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Linkages among forest, water, and wildlife: a case study from Kalapani community forest in the Lamahi bottleneck area of Terai Arc Landscape

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Abstract: Forests and water are important entities for sustaining life on earth. In a terrestrial ecosystem, linkages between the entities creates a mosaic benefiting wildlife. In turn, communities get benefits stemming up from ecosystem services such as fodder, fuelwood, and water. We present a case study from a forest restoration project to assess the linkages between forest, water and wildlife across the Lamahi bottleneck area in Terai Arc Landscape. We used a combination of surveys such as forest area and canopy cover change (2001–2016) analysis followed by identification of water sources, camera trapping survey, household questionnaire survey, and process documentation. Forest area has increased by ~20 km^2 in last 15 years followed by number of water sources along the identified tributaries. Water sources are conserved in the form of conservation ponds by communities living downstream and utilized irrigation water in vegetable farming. Communities have benefited financially (~US$ 1252) contributing to their income level from the sale of fresh seasonal vegetables in nearby markets. Camera trap surveys including the assessment of historical records has shown a presence of wildlife including elephants, hyenas, and other small carnivores in and around the bottleneck forest. Both, motivation and enthusiastic support from local communities followed by conducive government policies led to the improved condition of natural resources over the period. This has also created a mosaic for wildlife forming functional connectivity along the linear Terai Arc Landscape.

Keywords: Community forest, connectivity, forest, linkage, Terai Arc Landscape, water, wildlife

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1. Introduction

Forest and water are crucial entities in sustaining life on Earth, and those that constantly interact to produce healthy and productive ecosystems (Blumenfeld et al. 2009). It is necessary to understand how various ecosystems are linked with each other, including dependency of the human population that lives in the area where the availability and quality of water resources are insecure (Birch et al. 2014). Linkages between forests and water is evident within the watershed context (Calder et al. 2007). Forests play an important role in the hydrological cycle, contribute in reduction of disaster risks and provide an array of ecosystem services including provision of fuelwood, timber etc., regulation of water quality and flow, carbon sequestration, reducing erosion and supporting a wide array of flora and fauna (Smith 2013). Water hydrates forests, wildlife, and people; supports in growing their food; powers our home and industry; and nourishes our terrestrial and aquatic ecosystems (Birot et al. 2011). Thus, any loss of forest and water habitats is a direct threat to biodiversity conservation, and affects local livelihoods adversely (Chaudhary et al. 2007; Måren et al. 2013).

In Nepal, forest cover is almost 44.7% of the total geographic area, and plays an important role in maintaining the health of an ecosystem and fulfilling crucial needs of people for fuelwood, fodder, and income (DFRS 2015). The community forestry program was formally launched in Nepal in 1978 with the enactment of the Panchayat forest rules and the Panchayat protected forest rules (Acharya 2002) and widespread devolution of state forest areas in 1990s that created thousands of active forest user groups (Heinen and Kattel 1992). Community Forest User Groups (CFUG) are recognized as self-governing and autonomous institutions that can acquire, possess, transfer or otherwise manage property (Bluffstone et al. 2018). Three-quarters of community forests (CF) are in the hills, 16% in the high mountains, while 9% are in the lowland Terai. The forest handing over to the CFUGs were detailed in 1995 forest regulations and operation guidelines, which were revised in 2009 (MoFSC 2008). Till the end 2017, a total of 19,361 CFUGs covering 1.8 million ha of state forests have been handed over to forest beneficaries totalling 2.4 million users. Thus, Nepal is seen as a leader in setting conservation goals and creating progressive programs and legislations related to resource management and conservation (Agrawal and Ostrom 2001). Replication of successful community forestry programs have been crucial in maintaining the tenacious connectivity of forests along the Terai Arc Landscape (Wikramanayake et al. 2010). Terai Arc Landscape (here after referred as Terai Arc) is a linear terrestrial landscape that spreads along the foothills of the Himalayas forming a network of 16 protected areas (5 in Nepal and 11 in India) with high dominance of terrestrial ecosystems, and varying degrees of connectivity between the geographically segregated protected areas (Wikramanayake et al. 2004). Despite considerable success in conserving the landscape, forest degradation, and deforestation are still serious threats, with agriculture expansion, illegal harvesting, and encroachment into government lands as major drivers (MoFSC 2016).

