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Application of Recharge Ponds for Water Management: Explaining from Nature Based Solution Perspective

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SUMMARY

Growing urbanization along with the impact of climate change are the prominent reasons contributing to the increasing water scarcity situation in Himalayan towns. There are several emerging alternative solutions to traditional grey infrastructure to address the challenges of water scarcity. However, city government who are more familiar with hard engineering infrastructures does not seem to adopt them widely. In this chapter, we present the case of Dhulikhel municipality that promoted water recharge ponds and contour trenches to improve the ground water recharge and revive drying springs. We present the insights based on the experiential learning during participatory action research conducted from 2016 to 2019. Data were gathered from water forums, stakeholder meetings and field observation. We explained that the approach and technology that was implemented in the study site is principally aligned to the emerging concept of nature-based solution (NbS). The analysis showed that the implementation of the solution follows a cyclical and consultative process where both the local stakeholders and experts continuously learn and co-produce knowledge and co-design the context-specific nature-based solutions. The implementation framework that organically emerged from the process has practical implications to operationalize the 'concept' of NbS into successful 'action' towards sustainable water resource management in Himalayan towns.

1. INTRODUCTION

As cities grow the range of interconnected pressures, such as land-use change, loss or degradation of natural areas, competing demand of water, soil sealing due to the densification of built-up areas disrupts the functionality of the ecosystem – all contributing to the water stress (Kabisch et al., 2017). Water related challenges are more pronounced in the urban centers of the Himalayan region. These centers are vulnerable to water stress because of unplanned and unsustainable urbanization trend coupled with inherent geographical fragility, less adaptive capacity and weak water governance system (Chu et al., 2016; Devkota, 2018; Singh et al., 2020). Evidently, local government are struggling to cater the service of rapidly growing demand of clean drinking water of its citizens. Small and medium sized towns with limited provision of access to safe drinking water and waste water treatment will have to withstand the worst of future urbanization growth (UNHabitat, 2006). In addition, the impact of climate change can further aggravate water related challenges due to increasing temperature, disproportionate distribution of rainfall and the probability of more extreme events such as drought and flooding (Vinke et al., 2017).

Emerging towns across the hilly regions of Nepal traditionally rely on springs, streams and rivers in the catchments surrounding them for drinking water (Devkota and Neupane, 2018). These towns are reeling under the water crisis as local springs and streams are either vanished or are in the brink of extinction (Poudel and Duex, 2017). Changing rainfall patterns, increasing dry spell, unsustainable extraction of aquifer water coupled with unplanned road construction are said to be some of the driving factors for drying of these sources (DoLIDAR, 2013; Shrestha et. al., 2017; Gurung et al., 2019).

One of the examples of growing cities in Nepal is Dhulikhel Municipality. Because of its unique geographic and cultural features, over the decade, the landscape of Dhulikhel has changed significantly and is continuing to change. Eventually, concrete buildings and other infrastructure is slowly taking space of field or forest, open spaces are being narrowed to pocket parks and the hills in the proximity are turning into holiday spots cladded with luxury hotels. Such rapid transitioning from rural to urbanscape, has indisputably brought tremendous economic opportunities and transformed the quality of lives but the problem of resource depletion, environmental degradation, and disruption in ecological functions are also being felt simultaneously. Though the magnitude of the urbanization in Dhulikhel is not as higher as other bigger cities in Nepal, one of the various manifestations of impacts of urbanization is already evident broadly in the form of – water scarcity and specifically as – drying of springs around the hills. Once regarded as municipality with one of the best community managed water supply systems of the country, Dhulikhel is struggling to fulfill water demand of city dwellers.

