Implications of land cover change on ecosystems services and people's dependency: A case study from the Koshi Tappu Wildlife Reserve, Nepal

Sunita Chaudhary, Nakul Chettri, Kabir Uddin, Top B. Khatri, Maheshwar Dhakal, Birendra Bajracharya, Wu Ning

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A B S T R A C T
Protected areas, a corestone of biodiversity conservation, provide a vast array of ecosystem services to support livelihoods of people. However, protected areas, especially freshwater, are under threat with overexploitation of resources changing the land covers and degrading their capacity to supply services. Information on land cover changes and its implications on ecosystems, its services and people, especially in developing countries at a local scale, is largely absent. This study, therefore, seeks to understand people's dependency on ecosystem services and implications of land cover change on ecosystem services and people, with a case study in the Koshi Tappu Wildlife Reserve of Nepal. Using both qualitative and quantitative methods, our findings show high dependency of the locals on a vast array of ecosystem services provided by the reserve. More than half of the sampled households were found to directly derive income from ecosystem services of the reserve. However, land cover changes especially declines in forest (16%), swamps/marshes (4%), rivers (14%) and other ecosystems over a period of 34-years impacted the provision of ecosystem services and people's dependency notably. The services from forests declined by about 94%, swamps services by 36% and services from river by 57% which were reported to be the high service suppliers. People's dependency, as perceived by the locals, was reduced by 67% over the last ten years. The study highlighting the supply, demand and implications on ecosystem services and people helped to better understand the complex interaction between humans and ecosystems. These results can be used to develop holistic approaches to restore, conserve and manage the ecosystems, and its services by balancing equal supply and demand of ecosystem services required for a self-sustaining human-environment system. It can also contribute to development of important environmental policies and programs in the area.

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1. Introduction

Protected areas are the corestone of biodiversity conservation that conserve key habitats, endangered flora and fauna, provide refuge, allow species migration and ensure the maintenance of natural processes (Mulongoy and Chape, 2004). Considered for conservation without due recognition to the human needs, many protected areas were conceived with the goal of sustainable development between 1970 and 1990 focusing on human use, and recognition of participation of local communities and their cultural values. Today, protected areas covering 13% of the world’s terrestrial landscape not only conserve biodiversity, but are one of the major factors in ensuring global food security, by allowing local resource use and supporting livelihood of nearly 1.1 billion people (Mulongoy and Chape, 2004). Protected areas provide a vast array of ecosystem services (Balmford et al., 2002)—the benefits ecosystems provide to human wellbeing (MEA, 2005a). Recently, the ecosystem services concept has attracted widespread attention from both science and policymakers influencing multiple disciplines and initiatives across countries at various scales (Chaudhary et al., 2015). The concept has also been related to protected areas management for recognizing the economic benefits protected areas offer and the need of integrated ecosystem

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management for effective protected areas management (Palomo et al., 2011). Hence, protected areas serve multiple purposes of conservation, supply ecosystem services and are deeply embedded into socioeconomic development to meet the subsistence needs of local people and alleviate poverty (Naughton-Treves et al., 2005).

However, protected areas are under threat including climate change, invasive species, ineffective management and others. Among others, habitat change is one of the major threats caused by over exploitation of resources, agricultural expansion, and human settlement (Lambin et al., 2003). In particular, protected areas with freshwater ecosystems including estuaries and wetlands, are quite vulnerable (Mulongoy and Chape, 2004). Wetlands, which are well recognized for their significant role in supporting high biodiversity and providing food, water and livelihood security to the people living in the area (Rebele et al., 2009), are subject to overexploitation and continuous degradation (Gopal, 2012; Water Research Commission, 2007). Since the beginning of the 20th century, about half of wetlands have already been lost (TEEB, 2010) and more than 60% of the remaining wetlands are being degraded or used unsustainably especially from land conversion, pollution, and overharvesting (MEA, 2005b). These threats significantly change land covers and degrade the capacity of ecosystems to supply services. It is important to identify and focus on areas that are important for maintaining ecosystem functions and providing ecosystem services (Reyers et al., 2009). Recent studies by Sohel et al. (2014), Portman (2013) and Haines-Young and Potschi (2009) have clearly demonstrated the importance of land cover by showing how the changes in land covers, either natural or human-induced, can affect the flow of services over space and time. In this regard, the supply of services by specific or mosaic of land covers must be taken into account (Burkhard et al., 2010) for planning and management of the areas of concern. However, information on land covers, its capacity to supply services and the consequences of land cover change on ecosystem services at a local scale is largely absent (Adekola and Mitchell, 2011). Information on people’s dependency on natural resources at local scale is also limited though half of the world’s rural population is estimated to depend on natural resources for subsistence products or cash income generation (Angelsen and Wunder, 2003). Particularly, information on individual wetland and use of resources by people at the local level in South Asia including Nepal is scant (Gopal, 2012). In such instances where protected areas and/or wetlands serve as intertwined socio-ecological systems, both natural as well as social processes should be analyzed to understand its complexity for effective protected areas and wetland management. With these considerations, we seek to understand people’s dependency on ecosystem services; capacity of land cover to supply services; land cover change, and its implications on ecosystem services and people’s dependency. People’s dependency, in this study, is considered as the economic contribution obtained from ecosystem services to households, rather than only subsistence living. We address these objectives with a case study in the Koshi Tappu Wildlife Reserve of Nepal.

