

Assessing Hiti System as a Nature Based Solution in addressing Water Security in Kathmandu Valley

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Abstract

Water security is a global concern, with Kathmandu Valley, the largest urban agglomeration in Nepal, facing its own set of water issues such as water stress, water affordability, water resilience, declining ground water levels and urban pluvial flooding. Research from various regions has underscored that solely relying on built infrastructure is insufficient for resolving long-term water security issues. Consequently, a comprehensive approach that combines built infrastructure solutions with nature-based solutions is essential. Drawing inspiration from “sponge cities”, which is based on the ancient water management wisdom of China, and is a leading example of Nature Based solutions, this research explores the potential of Hiti System which is the indigenous water management system of Kathmandu Valley and is deeply rooted within the community, as the Nepalese version of Nature based solution for addressing water security. The study aims to showcase this by highlighting how the system acts to conserve the ecosystem, promotes local resource utilization and community engagement, through the two successful case studies of Alko Hiti and Pimbahal Pond of Patan. The research being mostly qualitative and having parts of descriptive results, the study has been carried out through field observations, key informant interviews, semi structured interviews with the community and literature review. The research then channelizes these findings to present how water security is being addressed through these efforts. Further the study attempts to view Hiti System as a sustainable means to address water security, and advocates that it should not be limited to the perspective of cultural preservation only. Lastly, the study also points out the shortcomings of the system owing to present realities, and works to propose a solution to it.

Keywords

Hiti System, Water Security, Sponge City, Nature Based Solution

1. Introduction

Water security is a pressing global issue for major cities around the world. About two billion people worldwide don't have access to safe drinking water today [1], and roughly half of the world's population is experiencing severe water scarcity for at least part of the year [2]. From 2001 to 2018, water related disasters accounted for 73.9% of all-natural disasters [3]. The Kathmandu Valley, which is the largest urban agglomeration of Nepal, is experiencing, its own set of water security challenges, which range from increased pluvial urban flooding [4], drastically decreasing ground water levels to heightened water stress [5]. To combat these challenges, built infrastructure alone is increasingly unlikely to provide reliable solutions in the future [6]. A combination of built and nature based solutions will be needed for efficient and effective management of water resources [7]. Nature based solutions are being increasingly used in different parts of the world, for e.g. Low Impact Developments (LID) approach in the United States, Water Sensitive Urban Design (WSUD) in Australia, and most notably in China through the concept of “sponge cities”. The sponge city concept based on the ancient farming and water management wisdom of China, uses the landscape to retain water at its source, slow down water flow and clean it throughout the process, to tackle the urban flooding in the cities in China. Similarly, in context to Nepal, particularly Kathmandu Valley, the Hiti system is the traditional knowledge base of sustainable usage of water. The Hiti system is a system of canals, ponds, stone spouts, conduits and

various such structures, which was not only utilized to bring water for drinking and domestic purpose to city, but also for irrigation, checking landslides and pluvial flooding and improving ground water recharge[8], with consideration to the ecology, in the traditional planning of the Valley. These services of the Hiti system are more so relevant to the challenges faced by Kathmandu Valley in the present scenario. In context to this, the research aims to assess the role of Hiti System as a Nature Based Solution in addressing water security in Kathmandu Valley. Further, the state of Hiti system is in a declining phase. The attempts to conserve Hiti system through cultural significance has only been partially successful. Inherent to the changing realities, newer meanings need to be attached to the system, and this research proposes the concept of Nature Based Solution as one such approach.

2. Literature Review

2.1 Nature Based Solution

Nature based solutions are defined as the actions to protect, sustainably manage, or restore natural ecosystems, which address societal challenges such as climate change, human health, food and water security, and disaster risk reduction effectively, providing human well-being and biodiversity benefits[9].The guidelines for Nature Based Solutions(NbS) are that NbS should not be thought as a substitute for decarbonizing our economy and, Nbs works to protect and manage ecosystems while fostering local involvement and enhancing biodiversity [10].

2.2 Water Security

Water Security is defined as "the capacity of a population to safeguard sustainable access to adequate quantities and acceptable quality of water for sustaining livelihoods, human well being, and socio-economic development, for ensuring protection against waterborne pollution and water related disasters, and for preserving ecosystems in a climate of peace and political stability" [11]. Accordingly, four key components to it are, Drinking Water and Human Well Being, Ecosystem, Water Related Hazards and Climate Change, and Economic Activities and Development. Further, under the framework of water security assessment [12], these key components have been sub divided. Amongst them, for the purpose of this study, water stress, water accessibility, water resilience, ground water recharge, water affordability and urban flooding control have been studied.

