Ecosystem Services 40 (2019) 101030

Contents lists available at ScienceDirect

Ecosystem Services

journal homepage: www.elsevier.com/locate/ecoser

Changing use of ecosystem services along a rural-urban continuum in the Indian Trans-Himalayas

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ARTICLE INFO

Keywords:
Provisioning services
Income
Indigenous community
Spiti Valley

ABSTRACT

Urbanization is changing the use of ecosystem services, especially in previously remote mountain areas in Asia, Africa, and South America that are now more accessible. Change in ES use is not uniform across society, but is impacted by socio-economic factors like income. We sought to understand changes in ES use along a gradient of urbanization, and as related to income differences along this gradient. Our study was conducted in Spiti Valley, a formerly remote region in the Indian trans-Himalayas that is undergoing urbanization. We employed household surveys and monetary valuation to assess use of local (wild plants, dung, wood, forage, water, fertilizer, barley) and imported (firewood and fertilizers) provisioning services. We used ANOVAs and ANCOVAs to test for differences in ES use with urbanization and income. We found that the use of local provisioning services decreased with urbanization, while that of imported provisioning services increased. In rural spaces, the use of local provisioning services did not change with income, while in small urban centres it increased with income. Across settlement types, imported ES use increased with income. Our findings highlight how ES use can change with relatively small amounts of urbanization. They also indicate that local provisioning services need to be made accessible not only to rural populations but also to those in relatively more urban areas.

1. Introduction

Urbanization is one of the most important environmental and societal global change processes (Haase et al., 2018). Currently, 54% of the world's population lives in urban areas, a figure that is projected to increase to 66% by 2050 (UN, 2014). The definition of urbanization is not a clear one, as it varies between disciplines and has also evolved through time (Seto et al., 2012). Early definitions of urbanization referred to it as a largely demographic process (Schwirian and Prehn, 1962), a conception that is still used for administrative purposes. For example, India categorizes urban areas as places where the population exceeds 5000 and at least 75% of the male working population is engaged in non-agricultural pursuits (Census of India, 2011). However, the conceptualizations of urbanization have evolved: where once it was viewed as a purely demographic process, it is now recognized as a complex spatio-temporal process that encompasses changes in the environment and socioeconomics, including consumption patterns and institutions (Bai et al., 2017; Haase et al., 2018). It includes changes in the magnitude and qualities of livelihoods, connectivity and place, which can be heterogeneous at smaller scales, but homogenous globally, creating similar human experiences and land configurations (Boone et al., 2014). While there is no standard definition of rural and urban areas, certain broad characteristics can be attributed to them. Rural systems are characterized by a relatively high direct dependence on local ecosystems and a limited import of natural resources from elsewhere (Cumming et al., 2014; Hamann et al., 2015). Agriculture, pastoralism, or the collection and sale of forest produce tend to be the primary income-generating activities in rural areas (Sunderlin et al., 2005). In contrast, in urban areas, employment is often the main income source (Malecki, 2007) and people meet their basic needs for food, water and other materials typically through import from ecosystems elsewhere (Gómez-Baggethun et al., 2013). Although urban and rural areas were conceptualized as dualities, it is recognized that urbanization involves a dynamic and transformative continuum, with big

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https://doi.org/10.1016/j.ecoser.2019.101030
Received 18 June 2018; Received in revised form 15 September 2019; Accepted 23 September 2019

metropolitan cities at one end, small hamlets at the other, and semi-urban and small urban centres in between (Ward and Shackleton, 2016).

Ecosystem services (ES) – the benefits that people obtain from nature – also differ along the rural-urban continuum (Hamann et al., 2015). On the urban side of the continuum, people tend to have relatively limited access to local provisioning ES (Bolund and Hunhammar, 1999). For example, water has to often be sourced from outside the city, and has to go through extensive cleaning processes before it can be used (Nagendra et al., 2013). On the rural side of the continuum, people have easier access to local ES and use them directly (Shackleton et al., 2007). For example, forage for livestock and timber for fuel wood are often sourced directly from the local ecosystem. In urban areas, there is often a decrease in the ecosystem's capacity to provide local provisioning ES (Grimm et al., 2008). Alongside, there is an increase in society's use of provisioning ES, as ES consumption per capita, especially of imported ES, is relatively high in urban areas (Chávez et al., 2018).

The transition from a rural to an urban environment is characterized by four broad trends (Cumming et al., 2014). First, the needs of the population exceed the resources that they can access directly. As settlements grow, surrounding ecosystems are modified to maximize the harvest of provisioning services, such as timber, often at the expense of other ES, such as carbon sequestration. Second, simple waste-disposal methods are no longer efficient and the settlements require more complex disposal systems. Third, households start relying less on local ES as import becomes easier. Fourth, there are more people in the population who do not contribute directly to food production, further increasing their distance from the local ecosystem. During the process of urbanization, there is therefore a change both in the ability of the ecosystem to provide ES as well as a change in their use by the society (Cumming et al., 2014; Hamann et al., 2015).

Human use of ES is not uniform across society but varies based on socio-economic factors such as income, gender, class, and education (MA, 2005). Researchers have emphasized the importance of disaggregating ES use in society, as failure to disaggregate can obscure the processes contributing to the well-being of individuals, and result in a lack of recognition of who benefits and who is harmed by changes in ES generation or access (Daw et al., 2011; Sikor et al., 2014; Bull et al., 2016). Disaggregation is especially relevant along the urbanization gradient, as urban societies tend to be more heterogeneous compared to rural societies (Zukin, 1998), and disparity in income tends to be more pronounced in urban areas compared to rural areas (Douglass, 2000). Different ES and biodiversity conservation measures will need to be implemented based on the differences in societal use of ES (Daw et al., 2011).

There has been substantial research on the relationship between income and ES, and the variation in this relationship across the rural-urban continuum (Stoian, 2005; Shackleton et al., 2008; Cocks et al., 2008; Ward and Shackleton, 2016; Joos-Vandewalle et al., 2018; Nagendra, 2018). In rural areas, some studies report that households with lower income are more reliant on natural resources (Ward and Shackleton, 2016). This dependence is often due to accessible natural resources, lack of access to markets, and limited alternatives (Kumar and Yashiro, 2014). On the other hand, studies also report that better access to natural resources and markets allow households with higher income to use more ES (Kamanga et al., 2009). It is likely that households with higher income use different kinds of ES compared to households with lower income (Daw et al., 2016). Research from urban areas report that lower income households tend to be closely reliant on local provisioning services and a decrease in local ES provision can greatly impact the well-being and resilience of the urban poor (Derkzen et al., 2017; Stoian, 2005). Higher income households generally tend to use more imported ES such as water and food, and their overall consumption is higher than lower income households (Zukin, 1998).