As a response to the increasing water scarcity, the municipality has been traditionally opting for grey or hard engineering infrastructure solutions. These conventional engineering solutions may solve the problem of water scarcity for short-term, but are energy-intensive with larger investment requirements and a greater impact on ecosystem functions (Sonneveld et al., 2018). Moreover, it has also been argued that this built infrastructure alone cannot keep up with future water security and resilience against predicted climate change impacts (Ozment et al., 2015). Thus, considering complex environmental and social issues, the focus is being gradually shifted from technocratic to alternative methods such as Nature based Solutions (NbS) that may not require major new engineering construction or work in parallel with grey infrastructure (UNWater, 2018). NbS is an emerging concept that is gaining attention as an alternative and/or complementary solutions for addressing water management problems more cost-effectively and sustainably (UN Environment-DHI, UN Environment and IUCN, 2018). However, city governments do not seem to adopt these alternative solutions as widely and willingly as infrastructure projects as these solutions might take relatively more time to have immediate impacts and also political, institutional and knowledge-related barriers exist (Sarabi et al., 2020).

In this chapter, we present our insights of action research in Dhulikhel municipality, focusing on exploration and application of climate adaptive, socially inclusive, resource-efficient and ecologically sustainable solutions to address water scarcity. We draw the major lessons while identifying and implementing this alternative water management practices and hence offer a framework to operationalize and mainstream those practices in the similar contexts. We also explained that our intervention underlies within the concept of NbS. The information and data were gathered from several multistakeholder consultations through *Pani Chautari* (see Chapter 8 of this book by Devkota et al., 2021), meetings with the municipal government and water users committee and field observation.

The chapter is organized as follows. In section 2, we will present the detailed case of Dhulikhel municipality including the emergence of water issues, design and implementation of solution that is more climate adaptive and socially inclusive based on the reflection of the action research. Then, in section 3, we discuss that the technology we adopted and the approach of our implementation resonate the emerging idea of nature-based solution and offer the implementation framework. We, thereby, conclude in section 4 by drawing key lessons.

2. EXPLORING AN ALTERNATIVE APPROACH FOR WATER MANAGEMENT

To deal with the increasing problem of water scarcity, Dhulikhel municipality has already been adopting various engineering solutions such as drilling sub-surface to extract water from deep aquifers, lifting surface water from the river and diverting water from other watershed several kilometers away from the town. These infrastructure projects fulfill the immediate needs of water supply but are often costly, unsustainable and are impacted by climate variability such as damage of the pipeline of the system by flood/landslide.

In the action research project, we targeted to identify innovative Climate Adaptive and Socially Inclusive Plans and Strategies to address the burgeoning issues of water scarcity. Based on the reflection of the pilot study, here, we will elaborate the processes we adopted in the simplified steps.

2.1 Assess and Design

We adopted multistakeholder forums to assess the major local issues within the drinking water management and design the innovative climate adaptive and socially inclusive solution. During a city scale inception workshop, the stakeholder suggested to create a common platform where they could come together to discuss on the water management problem and find the strategies to solve them and hence the concept of *Pani Chautari* forum emerged. Later this forum was organized in series to identify and prioritise problems and design solution. A rapid assessment to determine the feasibility of the said solution was done before piloting.

Identify problem

An institutional setting of *Pani Chautari* provided the platform for collective learning among researchers and stakeholders supporting in planning and managing complex problems of water scarcity. Representatives from government, civil society, private sector and local community representatives from users' committees and women's group participated ensuring inputs of knowledge from diverse stakeholders. Researchers facilitated the forum with diagnostic questions making the dialogue more systematic and interactive. To instigate the discussion, researchers also shared the current available knowledge on impact of climate change on water resources, gender perspective of urban water management, water and urbanization, and overview on currently constructed water supply project.

Intensive participatory discussion and exercise done with the stakeholders was vital to understand the complexities, challenges and opportunities of water management practices in Dhulikhel. The sectoral group division of the participants within the workshop helped to make an individual 'divergent' thinking into a 'convergent' thinking' (Pagano et al., 2019) and later on the release of the 'declaration paper' as a common agenda of the workshop also helped to build consensus among various understanding and interests. Participants prioritised – declining water volume from local springs – as one of the most crucial water related problems of the town. Therefore, a mutual dialogue among the stakeholders instead of conventional one-directional transfer of expert knowledge was found vital for information production as well as exchange in response to complex environmental challenges (Pahl-Wostl, 2002).

