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Assessing community values to support mapping of ecosystem services in the Koshi river basin, Nepal

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Highlights

- Water scarcity due to decrease precipitation, increased demand and population
- Sustainable management needed to avoid water- and soil depletion
- Multilevel and -method info allows cross-validation for informed decision-making
- Local participation critical to know which ESs are relevant at local level
- Spatiotemporal context critical to secure future ESs and local livelihoods

Abstract: Human activities and climate change are key factors impacting ecosystem functions and its goods and services, which are important to the livelihoods of mountain communities. In Nepal, community based ecosystem management has been widely adopted as a way to secure local management and empowerment, but local knowledge, perceptions and values of ecosystem change and services are often ignored, and perhaps inadequately understood, in decision-making processes at district or national level. Our objective therefore was to develop a multi-method approach to support mapping of ecosystem services and assessing their local values. Local perceptions of ecosystem use, -change and values were identified using participatory mapping, key informant- and focus group discussions, and an extensive household survey carried out in the upstream Koshi River Basin. Results were cross-validated with scientific literature, statistics and remote sensing data. Key ecosystem services identified are water, agricultural produce, and various forest products, most of which show a declining trend. We demonstrate that the use of different methods and levels of input results in different and complementary types of insights and detail needed for balanced and informed decision-making regarding sustainable management of ESs to secure current and future livelihoods and ecosystem functioning.

Key words: Ecosystem services; mapping community value; local perceptions; participatory approach

Abbreviations¹

¹ Abbreviations used in this article: Ecosystem service(s) (ES(s)), Household (HH), Focus group discussion (FGD), Community Forest User Groups (CFUGs), Village development committees (VDCs)

1 Introduction

Ecosystems provide goods and services to society on many levels, which have different values for society – the most basic contribute to income, food, water and shelter (Marc et al., 2005). Ecosystem values are determined on different scales, from local scale to regional and national scale to the international and global scale, depending on their use and context (Paavola and Hubacek, 2013). Locally, ecosystems may provide resources for food, drinking- and irrigation water, and firewood, while part of these resources are enjoyed and shared at the regional scale if there is a sufficient supply of these (water, agricultural produce) or even the global scale in case of some specialty items shared on the global market. Ecosystems may also provide global services such as climate regulation and biodiversity protection, or provide a cultural function such as recreation and tourism (MEA, 2005). This paper concentrates mainly on local and regional values of those ecosystem goods and services identified by local users themselves as the most important to their livelihoods.

Qualifying and quantifying ecosystem goods and services, and integrating their local value with their market-, national- and global value helps both local users and national decision makers to make balanced and sustainable management choices considering the equality principle (e.g. Crossman et al., 2013; Paavola and Hubacek, 2013). Many developing countries including Nepal regulate much of their forestry and land management via a community based approach such as Community Forest User Groups (CFUGs), a system designed to open for active local participation, management, empowerment and mobilization (Kanel and Kandel, 2004). Although this approach has improved forest management in general, the community based system provides challenges of linking community forestry with livelihood promotion, good governance, and sustainable forest management (ibid). Also, most of the costs of local management are borne by the CFUGs themselves and received minimal government support, while many forest users are living in poverty. While community forests are managed according to operational plans prepared by CFUGs, and CFUGs can act as self-governing entities to generate, utilize and sell forest products, plans have to be approved by the District Forest Office and follow management regulations. This can limit or constrain complete self-governance of these local decision-making bodies, and community perceived values of ecosystem services (ESs) may not be streamlined into district or national level management or development plans.

ES mapping and valuation is of great importance especially for conservation purposes and for local development planning including sustainable ES dependent livelihoods (Willemen et al., 2013). These two goals however may conflict at times, and the same authors highlight the need for spatial methods to assess ES trade-offs, as well as the main challenges for conservation measures to contribute to both livelihood improvement and conservation gains. While ES maps can play a crucial role in understanding and managing the trade-offs in ecosystem service flows resulting from conservation strategies, the validation of such mapping is crucial. Many studies use secondary data to map ES or their values, and to avoid bad decision making based on oversimplified maps or lack of validated data, there is an urgent need to combine and verify data collected at different scales and from different sources (Crossman et al., 2013; Martínez-Harms and Balvanera, 2012).

The objective of this paper is to design a holistic approach for the identification of ESs and their local values and distribution, with a special interest in their relevance for livelihoods and consequences of

changing conditions. We address this objective through a detailed case study using multiple ES mapping, identification and valuation approaches, combining and validating information obtained at different scales: 1) managers and local decision makers' knowledge and perceptions from key informants (CFUG members and managers at district level), 2) local knowledge and perceptions collected through focus group discussions (FGDs), participatory mapping and ecosystem status and -use calendar creation, and an extensive household (HH) survey, and 3) scientific knowledge such as satellite data and literature analysis. The use of multiple approaches allows for integration of complementary information and/or for verification of information across methods. Our method does not intend to give greater geographic detail of ESs, which can be derived from available satellite data on land cover and is also addressed by others in this special issue. Instead it aims to combine and verify data (Crossman et al., 2013; Martínez-Harms and Balvanera, 2012) and to give greater contextual detail to support informed decision making at every level regarding ES use, management, as basis for adaptation and mitigation plans and as potential for e.g. Payment for Ecosystem Services schemes.

2 Material and methods

Setting for our case study is the Jhiggu Khola watershed in the Central Region of Nepal (figure 1). The watershed, with population of around 63000 and approximately 14000 HHs (CBS Nepal, 2012), is mostly rural and its land cover is made up mainly of forest and crop-land.