High mountain regions, especially in Asia, South America, and Africa, formerly thought to be remote, are currently experiencing rapid urbanization (Parés-Ramos et al., 2013; Ding and Peng, 2018). It is important to understand how ES use in these regions are responding to urbanization dynamics, and the variety of changes experienced across the rural-urban spectrum. Income inequality is relatively high in these regions (Milanovic, 2013), which suggests that different sections of society might respond to urbanization differently. Often, changes caused by urbanization dynamics are reflected before regions become fully urbanized (Antrop, 2004).

In this study, we aimed to understand the difference in local ES use along a gradient of urbanization, and its interaction with household income. Based on patterns from larger conurbations, we expected that a) local ES use would decrease with urbanization, and b) income would impact ES use differently along this gradient. We expected the use of ES in lower income households to be greater in urban spaces, but in rural spaces we expected the use of ES to be greater in higher income households. The gradient of urbanization we examined was closer to the rural and semi-urban spectrum, but the changes in the semi-urban areas were driven by the underlying urbanization dynamics.

Our sampled gradient included mountainous hamlets, villages, and small urban centres in India, which have among the fastest urbanization rates in the world (UN, 2014). We conducted our study in the relatively remote and mountainous Spiti Valley in the Indian Trans-Himalayas, a region that has begun to experience urbanization in the last three decades. We estimated the economic value of provisioning ES used by households and used household income as a covariate to explore the relationship between ES use, urbanization, and income.

2. Methods

2.1. Study area

The Spiti Valley (lat 32°00′–32°42′ N; long 77°83′–78°30′ E; alt 3200 m to 6700 m) is a 7000 km^2 cold desert region in Himachal Pradesh, in the Indian Trans-Himalayas, with a population of 14,000 (Fig. 1). This represents a particularly relevant region for our study, as the people of the valley were traditionally agro-pastoral, and have recently shifted to a more market-based economy (Mishra et al., 2003b). Spiti Valley is experiencing ongoing urbanization, with three of the 75 settlements in the valley growing into small urban centres over the last three decades (Ghoshal, 2011). The population in the small urban centres has grown from approximately 300 people to about 1500 people in the last twenty years, with an increase in built infrastructure, change in livelihood away from agriculture towards non-agriculture-related activities, and a greater number of immigrants (more than three-fourths of the population is currently composed of immigrants) (District Administration, Himachal Pradesh, 2015).

While agriculture and livestock rearing are still the main sources of income, people also have jobs at the local government offices, take up private jobs as contractors, own hotels, and serve as tour guides, and taxi drivers. Individual families privately own agricultural land (Mishra et al., 2003b). The main cash crop grown is green pea (*Pisum sativum*), with apple (*Malus pumila*) planted in the relatively lower altitudes (c.3300 m) (Mishra et al., 2003b). Barley (*Hordeum vulgare*) and black pea (a local variety grown mainly for fodder) are the traditional crops cultivated. Agricultural production in the valley is largely dependent on snowmelt, brought to the fields by irrigation channels (Mishra et al., 2003b).

The livestock reared are sheep (*Ovis aries*), goat (*Capra hircus*), donkey (*Equus asinus*), yak (*Bos grunniens*), cattle (*Bos indicus*), dzomo (yak-cattle hybrid), and horses (*Equus caballus*) (Mishra et al., 2003b). Livestock are occasionally used for meat and other products, such as milk, manure and wool. The community has access to grazing pastures around the villages, with traditional grazing and collection rights in the pastures (Mishra et al., 2003b). Relatively smaller bodied livestock such as goats, sheep, donkeys, dzomo and cows, are herded to the pastures daily and brought back to stocking pens inside the villages in the

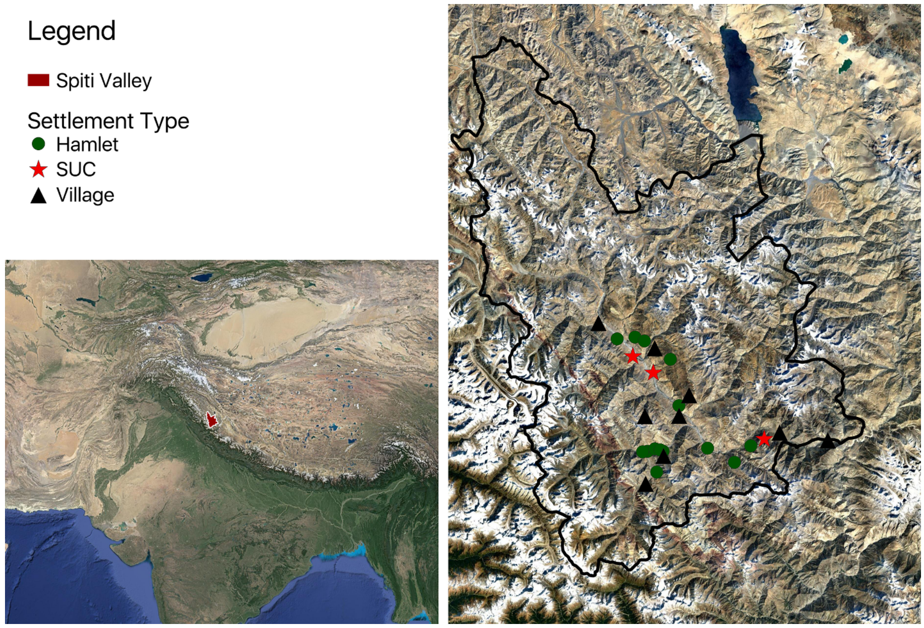

Fig. 1. Map of Spiti Valley, Himachal Pradesh, India, indicating the settlements that were sampled for the study. The three settlements types – hamlets, villages, and small urban centres (SUC) – are marked in the map.

evening. They are stall-fed during extreme winter. Winter forage largely comprises biomass from agricultural fields and plants collected from the pastures in late summer to autumn. Larger livestock, such as yak and horses, are mostly free-ranging through the year, except for a few weeks during extreme winter weather (Mishra et al., 2003b).

2.2. Selection of ES

For this study, we focused on local provisioning ES that were directly used by households. We focused on provisioning ES as local communities, especially in arid regions, tend to be closely reliant on them for their well-being (MA, 2005; Hamann et al., 2015). Previous research from this landscape recognized 17 types of provisioning ES belonging to 12 of the CICES (Common International Classification of Ecosystem Services) classes that were used by local people (Murali et al., 2017). For this study, we chose the most widely used local provisioning ES: wild plants, dung for heat, wood for heat, forage for livestock, water for agriculture, water for human consumption, fertilizer for agriculture, and barley (grown only for subsistence and not sold commercially). We focused on forage as an ES and therefore did not consider livestock. All local services were sourced from the pastures and agricultural fields surrounding the settlements. The settlements owned the pastures and fields surrounding them.