There have been many studies that link impacts of natural resource management on the livelihood of communities (Dev et al. 2003; Adhikari et al. 2004; Bajracharya et al. 2006). However, very few studies have looked into the linkages among natural resources, their collective services in enhancing the livelihood of communities, and its effect on the state of the resource over time. For example: the success of community based resource management model, such as community forestry program, has been well tested in projects such as community based forest restoration along wildlife corridors. Nepal's Forest Act 1993 provisioned for transfering the protection, management and use rights of forest products from the government to the communities (Acharya 2002). As a result, livelihood of communities living in the vicinity have been enhanced through engagement in small scale enterprises such as individual home stays etc, while ensuring forest restoration.

In this paper, we present a case study highlighting the linkages between forest restoration, water resource management, and wildlife conservation in critical watersheds that benefit local communities while providing refuge and/or facilitating connectivity for wide ranging mammals such as the tiger and elephant across the Terai Arc. Lamahi bottleneck area (LBA) has been identified as the critical strategic site within Terai Arc (Wikramanayake et al. 2004) that offers an opportunity to present our case study where Government of Nepal and WWF Nepal have been actively engaged for forest restoration since 2001 (MoFSC 2004; MoFSC 2016). Forest restoration measures in LBA have been identified as a successful initiative. Restoration measures can be categorized in three levels: 1) formation of new CFUG and/or strengthening the existing CFUG institutions with respect to forest protection and management, 2) mobilizing CFUGs in the protection of forested land for natural regeneration supplemented by enrichment planting, and 3) supporting CFUGs to reduce dependency on forests. Given the 15 years (2001–2016) of forest restoration measures in LBA, this paper tends to address two broad research questions:

1) What is the status of resources (forest and water) over the time?
2) What benefits have communities realised resulting from linkages among the resources triggered by restoration measures?

2. Method and methodology

2.1. Study area

2.1.1. Lamahi bottleneck area

LBA is a part of the Terai Arc, running east-west (82°31′–82°48′) covering an area of 245 km^2 (Figure 1). It connects Banke National Park in the west and provides refuge for big mammals enroute to Suhelwa Wildlife Sanctuary, India, located in the south. Within LBA, a total of 37 CFs have been handed over to the surrounding communities. Hill migrants have settled along the northern fringe of LBA, whereas indigenous Tharus, and other ethnic and minority groups occupy the southern part. Lamahi is the nearest local market with a human population of 87,114 individuals (CBS 2011). This market center has accelerated the excessive and unsustainable extraction of forest and water resources from surrounding areas, including LBA (MoFSC 2016).

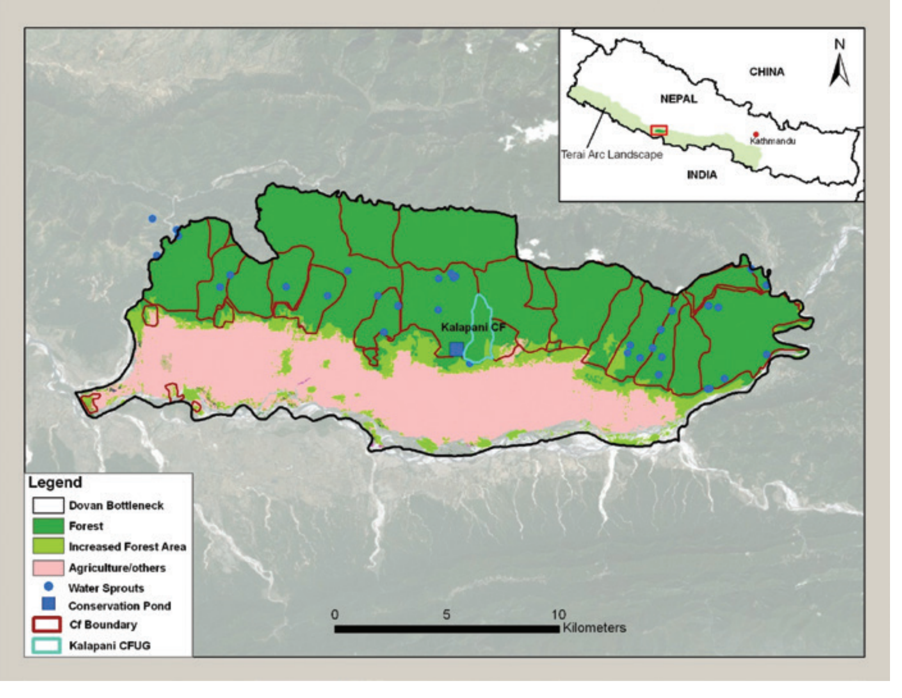

Figure 1: Study area, forest cover change detection and location of active water sources in Lamahi bottleneck area (LBA) including conservation pond. Kalapani CF is also shown along with network of community forest in LBA and inset showing the spatial location of LBA along Terai Arc Landscape.