Design solution

On the basis of series of discussion and knowledge exchange among stakeholders and researchers, we collectively identified and prioritised, "constructing recharge ponds" as the most appropriate intervention to revive drying springs. During the process, knowledge from diverse stakeholder about the recharge ponds was assessed and diagnosed. First, the stakeholders highlighted the traditional knowledge of how people used to construct ponds for religious, irrigation or other domestic purposes. Those ponds played key role to recharge local aquifers but over the years, those ponds have started to vanish drastically as people started relying less on those ponds because of declinement of livestock and the availability of a piped water supply system. Second, the assessment conducted by Dhulikhel municipality on the ground water potentials also recommended the installation of water recharge ponds as mitigation measures of proposed deep boring projects. Third, a collective field observation to Dapcha, a neighboring village where the traditional ponds were revitalised to revive local springs also reinforced the idea of "recharge pond" as the promising solution for spring revitalisation.

Feasibility study

As the consensus were being built upon the "recharge pond" construction, a team of experts including soil scientist, watershed expert, along with water resource engineer working in Dhulikhel conducted a rapid hydrogeological study in the Thuloban of Dhulikhel. The team visited watershed area to examine the basic geological structure, drainage configuration, catchment area and identify locations for recharge pond construction. The design and location of ponds within the watershed were determined considering three important factors: runoff collection, drainage channels and safe disposal of excess water. A micro catchment map (Figure 1) of the identified drying springs with catchment boundaries and discharge channels were developed to check the drainage flow of rain water and to locate the potential recharge areas. Figure 2 shows the location of springs and the potential recharge area within the forest cover. As the purpose of recharge ponds was envisioned to augment the groundwater so the location of pond was determined to be inside the forest at higher elevations away from the settlement area.

The national guideline provided by Department of Local Infrastructure Development and Agriculture Roads (DoLIDAR) for recharge pond construction was followed for the recharge ponds construction. Three types of recharge ponds, namely, excavated ponds, embankment ponds and contour trenches were found suitable for the topographical feature. An excavated pond is generally built on ridge of the hill where flat area is available whereas embankment pond is built without excavation by building a stone masonry or earthen dam to impound flowing water in a stream or on gently sloping gully. Contour trenches are ditches dug along a hillside to check the runoff on the slope (DoLIDAR, 2013).

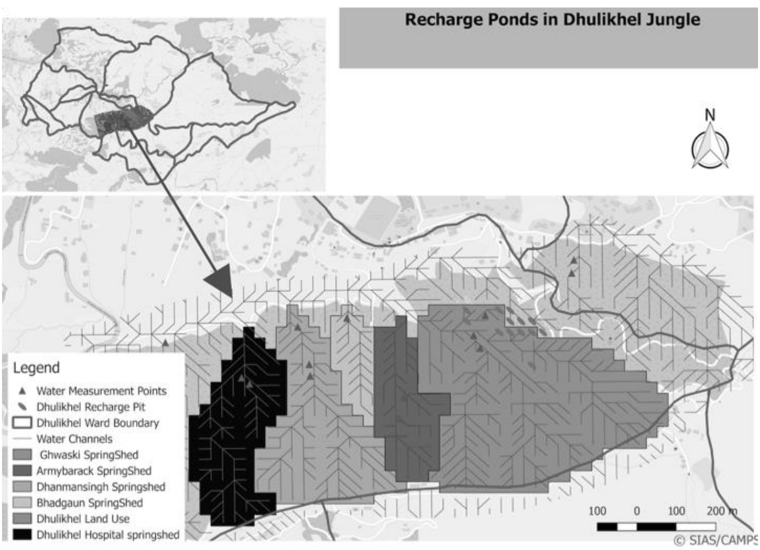

Figure 1 Map of micro catchment and recharge ponds located in Thuloban, Dhulikhel