2. Study area

The Koshi Tappu Wildlife Reserve (KTWR) was chosen, as the reserve is a complex web of natural and social processes (ICIMOD and MoFSC, 2014), making a good case to address the aims of this study. Situated between 86° 91’–87° 08’E and 26° 72’–26° 56’N in the foothills of the Nepalese Himalayas of Eastern Nepal, the KTWR is one of the most important protected areas with freshwater ecosystems, estuaries and wetlands (Fig. 1). The reserve is located in the floodplains of the Koshi River with the elevation range between 80 and 100 m above sea level from South to North. The river is also known as Sapra Koshi (in local language), meaning the confluence of seven rivers with strong upstream and downstream linkages (DNPWC/PPP, 2000). Events or activities either anthropogenic or environmental including hydrological events occurring upstream in the river with implications downstream are considered as upstream-downstream linkages (Nepal et al., 2014). The Koshi river, a natural and permanent river system, is the biggest river in Nepal that flows for a length of 730 kilometers in the Nepalese part (Shrestha, 1990) with an average flow of 1931 m$^3$/s (Rajbanshi, 2002).

The river, with heavy erosion and siltation, has prominent characteristic of meandering freely from one bank to other changing the course (Nayak, 1996) with likely changes on land covers. The River with its unique characteristics provides life to the Koshi Tappu Wildlife Reserve, a protected area under IUCN category IV (DNPWC, 2000; Chaudhary, 2007). The reserve was declared as a protected area in 1976 with an area of 175 square kilometers (17,500 ha) to conserve the last remaining populations of Wild water buffalo (Bubalus bubalis arnee) and was declared a

![Fig. 1. Location map of the Koshi Tappu Wildlife Reserve.](image-url)
first Ramsar site in Nepal in 1987. The reserve, a complex mosaic of lotic and lentic ecosystems (Shah, 1997), has 670 species of vascular plants, 21 species of mammals, 23 species of Herpetofauna, 77 species of butterflies and 494 species of birds (ICIMOD and MoFSC, 2014). The reserve area is an Important Bird Area (IBA) providing a key habitat for globally threatened species such as the Swamp Francolin (Francolinus gularis) and Bengal Florican (Houbaropsis bengalensis) (Baral et al., 2012). It has subtropical monsoon climate with temperatures between 3.3 °C and 33.4 °C, and annual rainfall of 2019 mm with spring, summer/monsoon, autumn and winter as four distinct seasons (DNPWC, 2000, 2009). It has an intricate mosaic of land covers namely grassland, swamp and marshes, forest, river, sand/gravel, and agriculture (Chettri et al., 2013). The reserve’s ecosystem is characterized by mixed deciduous riverine forest dominated by Sissoo (Dalbergia sissoo), Khair (Acacia catechu), and Simal (Bombax ceiba) while grassland ecosystem is dominated by Phragmites, Saccharum, Typha, Imperata and Cymbopogon species (DNPWC, 2009).

People in the area have been depending on natural resources of the reserve for decades. Historically, local people had open access to the reserve area and were heavily engaged in fishing, hunting, grazing livestock, and collecting fodder, firewood, and other resources influencing people’s occupations and way of life (Heinen and Kattel, 1992). However, local people lost their access with the declaration of KTWR, which resulted in serious park–people conflicts, overuse of resources and degradation of ecosystems (Shrestha and Alavalapati, 2006). In 2004, a buffer zone of 173.5 square kilometers was established surrounding the reserve (Fig. 1), with formation of buffer zone committees to address the needs of local people while conserving biodiversity. People in the buffer zone have legal rights to use and manage the reserve sustainably in collaboration with the reserve staff. The buffer zone covers 16 village development committees (VDC) with a total of 16,710 households. About 73% of total households are poor and the overall literacy rate is 44.6%. Subsistence agriculture, livestock rearing and remittance are the major livelihood strategies with agriculture being practiced by 87.3% of the total households, and with 1.5 cattle per household (CSUWN, 2009; ICIMOD and MoFSC, 2014). In spite of conservation and development efforts, the wetland biodiversity of the reserve is still under threat causing

![Fig. 2. Overall methodological framework.](image-url)
continuous degradation to ecosystems and species diversity (Chhetri et al., 2013). The reserve area, excluding buffer zone, was focused in this study, to analyze the reserve's capacity to supply ecosystem services.

3. Methods

The study used mixed methods (both qualitative and quantitative) to assess people’s dependency on, and capacity of land covers to supply, ecosystem services. A detailed literature, focusing on socio-economic and ecological aspects with a particular focus on resource use patterns and biodiversity of KTWR, was reviewed to prepare a list of ecosystem services. Resources as per their use and importance were first noted and the list was prepared. The listed ecosystem services was then categorized into provisioning, regulation, cultural and supporting services following the Millennium Ecosystem Assessment Framework (MEA), 2005. The list of literatures considered for review is given in Annex 1 in Supplementary material. While ‘Livelihoods Assessment Tool (LAT)’ (Gerlitz et al., 2012) and focus group discussions were used to collect the primary data. The overall methodological framework is given in Fig. 2.

