al. (2015) InVEST 3.2.0 User's Guide. The Natural Capital Project, Stanford University, University of Minnesota, The Nature Conservancy, and World Wildlife Fund

Soltani A, Angelsen A, Eid T, Naieni M, Shamekhi T (2012) Poverty, sustainability, and household livelihood strategies in Zagros. Iran Ecol Econ 79:60–70

Stringer L, Dougill A, Thomas A, Spracklen D, Chesterman S, Ifejika Speranza C, Rueff H et al (2012) Challenges and opportunities in linking carbon sequestration, livelihoods and ecosystem service provision in drylands. Environ Sci Policy 19–20:121–135

Su B (2013) Developing rural tourism: the PAT program and 'Nong jia le'tourism in China. Int J Tour Res 15(6):611–619

Suich H, Howe C, Mace G (2015) Ecosystem services and poverty alleviation: a review of the empirical links. Ecosyst Serv 12:137–147

Tang Z, Shi Y, Nan Z, Xu Z (2012) The economic potential of payments for ecosystem services in water conservation: a case study in the upper reaches of Shiyang River basin, northwest China. Environ Dev Econ 17(4):445–460

TEEB (2010) The economics of ecosystems and biodiversity: ecological and economic foundations. Earthscan, London

United Nations (2014) Learning to live together. http://www.unesco.org/new/en/social-and-human-sciences/themes/international-migration/glossary/poverty/ Accessed 21 May 2015

United Nations (2015) We can end poverty-Millenium Development Goals and Beyond 2015. http://www.un.org/millenniumgoals/poverty.shtml. Accessed 23 May 2015

Verma M, Negandhi D (2011) Valuing ecosystem services of wetlands—a tool for effective policy formulation and poverty alleviation. Hydrol Sci J 56(8):1622–1639

von Maltitz GP, Gasparatos A, Fabricius C, Morris A, Willis KJ (2016) Jatropha cultivation in Malawi and Mozambique: impact on ecosystem services, local human well-being, and poverty alleviation. Ecol Soc 21(3). http://doi.org/10.5751/ES-08554-210303

Walelign S (2015) Livelihood strategies, environmental dependency and rural poverty: the case of two villages in rural Mozambique. Environ Dev Sustain 18(2):593–613

Walelign S, Nielsen Ø (2013) Seasonal household income dependency on forest and environmental resources in rural Mozambique. Int J AgriSci 3(2):91–97

Wang P, Yan J, Hua X, Yang L (2019) Determinants of livelihood choice and implications for targeted poverty reduction policies: a case study in the YNL river region, Tibetan Plateau. Ecol Ind 101:1055–1063

Watmough G, Marcinko C, Sullivan C, Tschirhart K, Mutuo P, Palm C, Svenning J (2019) Socioecologically informed use of remote sensing data to predict rural household poverty. Proc Natl Acad Sci USA 1:201812969

WRI (2005) The wealth of the poor. Managing ecosystems to fight poverty. World Resources Institute, UNDP, UNEP and World Bank. World Resources Institute (WRI), Washington

Wu J (2013) Landscape sustainability science: ecosystem services and human well-being in changing landscapes. Landsc Ecol 28:999–1023

Wu J (2021) Landscape sustainability science (II): core questions and key approaches. Landsc Ecol. https://doi.org/10.1007/s10980-021-01245-3

Xie W, Huang Q, He C, Zhao X (2018) Projecting the impacts of urban expansion on simultaneous losses of ecosystem services: a case study in Beijing, China. Ecol Ind 84:183–193

Yamane T (1967) Statistics: an introduction analysis. Harper and Row Press, New York

Yang W, Dietz T, Kramer DB, Ouyang Z, Liu J (2015) An integrated approach to understanding the linkages between ecosystem services and human well-being. Ecosyst Health Sustain 1(5):1–12

Ye S, Song C, Shen S, Gao P, Cheng C et al. (2020) Spatial pattern of arable land-use intensity in China. Land Use Policy, 99:104845

Zhang D, Huang Q, He C, Wu J (2017) Impacts of urban expansion on ecosystem services in the Beijing-Tianjin-Hebei urban agglomeration, China: a scenario analysis based on the shared socioeconomic pathways. Resour Conserv Recycl 125:115–130

Zhao L, Xia X (2020) Tourism and poverty reduction: empirical evidence from China. Tour Econ 26(2):233–256

Zhao L, Zhang P, Zhu Y (2014) Relationship between cultivated land resources and farmers' income in Poverty Areas around Beijing and Tianjin cities——an analysis based on panel data of 7 poor counties in Baoding city. Bull Soil Water Conserv 2:255–261 (**in Chinese**)

Zheng H, Wang L, Peng W, Zhang C, Li C, Robinson B et al (2019) Realizing the values of natural capital for inclusive, sustainable development: informing China's new ecological development strategy. Proc Natl Acad Sci USA 116:8623–8628