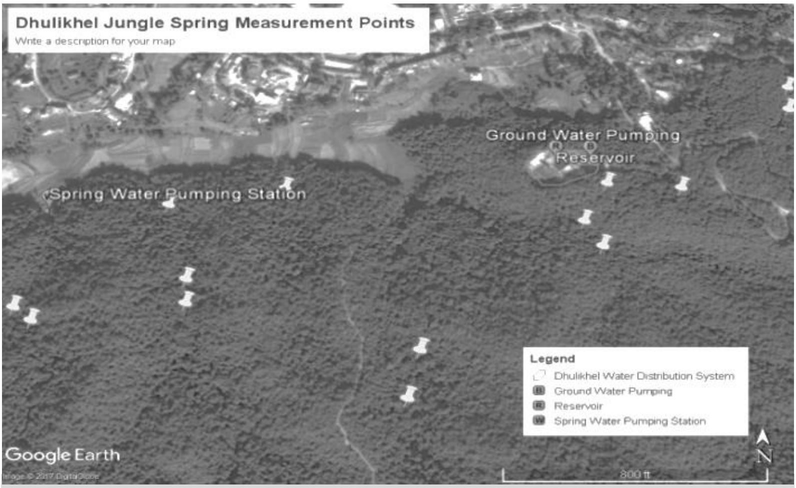

Figure 2 Locations of spring monitoring points in Thuloban, Dhulikhel

2.2. Piloting

After the identification and feasibility study of the potential of recharge ponds on augmenting spring discharge, the recharge ponds were built at piloting scale. The piloting allowed assessing what works and what not in the local context and allowed innovation. During pilot, the concept was demonstrated on the ground which provided an opportunity to assess the immediate effect of the solution, collaborate with institutions and estimate the cost and explore financing possibilities.

Demonstration

A combination of "recharge ponds" and " contour trenches" was deployed according to the geographical condition of the site. Altogether 64 small-scale ponds ranging from 3.45 m^3 to 35.69 m^3 were constructed in two phases at terraces of hills to cover a wider area as a recharge zone. The shapes of ponds were varied according to the location – from rectangle, circular and oval. Though the length and the breadth of the ponds were determined according to the location, the height of the ponds were constantly maintained less than 2m for the safety purpose. In some cases, network of ponds was formed by joining three or four ponds located at similar contour lines by the means of trenches that allowed to flow runoff from one pond to another within the cluster. Besides immediate runoff from the catchment, the overflow from the ponds network from the upper terrace is collected by the network of ponds situated at lower terrace. In addition, few recharge ponds were single without connection to suite the geographical location. Bottom of ponds were left unlined to allow infiltration. All ponds were tagged with number for identification to monitor the pond. The piloting phase contributed in enhancing the confidence level of stakeholders by generating evidence on effects, the idea of the cost incurred and the possibility of any negative impact on the society and environment.

Assessment of effects

A continuous monitoring mechanism was set to measure the discharge of the springs using a simple bucket method[1] to test the correlation between recharge ponds and spring flow. The spring discharge of ten selected local springs and streams below the recharge pond constructed area were monitored once a month (twice a month during monsoon) from May 2017 till Jan 2020. For this, a local person was trained to measure the springs, keep records and send us the data. Figure 3 shows a time series data of average monthly discharge with a linear trend line for the given period indicating a low but gradual increment of water flow from these sources. As this spring hydrograph has discharge peaks immediately after rainfall events, these 10 springs have rapid flow systems which means that these aquifers are generally unable to store water for long periods.

1 Bucket method: The bucket method is a simple way of measuring flow in very small streams. The entire flow is diverted into a bucket and the time for the container to fill is recorded. The flow rate is obtained simply by dividing the volume of the container by the filling time.