3.1. Household survey

LAT is a household questionnaire survey designed for collecting data on poverty and livelihoods vulnerability in the mountain context (Gerlitz et al., 2012). Before collecting data, LAT questionnaire with both close and open-ended questions was prepared and discussed with national and local institutions working in the conservation and development sectors in Nepal. LAT was first field tested by the local partners and was adjusted as per the context of KTWR. The data were then collected in collaboration with the Koshi Victim’s Society (KVS), a local non-government organization (NGO). Using the tool, a total of 369 households were randomly selected across the KTWR buffer zone and surveyed inbetween April and July 2011. With the verbal consent, the functional head of each household irrespective of the person’s gender was interviewed in local language, which lasted for seventy minutes on average. The questionnaire had three major dimensions: adaptive capacity (socio-demographic profile, livelihoods strategies/income sources and social networks), sensitivity (health, food and water) and exposure (natural disasters and climate vulnerability). The questionnaire also focused on people’s perception on dependency and change in their dependency over a gap of ten years. The questionnaire is given in Annex 2 in Supplementary material.

3.2. Household’s dependency

People’s dependency, as explained above, is considered as the economic contribution obtained from ecosystem services to households, rather than only subsistence living. Following Thondhlana and Muchapondwa (2014), and Mamo et al. (2007), we defined ‘dependency’ as incomes obtained through ecosystem services to the total household income. Based on this, a dependency equation, which is a ratio of direct income through ecosystem services to the total household’s income, was used (see Eq. (1)).

\[
\text{Dependency} = \frac{\text{Direct income from primary, secondary and tertiary sources}}{100} \times 100\%
\]

Information on direct sources of household income, collected through LAT, was used to estimate dependency. To do this, the direct incomes from primary, secondary and tertiary sources obtained through LAT were first linked with ecosystem services, and then Eq. (1) was used. As we focused on direct incomes, only provisioning and cultural (tourism) services found to linked with ecosystem services were used for analysis, while intangible benefits from regulating, supporting and cultural services (spirituality, etc.) were not considered.

3.3. Land cover change analysis

Remote sensing data of 1976, 1989, 1999 and 2010 covering the reserve area (17,500 ha) were used to assess the spatio-temporal land cover change over a period of 34 years. Medium spatial resolution Landsat Multispectral Scanner (MSS) of 1976; Thematic Mapper (TM) of 1989 and 2010; and Enhanced Thematic Mapper Plus (ETM+) of 1999 were used to assess land cover maps and change analysis. Landsat MSS, TM and Enhanced Thematic Mapper Plus (ETM+) imagery were accessed from USGS Global Visualization Viewer (GLOVIS) whereas a Shuttle Radar Topography Mission (SRTM) Digital Elevation Model was accessed from Consultative Group on International Agricultural Research (CGIAR)-Consortium for Spatial Information (CSI) GeoPortal (CGIAR-CSI). The acquired IRS LISS–4 and Landsat images were orthorectified into Universal Transverse Mercator (UTM). Zone 45 based on generated digital terrain model (DTM) from a topographic map and Ground Control Point (GCP) from the field. After rectifying all the images, eCognition developer software was used for object-based image analysis (OBIA). A hierarchical classification scheme was used with six major land classes based on Land Cover Classification System (LCCS) following Di Gregorio (2005) as this was necessary to harmonize the land use and cover legends with global standards (Bajracharya et al., 2010).

After detailed analysis of land cover types, the river flow patterns were found to significantly affect the land covers. We therefore decided to further analyze the changes in the river course. For the analysis, we first extracted the river flow patterns using the land cover maps of 1976, 1989, 1999 and 2010. Then, a centerline approach was used to calculate the shifted distance of the river following Khan and Islam (2003). In centerline approach, the river centerlines from 1976, 1989, 1999, and 2010 with equal

![Fig. 3. Changes observed in the river course channel from 1976 to 2010.](image-url)
distance from the riverbank were digitized at first. Then a straight line of 16 kilometers was drawn along the western bank of the river on the map (Fig. 3). In that straight line, 8 points with 2-km intervals were identified as base measurement points from south to north (downwards to upwards). Then from each point of base measurement, the distance to all centerlines of the river for four consecutive years (1976, 1989, 1999 and 2010) were measured. The mean distance for each base measurement point, as well as for each year were calculated (Fig. 3).

3.4. Focus group discussions

Discussions with two different groups were held between October 2011 and February 2012. Questions on ecosystem services, its use and the capacity to supply ES by different land covers of the reserve were discussed. A total of 17 participants attended the discussions. Participants were the hotel owners, bird watchers, nature guides, committee members from buffer zone committees, representatives of local NGOs, and the general user members of buffer zone committee. The chosen participants were also involved in various activities of the reserve such as nature tours, bird watching and hotel owners. We regarded them as local experts with knowledge on social, ecological and economic values of the reserve and buffer zone. The buffer zone committee members have legal rights to use and manage the resources in a sustainable way with influential decision-making roles (DNPCW. 2000). During the discussions, a list of ecosystem services prepared through literature review were given to the discussion groups to discuss, verify and rank those services based on their use and preference. Ecosystem services were then listed and ranked by removing the odd ones and adding the missing ones. After finalizing the list, the participants were asked to do the scoring for different land covers to supply ES in ‘ES and land cover matrix’ as explained in Section 3.5.