2.1.2. Kalapani community forest

Kalapani CF is a 19.5 km^2 forest block located within the south-east region of LBA. 300 households are registered with the Kalapani CFUG comprising of mostly the indigenous Tharu community but includes hill migrants as well. Livestock farming, wage labor, and remittance are means of livelihood (present study). Their energy demand is met with biogas (5%), liquefied petroleum gas (LPG, 50%), fuelwood (20%) and other residues (25%), respectively (present study). *Khauraha khola* (spring) originates from the Kalapani CF forming a micro watershed, providing clean drinking water and irrigation benefitting 36 households out of a total 300 households. Before 2001, the quality of the forest in Kalapani CF was highly degraded (Figure 2).

2.2. Methodology

We used an interdisciplinary approach incorporating multiple methods such as forest and canopy cover change analysis, identification of water sources, camera trapping survey, questionnaire survey, and process documentation to answer prescribed research questions.

2.2.1. Forest and canopy cover change analysis

We compared forest area and canopy cover extent between two timeframes (2001–2016) to measure ecological forest restoration measures (Aldrich et al. 2002). For this purpose, we used freely available Landsat satellite imageries between September and February for two-time periods: 2001 and 2016, respectively. Forest cover classification was done using ERDAS IMAGINE 2016. Post

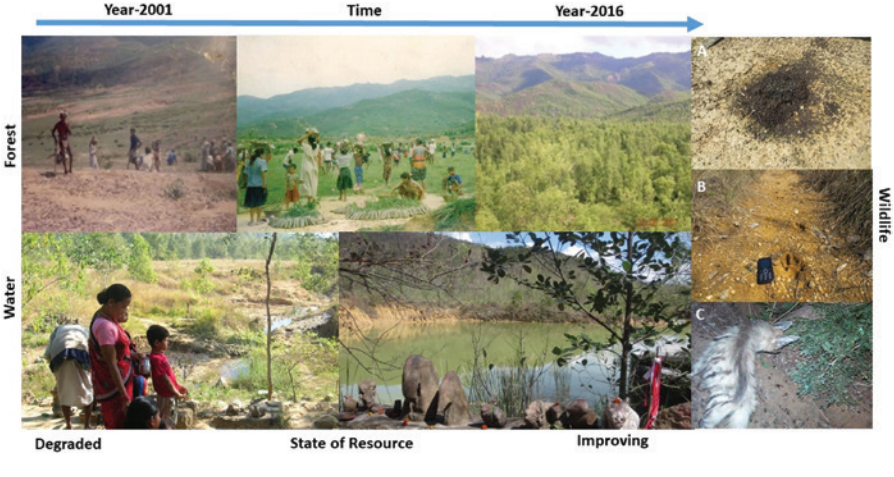

Figure 2: Interaction between forest, water, and wildlife in and around Lamahi bottleneck area. Presence of wildlife recorded between 2001–2016: (A) four horned antelope pellet group; (B) pugmark of leopard; (C) camera trapped hyena.

classification and change analysis was done in ArcGIS (Ver. 10.2). We used standard procedures for forest cover mapping analysis vis-à-vis image acquisition, image stacking, image registration/rectification and masking, supervised classification, and ground verification/truthing followed by an accuracy assessment.

We estimated forest canopy density using forest canopy density (FCD) mapper software, Ver. 1.1 (JOFCA 1999). We proceeded with initial image registration, image subset, and geometric correction followed by masking out the waterbody, cloud, and shadow area. We used indexing process using vegetation, thermal, and shadow indices. After indexing, we used FCD range process for getting required FCD classes. We followed the standardized protocol (Ekakoro et al. 2015) for getting required FCD range classification and classified as <10% coverage as "no vegetation", 10–40% classified as "open canopy", 40–70% classified as "moderate canopy", and >70% classified as "closed canopy", respectively.

At the fine scale, we also took digital photographs at three-time intervals (2001: degraded, 2010: recovering, 2016: improved) of the forest cover from a common vantage point. Archived photographs from the summer season of 2001, 2010 and 2016 timeframe were acquired through Kalapani CFUG and WWF technical records. These fine scale photographs broadly helped to visualize the dynamics in vegetation pattern (degraded, recovering, and improved) (Sonnentag et al. 2012) in and around LBA over time.

