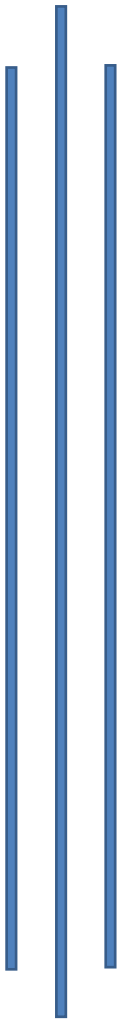
Impact Chain Assessment for Siltation Problem in Phewa Lake Pokhara, Nepal



September 19, 2021

Report prepared by Manoj Pariyar

Master's in Climate Change Management

Western Norway University of Applied Sciences, Norway

Table of Contents

List of Figures

Word count excluding texts from title page, table of contents, list of acronyms, tables, figures, and reference list: 2483 (515 + 1008 + 960)

Acronym:

IWMP	Integrated Watershed Management Plan
PES	Payment for Ecosystem Services
CFUGs	Community Forest Users Groups

1. Area of Interest

Pokhara is one of the top tourist destinations in Nepal and Phewa lake which lies at the heart of the city is the central point of attraction for all the tourists visiting the city. It is the second largest lake in Nepal which is geographically located at 28°12′51″ N 83°56′50″ E at an altitude of 742 m from the mean sea level. The lake gets water from Harpan, Adheri, and Phirke rivers which extend almost 4 km upstream from the lake. The catchment including the Phewa lake, and its feeding rivers is named as Phewa watershed which has a dam at its outlet (Wikipedia, n.d.).