3.5. Ecosystem services and land cover assessment matrix

Following Burkhard et al. (2010) and others, we applied ‘ecosystem services and land cover matrix’ to assess land cover’s capacities to provide ES. An assessment matrix proposed and applied by Burkhard et al. (2010) is becoming influential in assessing the landscape’s capacity to supply ecosystem services (Sohel et al., 2014). Recent studies by Sohel et al. (2014) and Paudyal et al. (2015) applied ‘assessment matrix’ for assessing the land cover’s capacity to supply ES. In this method, expert’s opinion or professional judgments are considered. Yapp et al. (2010) and Palomo et al. (2011), have also considered expert opinions of ES assessment. The matrix was developed with identified land covers (see Section 3.3) on x-axis and the list of ecosystem services finalized (see Section 3.1) on y-axis. Based on expert’s judgment, each land cover’s capacity to supply individual ES was assessed and ranked using the scale of: 0 = no service, 1 = low service, 2 = medium service, and 3 = high service. If a land cover has high capacity to provide services, then a value of 3 was assigned by the experts to that land cover and so on. For example: For fuel wood (provisioning service), forest was assigned ‘3’ for supplying fuel wood, while grassland was assigned ‘0’. Then, values for all ecosystem services assigned to each land cover were summed up to calculate the land cover’s capacity to supply services.

The scoring was done at two levels (i) experts at national level; and (ii) experts at local level. The criteria for choosing experts were: (i) detailed knowledge on ecological, social and economic aspects of the area; (ii) experience in use, conservation and management of reserve resources. Following the criteria, a total of six experts from the governmental, non-governmental and regional institutes for assessment at national level, and seventeen experts from the local area were involved during the discussions (see Section 3.4). A consensus was made at the end by bringing all the experts (national and local) together during a workshop and agreeing on a common score for each land cover and individual ES. Though some levels of disagreements were observed during the consensus building, facilitators played an important role in the agreement of the final scores. National level experts agreed with local level experts especially for the scores of provisional and cultural services. Meanwhile, local level experts agreed with national experts for regulating and supporting services. Then, the final values for each land cover were summed up, which provided the capacity of each land cover to supply ES. The assessment matrix was done for provisioning, regulating, supporting and cultural services (Table 2a and 2b).

3.6. Implications of land cover change on ecosystem services

The change in ES values with regard to land cover change between 1976 and 2010 was analyzed. First, we calculated the value of each category of ecosystem services (provisioning, regulating, cultural and supporting) per hectare by dividing the total service value of each category obtained during ‘ES and land cover matrix’ (Table 2a and 2b) with the total land cover area of the reserve.

ES value per hectare = \( \frac{\text{ES value (category) \times based}}{\text{Total land cover area of KTWR}} \) (2)

Then, the calculated ES value of each category (through Eq. (2)) was multiplied with the area of specific land cover (i.e., forest, swamps etc) for different years (1976 and 2010). This gave values of provisioning, regulating, supporting and cultural services for each land cover for two different years. The calculated values for the same land cover were compared for 1976 and 2010 and the observed changes were noted (Table 7). This showed the impact of land cover change on ES values over 34 years.

For mapping, ArcGIS spatial analyst was used to relate and merge the values of provisioning, regulating, cultural and supporting services obtained for 1976 and 2010 with land cover areas of 1976 and 2010. This analysis and mapping process showed visual changes in each land cover with reference to supply services over a period of 34 years.

3.7. Implications on people’s dependency

The implication of changes in provisioning services on people’s dependency was analyzed. As the dependency on ES was estimated based on direct incomes sources (see Section 3.2), only provisioning service was considered for implication analysis. For analysis, we first divided the total number of households who reported direct use of provisioning services during household survey, by the total listed number of provisioning services finalized during focus group discussions.

\[
\text{Dependence on one provisioning service} = \frac{\text{Total households dependent on provisioning services}}{\text{Total number of provisioning services}}
\]

(3)

This gave the number of households (HHH) dependent on one provisioning service. Then the obtained value (through Eq. (3)) was multiplied with the total provisioning services value of 1976 and 2010 for each land cover. The observed changes in the values between 1976 and 2010 for each land cover were compared and noted, which showed the implications of changes on provisioning services on people’s dependency over the time span of 34 years (Table 8).
4. Results

4.1. Ecosystem services and their ranking

A total of 33 ecosystem services, through literature review and group discussions, were identified from the reserve. Local people finalized 19 provisioning services, eight regulating services, four cultural services and two supporting services (Table 1). Among them, the provisioning services were ranked on the top, followed by regulating, cultural and supporting services (Table 2a and 2b). Based on the use and preference, the provisioning services (forest and wetland products) were further ranked during the discussions. Fuelwood was ranked on the top assuming that about 91% of households use fuelwood for cooking, followed by thatch assumed to be collected by 82% for roofing, timber by 54%, grass by 51%, poles/shafts by 44% and so on. The detail of the ranked services and their use by percentage is given in Table 3.