The importance and local valuation of ES was analysed using a combination of different levels of input (local and management level, scientific and district statistical information and data analysis), types of information (primary and secondary data) and tools (figure 2). The main aim and advantage of such multilevel input is the ability to cross validate information on ES use and highlight their spatiotemporal distribution. Cross-validation of different approaches is important as it may reveal 1) differences in perception of ES use and valuation across scales, 2) misconceptions of issues both at the local or management and decision-making level, which could misinform decision-making, and 3) generalization of multifaceted problems at the scientific level, thus identifying the complexity of problems to be dealt with.

There is great variety in use of ES typologies in the literature, with services, goods and benefits being defined differently and listed in different categories. While there may be a need for consistency and universally accepted typologies (see also discussion of this in Haines-Young and Potschin, 2009), we argue that typologies may differ per intended use in any given context. The use of ES typology per se however is considered advantageous as it points to the inter-dependencies between human well-being (livelihoods, development) and ecosystems (conservation and management), suggesting win-win solutions when sustainably managed, which resonate with policy makers, local users, and wider society. As this study is part of a larger project taking primarily a livelihood perspective, at each scale we document user and stakeholder defined ES and changes only. This has the advantage that we focus only on ES perceived as valuable and important at each level, but the disadvantage of missing out on services that are not directly obvious or of direct local importance.



Figure 1. Land use and river system in Jhiggu Khola watershed. The circled area indicates the Jhiggu Khola watershed and the black delineated areas indicate VDCs/Municipalities. The land use colouring shows that the watershed is made up primarily of cultivated land and forest. The inset upper left shows Kavrepalanchok district situated in Nepal, and the top middle inset shows Jhiggu Khola watershed within Kavrepalanchok district (Figure adapted from www.mofald.gov.np/districtmap/24Kavre).

Key informant discussions with district level authorities, using open ended questions, formed the basis of the locally perceived state and importance of ESs, and the degree of incorporation of community knowledge and perceived values in local development planning. The study included 7 key informants; the local development officer, presently acting as chief of the district government, the district soil conservation-, agriculture- and forest- officers, a former member of parliament, and a former village chairperson. FGDs followed the same set-up, with open ended questions regarding ES use, perceived status and importance and related issues in the local context, using participatory mapping techniques to guide these discussions. Open ended questions were tailored to the stakeholders, and did for example

not directly ask for “which ecosystem services do you identify and use?” but rather “what things in nature and the land around are important for you, for example for your livelihood, economy, health, or quality of life, and why?”

Many recent studies show the potential use of participatory mapping techniques for ES assessment (e.g. Raymond et al., 2009; Klain and Chan 2012; Brown, 2013; and Baral et al., 2014). Participatory mapping however is not geographically correct, and this technique was used primarily to provide context for discussion and visualize linkages between upstream and downstream locations and drivers of change. In the current case, detailed maps of forest and land-use areas already exist, and e.g. can indicate the detailed location of a forest, but the crux is that this forest does not necessarily provide all ES. Participatory mapping thus ensures that existing maps are cross-checked for their factual local ES function, and these participatory exercises also included the creation of calendars mapping the annual variations in availability and use of specific ESs, climate variables, and variations in HH size to cover the temporal aspects of variations. Finally, participatory mapping also played a role in including all FGD participants in the discussion, ensuring that the results reflect the perceptions of many and not of one spokesman only. Local perceptions were further quantified through a survey in 600 HH, covering the watershed’s 13 village development committees (VDCs) and its one municipality. The survey, developed in a multidisciplinary team, covered questions regarding HH, income sources, the importance of ES for livelihoods, their perceived change, drivers and management, in order to capture not only ES values but also their context. Covering 600 households across the watershed ensures representativeness of the results for ecosystem use and importance, and that certain ES stakeholders or groups are not disproportionately represented.

The relative importance of ES (high-medium-low) of course differs across households, and we therefore adopted a frequency distribution approach, counting how often an income source/ES was mentioned. To identify locally recognized ES (mostly water-, forest-, and land use resources) and their relative importance, we calculate (based on survey responses) 1) their respective importance to primary (high), secondary (medium) or tertiary (low) incomes, and 2) their respective impact on livelihoods in case of change. For calculations in table 1: when mentioned as important to primary incomes we counted the ES 3x, when important only to secondary incomes we counted the ES 2x, and when important only to tertiary incomes we counted it 1x. The resulting count was divided by 3 for the number of categories, resulting in a “weighed count” (table 1) for each ES; a combination of how often each was mentioned overall in the surveys and whether it was marked high, medium or low importance to as HH income. The importance of ES as based by their perceived impact of change on livelihood was assessed by simply adding the responses of positive and negative impacts, and by not counting “no impact” instances. Survey- and FGD ES results are presented in figure 3 in the form of a calendar to facilitate analysis and presentation of seasonal variation in (user defined) ES and their relation to the local climate. Local knowledge and perceptions of ecosystem and ES change were then compared with available statistical data for the area, secondary literature on status, change and impacts on the relevant ESs, and a detailed satellite image analysis on landscape change between 1990 and 2010 (for details on methodology for satellite image analysis see Shehzad et al., 2014).






Process	Tools for inputs and outputs	Input level, type and scale	
General problem definition	← past to present →	Key informants	Local input
			
Local problem definition and contextualization	← past to present →	Focus group discussions + Participatory mapping + ESS calendars	
			
Data collection, Local perceptions of current status and change	← past to present →	Household surveys	
			
Data collection, Recorded change, data comparison, verification	← past to present →	Statistics, satellite data (crops, landuse, water, population, etc.)	
			
Data generalization, projection	← past and present to future →	Impact analysis, Climate projections and impact projections	
			

Figure 2. This figure outlines the methodology including the processes, scale, data input type, tools and data output. Final communication of data to different levels is required for appropriate adaptation.