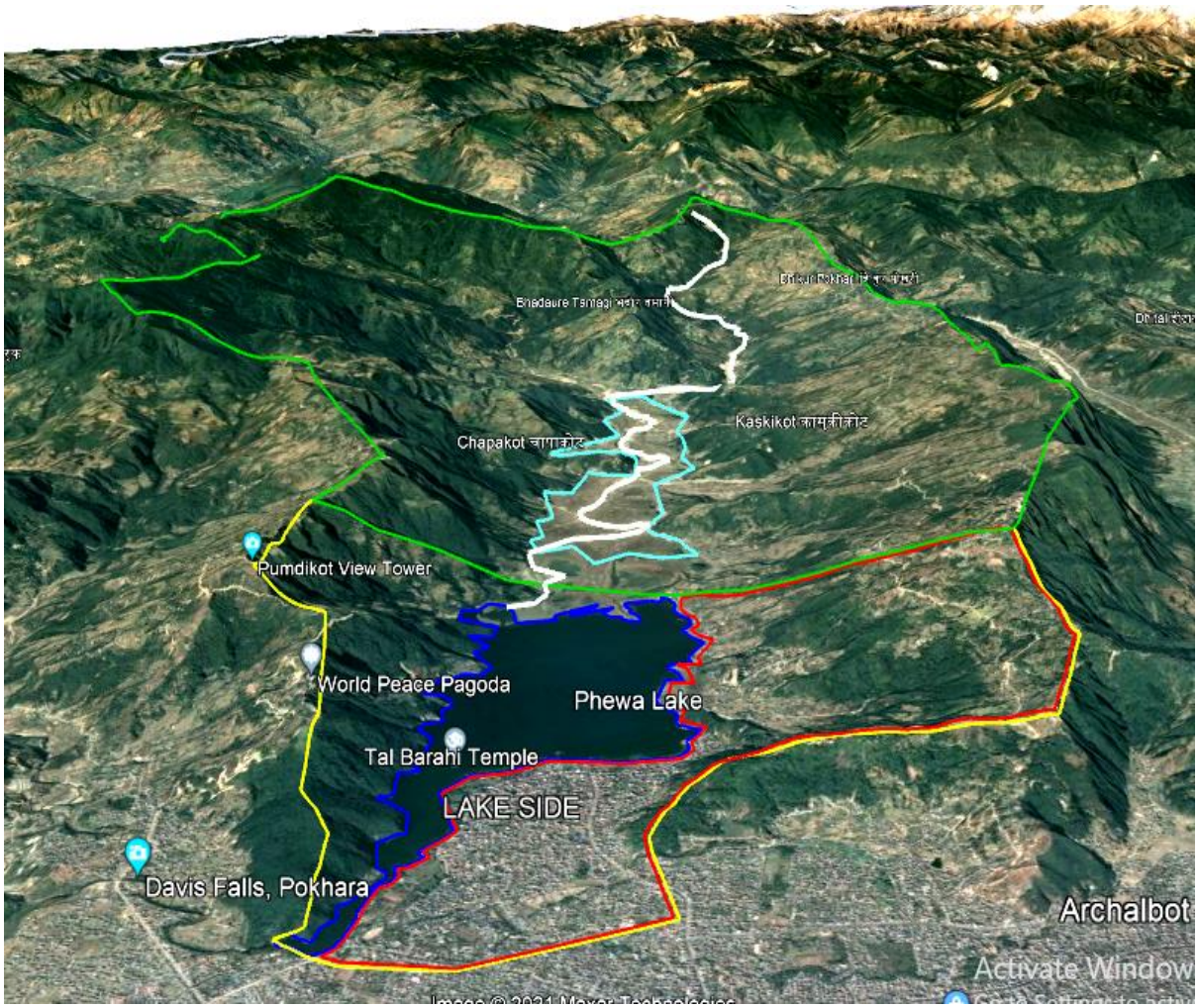


Figure 1: Phewa Watershed (Navy Blue: Phewa Lake, White: Major River, Cyan: Agricultural land upstream, Green: Upstream area, Yellow: Downstream area, Red: Downstream city area); derived from Google Earth

The total surface area of Phewa watershed is 122.53 sq. km. which can be divided into upstream and downstream sections as they possess differences in land use, economy, lifestyle, culture, interests, needs, and problems (Wikipedia, n.d.). The upstream section is rural, and the

communities are heavily dependent on agriculture for their livelihood, whereas the downstream section is urban which is full of hotels, restaurants, bars, shops, and many other tourist-related business entities. Meanwhile, there are a lot of linkages between them in terms of use of ecosystem services, socio-economic interactions, climate and disasters impact and responses. The upstream communities use water for irrigation, while the same is used for recreation, and fish farming in downstream communities. Since, the lake is a major source of attraction for the tourists, the quality of water in the lake is of much importance to the tourist-related business owners downstream (Dhakal & Jetten Ir Bart Krol, 2016). On a positive side, the agricultural products like cereal crops, vegetables, meat, and milk products produced by farmers in upstream area are consumed in downstream city area. Likewise, the people from upstream communities get job opportunities in hotels, restaurants, and other businesses downstream. Meanwhile, on a negative side, the climate or disaster related hazards like flood, landslide and soil erosion upstream pollutes the water in the lake and degrades the water quality which directly impacts the tourism business downstream (Alamy.com, 2016; Dhakal & Jetten Ir Bart Krol, 2016; eadarsh.com, 2021). Because of continuous deposition of sediments on the lake bed, and lack of protection measures in the upstream area, the size of the lake is decreasing gradually which has become a major concern in recent decades (MOFE, 2018; The Himalayan Times, 2021; Watson et al., 2019).

In such a situation, the farmers in the upstream area are desperate to protect their agricultural lands and practice sustainable agriculture, while the business owners in the downstream area want to protect the lake from siltation and enhance their tourism business by inducing water recreational activities in or near the lake. Sediment transport and deposition on the lakebed is a natural process but the process has been hastened due to climate related hazards. A study by (Watson et al., 2019), has estimated that the Phewa lake will lose 80 % of its storage capacity in coming 110 – 347 years based on rate of sediments influx from upstream, so protecting the lake from burial and ultimately extinction has become a major public concern.

2. Risk Mapping and Impact Chain Assessment

2.1 Risk Mapping:

There are several risks associated with the climate-driven hazards in Phewa watershed so, to help spatial planning for lake related recreational activities and protection of lake from burial and ultimately extinction, it is primarily important to identify the associated hazards, exposures, vulnerabilities, and risks. The following figure (*figure 2*) lists out all these aspects in Phewa

watershed.