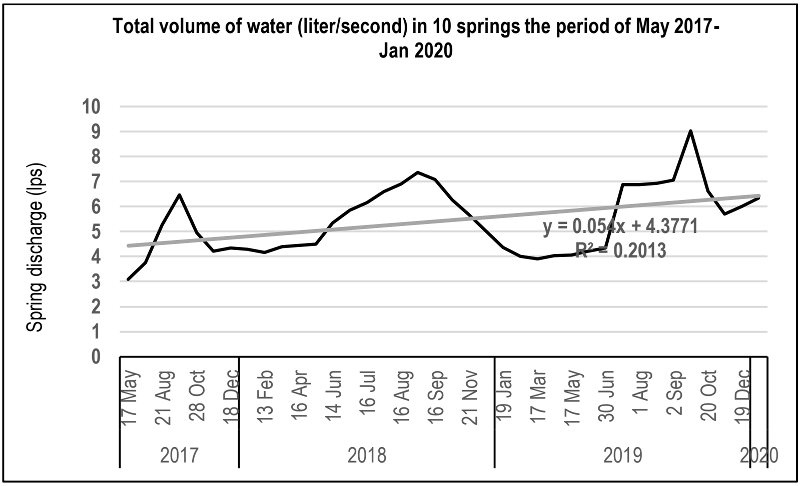

Figure 3 Trend of water discharge in the springs

The evidences generated by the monitoring revealed that there has been a gradual increment of water volume in the springs over the time. The graph in figure 3 clearly shows that there are seasonal fluctuations of the discharge, however, if we compare the yearly peak discharge then there is a gradual increase from 6.4 litre per second (lps), 7.3 lps to 9.0 lps on 2017, 2018 and 2019 respectively. In addition, the nature of peak discharge has also changed from 'abrupt' in the year 2017 to 'steady' in the year 2018 and 2019 depicted by the area under each hydrograph. The area implies the volume of discharged water for the recording period which is comparatively larger in following years of 2018 and 2019 than on the pilot year of 2017. While it may not be possible to attribute the increased volume of discharge entirely to the recharge pond-contour trench network, it is likely that the increment in the flow of spring discharge in the following years of intervention has been contributed by recharge ponds construction. This evidence created a strong base for stakeholders to realise the importance of recharge ponds and to upscale the idea to landscape level.

Partnership for implementation

The *Pani Chautari* created a conducive environment for the possible partnerships and collaboration with relevant stakeholders for implementing the solutions. In our site, Dhulikhel Municipality and Dhulikhel Drinking Water Supply and Sanitation Users Committee (DDWSUC), institutions actively engaged on the process of *Pani Chautari* from early on, also got ready for the financial contribution and provided institutional support for sustainable management of the interventions from the beginning. Hence, in Dhulikhel case, the existing institutional set up played a vital role in owning the process as well as pilot action and thus operation and maintenance of recharge ponds in future was secured.

> Dhulikhel will exploit its potential springs for augmenting water supply in future and therefore its proper utilization and conservation is of high priority for us. Hence the recharge pond concept is appropriate for conserving these springs. More recharge ponds need to be constructed in the surrounding hills of Dhulikhel (Deputy Mayor, Dhulikhel Water Forum V, 30th April 2019).

Because the major objective of the current intervention was to augment spring flow without other direct co-benefits such as recreation or livelihood enhancement, therefore the scope of collaboration with other institutions were found less in this particular case. Nevertheless, consultation was done with the representative of Division Forest Office, District Soil Conservation Office, Gokhureshwor Community Forest Users Committee to construct recharge ponds in the forest premises. Hence, the important role of community forest users community as a provider of the land was found to be crucial for the implementation of the intervention.

We found that the scope of the collaboration depends upon the major objective of the intervention, its type, location, feeling of stewardship of the stakeholders among others. To facilitate the collaboration, multistakeholder engagement process through water forum helped to explore probable institutional collaborators among stakeholders. Other local institutions such as university for knowledge generation, private sector for example hotels and resorts for finance and Nepal army for physical labor contribution were found potential for collaboration but not materialsed during this particular project.

Cost and financing

Dhulikhel municipality showed their strong willingness to financially contribute to construct the recharge ponds. While municipality agreed to allocate budget into it, DDWSUC made technical and in-kind contributions to construct the recharge ponds. The initial fund from the research project to pilot the action worked as a triggering factor to collect other financial support. On an average, it cost approximately Nepalese rupees 8500 to construct a pond of 7 cubic meters including materials like stone, gabion wire and labor cost (Rai et al., 2019). The first phase of construction was co-financed by Southasia Institute of Advanced Studies (SIAS) and Dhulikhel municipality whereas municipality alone allocated funds for the second phase of ponds construction.