In addition, we focused on two provisioning ES that were imported into the system – firewood and feed for livestock – as indicators of trends in imported ES along the urbanization gradient. These two provisioning services were direct substitutes for locally present ES with the least amount of human input. The list of ES measured and their types (local/imported) are provided in Table 1. A limited quantity of firewood is available in the pastures. However, over the last 15 years, firewood imported from other parts of the state has been available for purchase locally. Similarly, feed for livestock is available for purchase in the local market and these were easily separated from that available in the valley.

Table 1
List of local and imported ES measured in Spiti Valley. These were selected based on ES that were identified as being locally important by respondents from a previous study in the region (Murali et al., 2017).

ES Measured	Type of ES
Wild plants	Local
Dung for heat	Local
Wood for heat	Local
Forage for livestock	Local
Water for agriculture	Local
Water for human use	Local
Fertilizer for agriculture	Local
Barley	Local
Firewood	Imported
Feed for livestock	Imported

2.3. Data collection

We categorized each of the 75 permanent settlements in Spiti Valley based on urbanization parameters such as the relative number of households, proportion of immigrants, population size, infrastructure facilities, and presence of government offices. The least urbanized, typically smallest settlements were classified as “hamlets”, followed by “villages”, and “small urban centres” (hereafter referred to as SUC), which were the most urbanized.

Hamlets were defined as settlements with fewer than 25 households, having no government offices, minimal immigrants and limited infrastructure facilities. Hamlets had access to agricultural and grazing lands around them. Villages were defined as settlements with 26–60 households, no government offices, a few permanent or seasonal immigrants, and some infrastructure facilities such as tarred roads, government health centres, and schools. Villages had access to agricultural and grazing lands around them. SUC were defined as settlements with more than 60 households, presence of government offices, a higher proportion of permanent and seasonal immigrants, and the presence of built infrastructure such as tarred roads, hospitals and schools. Some households in SUC, which are mainly the older inhabitants, had access to agricultural and pastoral lands around the settlement.

We randomly sampled 30% of the households living in villages and SUC, following previous studies in this landscape which have shown that this provides a representative sample (Suryawanshi et al., 2014). In hamlets, we interviewed all the households. Hamlets had 1 to 25 households, with a mean of 10 households. In villages there were 25 to 60 households, with a mean of 45 households. SUC had between 100 and 300 households. The hamlets, villages, and SUC sampled are shown in Fig. 1.

We interviewed respondents above the age of 21 and below the age of 70, who were aware of household consumption. Immigrants were excluded from the interviews, as most of them were not users of local provisioning ES. Immigrants were shopkeepers or were hired as household or agricultural helpers. They did not own land or livestock and rarely collected local provisioning ES. A total of 287 interviews (hamlet = 85, village = 103, SUC = 99) were conducted across the valley. Ranjini Murali conducted the interviews in Hindi, and, where required, a local interpreter translated the questions into Spitian.

We used a modified version of the International Forestry Resources and Institutions (IFRI) questionnaire (Wertime et al., 2011) to determine household use of ES. The IFRI questionnaire has been used extensively to understand human use of common pool resources in forest systems (Epstein, 2017; Mohammed et al., 2017; Nath, 2018). We asked questions about the amount of agricultural produce (pea and apple) sold, barley harvested, water used, and about the collection of fodder, firewood, wild plants and dung from the pastures. The questionnaire is provided in the supplementary material to this paper. For the imported ES we asked respondents about the quantity of firewood and feed they purchased from the market. We collected data in July–August 2015, which was the harvest season, when relatively accurate estimates were easier to obtain. Fodder and wild plants are also mostly collected during this season and stored in reusable bags of a fixed volume that can normally hold 45–50 kg of green pea, the main commercial crop. Dung and firewood are collected through the year and stored in these bags. Respondents were able to tell us how many bags they collected in a year, and we measured the weight of 10 bags of each resource, to get an estimate of the average weight of the different resources utilized.

Household income was calculated as an aggregate value of all household income sources (Cavendish, 2002). In Spiti Valley the main income sources were from the sale of agricultural produce, jobs, and tourism.

2.4. Analysis of ES use

In this study, we focused on the economic value, which provided a comparable unit of measurement across ES types. We used the TEV framework (Pascual and Muradian, 2010) to assess the economic value of provisioning services. We used the economic value as it provided a comparable unit of measurement across ES types. The TEV framework is commonly used in economic assessments of ES and it expresses the utility derived from ES in monetary or any other market-based unit that allows comparison (Pascual and Muradian, 2010). Under this framework, provisioning services are assessed using direct use values, as this focuses on the ES that are directly used by humans. We used the market-price-based and replacement cost method to assess the value of provisioning services. Market-price-based methods are commonly used to assess the value of provisioning services, as they are often sold and the market price reflects their value (Pascual and Muradian, 2010). This method was used for the ES that had a market price in Spiti valley. Replacement cost method estimates the cost of replacing ES with artificial technologies. This method was used in Spiti for those ES that did not have a market price and could be replaced by artificial technologies, such as plant material used for roofing that was replaced with concrete. Local market prices were used. The local provisioning services used came from the areas around the settlements. Table 2 provides details regarding the ES measured, the economic valuation method, and the unit of measurement.

We distinguished the total ES used into two types, agricultural ES and pasture-related ES, as the way people used these two services were different. Agricultural ES included water for agriculture and local fertilizer. To use these services, people remained in the agricultural fields around the villages. Pasture-related ES included the use of grazing pastures, collection of dung and firewood, and collection of wild plants.

All statistical analysis was run using the open-source statistical computing software R (R Core Team, 2013). An Analysis of Variance test (ANOVA) was used to test for the difference in mean use of the total ES across the three settlement types. ANOVAs are used to compare the means of two or more groups for statistical difference. ANOVAs for agricultural ES and pasture-related ES were further used to test if the change in use was due to agricultural ES or pasture-related ES.

Analysis of covariance (ANCOVA) was used to test for the effect of income (a continuous variable) and settlement type (a categorical variable with three levels: “hamlet”, “village”, and “SUC”) on the total economic value of local ES used. ANCOVAs are regression models that have a continuous dependant variable and categorical and continuous independent variables. Table 3 provides the details of the variables used in the ANCOVA.

ANCOVAs were also used to test the effect of income and settlement type on the economic value of agricultural ES and pasture-related ES separately. The response variables, total economic value of local ES, agricultural ES and pasture-related ES and the explanatory variable household income were strongly right-skewed, so we used a log 10 transformation before running the models.