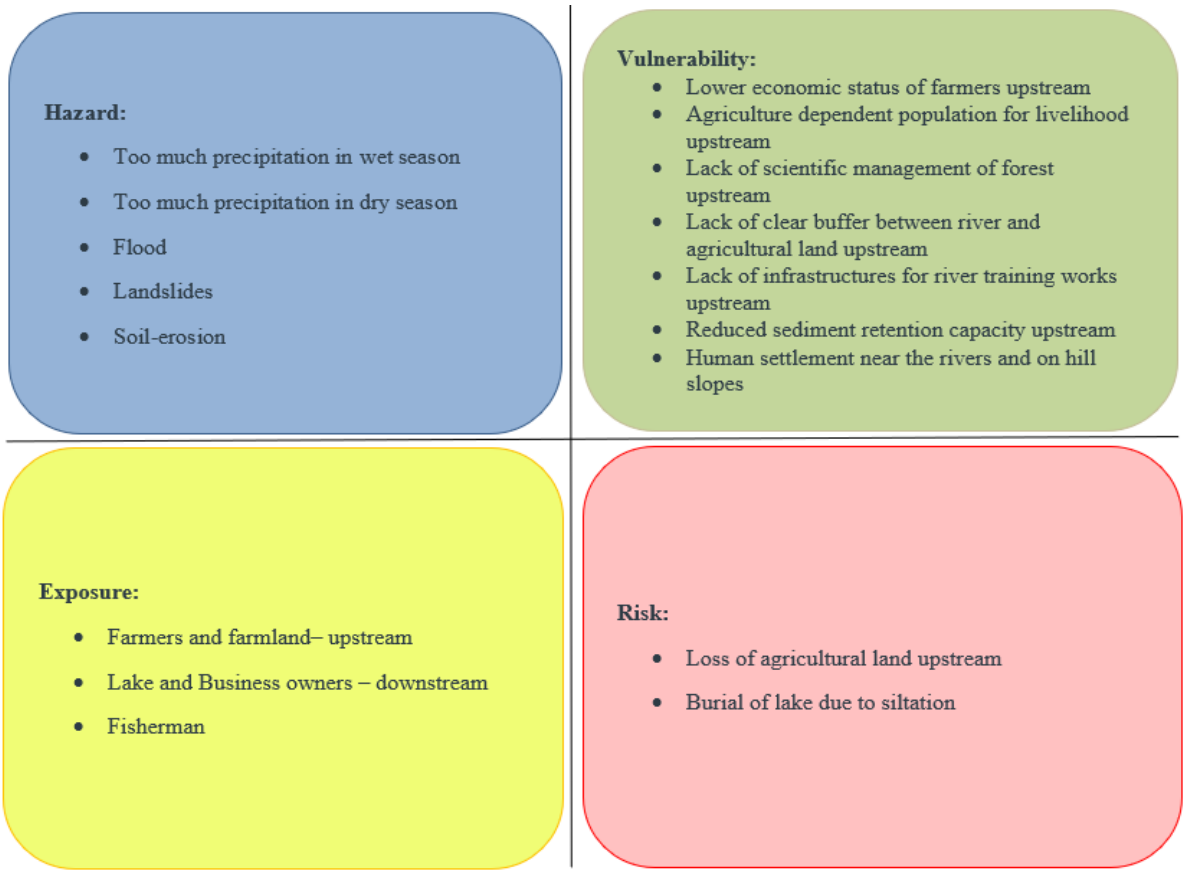


Figure 2: Risk Mapping in Phewa Watershed

The climate of Pokhara is sub-tropical so the summer is humid. Normally, the temperature in Summer range from 25°C to 30°C in summer and -2°C to 15°C in winter. Similarly, most of the rainfall occurs in monsoon season (July – September) but also in May and June (Word travels, n.d.). Meanwhile, like in other places, the global warming has also impacted the climate patterns in Pokhara. The summer days are becoming hotter and longer than ever and the rainfall pattern is totally unpredicted. In general, the rainfall nowadays has become more intense resulting in hazards like landslides, soil erosion and flooding (*" Climate Change Impact in Pokhara ,"* n.d.).

