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Impact of land use land cover change on ecosystem services: a comparative analysis on observed data and people's perception in Inle Lake, Myanmar

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Abstract

Background: A healthy wetland provides a range of goods and services contributing to human wellbeing. Inle Lake, the first Biosphere Reserve in Myanmar, has been supporting the local inhabitants with ecosystem services (ES) including habitat for a wide range of biodiversity. In the recent years, influenced by land use land cover change (LULCC), the lake has witnessed changes with altered flow of ES, affecting human well-being. Communities' perceptions are often undermined, when it comes to research LULCC. We analyzed LULCC change data from 1989–2000 to 2000–2014 using Landsat imageries. This was then linked to ES considering dependency through qualitative data collated from participatory rural appraisal tools and structured questionnaires focusing on people's perception to understand the LULCC dynamics and its implication.

Results: During 25 years (1989–2014), there has been a sharp reduction of 164 km^2 perennial wetland area in the Inle Lake, which is 4.2-fold higher in 2014 to that of 1989. Similarly, forest area has been declined by 92 km^2 (8.56%) in last 25 years. Contrary to this, cropland area showed an increment of 60.67% in 2000 and 64.53% in the year 2014 alone giving a total increase by 268 km^2 over the last 25 years and an expansion of 40 km^2 seasonal freshwater area were observed showing periodic increment over the time. Communities from the three study areas, namely, Kyaung Taung, Zay Gon and Kyar Taw are found to have high dependence in their surrounding ecosystems. These villages utilizes 17 ES from forest ecosystem, 13 from agro-ecosystem, 10 from seasonal and 4 from perennial water body for their livelihood respectively. Around 93% of the respondents opined that forest ecosystem has decreased over the last 10 years. Around 40% of the respondents reflected an increase in area used for cropland; 43% conversely perceived a declination. About 63% of the respondents perceived such changes have brought huge reduction in availability of freshwater ES. A significant number of respondents (92%) perceived an enormous reduction in seasonal water body during the dry season.

Conclusion: Observed decreasing trends in forest and perennial wetland areas were consistent with people's perceived changes. Communities associate loss of forest and wetland area with reduced availability of ES as well as degraded health of the lake.

Keywords: Ecosystems, Land use land cover change, Ecosystem services, Communities' perception, Wetland

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Introduction

A home to 40% of the world's species and 12% of all animal species (Mitsch and Gosselink 2000), wetlands cover around 6% of the world's land area (Zedler and Kercher 2005) of which the largest area (31.8%) is in Asia (Davidson et al. 2018). The wetland provides a wide array of provisioning, supporting, cultural and regulating services contributing to human wellbeing (Lamsal et al. 2015; Sharma et al. 2015; Chaudhary et al. 2016, 2017). Converting such benefits in economic terms, 12.8 million km^2 of the existing global wetland could yield 70 billion United States Dollar (USD, Schuijt and Brander 2004). The recent estimation for the total economic value of 63,000 km^2 of global wetland, a fraction of the total, revealed to be 3.4 billion USD per year (TEEB 2010). However, most of the wetlands across the globe are under stresses due to various drivers of change, including the land use land cover change (LULCC). Since 1900 AD, the wetland lost 64–71% of its original area and was faster for inland than coastal natural wetlands (Davidson 2014). As evident from the recent studies, the LULCC is one of the five major drivers of change for wetlands in Asia (Romshoo and Rashid 2014; Zorrilla-Miras et al. 2014; Chettri and Sharma 2016). As a result, wetland degradation and its conservation have been a subject of global concern (Gopal 2013; Reis et al. 2017; Davidson et al. 2018).

Inle Lake, the first Biosphere Reserve identified by the Man and the Biosphere Reserve Programme of the United Nations Organization for Education, Science and Culture (UNESCO) in 2015, is known among the global 200 ecoregions (Olson and Dinerstein 1998). With its 1.5 million years history of formation (Bertrand and Rangin 2003), the Inle Lake is lying at an average 884 m above mean sea level with high ecological significance (Su and Jassby 2000; Turner et al. 2000; Butkus and Myint 2001; Akaishi et al. 2006; Okamoto 2012). It provides numerous tangible and intangible ecosystem services (ES) to the local communities (Ma 1996). The lake regulates flow and supports natural water filtration, providing fresh water as one of the provisioning services to downstream (Thaw 1998) and is a major source of hydroelectric power for southern Myanmar (Su and Jassby 2000).

Designated as one of the freshwater biodiversity hotspot, Inle Lake is also habitat for numerous globally significant species (Annandale 1918; Roberts 1986; Ma 1996; Kottelat and Witte 1999; Groombridge and Jenkins 1998; Platt and Rainwater 2004; Lwin and Sharma 2012). It is the home for numerous threatened species like White-rumped vulture (*Gyps bengalensis*), Greater spotted eagle (*Clanga clanga*), Pallid harrier (*Circus macrourus*), Bare's pochard (*Aythya baeri*), Sarus crane (*Grus antigone*), and Ferruginous pochard (*Aythya nyroca*, Gyi et al. 2011). The lake is also an important nesting and breeding ground for amphibians and fishes (Ma 1967; Thant 1968; Kottelat 1986). More interestingly the lake is famous for floating garden or hydroponics cultivation (Myint and Maung 2000; Akaishi et al. 2006; Than 2007). The garden in the lake is a good source of vegetables and is an important tourist destinations in Myanmar (MoHT 2013). Considering the significance, the government supported tourism policy of 1996 has recognized Inle Lake as a major tourist hub (Butkus and Myint 2001; MoHT 2013). There is high number of tourists visiting lake, contributing to local economy (Ingelmo 2013; Munz and Molstad 2012; ICIMOD and MoNREC 2017).

Despite of being global significance, the lake and its catchment have undergone series of land use transformation over the years impacting its health (Lwin and Sharma 2012; Htwe et al. 2015). Deforestation in the mountains due to agricultural expansion and shifting cultivation, expansion of floating garden within the lake, sedimentation load and change in the water quality are some of the factors affecting the lake (Sidle et al. 2007). Those drivers have not only reduced the size of the lake, but have also affected ecosystem health and flow of ES, the major source of livelihood of the people.