2.3. Mainstreaming in municipal policy for scaling up

To up-scale the ponds construction and make it sustainable, Dhulikhel municipality, after the successful piloting of recharge ponds, adopted a policy of promoting recharge ponds. In the municipal policy and programs of the fiscal year 2017/18, the municipality has recognized the benefits of recharge pond. Specifically, it has adopted the policy of revitalizing existing and building new ponds in each municipal ward. For example, "one ward one pond program" considering climate change impact on ground water and small springs has been launched in the fiscal year 2017/2018 with the allocation of NPR 5 million. Additionally, NPR 2 million was allocated. NRs. 1.16 million[2] budget was allocated for the water resources (springs wells, ponds and stone spouts) conservation and management activities for the fiscal year 2017/18. Further, municipality is planning to adopt a public private partnership approach to build recharge ponds integrating component of tourism and livelihood.

> Municipality is happy to adopt the appropriate policy provision recommended by Dhulikhel Water Forum on sustainable water management of the city. Municipality will definitely take

2 https://dhulikhelmun.gov.np/sites/dhulikhelmun.gov.np/files/स्वीकृत%20बजेट%20तथा%20कार्यक्रमहरु%20...pdf

> ownership of such policy based on empirical research. Moreover, municipality is willing to make water security policy for which such initiative plays an important role. (Executive Officer, Dhulikhel Water Forum II, 10th February, 2017)
>
> Similar to how we recharge our mobile phone, if we recharge the ground water, it will contribute to revitalize local springs. With the technical support from SIAS, municipality has already built 70-72 recharge ponds in the Thuloban forest which will be further upscaled in other appropriate locations. Municipality has plans to promote existing traditional wells and ponds that contribute to recharge ground water for which we have allocated budget (Mayor, Dhulikhel Water Forum VI, 11th March, 2020).

On the planning and budget document of the fiscal year 2020/2021, it has been mentioned that Dhulikhel municipality will continue multistakeholder engagement through water forums, build recharge ponds and implement other conservation measures to ensure sustainable use of water resources (Dhulikhel Municipality, 2020)

2.4 Monitoring and feedback

Monitoring mechanism at two different levels – one of overall process and another of the ground action – were deemed necessary for checking the effectiveness over time and for the adaptive management of the intervention. For the ground action monitoring, the regular monthly monitoring of the discharge of the spring (figure 3) was continued. In our case, the yearly maintenance of the constructed recharge pond was found to be essential, as over the months, soil is accumulated in the ponds decreasing its original capacity to hold the rainwater. Therefore, a low cost maintenance was done to keep intact the performance of the recharge pond. For the long term monitoring and maintenance, local institutions ownership and collaboration is the must. Otherwise, it might be affected by the limited availability of funds, less prioritised by the stakeholders and sometimes also the lack of clarity on how long monitoring should be undertaken.

Besides, to reflect on the overall process and drawing the lessons learnt from the practice and policies implemented on ground was found to be the key for making improvements and adjustments to upscale these solutions on the landscape level. For this, *Pani Chautari* itself worked as a forum for internal reflection and feedback loops from wider stakeholders. The municipality and SIAS co-hosted *Pani Chautari* for review and self-reflection of these initiatives. Our reflection revealed that, we have been able to consolidate the scattered activities of water management through the *Pani Chautari* and document the lessons for future references. These sort of initiatives have fostered the collaboration among multiple stakeholders and create innovation for city specific water management strategies.

3. EXPLAINING THE INTERVENTION AS NATURE-BASED SOLUTION

Based on the process of learning and engagement with multiple stakeholders in Dhulikhel described in the above sections, we tried to summarize those steps into a simplified cyclical framework (Figure 4) with the four major steps – (i) **Assess** problem and **Design** solution (ii) **Pilot** testing (iii) **Mainstream** in policy for scaling up, and (iv) **Monitoring** for feedback and readjustments. The figure demonstrates that the overall process of identifying the major (water) issue, selecting locally attuned solutions, implementing and getting the space in the policy provisions was not simply linear rather it was an iterative process that needed continuous engagement among local stakeholders and researchers. First, we assessed the problems by engaging all the relevant actors, identified solutions through more inclusive, participatory and partnership approaches and studied feasibility. Secondly, we experimented the proposed solutions through pilot testing. During pilot, we collaborated with local government and other local institutions for co-financing and other institutional support. As an outcome of the regular engagement, prioritizing the local issue and demonstrating the solution supported us in mainstreaming the initiatives in municipal policy. With the consideration of complex and changing nature of landscape, the regular monitoring of the performance of the adopted solution and the regular consultation with the governing institutions was done for a feedback loop to redesign the practice, or to work on new policies if needed.