The final step, to place past and current ES use in context of projected changes, allows for a projection of ES value changes over time. While we touch upon the subject, a detailed projected impact analysis is beyond the scope of this article. However, the method is included in the figure as it is a logical and necessary next step for supporting informed decision-making.

3 Results and discussion

Results from Key informants, FGD, surveys and satellite image analysis are compared and discussed in context of available literature under each specific heading, from identification, importance and local value of ES, to recent and projected changes for ES and evaluation of the method.

3.1 Identification, local use and importance of ES

The remote sensing land cover analysis for 2010 finds that agricultural land accounts for 74% and forest for 26% of the watershed land cover. This relative importance of agriculture and forest was reflected in FGD and Key informant discussions on locally important ESs, which primarily identified provisioning

services related to incomes and livelihoods. An analysis of survey responses allows for quantification of the relative importance and value of ESs by 1) ranking them according to their overall importance in the watershed and 2) according to the impact of changes in ES on livelihoods (table 1).

Table 1. Relative value of ESs and their basis (forest area, agricultural land, barren land, forest condition/size) in number of responses and as percentage. ES are ranked according to ranked weighed count of importance and the impact on livelihood. Due to rounding, percentages do not always add up to 100%. Colouring in ES column same as described for section C and D in figure 3.

ES	Importance					Impact of change on livelihood				
	High	Medium	Low	Weighed	Relative	Negative	None	Positive	Weighed	Relative
Drinking water quantity	45 (96%)	2 (4%)	0	46,3	13	49 (72%)	4 (6%)	2 (22%)	51	10
Drinking water quality	29 (91%)	3 (9%)	0	31,0	9	37 (70%)	6 (11%)	10 (19%)	47	9
Irrigation water	27 (93%)	0	2 (7%)	27,7	8	43 (96%)	0	2 (4%)	45	9
Maize	21 (64%)	7 (21%)	5 (15%)	27,3	8	13 (29%)	5 (11%)	27 (60%)	40	8
Potato	22 (79%)	6 (21%)	0	26,0	7	22 (54%)	3 (7%)	16 (39%)	38	8
Fuelwood	19 (59%)	8 (25%)	5 (16%)	26,0	7	20 (49%)	7 (17%)	14 (34%)	34	7
Fodder	19 (63%)	9 (30%)	2 (7%)	25,7	7	23 (62%)	5 (13,5%)	9 (24%)	32	6
Rice	23 (89%)	3 (12%)	0	25,0	7	21 (54%)	3 (8%)	15 (39%)	36	7
Leaf litter	18 (64%)	6 (21%)	4 (14%)	23,3	7	16 (46%)	6 (17%)	13 (37%)	29	6
Other*	19 (79%)	2 (8%)	3 (13%)	21,3	6	12 (32%)	2 (5%)	23 (62%)	35	7
Vegetables	18 (78%)	2 (9%)	3 (13%)	20,3	6	15 (48%)	2 (7%)	14 (45%)	29	6
Forest area	11 (69%)	4 (25%)	1 (6%)	14,0	4	3 (13%)	5 (22%)	15 (65%)	18	4
Agricultural land	11 (92%)	1 (8%)	0	11,7	3	8 (44%)	1 (6%)	9 (50%)	17	3
Timber	7 (44%)	2 (13%)	7 (44%)	10,7	3	16 (59%)	6 (22%)	5 (19%)	21	4
Non-farm income	8 (67%)	2 (17%)	2 (17%)	10,0	3	3 (23%)	2 (15%)	8 (62%)	11	2
Livestock	6 (43%)	4 (29%)	4 (29%)	10,0	3	5 (33%)	2 (13%)	8 (53%)	13	3
Barren land	1 (50%)	0	1 (50%)	1,3	0	4 (57%)	1 (14%)	2 (29%)	6	1
Forest condition/size	0	0	0	0,0	0	0	0	0	0	0
Grand total				357,7	100				502	100

* Other: Mentioned twice or more in order of frequency: conservation and management, poaching, mis-use, less people collecting

The method used for weighing the importance and livelihood impact as based on the survey responses is but one approach. As highlighted by other authors (e.g. Dechazal et al., 2008), alternative approaches are possible especially where it comes to ranking the importance to the watershed in general. These alternatives include e.g. their relative land-cover, their accessibility or the absolute number of stakeholders using the respective ES – though the latter is obviously complicated by the need for statistics on that which goes beyond occupational use. Our case using the survey based ES ranking supports FGD and key informant findings that most important local ES are drinking and irrigation water, and secondly agriculture and forest resources. Our weighed ranking also matches well with the land cover statistics in the watershed. Water is an ES of utmost importance as it is essential both for agriculture, forestry and consumption. Drinking water quantity and quality are valued most, and changes in these ESs impact most on watershed livelihoods. The importance of water for agriculture is also highlighted in the survey results though its impacts on irrigated and rain-fed plots. A productivity calculation using the survey results for number and area of irrigated and rain-fed plots shows that rain-fed land delivers fewer harvests than irrigated land (1,97 vs 2,5 crop harvests per HH), with a total watershed production ratio of 44% for rain-fed and 56% for irrigated land.