In the recent global trend, understanding the linkages between ES with human wellbeing are emerging and also becoming a priority research area (Cardinale et al. 2011; Castro et al. 2014; Chaudhary et al. 2017; Ding et al. 2017; Omrani et al. 2017; Kandel et al. 2018). The concept of ES has been considered as products of coupled and nested social–ecological systems and emphasized to be measured in the complex context of those socio-ecological systems (Balvanera et al. 2006; Fisher et al. 2009; MA 2005; Mace et al. 2011; Bateman et al. 2013; Reyers et al. 2013; Scholes et al. 2013). However, the existing literature has limited integration with the broader social science literature about people's choices and behavior (Bryan et al. 2010; Milner-Gulland 2012). In response, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) endorsed an ES approach that explicitly recognizes the benefits people gain from nature building support for sustainable development goals (de Groot et al. 2010; Diaz et al. 2015; Schmalzbauer and Visbeck 2017; Diaz et al. 2018). Therefore, assessments and sustainable management of ES require an understanding of both supply and demand considering the qualities, quantities, spatial scales and dynamics forming a bridge between ecological and social systems (Nahlik et al. 2012). So far, researchers in the Inle Lake have been generating knowledge in a sectorial approach, considering mainly biodiversity, LULCC and sedimentations to name a few. The understanding of drivers and its impacts on ES and the implication for human wellbeing has not been explored. This study is an attempt to bridge gaps between social and ecological understanding. To justify the above context, following three questions were developed and the research was oriented to answer following questions.

A. How LULCC (temporal and spatial) has changed over the period in the study area?
B. What are the states of major ecosystems in the given study area and how the local people are dependent on these ecosystems?
C. What are the people's perception in terms of the LULCC and its impact on the ES they are depended on?

Materials and methods

Study area

Inle Lake, situated on the Shan plateau of Myanmar, is part of the Shwenyaung rift valley, nourished by surrounded by catchment areas (Ma 1996; Su and Jassby 2000). Its immediate catchment is inhabited by about 200 villages (Butkus and Myint 2001) that serve as watershed for Nyaung Shwe Township with various ES (Akaishi et al. 2006; Lwin and Sharma 2012). The study was carried out in and the surrounding areas of the Inle Lake (Fig. 1). Three representative villages—namely, Kyaung Taung, Zay Gon and Kyar Taw were selected on the basis of origin of watershed and level of local community's livelihood dependence on Inle Lake. The

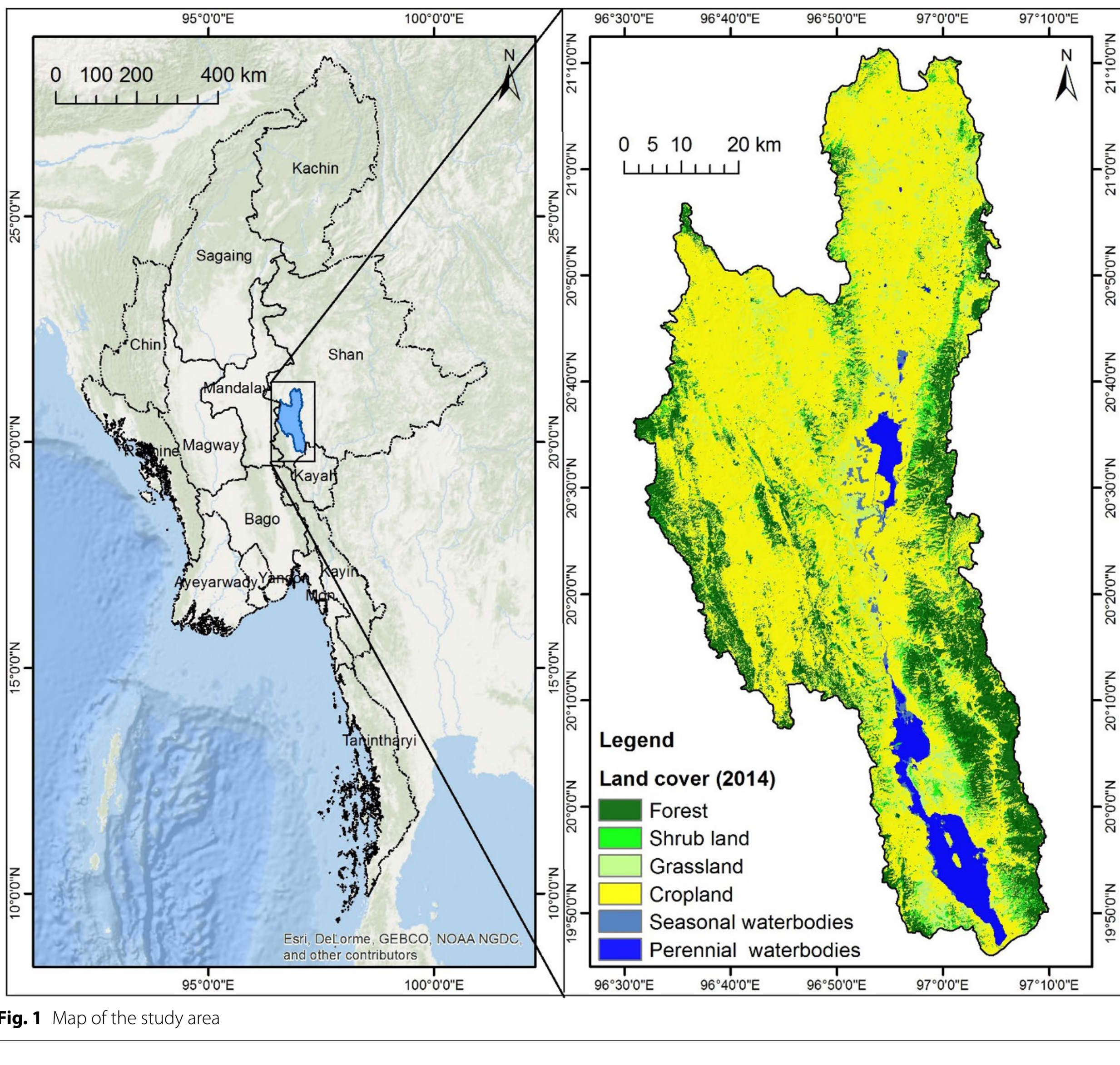

Fig. 1 Map of the study area

Kyaung Taung represents upstream catchment of the watershed and around 186 households inhibit in this area. Local communities in this village depend more on agricultural farming and livestock rearing. Rain-fed farming is more prominent due to lack of irrigation facility. Zay Gon, also called as market area, is a middle stream comprising 168 households. It is a tradeoff zone where number of ES brought from Kyaung Taung village and Kyar Taw village are traded. Similarly, Kyar Taw, famous as floating garden represents downstream of the study area and consists of 173 households. These floating gardens have a unique feature called hydroponic cultivation which was introduced in the early 1960s (Sidle et al. 2007). The overall conceptual framework used in this study is presented in Fig. 2 along with the detail in the following section.