We found that our experience of implementation of climate adaptive solution that promotes sustainability of nature as well as addresses societal challenge is conceptually the closest ally with the emerging global idea of NbS. The cyclical implementation framework (Fig 4) emerged from the case study has been proposed as the NbS implementation framework that puts multistakeholder engagement and ecological based solutions at its heart.

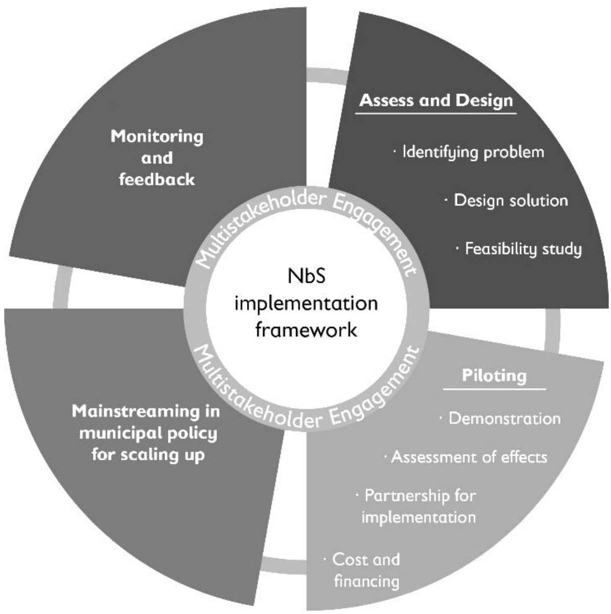

Figure 4 Proposed NbS implementation framework

As mentioned earlier, NbS is a concept that covers a range of ecosystem-based approaches and offers multitude of other benefits such as improvement on human well-being and biodiversity conservation and even improve stakeholder and community engagement. NbS are "actions which are inspired by, supported by or copied from nature to address societal challenges while providing multiple benefits and co-benefits" (European Comission, 2015). Conceptually, NbS considers local context (Cohen-Shacham et al., 2019) and the existence of a plurality of human perspectives on the understanding of environmental problems and solutions (Vasseur et al., 2017). Hence, the multistakeholder approach is preferred to integrate diverse types and systems of knowledge and values (Raymond et al., 2017) fostering the social innovation (Biggs et al., 2010) during the identification of the problem, solution, its implementation and beyond. In our case, as the project targeted to innovate "climate adaptive water management practices and policies" to address increasing water insecurity, the multistakeholder platform majorly *Pani Chautari* was used as a common platform for discussing and prioritizing issues, similar with the approach of NbS. The forum allowed a conducive environment of collecting substantial input from different stakeholders perspective and knowledge including traditional and local, institutional as well as emerging scientific knowledge that were crucial for determining and prioritizing the site-specific problem and locally suitable solution. In doing so, the (multistakeholder) approach during the implementation of the climate adaptive solution, as in NbS, helped to make the whole process socially accepted, increased inclusiveness and legitimise (Nesshover et al., 2017).

In terms of practice, NbS use nature for tackling challenges such as climate change and water resources management. Specifically, in the urban areas, NbS are being used for addressing water management issues by harnessing three functions of ecosystem – water supply regulation, water quality regulation and moderate extreme climate events (UN Environment-DHI, UN Environment and IUCN, 2018). In relation to mitigate the drying springs, the technology of the recharge system constructed in our study site has used the nature-based solution to enhance the natural process of infiltration. Similar to NbS, our intervention promotes the use of ecosystems (Canals and Lázaro, 2019) to address the challenge of the declining state of water supply of the town. Several ponds and trenches made, as piloting, at the surface of the recharge zone worked as extra pockets to store surface runoff. This helped in providing water for longer period and thus enhanced percolation rate depicted in the Figure 3 boosting the replenishment of the underlying aquifers and hence increasing the spring yield. The piloting was found to be an important step in order to demonstrate among city stakeholders the localized evidence of the efficiency of natural systems and the economic viability as described by Cohen-Shachamet al. (2019) for NbS pilot. The pilot part of the overall (action) research increased the level of trust (Frantzeskaki, 2019) and ownership (Raymond et al., 2017) of the stakeholders involved.