2.2.2. Identification of water sources

We surveyed for water springs sources along the seasonal tributaries (Poudel and Deux 2017) passing through Kalapani forest and mapped its spatial distribution with hand held Global Positioning System (GPS) in 2005 and 2010. One of the spring sources gradually became larger over the period (2005–2016) forming a conservation pond. We visually documented the changes in the physical structure of the conservation pond with photographs taken from a vantage point in 2005, 2010, and 2016. Again, archived photographs from summer season of 2005 and 2010 timeframe were acquired through Kalapani CFUG and WWF technical records.

2.2.3. Camera trapping survey and historical records of wildlife

We conducted an opportunistic camera trapping survey to enumerate the detection and non-detection of wildlife (Karanth and Nichols 2002) in Kalapani CF in summer of 2015. We selected 10 strategic locations to install camera traps at a height of 2.5 m off the substrate for 15 days to capture wildlife within the community forest. We used index (number of unique photographic detection per 100 trap night efforts) to measure the relative abundance of wildlife (O'Brien et al. 2003). We also conducted a rapid appraisal of records available in CFUGs and the District Forest Office to gain historical knowledge (dated back to 2001) on wildlife presence in LBA and surrounding areas. No camera trap record exists prior to 2001, hence recent camera trapping data and historical records only serves as an evidence of their detection in the LBA rather than evidence of increase in wildlife population in LBA.

2.2.4. Household questionnaire survey

To measure the benefits of the conservation pond amongst the community, we used household questionnaire surveys in the summer season of 2015. Out of the 300 households registered in Kalapani CFUG, we used stratified sampling techniques (Lohr 2009) with a sample size of 61 households (~20% of the total households in this CFUG). Further, we categorized 36 households (59%) as water users (case) and another set of 25 households (41%) as non-water users (control), respectively. Chosen subset of 36 households, also benefited from the conservation pond in vegetable farming. We pre-tested the questionnaires, and hired a local enumerator for conducting the survey using prescribed research design.

Each questionnaire had 10 sets of structured questions with dichotomous answers either yes (1) or no (0) (Table 1), except for the 11th question regarding the income level of the community which was measured in real numbers. We measured the income source of the communities (in Nepalese currency, 1 US$=NRs 105) as total annual income incurred from various sources (services, off farm and on farm activities, business, etc.). Annual income generated from sale of vegetables (with use of water from the conservation pond) was also incorporated in it. Annual household income estimated does not include any imputed input value such as labor cost and other household's inputs cost. We used frequency analysis on each of the 11 sets of questions. We used simple statistics with sample mean, standard deviation, and cross tabulation to assess the characteristics of the sampled households in Kalapani CFUG.

We adopted case-control study (Rothman and Greenland 1998) to examine the effect of water use from the conservation pond on three variables (well-being, food availability, and total income). Firstly, well-being of the communities (well off / improved, medium, and deprived) was measured as the social status of each of the households in the community. Process and criteria for measuring the social status is primarily based upon Participatory Well-being Ranking (PWBR) methodology (Mosse 1994). CFUG carries out PWBR either during the formulation of a new community forest operation plan or during its revision. Secondly, food availability in the community, proxy to food security (Jones et al. 2013), was measured as whether community (individual household) have food produced by themselves available for a whole year or not. Thirdly, annual income of the communities incurred from various sources were recorded (services, off farm and on farm activities, business, etc.).

Table 1: Forest and Canopy Cover Change between 2001–2016 in LBA.

Year	Canopy Cover (in Ha)				Total Forest Cover (in Ha)
	<10%	10–40%	40–70%	>70%	
2001	142	2617	7008	1334	11,101
2016	160	3638	7180	2124	13,102
Changes	+13%	+40%	+2.5%	+59%	+2001

LBA, Lamahi bottleneck Area; Ha, hectare.

We used logistic regression which allows a multivariate regression relation between a dependent variable and several independent variables (Zar 2009). The dependent variable is dichotomous or continuous, while the independent variable can be interval, dichotomous, or categorical. We regressed the use (1) and non-use (0) of conservation pond with three key variables: well-being, food availability, and total income. Odds ratio (Exp (B)) was used to express the relationship between the variables: odds greater than one (>1) indicates a positive association between the two variables; an odds ratio smaller than one (<1) denotes an inverse association. We used SPSS (Ver. 20.0) for all the statistical analysis.