Land use land cover change analysis

To identify the spatio-temporal changes of Inle Lake over a period of 25 years, LULCC analysis was undertaken. For the analysis, we acquired medium spatial resolution landsat thematic mapper (TM) of 1989 and 2000; and Landsat 8 of 2014. A classification scheme was used with six major land classes such as forest, shrubland, grassland, cropland, seasonal and perennial water bodies. The Thematic Mapper (TM), and Landsat 8 images were rectified into Universal Transverse Mercator (UTM) Zone 47. After rectifying, eCognition developer software was used for OBIA (a methodological framework for machine-based interpretation of complex classes using both spectral and spatial information (Lang et al. 2011). The six land cover types were classified using a multiresolution segmentation algorithm which consecutively merged pixels by identifying image objects of one pixel and merging them with neighbours using relative homogeneity criteria (Blaschke and Hay 2001). A land water mask was created during class modelling using band ratio and texture information based on spectral values and vegetation indices like the Normalized Difference Vegetation Index (NDVI). An NDVI image was created in a pre-processing stage using customized features: $NDVI = (RED - IR)/(RED + IR)$. The land and water mask was created using the formula $IR/Green * 100$. The image objects were labeled according to attributes such as NDVI, land water mask, layer value, and color, and relative position to other objects, using user-defined rules. Objects with an area smaller than the defined minimum mapping unit were merged with other objects. The classified land cover map was then exported to a raster file format for further analysis. To validate the accuracy of the maps, both field sampling and references through high resolution map were used.

Participatory approach and tools

We used a few participatory rural appraisal (PRA) tools such as focus group discussion (FGD), resource mapping, transect walk along with a structured qualitative survey using pre-set questionnaire to understand the people's dependency on the major ecosystems and their ES. The major ES listed were further categorized into four groups following MA (2005). The collected qualitative data were then used to compare with LULCC maps.

Household survey

We adopted an 'Ecosystem Services Cascade' framework that enabled the study to rationalize importance and significance of ES to human wellbeing. As explained by MA (2005) and Costanza et al. (1997), we considered the tangible and intangible benefits provided by an ecosystem as provisioning, regulating, supporting and cultural services that people derived from four ecosystems mainly forest, agro-ecosystem, seasonal and perennial water bodies. Because of the seasonal variation affecting the water bodies, we classified rain fed water bodies into seasonal and perennial water bodies. Seasonal rain influencing fresh water bodies like inundation are considered as seasonal water bodies, excluding seasonal influences are considered as perennial water bodies. Survey questions mainly focused on (i) dependency on ES by communities for their livelihood, (ii) community's perception on state of LULCC and ES and (iii) long term changes over the flow of goods and services derived from these four ecosystems.

A questionnaire was designed following Chaudhary et al. (2017) with some adjustment for the local context. Systemic stratified sampling (SSS) approach was applied to conduct household survey. We divided the study sites into three strata as explained in the study area as upstream, middle stream and downstream sites. The SSS approach was used in such a way that selection of first household from sample list is at random and then every kth household in the sample list is selected using $k = N/n$, where N is total households in the study site and $n =$ sample household. For example, if a 1st household on site is chosen, the next household would be 3rd household in the study area. Out of 527 households in three study sites, we selected 33% for household survey, where $N =$ 178. Description of the sampling area for household survey is illustrated in Table 1. Household survey was conducted during morning and evening at home in the local language. The head of the household was interviewed irrespective of gender (above 18 years). The survey focused on the perceptions considering dependency on different ecosystems for ES, and the impact of LULCC on their supply. The average time per interview was 45-min.