4.2. Dependency on ecosystem services

About 50.75% of the total households, identified using Eq. (1) (Section 3.3), were found to directly gain their income from ecosystem services of the reserve. A total of 14 sources of household’s income, through a survey of 369 households, were the combination of primary, secondary and tertiary incomes (Table 4). The primary source of income contributed a mean of 41.2% to the total yearly household income in the area, while 38.2% was contributed by the secondary sources and 20.7% by tertiary sources. Among these, we only considered the direct income sources from provisioning services related with ES, i.e., all the six sources of primary income were directly related to ecosystem services. While from secondary sources, only tourism contributing 9.55% to total household income related to ecosystem services was considered and none of the tertiary income sources were considered (Table 4). Besides the sources of income, a total of 184 households reported to directly depend on provisioning services for subsistence and/or cash income, for example, approximately 49.86% of households reported direct dependence on provisioning services such as fuelwood, thatch etc from the reserve.

4.3. Land cover change

In 1976, forest cover constituted 17%, while agriculture land was 12%, grassland 11%, swamps/marshes 9%, river 24% and sand/gravel by 27%. In 2010, the reserve experienced notable changes over a span of 34 years, especially in forest and grassland. Forests were found to decrease by 94% in 2010, covering only 174 ha of its original state of 2916 ha, whereas grassland with 1996 hectares in 1976 increased by 79% of its original state totaling to 9781 ha. Overall, forests, rivers, agriculture, sand/gravel and swamp/marshes decreased by 16%, 14%, 7%, 5% and 4%, whereas grasslands increased by 45% (Table 5). The Koshi River, through river course change analysis, was found to shift significantly from west to east forming multiple channels over a period of 34 years (Fig. 4) with changes in land cover.

4.4. Land cover’s capacity to supply ecosystem services

Different land covers were found to supply a range of provisioning, regulating, cultural, and supporting services (Table 6). Swamp was found to have the highest capacity scoring 69 to supply services, especially provisioning and regulating. It was followed by forest (66), river (64), grassland (47), agriculture (39) and sand/gravel (24). For provisioning services, swamps and rivers scored the highest with 33 each, while forests scored 29. For regulating services, forest and swamps scored 22 each followed by grassland (17), river (16) and others. For cultural services, rivers received the highest score of 11 followed by swamps (9) and forests (9). Forests and grasslands received the highest scores for supporting services, followed by river, agriculture and others.

4.5. Impacts on ecosystem services

With declines in all land covers except grasslands, all services (provisioning, regulating, cultural and supporting) were found to decline (Fig. 5). The services from forests declined by about 94%, swamps services by 36% and services from river by 57% which were reported to be the high service suppliers (Table 7). This means the major provisioning services, such as fuel wood, fodder, timber, medicinal plants, litter and edible plants; regulating services, such as erosion and flood control, pollination, habitat for species; recreation and aesthetic value under cultural services; and supporting services, such as biodiversity maintenance and soil formation, declined sharply. Similarly from swamps, food such as snails, fish, crabs, thatch, pater for mat weaving, and edible plants were impacted. Swamps were regarded as the highest service supplier, especially for regulating services such as ground water recharge, erosion control, water purification and habitat for species, which were found to decline. However, provisioning and regulating services from grasslands increased such as grass, thatch, litter, and habitat for species, water recharge and nutrient regulation.

4.6. Impacts on dependency

The dependency was impacted with decline in provisioning services. About 94% of households were impacted by the decline in forest ecosystem services, 58% were impacted by decline in services from agriculture, 57% from rivers, 36% of households were impacted from swamps and marshes, and 18% from sand/gravel, while about 80% of households benefitted from services supplied by grassland (Table 8). These results are in line with the results from household survey. Over the last ten years, majority of the households during LAT reported notable decrease in their dependency on provisioning services of KTWR (ICIMOD and MoFSC, 2012). About 67.7% reported a decrease in their dependency, with 20.4% reporting increase in

Table 1
Ecosystem services listed from the KTWR.

| Types of services (number) | Services recorded                                      |
|----------------------------|--------------------------------------------------------|
| Provisioning (19)          | Crops/vegetables, birds, crabs, fish, snails, tortoise, wild edible plants, fodder/grass, medicinal plants, leaf litter, timber/holes, fuelwood/ driftwood, thatch, pater/reeds, sand, drinking water, irrigation, water use by livestock, bathing/washing |
| Regulating (8)             | Carbon sequestration, flood control, pollination, ground water recharge, habitat for endangered species, climate regulation, nutrient regulation, water purification |
| Cultural (4)               | Recreation, aesthetic value, education and research, spiritual/inspirational value |
| Supporting (2)             | Biodiversity maintenance, soil formation |
Table 2a
Ecosystem services and land cover matrix for assessing land cover capacity to supply provisioning services.