People in the upstream live in small communities spread all over the watershed. Most of the settlements are closer to the river or on the hill slopes so there is high chance that the amount of damage and casualties will be higher in case of disasters. Since the majority of population living upstream are farmers, they along with their agricultural lands are the primarily exposed to the hazards upstream. Likewise, the lake is the major source of income for the people residing downstream so, the business owners are primarily exposed to the hazards. Due to

pollution in lake water and degradation of acquatic ecosystem, the fisherman will also be exposed highly.

There are some factors which make the farmers, business owners and fisherman more vulnerable to the hazards. Most people upstream are highly dependent on agriculture for their living. They do not have any alternative livelihood options to follow if they are abandon from farming so the farmers are the most vulnerable among all. The farmers do not have good economic status so that they can not cope for long period with the impacts of disasters. The agricultural land are either located at the flood plains or on unstable hill slopes which makes them most vulnerable. Likewise, their settlements are also located in similar hazard prone areas. In most places, there is no clear buffer between the agricultural land and rivers and the rivers keeps on chaning its direction during rainy season. There are some places where the communities have initiated the river training works to prevent the high current of water downstream but are not so effective as they were supposed to be. The upper parts of upstream areas have forest but they are not managed scientifically. Haphazard construction of road inside the forest area and random cutting down of trees makes the forest area prone to more landslide and the impact becomes even high at the time of flooding as the sediments from the landslides are swept away downstream causing more siltation.

Apart from all other risks, the major risks which are of more concern to the people living in both upstream and downstream areas are loss of agricultural land and burial of lake respectively. Both these threats are ongoing but it will be in large scale in near future because of high incidence of heavy rainfall in recent years. Among all, the risk of burial and extinction of lake stands out as a major public concern currently.

2.2 Impact Chain Assessment:

The impact chain assessment basically tries to seek for cause and effect relation between hazards, exposures, vulnerabilities, and risks and also between different factors within themselves (Hagenlocher et al., 2018). Therefore, the following figure (*figure 3*) also shows some logical linkages between all these aspects and factors within themselves for Phewa watershed regarding the potential risk of burial of lake, and water pollution downstream, and loss of agricultural lands upstream.