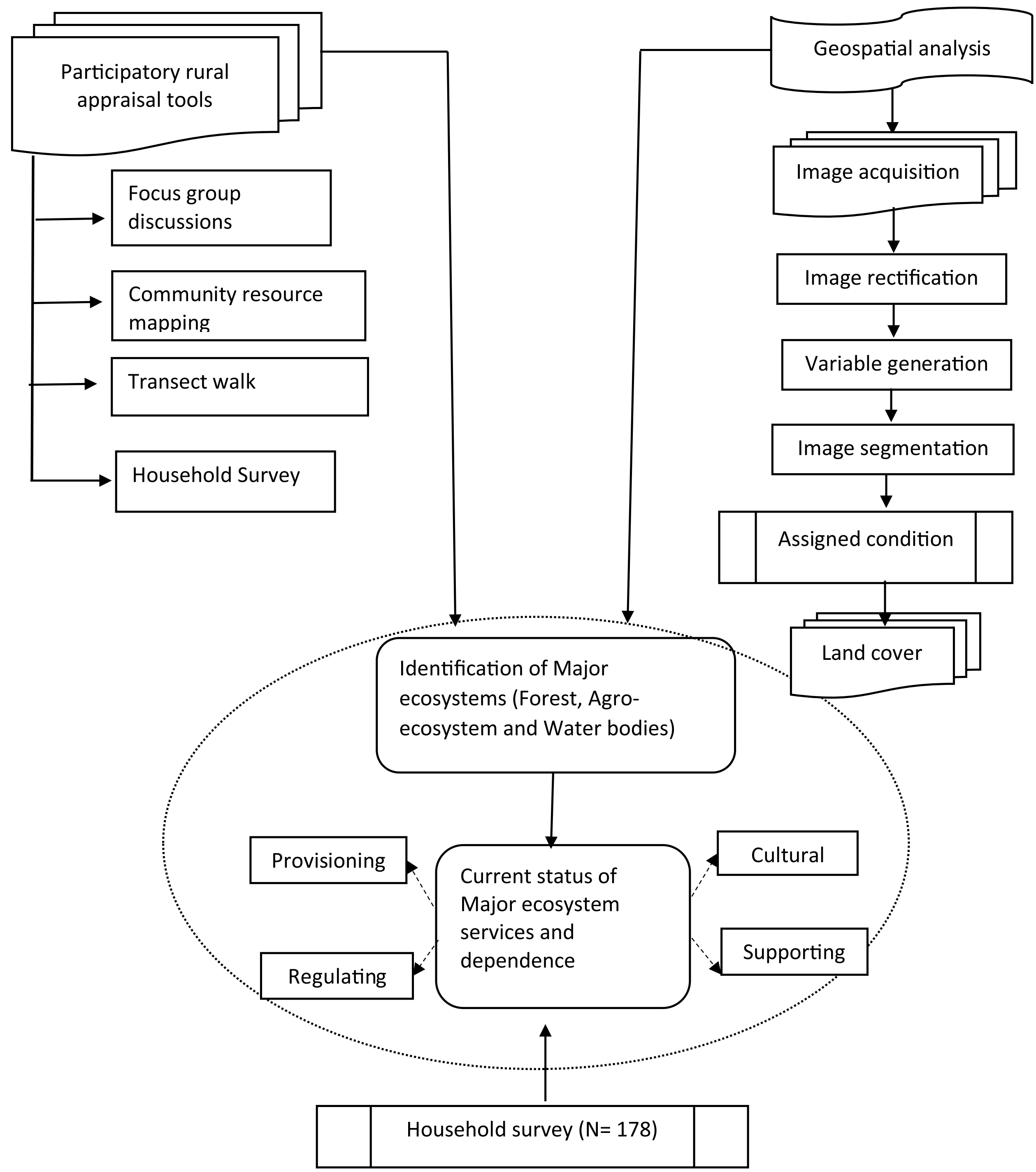

Fig. 2 Overall methodological framework (Source: Adopted and modified from Kandel et al. 2018)

The results, obtained from household survey on communities' dependency and their perceptions on changing LULCC and ES through qualitative analysis were then compared with the observed LULCC data for 1889–2000 and 2000–2014.

Results

Land use land cover change

Major land use land cover types in the study area consisted of forest, shrub-land, grassland, cropland, seasonal and perennial water bodies. In the year 2014, cropland was dominant land use types with 64.5% coverage followed by forest (18%) and the least was freshwater (4.2%). There have been a subsequent changes to these land use land cover over the period of 25 years (1989–2004, Table 2). We observed a sharp reduction of 164 km^2 seasonal water body area in Inle Lake in 2014 which is 4.2 smaller than in 1989. Similarly forest area has declined by 92 km^2, shrub land showed a negative change of 52 km^2 and 1 km^2 grass-land area has dropped down in last 25 years. Contrary to this, an increase of 268 km^2 cropland area and 40 km^2 perennial water body were observed (Table 2) showing periodic increment over the time. The periodic data of the year 1989 showed that the cropland was 59.5%. It further increased to 60.67% in 2000 and 64.53% in the year 2014 giving a total cropland increment of 268 km^2 in 25 years. Similarly, the perennial water body has increased by 40 km^2 against the baseline year 1989.

To further segregate the periodic changes of LULCC, the breakdown of the observed results in the form of change matrix of land cover from 1989–2000 to 2000–2014 are presented in Tables 3 and 4. Comparing Tables 3 and 4, an overall forest area of 92 km^2 has reduced during 1989–2017 but in the later years during 2000–2014 the rate of forest loss is 115 km^2. This 115 km^2 forest loss is mainly because of the conversion of forest land into crop land. Declinations of 1 km^2 of shrub-land and 1 km^2 of grassland were observed. Cropland has increased by 268 km^2 that has invaded wetland, shrub-land and grassland in 25 years of timeline. However, over those years,

Table 1 Description of sampling areas for household survey

Study area	Upstream mountain area	Middle stream market area	Downstream floating garden	Total
Village track	Lat Maung Kwe	Nan Pan	Nan Pan	–
Village name	Kyaung Taung	Zay Gon	Kyar Taw	–
Location	N20°39′24″ E96°51′48″	N20°27′56″ E96°54′13″	N20°26′57″ E96°54′52″	
Total households	186	168	173	527
Sample size	58	60	60	178

Table 2 Summary of land cover statistics for 1989, 2000 and 2014

ID	Land cover	Year 1989		Year 2000		Year 2014		LC changes in km^2 (1989–2014)
		km^2	%	km^2	%	km^2	%	
1	Forest	1074	19.79	1097	20.23	982	18.10	− 92
2	Shrub land	321	5.92	268	4.94	269	4.96	− 52
3	Grassland	394	7.27	394	7.27	393	7.24	− 1
4	Cropland	3232	59.58	3291	60.67	3500	64.53	268
5	Seasonal water bodies	214	3.95	183	3.37	51	0.94	− 164
6	Perennial water bodies	189	3.49	191	3.52	229	4.22	40
7	Total	5424	100	5424	100	5424	100	

Table 3 2 Change matrix of land cover (km^2) in 1989 to 2000

Land cover (km^2)	Forest	Shrub land	Grassland	Cropland	Seasonal water bodies	Perennial water bodies	Total (1989)
Forest	1074	0	0	0	0	0	1074
Shrub land	24	268	0	25	3	1	321
Grassland	0	0	394	0	0	0	394
Cropland	0	0	0	3232	0	0	3232
Seasonal water bodies	0	0	0	34	177	3	214
Perennial water bodies	0	0	0	0	3	187	189
Total (2000)	1097	268	394	3291	183	191	5424

Table 4 Change matrix of land cover (km^2) in 2000 to 2014

Land cover (km^2)	Forest	Shrub land	Grassland	Cropland	Seasonal water bodies	Perennial water bodies	Total (2000)
Forest	982	0	0	115	0	0	1097
Shrub land	0	268	0	0	0	0	268
Grassland	0	0	393	0	0	1	394
Cropland	0	0	0	3279	3	8	3291
Seasonal water bodies	0	1	0	104	47	30	183
Perennial water bodies	0	0	1	2	0	189	192
Total (2014)	982	269	393	3500	51	229	5424

perennial water body has been altered and an increment of 38 km^2 was witnessed. Referring to Table 3, perennial water body has influenced grassland, seasonal water body, and cropland. Likewise, spatial-temporal changes of forest, shrubland, grassland, cropland, seasonal and perennial water bodies are presented in Fig. 3.