The importance of agriculture and forest product collection is more mixed, with agriculture being perceived as slightly more important and valuable to livelihoods than forest products. Indeed, while agriculture is the single most important income in the watershed (85% HH sell crops as a source of income, and livestock is ranked second most frequent in 56% HH), forest ESs play an important role both for subsistence and trade, supporting livestock and agricultural activities, water regulation, and in landslide control. At the crop level, potatoes and rice are considered most important, followed by maize. Of the forest products, fuel-wood and fodder for livestock are most important. Although livestock is ranked as the second most important income source in the watershed involving 56% of HHs, it is valued very low in comparison to other ESs (table 1). The HH survey also reported on non-provisioning services: Soil regulating services of agro-ecosystems and forest, contributing to the quality of drinking water, also score high. Biodiversity, a supporting ES, is valued both in form of the variety of crops but also in a local preference for broadleaved forest which is perceived as having a better forest generation and better ES production (better quality fire wood, fodder and bedding for animals, and harbouring greater biodiversity) with a greater variety of tree species. Other ESs mentioned in FGDs and key informant meetings include regulating services such as landslide erosion and sediment control, and forest cover runoff and siltation control, while cultural services score lowest and they do not appear in the ranking, except perhaps masked within “non-farm income”.

Not all services are equally represented throughout the year. Figure 3 shows how ESs, including forest resources, and crop planting and harvesting, follow a seasonal pattern related with temperature and water availability but also with access rights and seasonal workload distribution. The calendar exercise also highlighted variations and combinations of important crops for rain-fed and irrigated land. Especially during the dry season, farmers may intercrop multiple crops at the same field and time.

Our results show that local information is extremely important and ESs cannot just be derived from land-cover data. The remote sensing data correspond well with other sources reporting on cropland covering around two-thirds of the watershed and forest covering around one third of the watershed (CBS Nepal, 2011; Schreier et al., 2006; Shrestha and Tuladhar, 1998), and water being the most important locally identified ES. Our FGD and survey approach however shows that land cover analyses cannot be used as a direct representation of local ESs.

Our ESs ranking and local value is consistent with earlier studies in the same watershed (Schreier et al., 2006). Water is of special importance, affecting health, agriculture and forest condition. Agricultural products are important both for HH use and the market, while forest ESs are important especially for HH use: non-timber forest products only make up 4% of the total contribution of forestry to the national economy (www.forestrynepal.org). Leaf litter typically is used for animal bedding, composting and fertilizer, while fodder collection (and grazing in the forest) has an important role in sustaining the great amount of livestock owned by more than half of the HHs surveyed in the watershed. Livestock provides milk, manure and labour (cattle and buffalo) and are used for meat for selling or HH food preparation (chickens, goats, pigs) or wool (FAO, 2008).