2.2.5. Process documentation

Lastly, we carried out qualitative data analysis using process documentation (PD) methodology (Borlagdan 1989; Shukla and Sharma 1997) to explain the dynamics of bio-physical resource and institutional process governing the resources in and around LBA. PD conceptually provides a basis to connect output to input by answering where-how questions. In summer of 2015, we conducted a series of interviews (n=9) with key informants (community leaders, CFUG members; n=2), district forest officials (n=2), and WWF staff (n=5), respectively. We drew major events against a time line to explain process (cultural, ecological, and institutional) governing the resources.

3. Results

3.1. Biophysical characteristics

Forest and canopy cover change analysis: Within the 245 km^2 study area, forests covered an area of 111 km^2 in 2001 and 131 km^2 in 2016, respectively (Figure 1). Analysis showed that forest areas have increased by ~20 km^2 in LBA within the fifteen-year period. Forest canopy density analysis confirms an increasing trend in forest quality where canopy cover changes were pronounced higher in closed canopy (greater than 70%) and open canopy (10–40%) cover category, respectively (Table 1).

Identification of water sources: The survey showed water spring sources (point sources, n=34) are distributed randomly along the seasonal tributaries which cascade down the Churia foothills (Figure 1) as of 2005. This has increased to 40 (+17%) in 2010. At one of the point sources in *Khauraha khola* (in 2005) increased to almost 500 m^2 pond (in 2016) holding approximately 1000 m^3 of water (Figure 2). Water is now used for irrigation and drinking purpose benefitting a total of 36 households. Irrigation is managed by the farmers and termed as farmer managed irrigation system (FMIS).

Camera trap survey: We amassed a total of 797 photographs (animal, blank and non-blank) from the camera trap survey with survey effort of 128 trap nights. We recorded striped hyena (*Hyaena hyaena*), small Indian civet (*Viverricula indica*), four horned antelope (*Tetracerus quadricornis*), and barking deer (*Muntiacus muntjak*) as major wildlife residing in and around LBA. Species relative abundance index was approximately 2 mammal photographs per 100 trap night efforts. Historical records showed an occurrence of elephant (*Elephas maximus*), common leopard (*Panthera pardus fusca*), sloth bear (*Melursus ursinus*), honey badger (*Mellivora capensis*), and Indian flying fox (*Pteropus giganteus*) in LBA. A herd of 20 wild elephants including bulls, cows, and calves were recorded in 2003. During their migration from Banke National Park (from western side) to the east of LBA, one of the tuskers died because of electrocution (Figure 3).

3.2. Characteristics of the Kalapani CFUGs

The average family size of sampled households (n=61) of the Kalapani CFUGs was 5.1 persons (SD 2.2). In terms of well-being ranking, the majority of the sampled households (56%) were in the medium category, followed by deprived (40.6%), with a much smaller percentage in the better off category (Table 2). Half of the sampled households had food security for almost 12 months while the remaining half of the respondents had variation in annual food availability. About 95% of the respondents had access to safe drinking water from a tube well and an underground well (Table 2). Only 47.5% of the respondents had access to alternative energy schemes such as biogas whereas the majority still rely on other regular energy sources (kerosene and fuelwood). Around 98.4% of the respondents had year-round grass availability harvesting from various legal sources like the community forest and private land (private forest and agro-forestry). 48% of the sampled households had representation of women in at-least one of the functioning natural resource management groups. The sampled communities had a total annual income of NRs. 3,379,000 (~US$ 32,806) of which NRs. 131,460 (~US$ 1252) alone was generated from the sale of fresh seasonal vegetables in nearby markets.

Figure 3: Male adult bull elephant electrocuted along the lamp post in Lamahi Bottleneck Area (left). Male elephant leading the herd of 20 elephants that visited LBA in October 2003. Female elephant was recorded in LBA in 2005 (right).

Table 2: Respondents (n=61) answers (in %) to ten standard structured question asked to each of the household representing Kalapani CFUG in and around LBA.