| Land use         | Provisioning services (Sum) | Birds | Crabs | Fish | Snails | Tortoise | Edible plants | Fodder/Grazed area | Medicinal plants | Litter | Timber/Poles | Fuelwood/Driftwood | Crops/vegetables | Thatch | Patriceeds | Sand | Drinking water | Water use by livestock | Waste/ashing | Irrigation |
|------------------|-----------------------------|-------|-------|------|--------|----------|---------------|---------------------|------------------|---------|-------------|-------------------|----------------|--------|------------|------|---------------|----------------------|--------------|-----------|
| Grassland        | 18                          | 3     | 1     | 0    | 0      | 2        | 2             | 3                   | 1                | 2       | 0           | 1                 | 0              | 0      | 0         | 0    | 0             | 0                    | 0            | 0         |
| Swamps           | 33                          | 3     | 3     | 3    | 3      | 2        | 2             | 1                   | 1                | 1       | 0           | 0                 | 3              | 0      | 1         | 2    | 1            | 1                    | 1            | 1         |
| Forest           | 29                          | 3     | 2     | 0    | 0      | 2        | 3             | 3                   | 3                | 3       | 0           | 0                 | 2              | 0      | 1         | 0    | 1            | 0                    | 1            | 1         |
| River/lakes      | 33                          | 3     | 3     | 3    | 3      | 1        | 0             | 1                   | 0                | 0       | 0           | 0                 | 3              | 3      | 3         | 3    | 3            | 3                    | 3            | 3         |
| Sand/Gravel      | 10                          | 2     | 1     | 0    | 0      | 1        | 1             | 1                   | 1                | 1       | 0           | 0                 | 1              | 0      | 1         | 0    | 0            | 0                    | 0            | 0         |
| Agriculture      | 19                          | 1     | 2     | 2    | 2      | 1        | 2             | 1                   | 1                | 0       | 3           | 0                 | 0              | 0      | 1         | 0    | 1            | 1                    | 1            | 1         |
| **Total**        | **142**                     |       |       |      |        |          |                |                     |                  |         |             |                   |                |        |           |      |               |                       |              |           |

0 = no service, 1 = low service, 2 = medium service, and 3 = high service.

Table 2b
Ecosystem services and land cover matrix for assessing land cover's capacity to supply regulating, cultural and supporting services.

| Land use          | Regulating services (Sum) | Co2 sequestration | Erosion/flood control | Pollination | Ground water recharge | Habitats for native species | Climate regulation | Nutrient regulation | Water purification | Cultural services (Sum) | Recreation | Aesthetic value | Education & research | Spiritual /esthetic value | Supporting services (Sum) | Biodiversity maintenance | Soil formation |
|-------------------|---------------------------|-------------------|-----------------------|-------------|-----------------------|-----------------------------|--------------------|---------------------|----------------------|-------------------------|-------------|-----------------|-----------------------|---------------------------|---------------------------|------------------------|---------------|
| Grassland         | 17                        | 2                 | 2                    | 3           | 3                    | 3                           | 2                  | 2                   | 2                   | 6                       | 2           | 2               | 1                     | 1                         | 6                    | 0                      | 3  |
| Swamps/marshes    | 22                        | 2                 | 3                    | 3           | 3                    | 3                           | 3                  | 3                   | 2                   | 3                       | 2           | 3               | 2                     | 2                         | 5                    | 0                      | 3  |
| Forest            | 22                        | 3                 | 3                    | 3           | 3                    | 3                           | 2                  | 2                   | 2                   | 3                       | 3           | 3               | 2                     | 2                         | 6                    | 0                      | 3  |
| River/lakes       | 16                        | 1                 | 0                    | 1           | 3                    | 3                           | 2                  | 3                   | 2                   | 3                       | 2           | 3               | 2                     | 2                         | 4                    | 0                      | 3  |
| Sand/Gravel       | 8                         | 1                 | 1                    | 1           | 1                    | 1                           | 1                  | 1                   | 1                   | 1                       | 1           | 1               | 1                     | 0                         | 2                    | 0                      | 1  |
| **Total**         | **96**                    |                   |                      |             |                      |                              |                    |                     |                      |                         |             |                 |                       |                            | **44**               |                          | **27**       |

Table 3
Ranking of provisioning services (forest and wetland products).

| Products                  | Purpose                           | Percentage of households | Rank |
|---------------------------|-----------------------------------|--------------------------|------|
| Firewood                  | Cooking                           | 91                       | 1    |
| Thatch                    | Roofing                           | 82                       | 2    |
| Timber                    | Construction, cattle-shed, fencing, agriculture etc | 54                       | 3    |
| Grasses                   | Livestock feeding                 | 51                       | 4    |
| Poles/shafts              | Construction of house             | 44                       | 5    |
| Fishes                    | Food and sale                     | 38                       | 6    |
| Driftwood                 | Firewood                          | 31                       | 7    |
| Pater                     | Mat weaving (use and sale)        | 30                       | 8    |
| Wild edible vegetables, roots, tubers | Food and sale | 26                       | 9    |
| Snails, crabs, tortoise   | Food and sale                     | 23                       | 10   |
| Reeds/canes               | Construction/repairing houses     | 20                       | 11   |
| Wild edible fruits        | Food                              | 19                       | 12   |
| Fodder                    | Livestock                         | 17                       | 13   |
| Leaf litter               | Animal bedding, manure             | 10                       | 14   |
| Sand                      | Construction material             | 9                        | 15   |
| Edible fruits             | Pickles/vegetables                | 5                        | 16   |
| Medicinal plants          | Use and sale                      | 3                        | 17   |
| Birds                     | Food and sale                     | 2                        | 18   |

dependency and 12% reported no change in dependency (Fig. 6). One of the major reasons for decline in their dependency reported was the reduced forest cover and the over exploitation of swamps/marshes in the area.