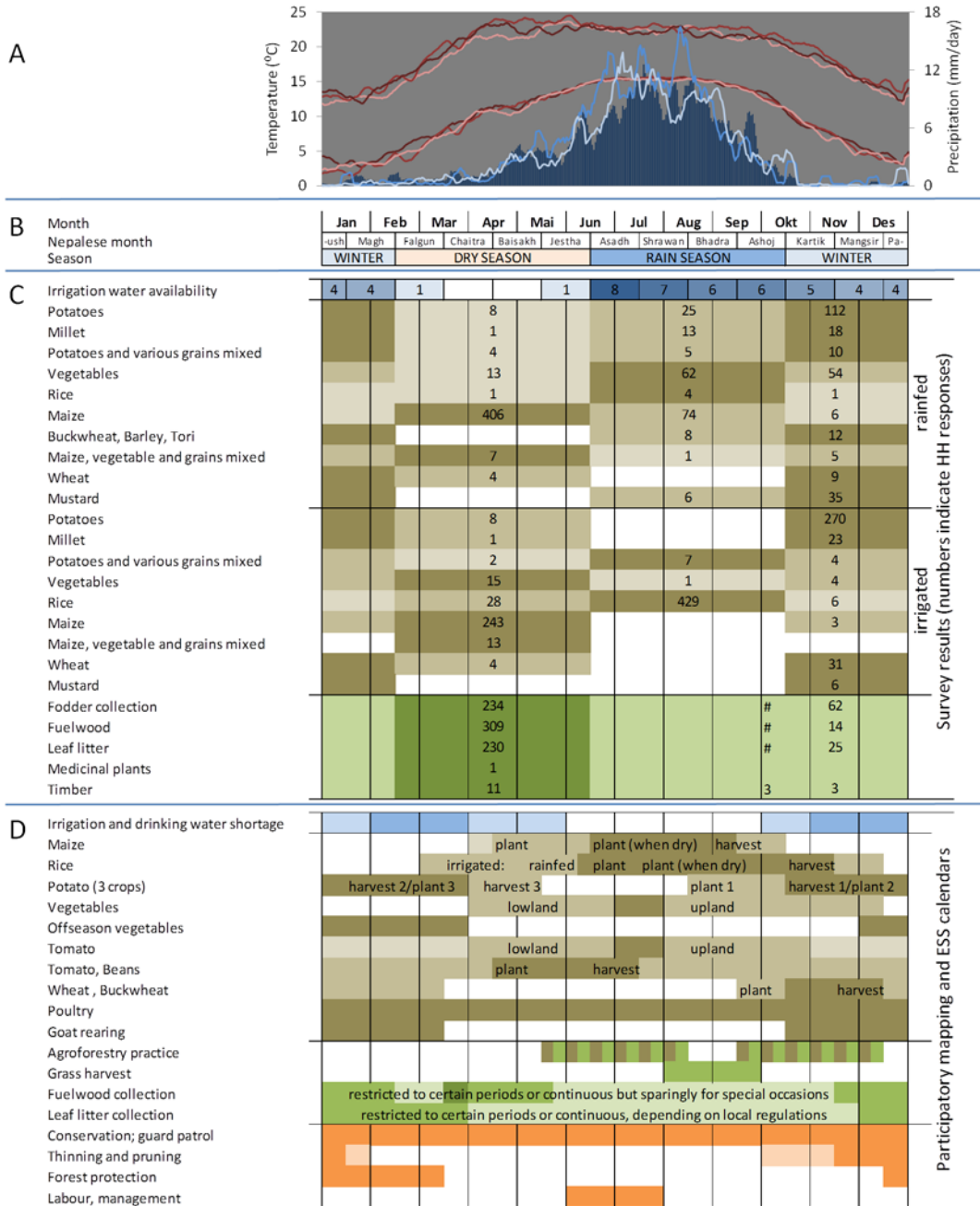


Figure 3. Climate and ES calendar for the watershed. Section A: maximum and minimum temperatures throughout the year averaged for 3 decades (light red: 1980-1990; middle red:1991-2000; dark red: 2000-2010). The same graph shows average daily precipitation averaged for 3 decades, with the light blue line for the 80s, the dark blue line for the 90s and the dark blue bars for 2000-2010. Section B: the months and seasons. Section C: Survey results indicating the number of HH replies for water availability, planting and harvesting periods for various crops and forest resource collection. Differences for irrigated and rain-fed agriculture are also indicated. Section D: Results from participatory calendar mapping. Details for planting, harvesting, and upland/downland or irrigated/rain-fed differences are indicated. For both sections C and D: Brown colours are related to agriculture, green colours to forestry, blue colours to water and orange colours to others. The darker the colour, the more intensive the use for that crop/product.

Crop calendars are a well-known tool to show seasonality in agricultural activities, but here (figure 3) we show how not only crops, but all ESs have a seasonal cycle, how they influence each other and how important the temporal aspect is in the value creation of the different activities. Different ESs provide income and have their value at different times of the year, and differences exist between upland and lowland locations and irrigated and rain-fed locations. Both the survey responses and the ES calendar indicate a continuous use of ESs throughout the year, but with different resources and crops being used at different times of the year. ES availability (especially forest resources and water) also depends on regulations, climate, and peoples' workload in agriculture as well as seasonal outmigration issues (e.g. Aase et al., 2009). Seasonal water availability for example impacts crops differently, as different crops have different water demand (Schreier et al., 2006), and many farmers already used this knowledge by substituting wheat with the less water demanding potato (see table 1, importance of potato). Water availability further depends on retention in the soil which is also associated to forest vegetation (e.g. Power, 2010), regulating services which make that water availability differs per location, forest and water source presence and elevations through the watershed – especially upstream locations experiencing many months of irrigation water shortages.

Locally identified ESs are mostly represented by how they affect human well-being (Marc et al., 2005) and while mostly covered by provisioning services, they also include supporting, regulating and cultural services (MEA, 2005). While the stated importance of biodiversity does not correspond well with the low ranking of forest condition and size (table 1), it does correspond with FGDs reporting on agroforestry, the use of different hybrid seeds and increased variety of crops, linking agriculture with biodiversity and further supporting local biodiversity. Landslides are one of the major problems in this watershed, especially during monsoon. FGDs highlighted that the forest cover around the watershed is instrumental in controlling landslide and siltation, although it was also pointed out that the forest type (mainly pine) is problematic, as it does not support regeneration and makes the soil more acidic. This opens up for Payment for Ecosystem Service schemes (PES), where linkages between upstream water shortages but management and land-slide control options and downstream water and land-slide prevention needs could be used to improve management of forest, land and water sources upstream.

3.2 Recent trends and reasons of change

Key informants reported that vegetables have become increasingly important. FGDs confirmed this and reported an increase in production from 1-2 crops to 3-4 crops per year over the last 20 years, attributing this not only to a shift from grains to vegetables, but also to improved hybrids and seeds. They also stressed the role and importance of the nearby market in this, reporting that around 90% of the vegetables produced in the watershed are sold in Kathmandu. FGDs also detailed that new seeds are more susceptible to both old and new pests and diseases and drought, and that the increased demand has led to increased need and of chemical fertilizer and pesticides which in turn affect drinking water quality and contribute to soil degradation. FGDs further reported on the shortage and unsustainable use of water in the watershed and its risks to cash cropping, how current tree species are inappropriate for fodder, fuel-wood and compost, and how the distribution and planting of trees is detrimental for water conservation and erosion.

Survey results on the perceived trends of change for the identified ESs quantify these findings, and confirm the reported changes. There is large agreement between the respondents that water quantity and quality decreased the most, followed by forest products. Soil is not mentioned specifically, but leaf litter, agricultural land and forest condition and area may be indicators for the degradation of soil. Respondents disagree on changes in crops, including rice and vegetables, which may depend on respondents referring to irrigated or rain-fed land. Non-farm income has increased substantially due to market changes (table 2).

Table 2. Perceived trends and perceived reasons for change in ESs and their basis (forest area, agricultural land, barren land, forest condition /size), quantified in number of survey responses and as percentage. ES are ranked according to the overall perceived direction of change. Due to rounding, percentages do not always add up to 100%. Colouring in ES column same as described for section C and D in figure 3.