An ANCOVA was used to test for the effect of income and settlement type on imported ES (purchased firewood and feed). Household income was also log 10 transformed as it was strongly right-skewed.

There were two zero values of income that were removed from the calculation as it is unlikely that respondents had zero income. They were probably supported by family or friends, which our questionnaire was unable to capture.

Percentage change in ES use was assessed along with percentage change in income along the gradient of urbanization using the standard accepted formula:

$$y_z = [(1.01^{\beta} - 1)] * 100,$$

where y is ES use, z is the settlement type, and β is the model estimate.

(For the complete derivation of formulae, see (Cornell Statistical Institute, 2012)).

3. Results

3.1. Difference in income across the settlement types

The mean annual household income (± SE) in hamlets was 3595 ± 322 USD HH^{-1} $Year^{-1}$, compared to 4424 ± 411 in villages, and 6288 ± 640 in SUC (ANOVA, $F_{(2,284)} = 9.059$, $p < 0.005$).

In hamlets, 51.8% of the respondents depended only on agriculture for their total income, compared to 31% in villages and 3% in SUC. 32.3% of SUC households did not depend on agriculture at all (Fig. 2). No income was derived from livestock, but they were used to provide meat, milk, wool, transport, and for tilling agricultural land. Households in villages had the largest livestock holdings (8.7 ± 6.8 total livestock HH^{-1}), followed by those in hamlets (7.3 ± 5.2 total livestock HH^{-1}), while those in SUC (1.9 ± 2.9 total livestock HH^{-1}) had the least livestock (ANOVA, $F_{(2,284)} = 46.49$, $p < 0.005$). The Tukey HSD test demonstrated a significant difference in livestock holdings of households between hamlet and SUC ($p < 0.05$), and village and SUC ($p < 0.05$).

3.2. Change in ecosystem service use with urbanization

Households in the villages used the most local ES in terms of economic value (4664 ± 284 USD HH^{-1} $Year^{-1}$), followed by households in

Table 2
Methods used and units of measurement for estimating the economic value of provisioning ES used by agro-pastoral people in Spiti Valley, India. We used the Total Economic Valuation Framework (TEV). HH = household.

Ecosystem services (CICES categories)	Economic valuation method	Unit price
Reared animals and their outputs	Market-price-based approach	Number of livestock HH^{-1}
Wild plants and their outputs	Market-price-based approach	Kg HH^{-1} $Year^{-1}$
Water for household purposes	Market-price-based approach	Litres HH^{-1} $Year^{-1}$
Fibres and other materials from plants, and animals for direct use or processing	Market-price-based approach and replacement cost method	Kg HH^{-1} $Year^{-1}$
Materials from plants, and animals for agricultural use	Replacement cost method	Kg HH^{-1} $Year^{-1}$
Plant and animal based resources	Market-price-based approach	Kg HH^{-1} $Year^{-1}$

Table 3
Description of the variables used in the ANCOVA models to test for the differences in the use of ES along a rural-urban gradient in Spiti Valley, India. Total household income and settlement type were the explanatory variables. ANCOVA's models were built for each of the response variables. HH = household.

Variable type	Variable name	Measurement	Mean ± SE	Median	Unit
Explanatory variable	Total income	Continuous	5192 ± 290	4000	USD HH^{-1} $Year^{-1}$
Explanatory variable	Settlement type	Categorical			
Response variable	Total local ES	Continuous	3620 ± 170	3097	USD HH^{-1} $Year^{-1}$
Response variable	Agricultural ES	Continuous	508 ± 40	327	USD HH^{-1} $Year^{-1}$
Response variable	Pasture- related ES	Continuous	3087 ± 148	2698	USD HH^{-1} $Year^{-1}$
Response variable	Imported ES	Continuous	116 ± 4.9	102	USD HH^{-1} $Year^{-1}$

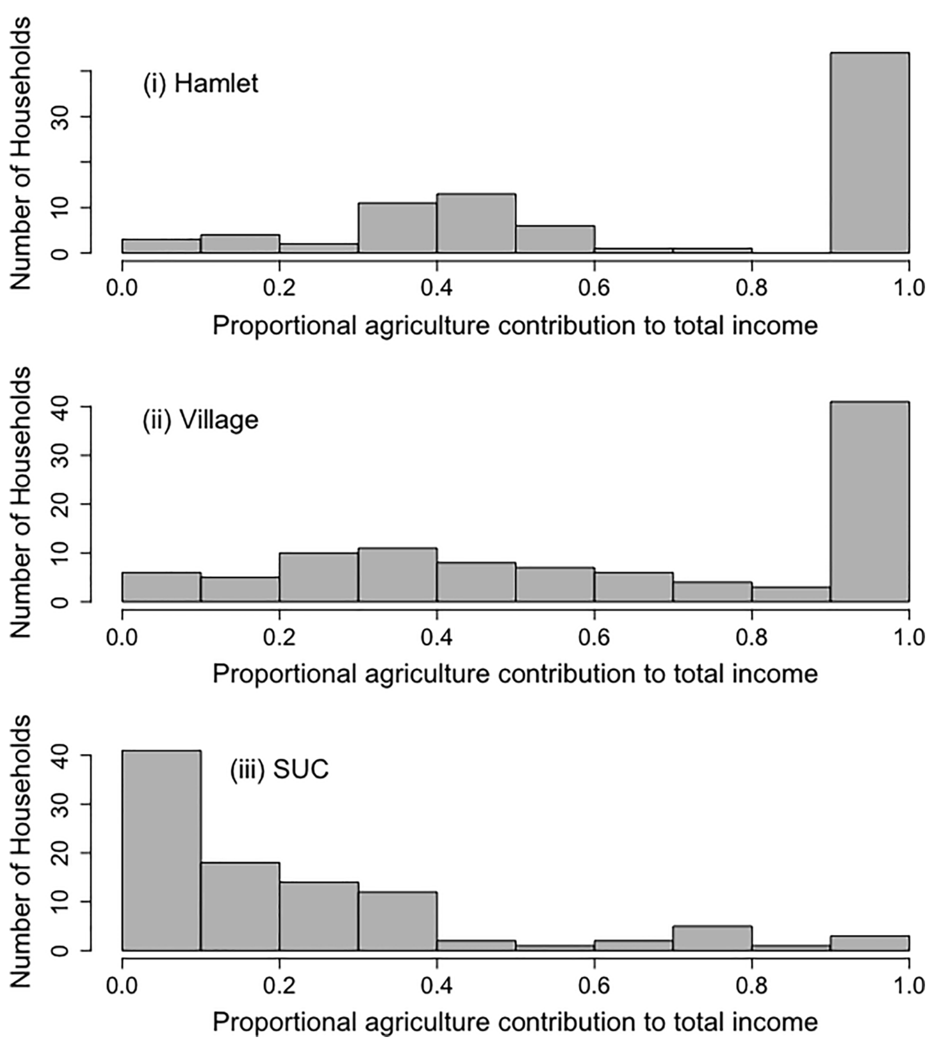

Fig. 2. Proportion of income from agriculture in relation to the total household income of the respondents in different settlement types along an urbanization gradient in Spiti Valley, India.