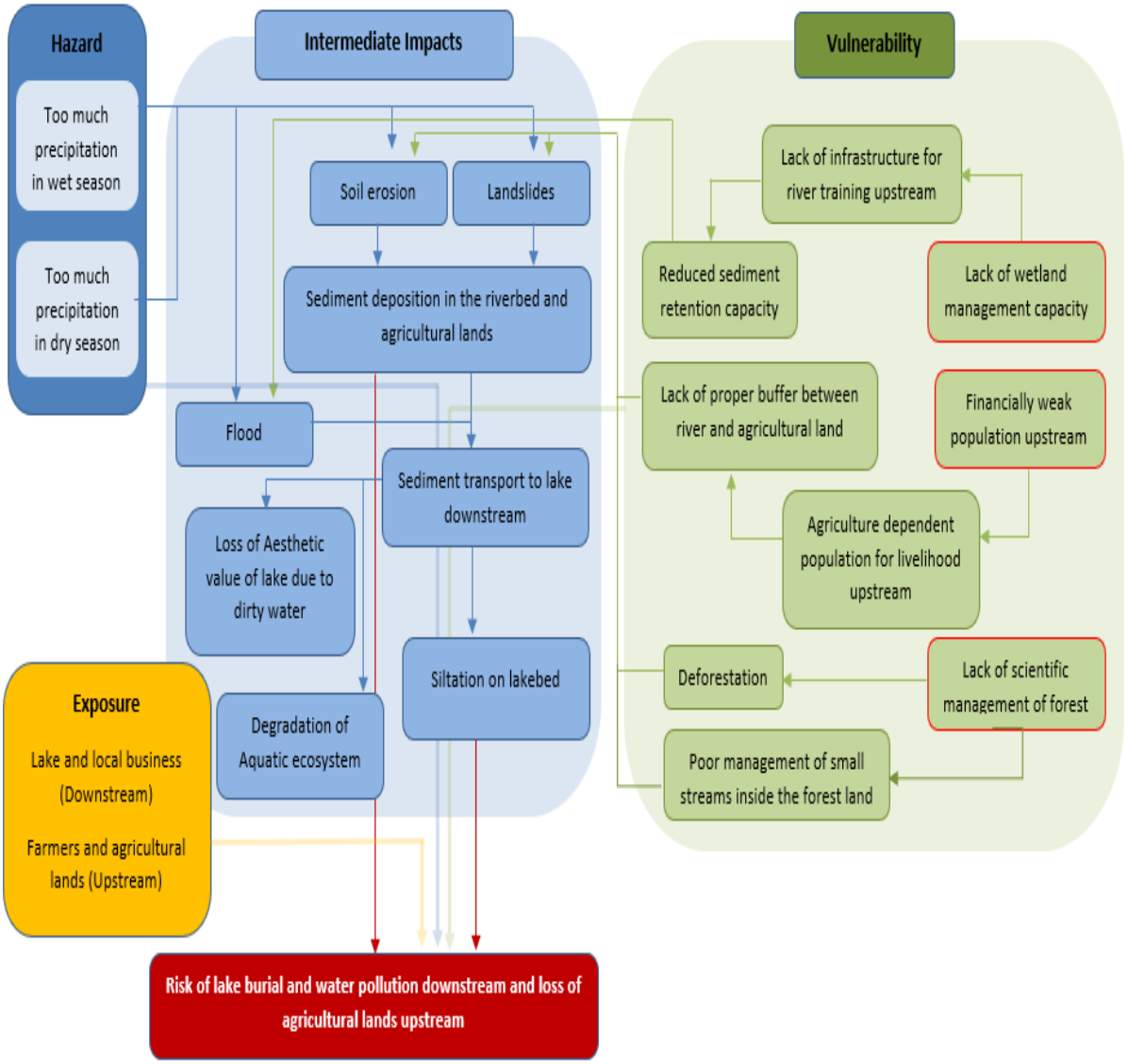


Figure 3: Impact Chain Assessment of Phewa Watershed

As mentioned earlier, the intensity of rainfall has increased drastically than ever and its pattern is also not predictable. The precipitation is high both in dry and wet seasons than before. As a result, the events of soil erosion and landslides are more frequent in upper parts of Phewa watershed. The farmers and their lands are primarily exposed and they are highly vulnerable because of poor management of forest land and weak financial status of communities upstream. On one hand, even if there are community forests and protected forests upstream, their management is not adequate. Deforestation is still a problem. Especially due to poor management of small water streams flowing through the forest land, a large part of forest is destroyed during flooding. The debris from soil erosion and landslides in forest land are swept down to the main river and agricultural lands along side the river. Such a context clearly tells us how sensitive is the community upstream. On the other hand, their adaptive capacity is also

very low because of their weak financial status. Their source of livelihood is agriculture and they do not have capacity to build strong buffer between their agricultural lands and the river.

Poor management of wetland is another factor for increasing the vulnerability in the watershed. As the rainfall pattern is unpredictable, the rivers may be flooded at anytime covering the adjucent agricultural lands with sediments. Eventually, the sediments from upstreams are directly deposited on the lakebed downstream. This problem has become more intense as there is no any sediment retention infrastructures built upstream.

Once the flood enter the lake, the river water becomes dirty degrading the aesthetic value of lake. It takes many days to regain its clean water. On the other hand, due to pollution, the aquatic ecosytem is also affected. There is abundance of invassive species like water hyacinth (*Eichhornia crassipes*) which covers the lake and degrades its beauty (Rai & Pradhan, n.d.). Above all, the water storing capacity of Phewa lake is significantly decreasing due to higher rate of siltation risking the existance of lake in near future.

3. Climate Adaptation Alternatives

According to the UK Climate Impact Program, Adaptation is "the process or outcome of a process that leads to a reduction in harm or risk of harm, or realisation of benefits associated with climate variability and climate change" (Levina & Tirpak, 2006). Adaptation, so far, has been categorized into different types based on different aspects. Some of them are incremental, transformational, anticipatory or proactive, reactive, private adaptation for private benefits and public benefits, and public adaptation (CoastAdapt, 2017). However, according to the IPCC, the focus of adaptation should be on technical measures, institutional measures, as well as nature-based measures (Levina & Tirpak, 2006).