ES	Perceived trend				Perceived reason for change							
	Decreasing	No change	Increasing	Overall direction	Forest	Fertilizer Pesticide	Seed quality	Population increase	Rainfall	Profitability of Market	Other	Total
Irrigation water	407 (80%)	83 (16%)	16 (3%)	-391	40	10	1	94	307	1	34	487
Drinking water quantity	410 (70%)	110 (19%)	66 (11%)	-344	61	12	2	129	328	3	71	606
Drinking water quality	289 (50%)	234 (40%)	61 (10%)	-228	30	10	1	94	199	1	69	404
Fuelwood	293 (55%)	134 (25%)	103 (19%)	-190	178			110	73	3	67	431
Fodder	264 (50%)	158 (30%)	107 (20%)	-157	168	2		98	79	2	50	399
Leaf litter	250 (47%)	162 (31%)	119 (22%)	-131	170			94	70	2	52	388
Timber	205 (50%)	120 (30%)	82 (20%)	-123	136		1	73	70	2	43	325
Agricultural land	121 (31%)	219 (56%)	50 (13%)	-71	12	22	20	43	43	11	38	189
Rice	205 (43%)	120 (25%)	156 (32%)	-49	1	156	157	3	129	11	30	487
Potato	196 (42%)	109 (23%)	163 (35%)	-33		162	151	3	143	22	31	512
Vegetables	156 (38%)	128 (31%)	130 (31%)	-26	1	115	107	3	103	22	31	382
Forest area	130 (33%)	165 (41%)	104 (26%)	-26	88	6	2	47	40		48	231
Maize	212 (39%)	142 (26%)	197 (36%)	-15	1	167	160	1	145	11	32	517
Livestock	75 (28%)	128 (47%)	69 (25%)	-6	2	15	27	1	33	42	21	141
Forest condition/size	3 (21%)	8 (57%)	3 (21%)	0		1			3		2	6
Barren land	34 (18%)	121 (63%)	37 (19%)	3	4	1	1	18	15		24	63
Other*	155 (35%)	106 (24%)	180 (41%)	25	148	1		62	53	1	61	326
Non-farm income	24 (9%)	124 (49%)	107 (42%)	83	1	7	6	6	4	87	25	136
Grand total	3429	2371	1750 (23%)	-1679	1041	687	636	879	1837	221	729	6030
%					17,3	11,4	10,5	14,6	30,5	3,7	12,1	100

* Other: Mentioned twice or more in order of frequency: conservation and management, poaching, mis-use, less people collecting

Table 2 indicates that according to local observations, ESs are much affected by external factors. Rainfall is the single most indicated driver of change (30,5%). Figure 3A shows how precipitation in the watershed indeed has decreased over the last 3 decades, especially during monsoon and post monsoon, while temperature especially in winter and spring has increased. These findings are consistent with FGD and key informant reports on increased water scarcity, attributed to the increase both in population and land use intensity, in addition to a perceived and recorded decrease in precipitation (figure 3). Moreover, detailed reports (both from survey and participatory mapping) on number and location of water-sources and duration of water availability in these indicates differences between upstream and downstream locations: draught is more common upstream, and more water is available for longer periods but from fewer sources downstream. FGDs report that the high water demand and cropping intensity has led to people drilling wells to use the ever decreasing ground water, and the river is now visible only as an above ground stream during the wet season, though its subsurface water flow persists during the dry season.

Other important perceived reasons for change include the forest (especially in relation to forest produce), a general population increase (especially in relation to water and forest product availability) and fertilizer/pesticide and seed quality (especially in relation to agriculture). FGDs too point at the pine forest upstream, planted in a major reforestation program in the 60's-70's (Nepal-Australia Forestry Program), as a reason for the decrease of water availability. Satellite image comparison for the period 1990 to 2010 moreover singles out land-use change, showing that forest cover (various species and density) decreased from around 27% in 1990 to 26% in 2010, a change of 117 hectares, lost largely to extending agricultural land. Cropland increased from 72% in 1990 to 74% in 2010, (a net gain of 164 hectares) and a bare land decrease with 45 hectares in favour of cropland. When asked about suggestions to improve the situation, most responses related to 1) improving water availability through construction of a conservation pond (24%), deep boring (26%) and improve management and sustainable use (26%), 2) improving forest produce and management, and 3) introducing drip irrigation or planting crops with low water demand. The current management system is not perceived as having any impact on the availability of water.

Literature confirms most of our findings regarding local ES use and value changes in the Jhiggu Khola watershed. Schreier et al. (2006) found that farmland is under great pressure of increased cropping intensity, increased water use for irrigation for several decades. Also the increased use of pesticides and fertilizers and a decreased water quality as a result of that, and the unsustainability of these management practices especially on irrigated plots is consistent with earlier findings (ibid.), and population is indeed on the rise (CBS Nepal, 2011). Agriculture in the watershed shifted from unsustainable cultivation of food grains, insufficient to sustain HHs, to off-season vegetables, with the watershed's close proximity to the Kathmandu market being a key driver for this value change (Nagpal, 1999, Schreier et al., 2006). This shift led to a near doubling of cropping intensity between 1995 and 2000 (Schreier et al., 2006), and production has only increased since with national statistics reporting a gross national value increase for the combined agriculture and forestry industry with 44% between 2000 and 2012 (CBS Nepal, 2011; table 2.3). Of those products relevant in the watershed, cash crops such as potatoes and vegetables have increased with 138% for each. As discussed by Schreier et al. (2006), this increased production is likely related to a "land grab" following the Private Forest Nationalization Act (1957) which placed all non-cultivated land (forest and rangeland) under the jurisdiction of the Forestry Department, and likely accelerated large scale forest conversions to agricultural land, as land with trees on it could not be registered as private land.

An earlier participatory study in the same watershed finds that the forest is under great pressure due to an increasing demand of the growing population (Shrestha and Tuladhar, 1998). The same study supports our FGD results on how the current chir-pine species impede soil water uptake by creating a dense and impenetrable cover of pine needles, how they acidify the soil, and that pine does not hold much value in terms of fodder or leaf litter and compost. Also, with a reduction in the area of grazing lands, more animals are stall fed and pressures on forests for animal fodder continues to grow.