Utilization of ES for livelihood

Communities from the three study areas, namely-Kyaung Taung, Zay Gon and Kyar Taw showed varied dependency depending upon the proximity of the ecosystems (Fig. 4). It was observed that all the depended communities seem to use available ecosystems optimally. Our qualitative data revealed that the local inhabitants utilizes 17 types of ES from forest ecosystem, 13 from agro-ecosystem, 10 from seasonal and 4 from perennial water body for their livelihoods (Table 5). Almost all of the respondents in Kyaung Taung village mentioned that they consume mushroom (100%) and wild edible fruits/vegetables (97%) from forest ecosystem. About 83% of the same village collects fuelwood. Despite deforestation and degradation in the forest areas, forests still account for the supply of fuelwood in Kyaung Taung village. Only 7% of the respondents in Kyar Taw village and 8% in Zay Gon village consumed fuelwood from forests. Likewise, a wide range of wetland services are utilized by floating garden communities. About 91% of respondents use water for bathing, 66% for fishing, 28% as source for fodder, 24% as source for seaweed and 14% for irrigation. The agro-ecosystem seems very productive in mountain area. About 93% of the households cultivate vegetables, 87% cultivate paddy and mushroom, 65% collect fuelwood from agro-ecosystem in mountain area. Similarly, the agro-ecosystem in market area looms vegetable production (87%), ornamental plants (67%), fuelwood supply (38%) and wild and edible fruits (37%). In an average, fresh water (perennial and seasonal) attributed to drinking water supply (93%), water for bathing (61%) and water for irrigation (6%) in three study sites. Apart from the forest, study results elucidated that the fuelwood and fodder requirements in the community are met from agro-ecosystems and wetlands.

Community perception on state of ES and LULCC

Figure 5 illustrates the communities' perception on the changes of flow of ES over the last decade. Around 93% of the respondents opined that forest ecosystem has decreased over the last 10 years. Fuelwood extraction, illegal logging, charcoal making, shifting cultivation, extension of agricultural land and population growth played an influential role to the exacerbated forest ecosystem. Also, the communities' claimed that almost no forest has remained in the village area. Around 40% of the respondents reflected an increase in area used for cropland; 43% conversely perceived a declination. Communities mentioned that maximum use of chemical fertilizer has affected the soil fertility and water. Interestingly, 17% mentioned there is no change in such practices.

About 63% of the respondents perceived such changes in four ecosystems have brought huge reduction in availability of freshwater. The reduction of freshwater has caused inland water transportation used for tourism and other use a challenge. Also, respondents reiterated that lake water is not potable since last 10 years and retrograding water quality has affected natural aquaculture. Major apprehensions are depletion of forests and increased soil erosion leading to sedimentation, erratic rainfall and drying out of rain water collection pond. About 30% also mentioned that reforestation had somewhat contributed to reduce those negative changes. A significant number of respondents (92%) perceived an enormous reduction in seasonal water body in dry season (Fig. 5).

Comparison of LULCC and perceived changes in ES

Observed loss in forest area and seasonal water body through LULCC are consistent with community's perceived changes. Around 93% of the households mentioned flow of ES from forest ecosystems has declined. Comparing this information with the LULCC (Table 2), 92% of the forest area has been lost in the last 25 years