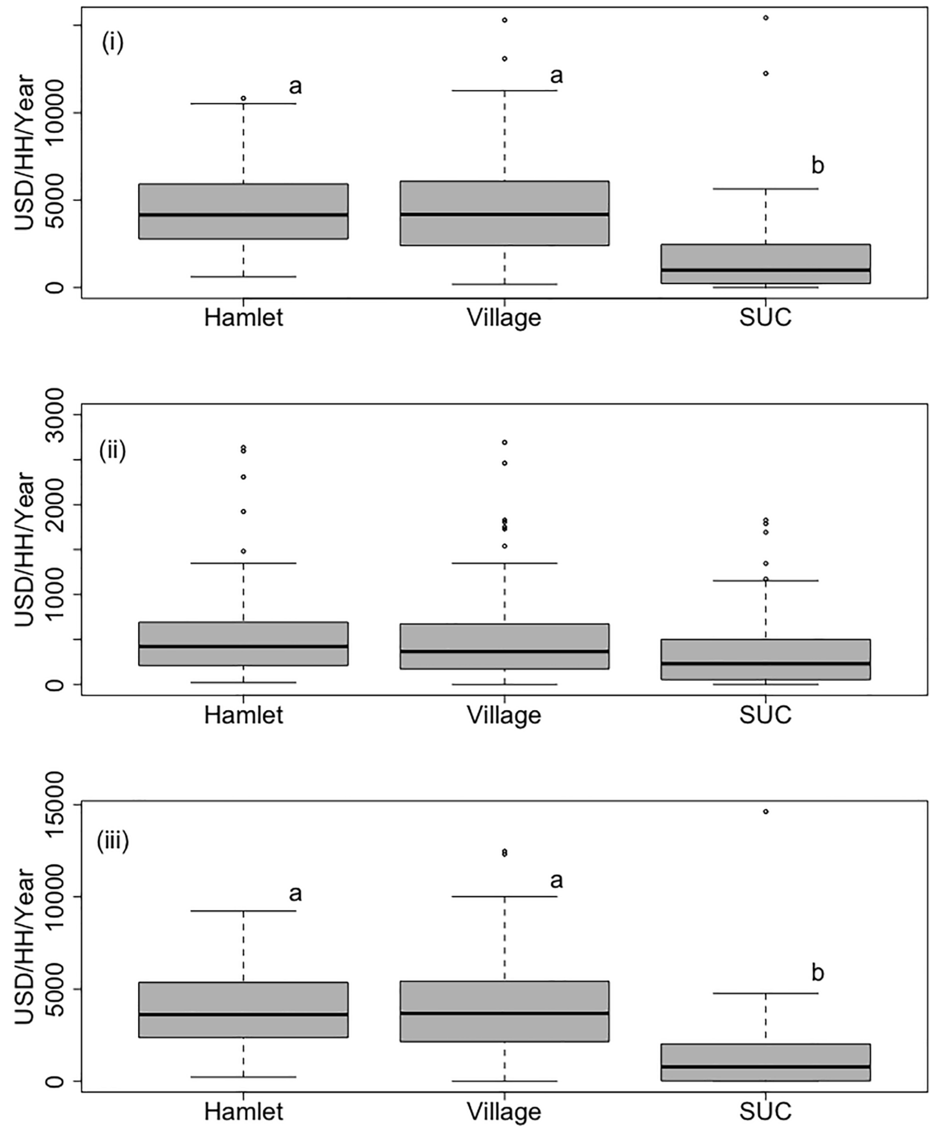

Fig. 3. Difference in total local ES use (3 i), agricultural ES (3 ii), and pasture-related ES (3 iii) across different settlement types along an urbanization gradient in Spiti Valley, India. The y-axis represents the value of ES in USD HH^{-1} $Year^{-1}$. Superscripts "a" and "b" indicate the difference in mean ES between settlement types, as given by the Tukey HSD test. Same subscripts indicate no difference while different subscripts indicate difference in ES use between settlement types. Lack of subscripts indicates no difference between means.

hamlets (4510 ± 257 USD $HH^{-1}Year^{-1}$), while those in SUC (1772 ± 232 USD HH^{-1} $Year^{-1}$) used the least local ES (ANOVA, $F_{(2,284)} = 39.93$, $p < 0.005$). There were significant differences between hamlet and SUC (Tukey HSD $p < 0.05$), and village and SUC (Tukey HSD $p < 0.05$) (Fig. 3 i).

Analysis of only those local ES used for agricultural production showed no significant difference between hamlets, villages, and SUC (ANOVA, $F_{(2,284)} = 0.963$, $p = 0.383$) (Fig. 3 ii).

Households in the villages used the most local ES in terms of economic value from the pastures (4086 ± 249 USD HH^{-1} $Year^{-1}$), followed by households in hamlets (3913 ± 226 USD HH^{-1} $Year^{-1}$), while those in SUC (1337 ± 184 USD HH^{-1} $Year^{-1}$) used the least (ANOVA, $F_{(2,284)} = 49.01$, $p < 0.005$). There were significant differences between hamlet and SUC (Tukey HSD $p < 0.05$) and village and SUC (Tukey HSD $p < 0.05$) (Fig. 3 iii).

More than 75% of the total local ES came from pastures in all three settlements. Villages had the highest percentage from pastures (88.5%), followed by hamlets (87%) and then SUC (75.5%). Conversely, SUC had the highest percentage of their ES related to agriculture.

3.3. Ecosystem services, urbanization and income

The log of the total local ES was modelled against the interaction between the settlement type and the log of income (Table 4). The relationship was found to be significant ($p < 0.005$) and explained 23% of the variation (adjusted $R^2 = 0.2$).

For every 1% increase in income, there was a 0.15% increase in the total local ES used per household. There was no significant difference in household use of local ES between hamlets and villages. Household use of local ES in villages was 0.72 USD $Year^{-1}$ greater than in hamlets, at intercept. There was a significant difference in household local ES use between SUC and hamlets. In SUC, local ES use was 9.1 USD $Year^{-1}$ lower than in hamlets, at intercept. The intersection between the lines indicates the points at which local ES use increases or decreases for settlement types, in relation to the other settlement type. At log income 3.5, local ES use in villages decreased slightly from those in hamlets, and at log income 4.3, local ES use in SUC, increased from those in hamlets and villages.