While a detailed analysis of the drivers of change is not in the scope of this paper, it is clear that change comes from many drivers, which continuously affect values of ESs, both in positive and negative directions. Water availability affects agricultural production and forest productivity alike, forest and soil

affect water quality (Power, 2010) and local land use and climate and changes therein are thus an important factor affecting ES values. Additionally, the market plays a large role in local valuation of natural resources and ES. Our results and the literature make clear that current ESs are challenged by an increasing focus on income rather than reinvesting earnings in the land and loss of traditional farming techniques (Nagpal, 1999). To deal with such value changes it is important to understand the reasons behind these changes, and to address their combined effects holistically. While detailed studies are necessary to establish linkages between cause and effect, local perceptions are important as they give an indication and sometimes local and easy to explain reasons why a certain change in ESs occurs.

3.3 Projections of ES value change

Water availability in the watershed decreases due to various reasons, most notably due to decreased precipitation and increased water demand for intensive land use and increased population. Market demand is one of the main driving forces for the current unsustainable use of water, forest and agricultural land. Future climate change may hold further challenges to water availability and changes in temperature may affect agricultural opportunities. Indeed, Joshi et al. (2011) state that climate variables have an important impact on crop growth and yield and that climate change may positively affect some and adversely affect other crops. Others also associate ongoing climate change in the Himalayas with changes in local ecosystems (Shrestha et al., 2012), and point out that the growing season has increased on average, but that there is considerable spatial and seasonal variation. For the greater Himalaya region, climate scenarios project increasing temperatures and, depending on the region, increasing precipitation especially during the monsoon period (e.g. Immerzeel, 2008). However, with a region as geographically diverse as the Himalayas, downscaled scenarios are of utmost importance. For Jhiggu Khola watershed, large-scale projections are confirmed by preliminary results using detailed downscaled projections (van Oort, forthcoming).

Although river basins that depend on monsoon rains and glacier melt will continue to sustain the increasing water demands expected in these areas (Immerzeel et al., 2013), local experience shows that the current combination of land use and water availability is not sustainable. Moreover, many hill sites depend on rain rather than melt-water to support their agriculture and water needs. To enable informed decisions, current ES values thus need to be assessed against the challenges of decreased water availability, especially outside the monsoon season, and increased run-off and erosion problems during the monsoon, which both will have negative consequences for the region's agriculture. Increased temperatures may balance some of these consequences by allowing for growing different crops and tree-line changes at higher elevations (Xu et al., 2009), given that enough water is available at these heights. The increased prevalence of new pests and diseases affecting biodiversity and endemic species (ibid.) may affect agriculture and lead to further pesticide use, affecting water quality. Forest produce much depends on standing trees and regeneration, which too may feel the impacts of new species, pests and diseases. Indeed, FGDs reported infestations of new plant species impeding regeneration of broadleaf trees.

Changes in ES availability and values not only depend on a changing climate at the local level, but also at the global level. Global climate change and population increase is likely to trigger a food crisis, which can

be expected to have important impacts on both global and local food markets and affect local agricultural decisions (e.g. Shively et al., 2011; Xu et al., 2009). Also, forest may become increasingly important in climate change mitigation. Current and future ES values and the trade-offs that may occur between provisioning and other services or disservices need to be placed in a larger spatiotemporal perspective, and include a perspective of future climate-, ecologic- and socio-economic changes and reversibility in order to make balanced decisions for sustainable development (Power, 2010).

3.4 Evaluation of the local valuation and multi-method approach

Current and future climate, linked with continued intensive agriculture aimed at improving livelihoods has large consequences for the availability and value of ES. However, unsustainable use rather than climate change appears to be the immediate threat to livelihoods in this region. The watershed appears to be trapped in a tragedy of the commons, with a market driven demand for produce driving unsustainable land-use with increasing harvests leading to soil degradation and water shortage. To secure sustainable livelihoods and avoid further unsustainable water- and land use and soil depletion, informed management and development decisions in addition to local involvement and engagement are needed to enable sustainable solutions. Our approach adds local value and context to the two-pronged challenge on the food-production front: increasing the production at a much rapid rate than before to cope with the demands of the ever-increasing population, and to do that sustainably (Nair, 2014). Key points from district officials revealed that despite being crucial for development planning, community ES values and knowledge of ecosystem management has not been incorporated in development plans. Decision-making is ultimately in hands of different sectorial district officers, and input from different sources and with a different degree of detail is essential for informed and balanced decision-making regarding ecosystem conservation, livelihoods and development. A common understanding of climate change needs to be developed through regional and local-scale research so that mitigation and adaptation strategies can be identified and implemented, and challenges can only be addressed through increased collaboration between and incorporation of local knowledge, scientific research and policy making (Xu et al., 2009).

The combination of local perceptions and knowledge, insights from different district management levels, and scientific input allows for a holistic, contextual analysis of locally relevant ESs and their spatiotemporal variations in presence and value (Seppelt et al., 2011). While literature gives a comprehensive overview of all services related to specific ecosystems, local knowledge is essential as it typically results in a very different, and more locally relevant, list of services to consider (Fagerholm et al., 2012; Malinga et al., 2013). This ensures that science, policy and management address relevant user needs, improve mutual understanding across levels, and invite to local engagement necessary to support plans and management action. Including local values, knowledge and perceptions is also important because local impacts may be much more complex than linear assumptions of scientific analysis, and reveal local context, misconceptions, capacities or incapacity to change that politics and management may not be aware of. Scientific information is important as a validation tool to corroborate perceptions, reveal misconceptions and stimulate new insights, thinking and actions. The HH surveys quantify ES use, value, status and perceptions of change at the local level, and fits with current efforts for cross comparison of methods on a global level as the survey is very similar in set-up to the blueprint

as suggested by Crossman et al. (2013), but extended with an assessment and general valuation of ESs important to livelihood. Local participatory approaches such as mapping identify spatial relationships, limitations for extraction or use and upstream-downstream linkages with other communities, while ES calendars add a dynamic temporal component that places services and their associated values in context of the local climate. The visualization of these linkages also facilitates analysis of climatic change impacts on ESs, and the associated changing values for local livelihoods and beyond (e.g. Burkhard et al., 2012).