5. Discussions

One of the major knowledge gaps in ecosystem services research is the assessment of human demand for ecosystem...
services. ES research is heavily dominated by measurement of biophysical values, but less focused on social-cultural values. This means the supply side of ecosystems is well researched, but the demand side is not of particular importance in ES research, in spite of its need for better planning and management of ecosystems (Sturck et al., 2014). In this regard, our study explored both the supply and demand of ecosystem services by assessing the landscape’s capacity to provide services, as well as people’s

| Primary (41.2%) | Secondary (38.2%) | Tertiary (20.7%) |
|----------------|------------------|-----------------|
| 1. Crop, vegetables, fruits (ES) | 1. Daily wages (Not ES) | 1. Remittances (Not ES) |
| 2. Livestock and their products (ES) | 2. Salaried employment (Not ES) | 2. Development aid projects (Not ES) |
| 3. Fish sales (ES) | 3. Tourism (ES) | 3. Gifts and begging (Not ES) |
| 4. Forest products (ES) | 4. Other business and trade (Not ES) | 4. Governmental social benefit schemes (Not ES) |
| 5. Herb sales (ES) | | |
| 6. Medicinal plants (ES) | | |

100% based on ES = 41.2%

Tourism contributes 9.55% to total household income. 0% based on direct ES = 0%

Source: ICIMOD and MoFSC (2014).

### Table 5

Land cover change over a time period of 34 years. The unit area is in hectare and the numbers in parenthesis are the percentage of the total land cover.

| Land cover/ecosystem | 1976 (ha) | 2010 (ha) | Change between 1976 and 2010 |
|----------------------|-----------|-----------|-----------------------------|
| Agriculture          | 2155 (12) | 900 (5)   | -1255 (7)                   |
| Forest               | 2916 (17) | 174 (1)   | -2742 (16)                  |
| Grassland            | 1996 (11) | 9781 (56) | +7785 (+45)                 |
| Marshes/swamps       | 1491 (9)  | 956 (5)   | -535 (4)                    |
| River                | 4211 (24) | 1798 (10)| -2412 (14)                  |
| Sand/gravel          | 4729 (27) | 3887 (22)| -842 (5)                    |
| Total                | 17,500    | 17,500    | -                            |

Source: ICIMOD and MoFSC (2014).

### Table 6

Land cover’s capacity to supply ecosystem services.

| Swaps | Forest | River | Grassland | Agriculture | Sand/gravel | Total |
|-------|--------|-------|-----------|-------------|-------------|-------|
| 33    | 29     | 33    | 18        | 19          | 10          | 142   |
| 22    | 22     | 16    | 17        | 11          | 8           | 96    |
| 9     | 9      | 11    | 6         | 5           | 4           | 44    |
| 5     | 6      | 6     | 4         | 4           | 2           | 27    |
| Total | 69     | 66    | 64        | 47          | 39          | 306   |

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Fig. 4. Land cover maps of 1976 and 2010.
dependency on those services. The KTWR provides a vast array of ecosystem services and about 51% of the sampled households were found to directly depend on provisioning services of the reserve.

This suggests that the reserve is of high value to the local community, also confirmed by Sharma et al. (2015) who calculated the economic values of ecosystem services of the reserve showing...
Table 7
Changes in ecosystem services with respect to land cover changes.

| Services      | Provisioning | Regulating | Cultural | Supporting |
|---------------|--------------|------------|----------|------------|
| Land cover    | 1976 | 2010 | 1976 | 2010 | 1976 | 2010 | 1976 | 2010 |
| Agriculture   | 17.45 | 7.29 | 11.82 | 4.86 | 5.38 | 2.25 | 2.23 | 1.35 |
| Forest        | 23.61 | 1.39 | 15.74 | 0.93 | 7.29 | 0.43 | 4.37 | 0.26 |
| Grassland     | 16.16 | 79.22 | 10.77 | 52.81 | 4.99 | 24.45 | 2.99 | 14.67 |
| Swamps/marshes| 12.07 | 7.74 | 8.05 | 5.16 | 3.72 | 2.39 | 2.23 | 1.43 |
| River         | 34.10 | 14.36 | 22.73 | 9.70 | 10.52 | 4.49 | 6.31 | 2.69 |
| Sand/gravel   | 38.30 | 31.48 | 25.53 | 20.98 | 11.82 | 9.71 | 7.09 | 5.83 |
| Total         | 141.69 | 141.68 | 94.64 | 94.44 | 43.72 | 43.72 | 26.22 | 26.23 |

Table 8
Impacts of declined provisioning services on dependency.

| Land cover    | Provisioning services | Households for different years (Number) | Households impacted (%) |
|---------------|-----------------------|-----------------------------------------|-------------------------|
|               | 1976 | 2010 | 1976 | 2010 | 1976 | 2010 |                      |
| Agriculture   | 17.45 | 7.29 | 172 | 72 | –58.13% |
| Forest        | 23.61 | 1.39 | 232.32 | 13.67 | –94.11% |
| Grassland     | 16.16 | 79.22 | 159.01 | 779.52 | +79.60% |
| Swamps/marshes| 12.07 | 7.74 | 118.76 | 76.16 | –36.86% |
| River         | 34.10 | 14.36 | 335.54 | 142.83 | –57.43% |
| Sand/gravel   | 38.30 | 31.48 | 376.87 | 309.76 | –17.80% |

high dependency. Similarly, Heinen and Kattel (1992); DNWPWC (2000) and CSUWN (2009) reported a high dependency of local people on the reserve, contributing to the local economy of the area (Rayamajhi, 2009).