S. no.	Statement on resource management	No	Yes	Well off	Medium	Deprived	Completed	Not completed
1	Access to safe drinking water through tube well and underground well	4.9	95.1	–	–	–	–	–
2	Food security all-round the year (have food availability at the household level for 12 months)	50.0	50.0	–	–	–	–	–
3	Access to improved toilet in their backyard	100.0	–	–	–	–	–	–
4	Access to alternative energy at the household	47.5	52.5	–	–	–	–	–
5	Grass availability from legal sources: private land, community forest etc. (have grass availability at the household level for 12 months)	1.6	98.4	–	–	–	–	–
6	Children (6–16 years) going to school in their communities	21.3	78.7	–	–	–	–	–
7	Female representation to Natural Resource Management committee	50.8	49.2	–	–	–	–	–
8	Use of pesticide in the farmland	–	100.0	–	–	–	–	–
9	Female participation in economic engagement in their day to day activity	83.6	16.4	–	–	–	–	–
10	Well-being status based on participatory well-being ranking conducted by CFUG	–	–	1.6	55.8	42.6	–	–

Well-being status calculated based on participatory wealth being ranking derived from the record of community forest user group. 11th question was on total income (cash and kind) in the household. CFUG, Community Forest User Group; LBA, Lamahi bottleneck area.

3.3. Comparison among the case-control group

Percentage share of total income earned by the sampled communities was found to be higher (66%) among households from non-water user (control) group than households from water-user (34%, case) group (Table 3). Among the water users, ratio of income share (from vegetable sale) with respect to total income earned by communities was found to be a mere 4%. Among the water users, majority of the households (64%) have deficiency in year-round food availability; whereas majority of the households (71%) have year-round food availability among non-water users. Water from conservation pond is also used by households who had no access to clean drinking water (5%, Table 2). Majority of households (60%) were found to be in medium and better off category in non-water user group than in water user group (36%).

Among the three variables, logistic regression analysis showed that well-being and income of communities have significant positive relationship (odd ratio >1, p<0.05, Table 4) with regards to use and non-use of conservation pond by the CFUGs; while food availability/security has significant negative relationship (odd ratio <1, p<0.05, Table 4). The model predicts that odds of using water from well off households is 16.94 times more than that of medium category households. Similarly, we expect to observe about 1.061 times increase in the odds of using water for a unit change of 1000 NRs in income. In comparison of water use from conservation pond and food security, the model shows that the odds of using

Table 3: Comparison of covariates (income level, food availability and well-being status) against the user and non-user of conservation pond among the Kalapani CFUG.

Variables	Qualifiers	User (case, in %)	Non-user (control, in %)
Income level*		34	66
Food availability	Yes	36.1	70.8
	No	63.9	29.2
Well-being status	Deprived	64	40
	Medium	36	56
	Better off		4

*Of the total income; CFUG, Community Forest User Group.

Table 4: Logistic regression between the dependent variable (use of conservation pond) and three independent variables (food availability, well-being status, and income).

Parameters	B	S.E.	Wald	d.f.	Sig.	Exp (B)
Food availability/security	−1.802	0.884	4.161	1	0.041	0.165
Well-being status	2.830	1.206	5.509	1	0.019	16.940
Income	0.059	0.019	9.371	1	0.002	1.061
Constant	−3.982	1.379	8.338	1	0.004	0.019

d.f., Degree of freedom; Sig, significant; Exp (B), odd ratio.

water for food secure households is 0.165 times less than that of food insecure households.

3.4. Process documentation

A series of chronological external and internal events led to forest restoration in LBA (Figure 4). Government of Nepal nationalized all forests as state forests in 1957. The nationalization resulted in rapid loss of forests in the country due to insufficient number of forestry professionals, trained staffs, and inadequate infrastructures within the government. Lack of ownership of local people towards the state-owned forests also contributed to forest loss through encroachment and deforestation. Therefore, realizing the need of people's participation in forest management, community forestry was initiated in the mid-hills of Nepal in the 1970s. Given the success of community forestry program in the mid hills, the government replicated the program in Terai forests, handing over the management of forests to the communities during the 1980s. Communities in Kalapani CFUG and other CFUGs have a strong traditional belief in "*rakauna*" meaning "the need to preserve". Under "*rakauna*" communities usually preserve a patch of forest area, used only during religious ceremonies while strictly protected at all other times. Over the years, communities experienced deforestation and decrease in forest quality in forests around the LBA, while good forest regeneration was seen in lands set aside as "*rakauna*". Coupled with the declaration of the community forest program, communities