When combined with remote sensing, valuation of ES obtained from e.g. HH surveys can easily be used to create spatial maps of identified ES values. Interviews and surveys can be used to identify and quantify the relative value of certain ecosystem or land-cover types for certain times of the year, while using land-cover maps in participatory mapping exercises can identify which areas actually are available, accessible and in use/demand for the identified ESs, thus leading to “informed land-use maps” (see e.g. Burkhard et al., 2012; Willemen et al., 2012). A colour scale can be used to indicate the relative (local) importance and value of areas to livelihoods as identified either by ranking or using related economic indicators for the services. This type of visualization may also be extended to include regional or globally important linkages to the ecosystem, using statistics to indicate how many people are implicated. The resulting maps may moreover be presented for different times of year covering changes in availability or accessibility of ES, or superimposed with seasonal downscaled climate change projections to facilitate identification of high impact risk areas. This may be linked with risk zones related to land use change in border areas between forest and agricultural land. Participatory mapping, where local knowledge and management is included, is also of importance to validate these resulting of maps. This paper has not produced such maps due to the absence of precise downscaled climate projections for the region, but ongoing (HICAP-project) work may bring resolve.

Using criteria and ranking methods are important tools that facilitate (multi-criteria) decision making processes (Ananda and Herath, 2009; Seppelt et al., 2011). Because there are many approaches and conflicting interests, it is important to be critical when selecting the information sources and describe the ranking methods and criteria well. While the literature increasingly stresses the importance of stakeholder engagement, selection of stakeholders can skew results. Thus, in line with Seppelt et al. (2011), we suggest that stakeholder involvement is one in a set of different approaches to gain a wider picture and aid in ground-truthing of scientific results and decision-maker impressions. Our approach combines and expands on the blue-print methodologies proposed by Seppelt et al. (2011) and Crossman et al (2013); it uses a similar survey as suggested by the latter, and ensures a holistic combination of different types of information as suggested by the former. Moreover, it includes more diverse sources, including existing literature, an in-depth survey, various experts (local, political, scientific) and also covers the seasonal aspects (ES calendars) and local linkages (participatory maps).

Ultimately, the value of an ES is a snapshot in time and place, changing with the demand for the service. The current discussion on valuation of ES focused on the local and regional level, but local ES valuation may be very different when globally important services such as climate regulation (carbon sequestration) or recreation are taken into account (e.g. de Groot et al., 2012). To ensure valuation based on both a global context and commitments, our methods must be integrated with results accounting for the global values of ES, such as on-going work of TEEB (www.teebweb.org). Our objective however was to design a

multi-method approach to identify ESs, their local values and spatial relationships, with a special interest in their relevance for livelihoods impacts of climate change. The combination of methods answers some of the main questions related to how to move forward with mapping ES, to secure proper identification of multiple and locally relevant ESs with a focus on practical application (see for details regarding this issue also www.esp-mapping.net). The combination of local importance with global importance will aid informed decision-making regarding local ES.

The combination of methods also reveals the need for further cause-effect studies to validate local perceptions such as pine forest affecting water availability, and decreased water availability being linked mostly to reduced precipitation rather than intensification of land use and increasing population. These studies are needed to ensure correct management decisions, made not only on local perceptions and relevance, but also on a correct scientific basis. Programs aiming for solutions on how to increase water availability for irrigation may help food production, but may also encourage and continue the current unsustainable land use. With climate change as an additional threat on top of the current unsustainable land-use, research may instead need to focus on sustainable land use and management rather than water and livelihood improvements or alternative water sources to support livelihoods in the prospect of climate change.

4 Conclusions

ESs are vital for livelihoods in many regions, especially in rural areas such as the Himalayas, where people depend on agriculture and forest produce for sustenance and income. In a detailed case study, we reveal locally important ESs, and show how water availability in the Jhiggu Khola watershed in the Koshi river basin in Nepal is decreasing, most notably due to decreased precipitation, increased water demand due to market driven intensive land use and changed crops, and an increased population. Key informant discussions with district level authorities revealed that local knowledge and values of ESs are rarely incorporated in local development planning. However, local participation, input and definition on ES use is critical to understand which ESs are relevant for livelihoods, sustenance and well-being, and generates engagement to support sustainable change. We analysed the importance and value of different ESs at the local level, their current status and trends, and placed them in a spatiotemporal context of climate change, upstream-downstream linkages, and economic drivers. We used a multilevel approach combining participatory methods and inputs from local stakeholders with district level key informant discussions, statistics, scientific literature and watershed level remote sensing land-use change analysis, which allowed for cross-validation of perceptions and assumptions at all levels, and strengthened the local level ES valuation.

Our findings are consistent with earlier suggestions of already decennia of unsustainable land-use with increased cropping intensities and increased use of water demanding crops, thus challenging sustained provision of ES in terms of water, agricultural and forest produce. These challenges will only increase with super-imposed projected changes of more intense rainfall during monsoon and a decreased rainfall during the off-monsoon season. Our combined results underline the importance of introducing sustainable management of ESs to secure sustainable livelihoods and to avoid further unsustainable water- and land use and soil depletion. We demonstrate that the use of different methods and levels of

input results in different, complementary types of insights and detail needed for balanced and informed decision-making. The approach is multidisciplinary in set-up, fits with proposed blueprints for best practices for ES mapping and allows for further analysis of multi-driver impacts and mapping of consequential changes in ES values to support local development and adaptation strategies.

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