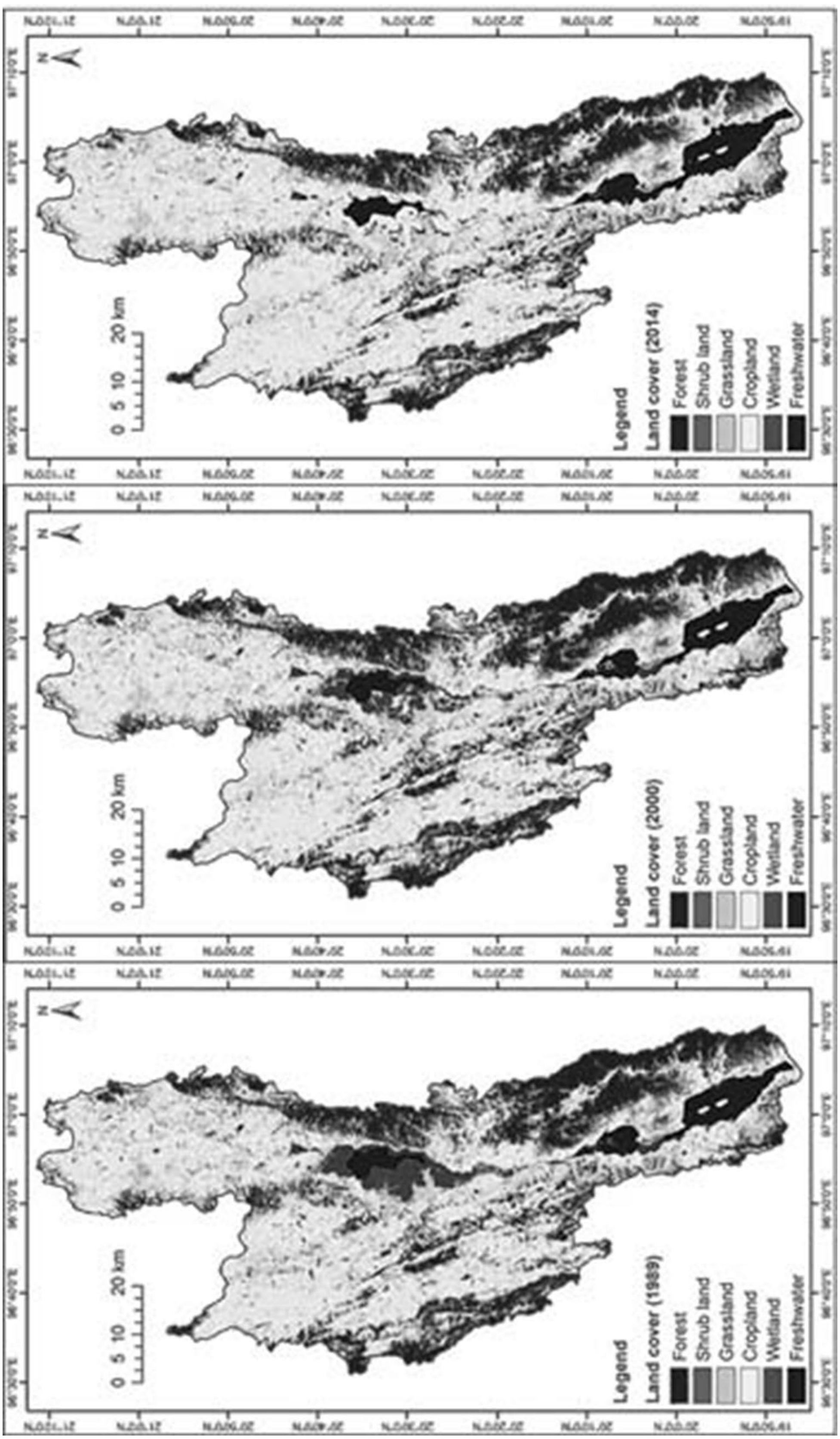

Fig. 3 Land use land cover map 1989, 2000 and 2014

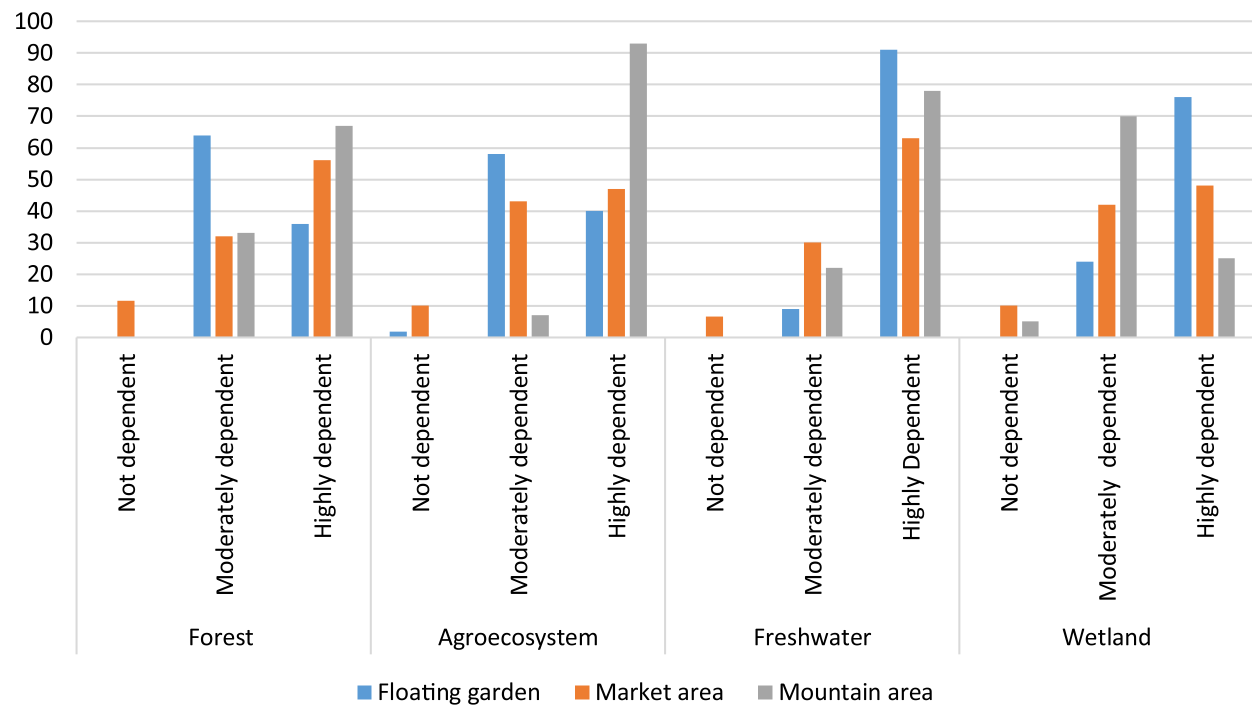

Fig. 4 Figure showing dependency of people in different ecosystems across the study sites

Table 5 Number of provisioning ES utilized by local communities for their livelihoods

Ecosystem	Forest (17)	Agro-ecosystem (13)	Perennial water bodies (4)	Seasonal water bodies (10)
Provisioning goods and services	Fuel wood Fodder Grazing Timber Poles Medicinal plants Ornamental plants Wild edible vegetables/ mushrooms Fruits Fiber Thatch Bush meat Paddy Cereals Drinking water Water for bathing Water for irrigation	Fuel wood Fodder Grazing Timber/poles Medicinal plants Ornamental plants Wild edible vegetables/ mushrooms Fruits Fiber Thatch Dyes Paddy Cereals	Fish Drinking water Water for bathing Water for irrigation	Ornamental plants Wild edible vegetables Fruits Fish Drinking water Water for bathing Water for irrigation Silt soil Source for seaweed Source for fodder

which is evident to the community's belief on declining ES from forest ecosystems. Furthermore, this has been evident from the visible change observed on the ES during the last 25 years (see Fig. 6). Communities associated loss of forest and water body area with reduced ES that they are receiving. They mentioned that ES listed in Table 5, are nowadays in declining trend. An observed data of increased cropland area by 8.3% (Table 2) reflected a mixed perception (Fig. 5). However, observed increased perennial water body area through LULCC analysis contradicts to 63% of the communities' belief. Communities believed that the availability of freshwater in all three study sites has been reducing (Fig. 5). But LULCC analysis (Tables 3, 4) showed that perennial water bodies have increased. In terms of changes in flow of goods and services from agro-ecosystem (Fig. 5), 43%

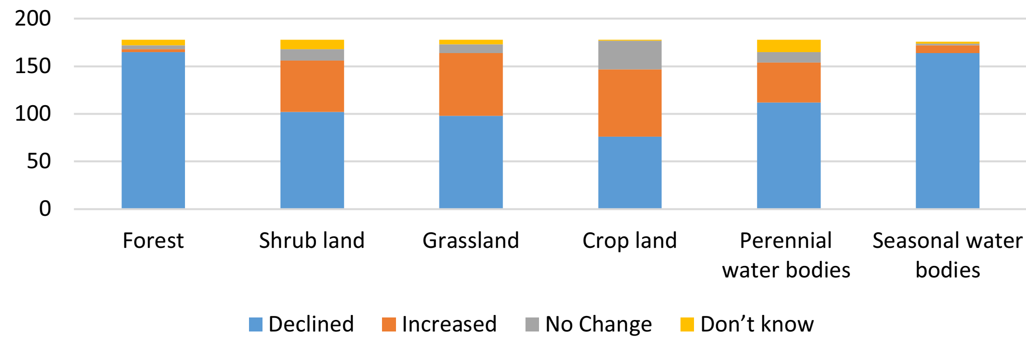

Fig. 5 Perceived changes on the flow of ES from four ecosystems over the last 10 years

of the households mentioned the agricultural productivity have increased but 40% expressed that the productivity has reduced and 17% mentioned there has been no changes in the agricultural productivity. Community's perception over such changes might be mainly due to the degraded land converted into agricultural land and economic return from land conversion over to the population growth. Due to limited outmigration from Inle Lake, the growing population demand more land and irrigation for farming, but less water availability for irrigation results into less productivity. However, there is a clear indication of increased in crop area by 8.29% from 1989 to 2014 suggesting agricultural intensification.

Discussion

How the LULCC (temporal and spatial) has changed over the period in the study area?