The impact of climate-related disasters has become higher in the Phewa watershed in recent years. Therefore, a combined effort from technical, nature-based and institutional measures can only help both the human and nature to adapt to climate change impacts in Phewa watershed.

3.1 Technical measures:

Particularly, landslide, soil erosion and flood are the major hazards triggered by heavy rainfall in the watershed so as a promt measure, building engineering infrastructures in upstream areas can be best option to adapt to these hazards. The forest areas which are prone to landslide and soil erosion can be checked with retaining walls so that they do not supply sediments downstream. The river training activities like contruction of dams, spurs and embankments can

be implemented upstream to regulate the flow of water in the main river channel. The embankments at both sides of the river play important role as buffers between agricultural lands and the river and prevent sediment deposition on agricultural lands. The spur helps to direct the flow of water in the main river channel and protects the river banks from erosion. The dams, especially the siltation dams, help to reduce the flow velocity of water in the river and prevent the sediment transport downstream. The sediments collected in the siltation dams should be removed in a regular basis to keep it functioning.

3.2 Nature-based Measures:

Afforestation in the barren and eroded land upstream is a long term solution to landslide and soil erosion. Alongside, gully erosion which happens to be a major type of erosion in upstream area can be prevented using bio-engineering techniques. Bamboo species can be used to make fences in the gullies where the sediments from higher elevation are blocked and in long run, the bamboo shoots regenerates as a permanent fence to erosion. This technique has been proven to be very effective in water and nutrient conservation, soil protection and runoff control (Tardio, Mickovski, Rauch, Fernandes, & Acharya, 2018). Likewise, different types of grasses like *Thysanolaena maxima* (Amliso), *Eulaliopsis binata* (Babio), *Saccharum pontaneum* (Kans), *Cymbopogon microtheca* (Khar), shrubs like *Salix tetrasperma* (Bains), *Butea minor* (Bhujetro), *Woodfordia fruticosa* (Dhanyero), and large trees like *Schima wallichi* (Chilaune), *Acacia catechu* (Khayer), *Fraxinus floribunda* (Lankuri), and *Alnus nepalensis* (Utis) can be used for this purpose. Basically, the grasses are more effective in flood plains to reduce the water velocity and retain the sediments upstream (Dhital, Kayastha, & Shi, 2013). Therefore, nature-based adaptation measures like bio-engineering techniques are more sustainable and cost-effective compared to others.

3.3 Human/Social/Institutional Measures:

It is clear that there are direct and indirect linkages between downstream and upstream resources and communities. Therefore, the aforementioned climate hazards are a common issue for everyone residing in the watershed and the only way to work effectively and efficiently is to follow the upstream-downstream linkages approach. Meanwhile, the hazards are affecting different sectors like forest, agriculture, water sources, and wetland, and each of these sectors are locally managed by natural resources management (NRM) groups such as Community Forest Users Groups (CFUGs), farmers groups, drinking water committees, and local youth and women groups, so it is very important to strengthen their capacity to adapt to climate

impacts. In this context, awareness raising programs related to sectoral impacts of climate change (for example; increase in gully erosion in forest area and increase in sedimentation on agricultural land) and knowledge and skill development programs on how to reduce such impacts should be provided to NRM groups. Likewise, an active local disaster preparedness and response mechanism helps to reduce the casualties. In overall, an Integrated Watershed Management Plan (IWMP) which includes all sectors (from upstream and downstream) with major focus on climate related hazards, and vulnerable groups, communities and places based on intensive differential impact analysis, would be highly effective to adapt in an institutionalized way.

3.4 How the alternative measures will reduce the overall climate risk:

The ultimate objective of climate change adaptation alternative measures is to reduce the siltation in the lake and protect it from burial and extinction and, as mentioned earlier, these measures should be applied in the upstream areas. In this context, these alternative measures not only benefit downstream area but also benefit the upstream area. A combination of technical and nature-based measures helps reduce soil erosion and landslides and sediment deposition on the agricultural lands upstream. These measures also reduce flow velocity in river during flooding and rentain the sediments upstream.