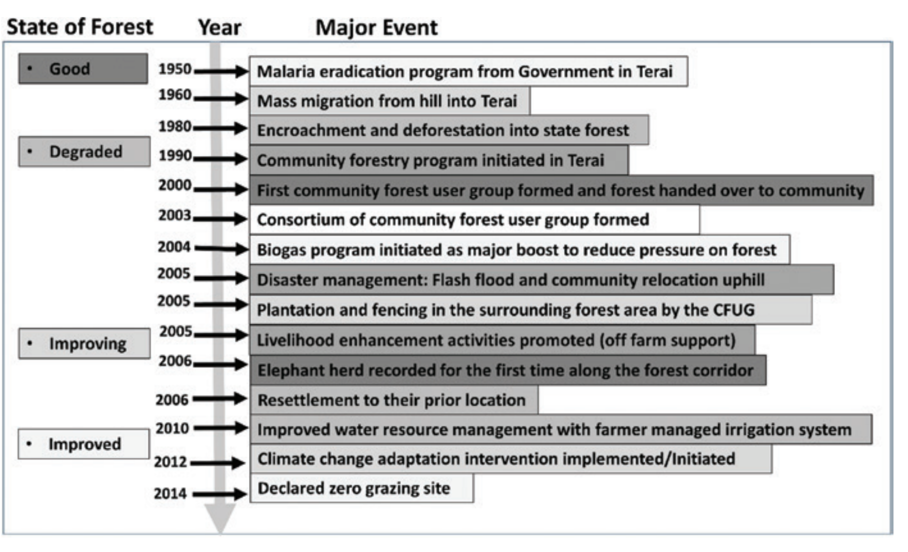

Figure 4: Chronological event (1950–2014) leading to restoration of forest in and around Lamahi Bottleneck Area.

also started to conserve surrounding forests as *"rakauna"*. Between 2001–2014, after initiation of the community forest program, successful community based livelihood interventions, and biogas programs collectively reduced the dependency on forests leading to improvement in forest condition in and around LBA. Major flood prior to 2006 and subsequent resettlement made communities realize the importance of forest restoration to secure themselves from potential natural disasters in the future. Climate change adaptation measures such as slope stabilization through bioengineering measures were implemented in the catchment to control possible sedimentation in the water sources. In 2014, Kalapani CF, a part of LBA was declared as a zero-grazing site by the District Forest Office which helped in erosion control in the catchment through healthy natural regeneration.

4. Discussion

This study is a compilation of 15 years of effort in forest restoration by local CFUGs promoted by Government of Nepal through its conducive participatory natural resource management policy (Acharya 2002). This is the first case study that stems up from changes in resource conditions over time from forest restoration initiatives and the services (benefits) it has brought to the communities living along the edges and wildlife living in the core forest habitat. LBA is now identified as a key strategic site within the landscape that provides improved forest space for enhancing connectivity as wildlife corridors and thereby providing ecosystem services (provisioning services: water availability, fuel wood; regulating services: preventing soil erosion and maintaining soil fertility; habitat services: shelter for various floral and faunal species; cultural and amenity services: landscape integrity and heritages) to the users living alongside. The results corroborate with Lamb and Gilmour (2003) that highlights degradation of forest as the cause of significant losses of biodiversity and decrease in human well-being. They emphasized that forest restoration renews the provisions of goods and services to those areas that helps to conserve the biodiversity and improves well-being of local communities as well.

Forest cover and canopy cover showed increase in forest area (18%) and canopy cover (3–59%) in the last 15 years. Results showed an agreement with positive change in district (Dang) forest area during the same period (DFRS 2014). Thus, our analysis supports the argument that effective forest management institutions such as Kalapani CFUG could have shaped forest conditions over a period (2001–2016) (Gibson et al. 2000). Few salient features led to the effective governance over forest management. Firstly, a pre-requisite for government legislations as the precursor for communities to initiate protection of resources in and around LBA (Heinen and Kattel 1992; Agrawal and Ostrom 2001). Community's collective effort in forest restoration initiatives as evident in LBA took more than a decade (since 2001) for forest to be restored in both quality and quantity. Secondly, transferring the use rights of forests resources from the state to local communities with formation of CFUG may be a critical factor in accounting for improved forest conditions. Forest restoration initiatives in LBA started with conducive NRM policy of the government to hand over forest products use rights from state to local communities (users). This helped in forest restoration as evident in the mid hills of Nepal and established strong relationship between institutions and regeneration of once denuded hill forests (Branney and Yadav 1998; Gautam et al. 2003). Thirdly, local forest users were able, in some cases, to devise rules regulating access, and use that reduce the pressure due to overharvest. This engagement may be further enhanced by the community's traditional beliefs aka "*rakauna*" as evident in process documentation.