The LULCC has been identified as one of the main drivers of change worldwide (Pandit et al. 2007; Chettri and Sharma 2016). Such LULCC, as a continued socio-ecological disturbance, changes the flow of ES (Janssen and Anderies 2007). A widespread deforestation and unplanned LULCC threatens natural ecosystems (United Nations 2002; Sidle et al. 2007), decreases multi-functionality (Kandziora et al. 2014) and limits the habitat of globally important species (Chettri et al. 2013). Myanmar has been witnessing major LULCC in the recent years (Htwe et al. 2015) and our study also validate it. The Forest Department Statistics of Myanmar showed 37.4% of 343,587 km^2 natural forest area deforested in 1998 (United Nations 2002). A similar trend of 40.4% of forest cover loss from 2001 to 2012 has been reported by (Khaing 2014). The rate of deforestation and degradation were −1.17% from 1990 to 2000, −0.90% from 2000–2005 to −0.95% 2005–2010 (FRA 2010) showing increasing trend of deforestation lately.

Major LULCC in the study area depicted a reduction in forest, seasonal water body and increase in cropland and perennial water body. Such changes have increased siltation in the lake, affecting fresh water hotspots that is home to worldwide threatened species and depended on the health of these ecosystems (Leimgruber et al. 2005; Htwe et al. 2015). Such changes, on the other hand, also bring challenges to the communities with changed in ES availability needed for their livelihood (Chaudhary et al. 2016). This also affects hydropower plant with decreased flow (ADB 2006). Communities in Kyaung Taung village, despite huge reduction in the forested area, still rely on forests to get forest products. In the study site some good initiations like stall feeding to reduce open grazing practices and government providing free seedling to motivate communities in conservation has started. However, due to the low survival rate of these planted seedlings, results from such good initiative seems insignificant.

Crop land expansion due to increase in intensity of agriculture in the forested catchment areas, sediment load from tributaries from the catchment areas, siltation inflow to the lake and marshland transformed into agricultural areas as hydroponic expansion are major determinants of reduced wetland area in the study site. Our study showed that Inle Lake is experiencing an expansion of cropland by 268 km^2 from 1989 to 2014. Similar significant changes have also been reported on the lake and its surrounding catchments by many earlier studies (Ma 1967; Thiha 2005; Htwe et al. 2015; Pradhan et al. 2015). Thus, it symbolizes a continuous transformation in size of the lake. Additionally, sediment load from tributaries amounting 2.63106 m^3/year (Su and Jassby 2000) and siltation from inflowing stream equivalent to 6,23,000 m^3/year clearing the natural vegetation for cultivation (Akaishi et al. 2006) are other factors in shrinking wetland area. Also, our result was supported by an estimated decline of open water surface in Inle Lake by 32.4% between 1935 and 2000 (Sidle et al. 2007). Furthermore, houses and restaurants built inside lake with poor sanitation and improper management of waste are also

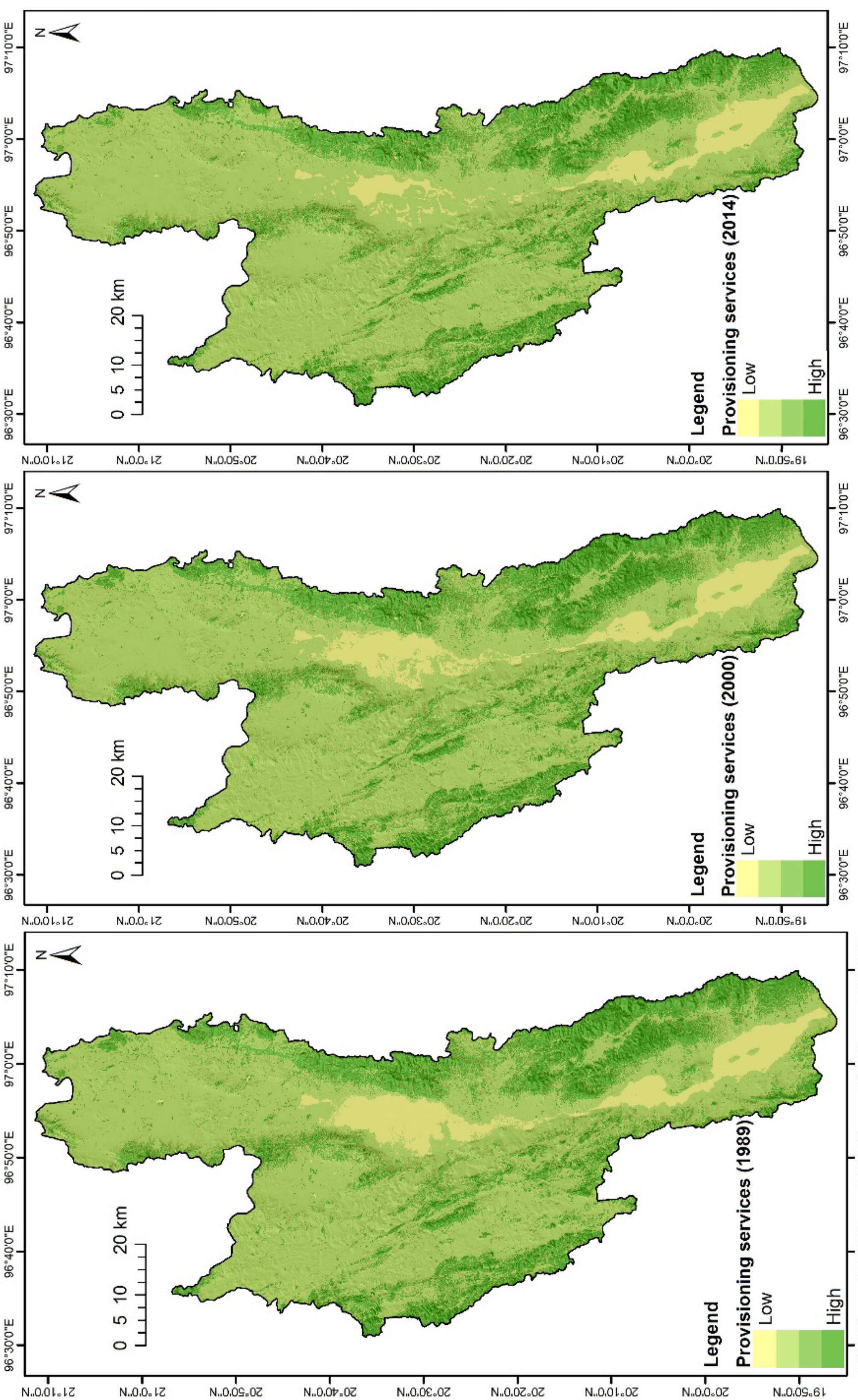

Fig. 6 Map showing spatio-temporal change on flow of provisioning services in Inle Lake

adding challenges on the health of the lake (ADB 2006; May 2007; San and Rapera 2010; Lwin and Sharma 2012). Simultaneously, the heavy rainfall trend (DMH 2016) has increased the rate of landslide impacting the lake further.