3.5 How this can be implemented in the planning system

As mentioned in section 3.3, an IWMP which contains all technical, nature-based, and human/social/institutional measures could be an effective tool for the whole watershed to work on adaptation activities. In order to fund the plan, it would be ideal to form a mechanism for Payment for Ecosystem Services (PES), where the business owners who are directly benefited from the lake would raise a fund which could be utilized by the upstream communities for adaptation activities. Such an institutional mechanism creates a win-win situation and help everybody cope with the adverse impacts of climate change. In addition, the IWMP could be mainstreamed in the municipality plans so that its implementation becomes more easy.

References:

“ Climate Change Impact in Pokhara .” (n.d.).

Alamy.com. (2016). Portrait of men standing on Harpan Khola floodplain in Bhaudare Tamagi, Kaski district, Gandaki, Nepal. Villages along the waterways in Bhaudare Tamagi area have suffered from floods and landslides caused by torrential rains, few months after the 2015 ear. Retrieved September 14, 2021, from https://www.alamy.com/portrait-of-men-standing-on-harpan-khola-floodplain-in-bhaudare-tamagi-kaski-district-gandaki-nepal-villages-along-the-waterways-in-

bhaudare-tamagi-area-have-suffered-from-floods-and-landslides-caused-by-torrential-rains-few-months-a

CoastAdapt. (2017). What is adaptation to climate change? | CoastAdapt. Retrieved September 19, 2021, from https://coastadapt.com.au/overview-of-adaptation

Dhakal, S., & Jetten Ir Bart Krol, V. (2016). *THE ROLE OF LANDSLIDES ON THE SEDIMENT BUDGET IN UPPER PHEWA LAKE WATERSHED, WESTERN NEPAL*.

Dhital, Y. P., Kayastha, R. B., & Shi, J. (2013). Soil bioengineering application and practices in Nepal. *Environmental Management*, *51*(2), 354–364. https://doi.org/10.1007/S00267-012-0003-7

eadarsh.com. (2021). Siltation dam built on the Harpan river swept away by flood, 6 houses damaged | eAdarsha.com – English Version. Retrieved September 14, 2021, from https://www.eadarsha.com/eng/siltation-dam-built-on-the-harpan-river-swept-away-by-flood-6-houses-damaged/

Hagenlocher, M., Schneiderbauer, S., Sebesvari, Z., Bertram, M., Renner, K., Renaud, F., … Zebisch, M. (2018). *Climate Risk Assessment for Ecosystem-based Adaptation*. 1–116. Retrieved from https://www.adaptationcommunity.net/?wpfb_dl=203

Levina, E., & Tirpak, D. (2006). *ADAPTATION TO CLIMATE CHANGE: KEY TERMS*. Retrieved from www.oecd.org/env/cc

MOFE. (2018). Ministry of Forests and Environment.

Rai, A. K. ., & Pradhan, B. R. (n.d.). Aquatic weeds in the Lakes Phewa, Begnas and Rupa in Pokhara Valley, Nepal. Retrieved September 19, 2021, from https://www.cabi.org/isc/abstract/20023063228

Tardio, G., Mickovski, S. B., Rauch, H. P., Fernandes, J. P., & Acharya, M. S. (2018). The Use of Bamboo for Erosion Control and Slope Stabilization: Soil Bioengineering Works. *Bamboo - Current and Future Prospects*. https://doi.org/10.5772/INTECHOPEN.75626

The Himalayan Times. (2021). Local community’s involvement in Phewa Lake conservation. Retrieved September 14, 2021, from https://thehimalayantimes.com/nepal/local-communitys-involvement-in-phewa-lake-conservation-mulled

Watson, C. S., Kargel, J. S., Regmi, D., Rupper, S., Maurer, J. M., & Karki, A. (2019). Shrinkage of Nepal’s Second Largest Lake (Phewa Tal) Due to Watershed Degradation and Increased Sediment Influx. *Remote Sensing 2019, Vol. 11, Page 444*, *11*(4), 444. https://doi.org/10.3390/RS11040444

Wikipedia. (n.d.). Phewa Lake. Retrieved September 14, 2021, from https://en.wikipedia.org/wiki/Phewa_Lake

Word travels. (n.d.). Tokyo Climate and Weather. Retrieved September 14, 2021, from http://www.wordtravels.com/Cities/Nepal/Pokhara/Climate