Household survey and community records shows that communities are homogenous in nature, and thus helped to garner strong local political will and create an incentive to collectively participate in conservation initiatives (as mentioned during the interviews). But why community participated in the conservation efforts was essential? thus "process or situation" was important as it led to mutual relationships between people and forests (Jordan 2003). Process documentation suggests that cultural beliefs of the communities (*Rakauna*) in the early days coupled with time specific CF programs initiated (process) positive changes in the state of forest resources and their management in and around LBA. Climate induced disasters such as landslides and flooding observed in and around LBA (scenario) further strengthened the case for nature based disaster risk management through forest conservation as evident in process documentation. Few other initiatives that promoted forest conservation includes plantation, promotion of alternatives energy, and livelihood options. Successful biogas alternatives to fuelwood with a subsidy from state and conservation partners is reflected through the reduced pressure on forests. Thus, process demanded a long-term investment (~US$ 0.3 M) in initiatives that reduces and diversifies the pressure on forests. As evident in the household survey the majority of surveyed household have access to the alternative energy.

Our result highlights the use of water from conservation ponds in benefitting the community's agricultural practices (e.g. small-scale irrigation system), thus improving food security and income especially among deprived communities. Logistical model predicted that food insecure communities are using more water from the conservation pond while deprived and low-income families showed less odds towards water use from the conservation pond. Thus, vulnerable communities benefited over time albeit low share from sale of vegetables (4%). However, these incentives (seasonal vegetables, income, and resource use) have also buy-in support (or motivation) from the communities (especially marginalized communities in our case) in protecting and managing these common property resources in and around LBA. It should be noted that these by-products/incentives are the outcomes of years of investments in forest restoration initiatives by the communities in LBA. These successful efforts need to be replicated in the adjoining user groups and scaled up in the same communities by engaging more deprived households as the logistical model reveals. Few other examples (products) that supports our study includes the tourism model in Baghmara community forest in Chitwan National Park (CNP) (Dinerstein et al. 1998) and home stay models in corridor, and buffer zone in CNP (TAL 2016). These successful products exemplify the importance and benefits of linkages between available natural resources and communities living across the vicinity.

It is often argued that prior experience with other forms of local organizations greatly enhances the repertoire of rules and strategies known by local participants and is potentially useful to achieve various forms of regulations (Ostrom 1999). Forest and water being an integral part within the Kalapani micro-watershed, the organizational experiences and leadership under the CFUG regime also helped to replicate forms of regulation for effective management of conservation pond for the poor and deprived communities (farmers) in Kalapani CFUG. Thapa (2002) showed that organizational experience in one of the resource regime (farmer managed irrigation system) helped in management of others common natural resources such as formation of community forest in Chitwan.

LBA provides a critical habitat to existing forest connectivity in the Terai Arc (Wikramanayake et al. 2004). It provides refuge to wildlife migrating along the forest connectivity blocks. Over the years, linkages among forest and water developed a mosaic habitat for wildlife and provided additional benefits (as highlighted in preceding paragraph) to the communities living in the vicinity. These benefits have created an opportunity and motivation for communities in restoring habitat and thereby maintaining the connectivity along the landscape. This LBA model is like the Khata corridor model whereby the once highly degraded forest corridor has been restored and transformed into a functional corridor, with evidence of dispersing mega fauna (such as tiger, rhino and elephant) between the protected areas: Bardia National Park, Nepal and Katerniaghat Wildlife Sanctuary, India (Wikramanayake et al. 2010).

5. Conclusion

Our analytical results from multipronged approach used in the study; evidence based information (forest and canopy cover change analysis, camera trapping survey, and identification of water source), empirical information (statistical analysis of household data), and qualitative information (process documentation) provides an opportunity to present a case study at micro watershed level. Effective forest management institutions such as CFUG, and local cultural belief of the homogenous communities triggered improved conditions (state) of the resources (forest and water) over time. Collective actions provided additional benefits to the communities living in the vicinity in improving their food security, income, and wellbeing through use of water from conservation ponds. In a terrestrial ecosystem, linkages between (forest and water) resources developed a mosaic providing space/habitat for wildlife and provides communities with useful commodities.

There is wide potential to replicate the model elsewhere for ecosystem restoration projects.

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