In hamlets, total local ES used increased slightly with increasing household income (Fig. 4 i). In villages, total local ES used decreased

Table 4
Results of the ANCOVA models of the log of total ES, agricultural ES, and pasture-related ES as response variables and log of annual household income and settlement type (hamlet is the intercept, v = village, and SUC = small urban centre) as predictor variables. Model estimates, standard error, and p-values are reported.

Model parameters	Total ES		Agricultural ES		Pasture ES	
	Estimate ± (SE)	p value	Estimate ± (SE)	p value	Estimate ± (SE)	p value
Intercept	3.5 ± (1.4)	0.03	0.62 ± (1.6)	0.70	3.15 ± (1.9)	0.10
Log income	0.16 ± (0.4)	0.7	0.56 ± (0.5)	0.23	0.11 ± (0.5)	0.85
Settlement type (v)	0.72 ± (1.8)	0.7	0.36 ± (2.1)	0.86	1.14 ± (2.5)	0.64
Settlement type (SUC)	−9.13 ± (2.2)	< 0.005	−7.36 ± (2.2)	0.004	−9.41 ± (3)	< 0.005
Log income: settlement type (v)	−0.21 ± (0.5)	0.69	−0.13 ± (0.5)	0.83	−0.35 ± (0.7)	0.62
Log income: settlement type (SUC)	2.07 ± (0.6)	< 0.005	1.60 ± (0.7)	0.02	1.98 ± (0.8)	0.01

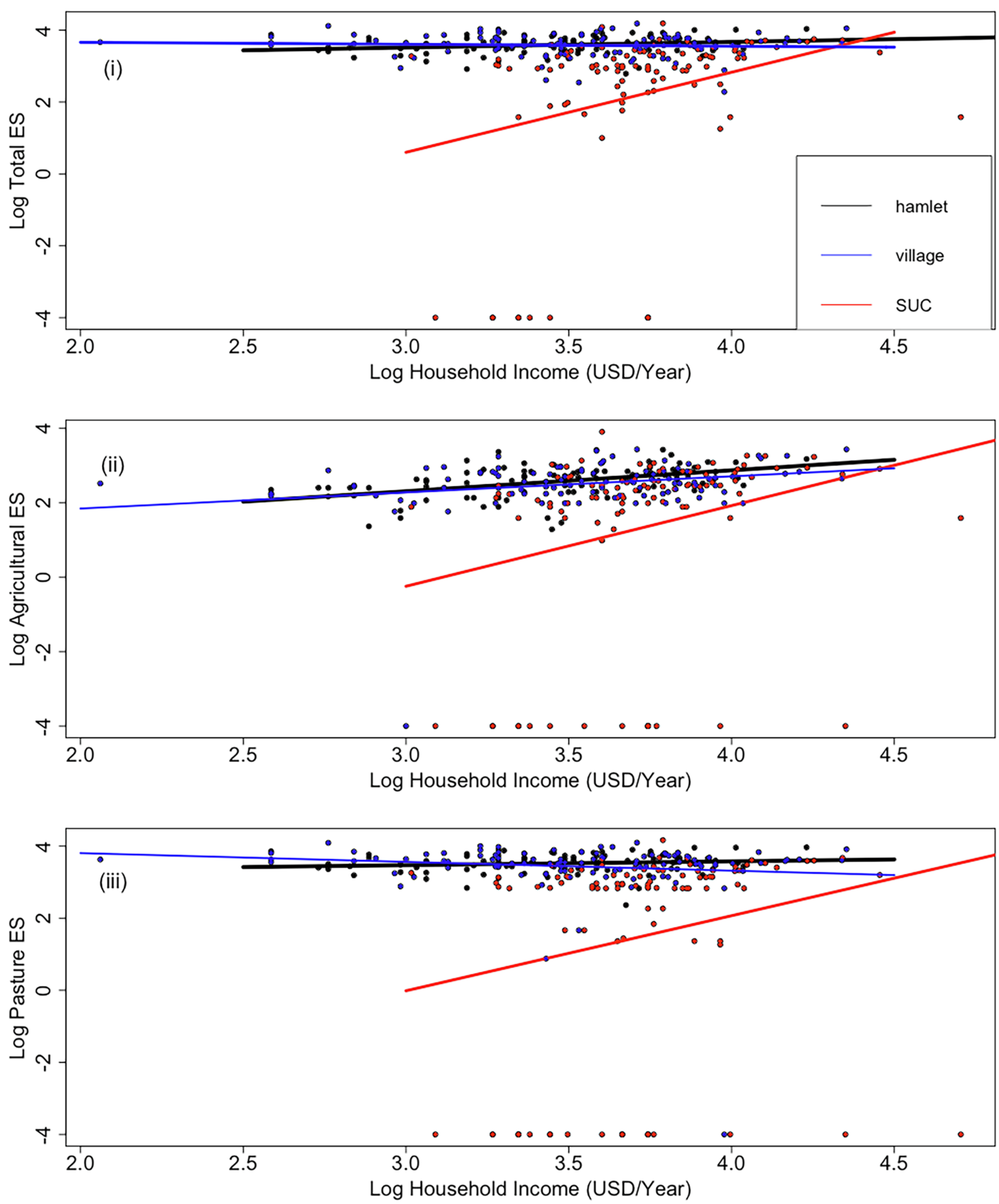

Fig. 4. Change in household (HH) ES use along a gradient of HH income in the three settlement types along an urbanization gradient in Spiti Valley, India. Both y-axis and x-axis are on the log scale.

slightly with household income. In SUC, the use of total local ES increased rapidly with income. In villages and hamlets, there was little variation in the use of total local ES while in SUC, there was greater dispersion in the use of total local ES (Fig. 4 i).

The log of local agricultural ES was modelled against the interaction between settlement type and the log of income (Table 4). The model explained 17% of the variation (adjusted $R^2 = 0.17$) and the relationship was found to be significant ($p < 0.005$). For 1% increase in the income, there was a 0.6 % increase in the local agricultural ES used per household. With income constant, local agricultural ES use in villages was 0.36 USD $Year^{-1}$ greater than in hamlets, and in SUC it was 7.36 USD $Year^{-1}$ lower than in hamlets. For local agricultural ES, in hamlets and villages, use increased slightly with income while in SUC, it increased rapidly (Fig. 4 ii).