In contrast with hard engineering solutions, NbS is affordable and offers multitude of co-benefits (Kabisch et al., 2016). Similarly, we adopted the low cost method among the available options to recharge groundwater with other multiple usages such as maintaining soil moisture for vegetation, store storm water during extreme events reducing downstream flooding and potentially mitigate forest fire. For sustainable management of the solution, we collaborated with municipality and DDWSUC from the beginning and we also tried to make partnerships with other institution in the process. Institutional collaboration amongst different policy areas, sectors and stakeholders enables for adoption and sustainability of NbS (van Ham and Climmeck, 2017). Long-term collaboration with both non-profits and policy makers is required to fully operationalizing NbS (The Nature Conservancy, nd). In Dhulikhel case, the partnership with local government created synergies to operationalize climate adaptive solutions in the ground by contributing financially and institutionalizing the practice into policy.

4. LESSONS LEARNT AND KEY MESSAGES

In this chapter, we documented the experiences of implementing climate adaptive solution in Dhulikhel Municipality and concluded that the solution, both in practice and in principle, build upon largely on the emerging concept of NbS. In the context of environmental change and the high dominance of modern engineering solutions, NbS as illustrated in the case of Dhulilkhel, is alternative to addressing the issue of declining water yield in the springs. The experiential learning from the implementation of this solution in the real life showed that it follows a cyclical and consultative process where both the local stakeholders and experts continuously co-produced knowledge and co-designed the context-specific solutions.

Dhulikhel has become an exemplary to lead the piloting of climate adaptive and socially inclusive solution for water management and mainstream it into its planning and policy. Municipalities across the Himalayas, can adopt this sort of implementation framework. Further, the process and initial outcomes of piloting this solution in Dhulikhel has helped in drawing important lessons summarized into three major points (a) engagement, (b) evidence and (c) ownership for the success of any NbS at ground level.

First, the engagement of relevant stakeholders at all stages – from prioritizing the issue of water management to the selection of suitable solution and its implementation is critical. Continuous engagement with technical experts, municipal authorities and local stakeholders helped to bring multiple ideas, address concerns and interest, generate new knowledge, share outcomes from the pilot study and more importantly facilitate the social acceptance.

Second important factor is the solution must be backed up by as much evidences as possible. Ideation, planning, designing, implementing, monitoring and upscaling phases need integration of evidences from both biophysical and social aspects as well as local experiential and traditional knowledge. Regular consultation with local community and sectoral experts, assessment of local context to identify best suitable solutions, feasibility study, local best practices, gathering necessary data of biophysical, economic and social aspects and the assessment of effectiveness are very important. In addition, gradual revisions in the design of the solution and thereby in the municipality level policies and plans with the reflection of monitoring data, experts updated knowledge, institutional learning and feedback of local stakeholders are required.

Third, the ownership of municipal leaders and community is important to build consensus on actions and processes for addressing water management issues. This often require substantive efforts, time, and resources. With ownership, there comes openness towards acknowledging scientific knowledge and technological innovations and political willingness to translate evidence into policy. Dhulikhel municipality stepped forward to integrate the recharge ponds to municipal planning that ensured the sustainability of the intervention. Not only municipality but also other institutions such as forest department or soil conservation department or private company who can benefit from this approach have owned the process. In that case, inter-departmental ownership, responsibility sharing and resource leverage are essential.

The emerging concept of NbS in Nepal is still on its initial stage though it holds considerable promise to address various societal challenges including water management. There are already some examples but they are implemented on a fragmented and ad hoc basis without systemic interventions. The case of Dhulikhel, presented on this chapter, can be taken as a successful case of NbS in the form of climate adaptive and socially inclusive solution and the lesson learned can be taken into consideration by other municipalities of Nepal in Himalayas to operationalize the 'concept' into successful 'action' to sustain the water security of the area.

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