However, the supply of ecosystem services and dependency of people have been impacted by the changes in land covers of the reserve. This means the sharp change in land covers over the last three decades, especially declines in forest, swamps and marshes identified as the highest service providers, is of serious concern for biodiversity and people depending on the reserve. The changes in land cover can affect ecosystem functions and processes (Lovell and Johnston, 2009), water regulation (Geng et al., 2015), thus affecting the ecosystem integrity of the reserve. This has a direct impact on biodiversity of the reserve, especially the globally threatened species with limited habitat range such as Swamp Francolin, Ganges River dolphin and Wild water buffalo. Chhetri et al. (2013) and Chaudhary (2007) already noted degradation of ecosystems and the likely consequences for globally threatened species with limited habitat range in the reserve.

Equally important are the implications on people depending on ecosystem services of the reserve. About 67% of the sampled households perceived a decrease on their dependency as a result of decline of ecosystem services. Even the basic material needs of local’s wellbeing such as fuelwood, wild food, etc were found to decrease sharply. This clearly shows degradation of wellbeing of people and local economy of the area. This could further decrease the adaptive capacity of the locals, thus making the population more vulnerable and trap them into poverty (Gerlitz et al., 2012). This also raises questions of coping strategies by the locals over the years. Coping strategies in the area, according to ICIMOD and MoFSC (2014), were short term such as kerosene use, buying food on credit, labor migration, borrowing money, and cutting down the living expenditure. However, these short-term strategies are not enough for them to adapt to the changing scenario sustainably. This might force people to further depend on the remaining ecosystems of the reserve legally/legally to fulfill their basic needs. This means further degradation of ecosystems with implications both on people and biodiversity. This situation mirrors trends of wetland ecosystems around the world with a high degree of degradation making ecosystems and people vulnerable (MEA, 2005a). In such scenario, urgent actions by the concerned organizations at local, national and global levels should be taken to restore the degraded ecosystems and conserve the critical habitats of biodiversity with a particular focus on the globally threatened or flagship species.

In this regard, our findings have timely policy implications for improving livelihoods of people and managing ecosystems. Given the dependency of people on provisioning services of the reserve, our results suggest biogas or solar energy as alternatives of fuel wood for cooking. For renewable energy, community institutions like buffer zone management committee or youth organizations could collaborate with government and non-government organizations and play an important role in raising awareness and promoting renewable energies schemes. Promoting agroforestry could also reduce the dependency on fuel wood and grass from the reserve, while private fishponds could reduce fishing in the river, swamps and marshes of the reserve. More importantly, interventions for alternative livelihoods should be promoted. Options could be pro-poor ecotourism, homestays and up scaling of tourism products such as mats in the area (ICIMOD and MoFSC, 2014). In fact, some organizations like Bird Conservation Nepal (BCN) initiated private fishponds as an alternative sustainable livelihood. Such alternatives should be further continued and local’s capacity should be built up for sustainable fisheries management.

Along with these, our study could also help in balancing equal supply and demand of ecosystem services for a self-sustaining human-environment system (Burkhard et al., 2012). In this regard,
our study has implications on planning and management of ecosystems of the reserve. First, we believe that such a study helps in identifying ES trade-offs, which can be used for identifying areas where services are declining or increasing, and hence prioritize those areas for conservation and management. Trade-offs of ES and sustainable land use management are intricately linked with each other (Briner et al., 2013). Second, it also helps in identifying the trade-offs of land cover, which can be used by managers to maintain the composition of land covers for ecosystem integrity. We also believe that our study incorporating the local opinion of ecosystem services helps to understand local preference for land covers; for example, swamps and forest were the major land covers used by the local community. This can be used to promote sustainable use of ecosystems by restricting the mobilization of local people in land covers with less capacity to supply services. The local opinion in conservation and management of ecosystems is important not only for local (Martín-López et al., 2012; Egoh et al., 2008), but also for national and regional policies (Kumar et al., 2013). With these, such protected areas like the KTWR, which are the last bastions for biodiversity conservation and livelihood for people, could be restored and managed sustainably.

6. Conclusion

Our findings show that the land covers of KTWR have changed significantly over the span of 34 years with implications on ecosystem services and people’s dependency. The reserve’s land cover capacity has been degraded with sharp decline in forests (16%), swamps/marshes (4%), rivers (14%) and other ecosystems, except an increase in grasslands (45%). With significant changes in land covers, especially forests and swamps, ecosystem services were found to decline with implications on people’s dependency. The dependency of people, as perceived by the locals, was reduced by 67% over the last ten years. With degradation of forests and other ecosystems, biodiversity with specific habitat range are at risk. With the impacts on the majority of people’s dependency, their subsistence livelihood is at risk. We discussed the alternatives to reduce dependency of people on reserves, and ways to restore and better manage the reserve to maintain ecosystem’s integrity and conserve its unique biodiversity. The study contributes to a better understanding of a complex interaction between humans and the environment, highlighting the demand and supply of ecosystem services. The results of this study can be used to develop holistic approaches to restore, conserve and manage the ecosystems and its services.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecocom.2016.04.002.

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