The log of local pasture-related ES was modelled against the interaction between settlement type and the log of income (Table 4). The model explains 24% of the variation (adjusted $R^2 = 0.24$), and the relationship was found to be significant ($p < 0.005$). For a 1% increase in income, there was a 0.1% increase in the local pasture-related ES used per household. With income constant, in villages, the use was 1.14 USD HH^{-1} $Year^{-1}$ greater than in hamlets and in SUC it was 9.41 USD HH^{1} $Year^{-1}$ lower than in hamlets. For local pasture-related ES, in hamlets, there was a slight increase in the use of ES with income. In villages, there was a decrease with income and in SUC there was a rapid increase with income (Fig. 4 iii). For both local pasture-related and agricultural ES, SUC had a greater dispersion of use as compared to hamlets and villages.

3.4. Imported ecosystem services

Households in the SUC used the most imported ES (162 ± 9 USD HH^{-1} $Year^{-1}$), followed by villages (112 ± 7 USD HH^{-1} $Year^{-1}$), while those in hamlets (84 ± 8 USD HH^{-1} $Year^{-1}$) used the least imported ES (ANOVA, $F_{(2,243)} = 20.08$, $p < 0.005$). There were significant differences between hamlet and SUC (Tukey HSD $p < 0.05$), village and SUC (Tukey HSD $p < 0.05$), and village and hamlet (Tukey HSD $p < 0.05$).

Table 5
Results of the ANCOVA model with imported ES as the response variable and log of annual household income and settlement type (hamlet is the intercept, v = village, and SUC = small urban centre) as predictor variables. Model estimates, standard error, and p-values are reported.

Model parameters	Imported ES	
	Estimate ± (SE)	p value
Intercept	−144.32 ± (78)	0.065
Log income	65.89 ± (22.4)	0.004
Settlement type (v)	−57.44 ± (101)	0.56
Settlement type (SUC)	253.04 ± (146.3)	0.09
Log income: settlement type (v)	22.83 ± (28.8)	0.43
Log income: settlement type (SUC)	−51.57 ± (40)	0.19

Imported ES were modelled against the interaction between settlement type and the log of income (Table 5). The model explained 25% of the variation (adjusted $R^2 = 0.25$) and the relationship was found to be significant ($p < 0.005$). For a 1% increase in the income, there was a 0.66 USD HH^{-1} $year^{-1}$ increase in imported ES used per household. For villages and hamlets, there was a steep increase in the use of imported ES with income and in SUC, there was a small increase in the use of imported ES with income. At high incomes, households in villages used more imported ES than households in hamlets. At log household income 4.0, on the x-axis, imported ES use in villages increased from those in SUC (Fig. 5).

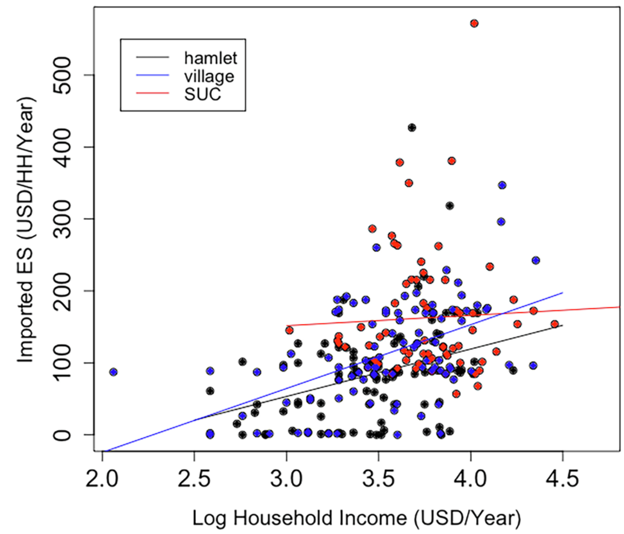

Fig. 5. Change in the household (HH) use of imported ES use along a gradient of HH income in the three settlement types along an urbanization gradient in Spiti Valley, India. The x-axis is on the log scale.

4. Discussion

Our findings show that along the urbanization gradient from hamlets to SUC in Spiti Valley, the proportion of income derived from agriculture (which depends significantly on local ES) decreased, while income from employment opportunities (which do not depend on local ES) increased (Fig. 3). While this is an expected transition across the rural-urban continuum (Joos-Vandewalle et al., 2018; Baró et al., 2017; Hamann et al., 2015; Cumming et al., 2014), our study highlights that these changes caused by urbanisation dynamics appear quite early on in the rural-urban continuum, even with little urbanization. Several complex factors account for this decrease in human use of local provisioning ES. Land and livestock holdings decrease across the rural-urban gradient, decreasing human use of associated ES (Ward and Shackleton, 2016). Technological advancements and increased employment opportunities enable a higher proportion of people living closer to the urban end of the spectrum to earn a living through ways unrelated to agriculture (Satterthwaite et al., 2010). Access to local provisioning ES is limited when villages expand to urban areas, as they have fewer available natural spaces and the capacity of the ecosystem to supply ES decreases in urban spaces (Mcdonald et al., 2008).

As the use of locally sourced provisioning services decreases, these needs are met by importing the same services from other regions (Hamann et al., 2015). This is also indicated by our findings on the two ES that were imported – firewood and feed for livestock. Incomes rise along the urbanization gradient, which provides people with greater ability to substitute local ES (Haase et al., 2018). We expect similar patterns to hold for most of the other local provisioning services as well. Wild plants and barley are likely to be replaced by food imported into the system, dung for heat is likely to be replaced by either wood, gas, or electricity, and fertilizer for agriculture is likely to be substituted with chemical fertilizers. However, water for agriculture and human consumption is likely to follow a different trajectory. While water consumption increases along the urbanization gradient (House-Peters and Chang, 2011), it will continue to be drawn from the surrounding ecosystem as the capacity to transport large volumes of water across great distances is limited (Decker et al., 2000). The increased demand for water and the limited potential to import water can lead to water scarcity, an urgent issue facing many global cities (Vairavamoorthy et al., 2008).

We found no significant difference in the use of agricultural-related ES between the three settlement-types along the urbanization gradient.

In the SUC of Spiti Valley, there was a mix of livelihood strategies that included agriculture. Residents still have access to some land which is cultivated, and some even have small-livestock holdings. The diversity of livelihood strategies in small urban centres, creating spaces that are a mix of traditionally urban and traditionally rural spaces, are characteristic of low income and middle income countries (Ward and Shackleton, 2016; Joos-vandewalle et al., 2018; Wang et al., 2010; Schlesinger et al., 2015). These patterns are anticipated to change over time in response to greater levels of urbanization, increasing demand and the increasing real estate value of land in urban spaces, which are likely to reduce the extent of land under agriculture (Satterthwaite et al., 2010). As expected, we found a decline in the use of pasture-related ES with urbanization.