The reduction in wetland area not only threatens and limits the habitats of globally important species but also adds the leeching of agrochemicals from cropland and hydroponic cultivation into lake, further affecting water quality and promoting algal bloom in the lake (Ma 1996; Akaishi et al. 2006; Gyi et al. 2011). Increased population with double digit in Nyaung Shwe and Taunggyi Township from 1968 to 2010, limited out migration and local economic development opportunities could be other prime transforming agents converting water and marshland into agriculture (Lambin et al. 2001). An increased agricultural production rate degrades 40% of the land area posing great threat to biodiversity (Foley et al. 2011). A study conducted in China showed total food production and expanded arable land secured a negative effect on biodiversity (Hou et al. 2015). Intensive cultivation techniques and use of herbicides increasingly affect the landscapes' natural capacities in maintaining biodiversity and ecosystem functioning, including supply of ES abrading health of the perennial and seasonal water bodies.

What are the states of major ecosystems in the study area and how much the local people are dependent on these ecosystems?

Human life largely depend on forest and agriculture as important economic resources and means of development (SDG, Agenda 15). This is more relevant to Eastern Himalaya for local people with limited livelihood options (Chaudhary et al. 2015). A maintained resilient ecosystem for a continued flow of ES requires a harmonized relationship between human and nature (Gómez-Baggethun and Kelemen 2008). Communities in Inle Lake, largely depend on ES derived from forest, agro-ecosystem, and perennial and seasonal water bodies.

Comparatively higher dependency on ES in the mountain regions are well documented facts due to limited options (Chaudhary et al. 2016). Interestingly, our study found that dependency on the ES varied as per the proximity of ecosystems. Since ES have been shaped through human history by land allocation and management choices (Crouzat et al. 2015), our study illustrated that Kyaung Taung communities have more agro-ecosystem productivity and have higher access to forested area, while Kyar Taw village largely depends on ES generated from perennial and seasonal water bodies in Inle Lake. However, being a trading zone, Zay Gon sells some of the ES collected from Kyar Taw, in addition to the ES derived from their own agro-ecosystems. Livelihood of the communities in Zay Gon largely depend on trading, thus, a subtle change in supply of ES from Kyaung Taung and Kar Taw village could affect their livelihoods. These relationship clearly indicates the existing social and ecological linkages as well as the highland and lowland linkages. Both the communities living in forest ecosystems and wetland ecosystems were directly or indirectly dependent on the urban (market area) ecosystem for ES flow and trade-off and *vice versa*.

What are the people's perception in terms of the LULCC and its impact on the ES they are dependent on?

Wetland has been facing the major brunt due to LULCC in Asia (Romshoo and Rashid 2014; Zorrilla-Miras et al. 2014; Chettri and Sharma 2016). There has been significant reduction in wetland area globally making it a subject of global concern (Gopal 2013; Reis et al. 2017; Davidson et al. 2018). The perception and the observed data in Inle Lake showed consistency with the observed trend. The people's perception and LULCC analyses data revealed that there is significant change in the area as also reported by others (Htwe et al. 2015; Gyi et al. 2011). Communities in the study sites reiterated that quantity and quality of potable water has been worsen since the last decade as also reported by Akaishi et al (2006). The amount and quality of water could easily impact on possible crop yields as well as a direct impact on human health (Burkhard et al. 2015). Also communities in the study area mentioned that two perennial water bodies have dried up and people nowadays purchase drinking water. Enduring fish population loss as a poor water quality has forced fishermen to shift their occupation to farming in the study area. Additionally, in dry season reduced water level in the lake has affected the boat rowing and travelling.

Conclusion

The significance of the biodiversity and ES of Inle Lake to the local communities is important for livelihood and has been recognized by the UNESCO's man and Biosphere Reserve programme by notifying it as the first Biosphere Reserve in Myanmar. The study reiterated that LULCC is happening and it has implication to the sustained flow of ES for human wellbeing. The main drivers seem to be expansion of cropland manifested by increased siltation from the catchment area and chemical leeching that has affected the world's threatened floral, faunal and endemic species in the lake. Similarly, the rate of deforestation and forest degradation is increasing. As a result, the local communities are exploring adaptive measures to tackle the challenges. Interestingly, the people's perceptions are also supportive to the observed analysis of LULCC with some exceptions.

Our study showed that the local communities living in Inle Lake and its surrounding catchments have high dependence on the ES supplied by forest, agro-ecosystem, seasonal and perennial water bodies. The provisional ES use pattern vary as per the proximity of the ecosystems and availability of the alternative options. Moreover, the study also showed a strong upstream-downstream linkages in terms of trade-off among the communities living at different ecosystems. The study suggests following actions to address the changing effect of LULCC. First of all, looking into the tourism driven local economy, and people's high dependency on ES, demand and supply chain gap from need special attention with socio-ecological system approach. Second, restoration of the degraded areas through the inspection and regular monitoring of survival rate of planted seedlings. Third, alternative energy (improved cooking stoves, biogas) installation would add significant results to reduce further pressure on the resources. Fourth, an investment on establishing natural water ponds might be some viable options to collect rain water runoff to cope up with water scarcity to some extent. Lastly, an effort of establishing Payment for Ecosystem Services (PES) may further address the issue of siltation that is affecting hydropower plant and electricity generation. In order to draw detailed conclusions for decision-making and management of ecosystems in the study site, a socio-ecological linkage would give a better picture. A socio-ecological system approach would enable a clear policy reformulation that would support to keep ecosystems a healthy.

Abbreviations

ES: ecosystem services; FGD: focus group discussion; LULCC: land use land cover change; NDVI: Normalized Difference Vegetation Index; OBIA: object-based image analysis; PRA: participatory rural appraisal; SSS: systemic stratified sampling; TM: thematic mapper; UNESCO: United Nations Organization for Education, Science and Culture; USD: United States Dollar; UTM: Universal Transverse Mercator.

Authors' contributions

NC, KA and KU conceptualised the study. SK, AMT, ST, WMA and KA collected and analysed the data, SK, PKKU and NC wrote the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

Data is available with authors at ICIMOD and will be provided if need be.

Consent for publication

All authors approved the manuscript for its publication.

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