More than 75% of the total local provisioning ES came from pastures in all the three settlement types. In SUC, this percentage from pastures was the least among the three types, and it was the highest from agriculture. This was expected, as fodder for livestock was one of the ES with the highest value. This contributed to pasture services being valued much higher than agricultural services. Even though total livestock holdings decreased in SUC, the proportion of ES from the pasture was still higher than from agriculture. Spiti traditionally has limited land for cultivation due to environmental constraints such as the mountainous terrain, aridity of the landscape and a single, relatively short growing season (Mishra et al., 2003b). This trend is likely to be different in agricultural societies that have large landholdings and fewer livestock. While local ES use decreased along the urbanization gradient, households in urban areas showed a greater variation in local ES use. Urban spaces tend to be more heterogeneous with the population engaged in different kinds of employment and activity (Cumming et al., 2014), presumably leading to greater differences in ES use among households, compared to villages and hamlets.

In SUC, use of local provisioning ES increased with income. Our results are in line with recent research that has documented greater use of local ES by households with higher incomes (Chaudhary et al., 2018; Kumar and Yashiro, 2014). These studies have reported that households with higher income often use more ES as they have better access to ES and have more land and livestock (Chaudhary et al., 2018). Often, households in higher income groups can afford to hire labour to collect ES, such as fuelwood and fodder, without compromising on earning. Whereas those from lower income groups may have to compromise on earning income during collection times, as a result of which they collect fewer ES (Kumar and Yashiro, 2014). People from higher income groups often also tend to have better relationships with key persons like government officials who can facilitate easier access to ES such as timber (Chaudhary et al., 2018). Further, they may have access to ES of higher value as opposed to lower income groups who have access to lower value ES (Daw et al., 2011; Kibria et al., 2018). Households from higher income groups can extract greater benefits from ES due to their ability to invest in machinery that could better utilize ES, such as machinery for harvesting timber (Felipe-Lucia et al., 2015). While higher income groups might use more ES, it is likely that local ES are more valuable to people with lower incomes as they have lower substitution power and ES can act as a safety net (Daw et al., 2011; Kibria et al., 2018).

The use of imported ES increased with income in all three settlement types, although it increased more steeply in villages and hamlets, as compared to SUC. This increase in the use of imported ES with income – and thus purchasing power – is expected (Rosenzweig and Wolpin, 1993; Wilting et al., 2017). Households with higher incomes, in all three settlements types, especially in SUC, use more local and imported provisioning ES. This pattern is seen across the globe, where several studies have shown that consumption of energy and resources increases rapidly with income (Weinzettel et al., 2013; Miao, 2017; Wilting et al., 2017; Mancini et al., 2018; Wiedenhofer et al., 2018). In our study, we measured only two imported ES, to indicate a potential trend. If we were to add more services, it is likely that these patterns would be further accentuated.

We focused on comparing the economic value of ES across urbanization and income gradients. While market prices can be used to arrive at a monetary value for ES, these are often underestimates, as people in rural areas are closely reliant on ES for their subsistence and lifestyles, and market prices alone cannot capture these (Murali et al., 2017; Kibria et al., 2017). Using economic values can capture only a fraction of the total range of values that people have for nature (Iniesta-Arandia et al., 2014; Arias-Arévalo et al., 2018) and the importance of socio-cultural values must also be explored (Arias-Arévalo et al., 2017).

While our study captured the urbanization gradient in Spiti Valley, our study area was a low human-density mountainous region (0.6 people per sq. km) (District Administration, Himachal Pradesh, 2015) with even the SUC having approximately 300 households. Although small, these SUC have already seen a significant change in human lifestyles compared to villages. Our study helps generate an understanding of the variation of the use of ES at the early stages of urbanization. Such an understanding is important in the context of land use planning, natural resource management, and conservation. For instance, livelihood enhancement is often used as a strategy for decreasing local dependence on natural resources (Roe et al., 2014). Our study suggests that livelihood enhancement may not be an effective strategy by itself, given the weak or negative relationship between income and ES use in villages. Such efforts would need to be combined with other measures such as conservation set asides (Mishra et al., 2003a) and collection quotas (Christensen et al., 2009) that ensure local ecosystems are not overexploited. Our results indicate that people in small urban centers also use provisioning services, and therefore urban planning should account for this use and allow for easy access to provisioning services in such spaces.

5. Conclusion

Our study provides an indication of how mountain systems can change as they grow from hamlets to small urban centres, and the scales at which ES are generated and used. It crucially highlights that ES use patterns can change even with small levels of urbanization, and that the urbanization processes begin early in the rural-urban continuum.

We found that the use of local provisioning ES decreased along the urbanization gradient, early in the rural-urban continuum, even when regions are not fully urbanized. Secondly, parts of the population in SUC still use local provisioning services. It is essential that local provisioning services are made accessible not only to rural people but also to people living in more urbanized regions, and at the same time, ensure that these are not overexploited. Local institutions are often in place to prevent overexploitation, and strengthening them and reinforcing human connections with nature would be valuable, such as agro-ecological initiatives like the Timbaktu Collective in India, which works with farmers to promote local and climate-resilient farming practices (Nagendra, 2018).

Thirdly, the use of imported provisioning services increased along the urbanization gradient, increasing the distance from nature, which could weaken human connections with nature. This could also encourage exploitation, as the impacts of overconsumption are not directly visible when they are displaced to a location further away. This could erode local institutions that are often in place to prevent overexploitation. The scale at which these issues are addressed is often regional or global, but it is important that responsible consumption be encouraged and connections with nature reinforced at local scales, irrespective of the level of urbanization.

Finally, different sections of society can respond differently to urbanization. Land-use planning and resource management need to account for the sustainability challenges faced by different sections of society – such as resource degradation due to over-extraction by the relatively poor or due to overconsumption by the relatively affluent. Successful conservation intervention requires different policy interventions for these issues, at different scales. ES used by people need to be prioritized when people are dependent on ES for their survival. However, if use is high due to overconsumption, checks need to be implemented to reduce consumption.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to thank the Whitley Fund for Nature and the Wildlife Conservation Network for funding this study. We would also like to thank Sartaj Ghuman, Sanju, Thuktan, Kalzang Gurmet, and Tenzin Thilley for help with data collection. We would like to thank the anonymous reviewers for improving the manuscript. Thank you to Ajay Krishnan for proof-reading the manuscript.

The Whitley Fund for Nature and the Wildlife Conservation Network provided financial support for this study. Neither of the funding sources had any involvement in designing the study, analysing the data, or writing up the manuscript.

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