2.3 Relationship between water security and Nature Based Solution

About two billion people worldwide don not have access to safe drinking water today [1], and roughly half of the world's population is experiencing severe water scarcity for at least part of the year [2]. Asia-Pacific regions face an ever growing water crisis. Water-related disasters have been dominating the list of disasters over the past 50 years and accounting for 70 per cent of all deaths related to natural disasters [9]. In this context of water security, built infrastructure on its own is unlikely to provide future water security and resilience against predicted climate change impacts [6]. New demands on solutions for water security are emerging in a global context. Usage of NbS by harnessing the water-related services of 'natural infrastructure', such as forests, wetlands and floodplains, can help combat the risk of water crisis, particularly in the face of future climate stresses [6]. However, nature alone cannot guarantee water security for people in every situation. Both built and natural infrastructure are needed for efficient and effective management of water resources [7]. The global assessment report on Biodiversity and Ecosystem Service estimates that Nature-based solutions can provide up to 37 per cent of climate change mitigation until 2030 [13].

2.4 International Case Area for Nature Based Solution: Sponge City, China

The urban areas of China are prone to severe flooding and waterlogging. After decades of rapid urbanization, China now faces with water shortages and flooding - only exuberated by the effects of climate change. In Zhengzhou, the capital city of Henan province having a population of more than 10 million, an extreme rainfall event on July 20 2021, caused severe pluvial flooding which reportedly resulted in over 290 deaths and economic losses of more than CNY 65.5 billion (equivalent to US 10 billion) [6].

To combat this situation, realizing that conventional urban flood management approaches alone might no longer be sufficient to provide the level of climate resilience and services required to address the heightened threats, the Chinese government announced the sponge city program in 2014. A "sponge city" is a nature based solution that draws on the

landscape to hold onto water at its source, slow down water flow, and clean it as it moves through. It is motivated by historic farming and water management knowledge. This method that takes advantage of the rainwater, which is absorbed, stored, and slowly released by the city facilities, such as waterways, sunken rain garden, green spaces, permeable pavement and floor tiles, and green roof buildings to control storm water runoff and to accumulate, infiltrate, and purify naturally [14]. In the city of Shenzhen, a mega-city in southern China with a population of over 17 million (2020), 28.3% of the total area has been converted into sponge area [14]. Initiatives such as Futian Mangrove Ecological Park Restoration is contributing to 92% control rate of run off towards the park, Dadingling Forest Park development worked to eliminate flooding in six flood prone areas and Shenzhen Bay Park which is a hybrid of floodway and cycling route, are some excellent examples of the Sponge City Program in Shenzhen.

2.5 Historical Development of Kathmandu Valley

The earlier urban development of Kathmandu Valley can be traced back to Kirat period (ca. 500 BC to 78 A.D.). The Kirata settlements, named Pringaa, would be centered around a built space protector god, which came to be known as Dyochhen. Several religio-cultural (rituals) and socio-cultural (festivals) practices were developed to continuously remind the city dwellers of the limits of the protection of town was dependent on the protection of Nature and its place specific micro-ecology [15]. With the Lichchhavi development (78 A.D to ca. 880 A.D), settlements started growing causing insufficient water supply. The spring sources, ponds and the lakes protected as pith, were not being able to meet water supply needs of expanding towns. So, water was brought through canals that stretched from the foothills of the valley to towns to feed ponds, which in turn recharged supply to recessed pit conduits, a technology that is working to this day in Kathmandu [15], which is known as the Hiti system. In the Malla Era (1200 to 1768 A.D.), larger towns developed which led to the gradual expansion of the Hiti system.

2.6 Hiti System

Hiti system is a water supply and management system, which is indigenous to the Kathmandu Valley, with its functioning deeply tied to the community. Hiti system, worked to not only provide drinking water, but also acted for irrigation purpose, controlling landslides and pluvial flooding, promoting ground water recharge, which worked to enhance the overall water security and resilience of the community [8]. Adding to this, is the architectural beauty of the system. The below-ground level traditional structures i.e, the Hiti's are architectural monuments in their own right which compete with the best above-ground ones [15]. The system consists of Rajkulo (State Canals) which transport water from river sources, into well connected ponds. The ponds work to recharge the ground aquifers and are also connected via canals to act as irrigation channels. Water is tapped from the aquifer source and through conveyance system, brought to the Hiti Complex, which is then ultimately drained to fields or rivers or pond.

Socio-Cultural Dimensions of Hiti System Newar Society has a particular feature of translating social values into culture,

and bringing about a sense of ownership, [8]. This is the case in Hiti system too. Through the process of ritualization or religious mediation and institutional backing of “guthi system”, the Hiti system has been interwoven in such a way that it makes up the “water heritage” of Kathmandu Valley. An excellent example of this is the festival of Rato Machhindranath Jatra in Patan, which a chariot procession with the highest fanfare. For the Jatra to commence, all the strategic ponds in the in Lalitpur must be full with water. The procession takes place in the dry months, so the water must be filled through the state canals. This means that the maintenance work of state canals must have been completed before the monsoon [8]. To mobilize this procession various ethnic groups have their management institution as guthi, which delegates responsibilities and tasks of the procession.

Destruction of Hiti System The system of Hiti was pioneered with the mixture of knowledge from Kirat and Lichhavi period, which was extensively developed in the Malla period. With every new ruler, they embraced the technology and further contributed in its growth. However, during Shah and Rana rule, the rulers were rather ignorant to the richness of knowledge of Hiti [8]. This led to gradual introduction of Municipal Water Supply System. But, the municipal water could never meet the demand of water. The pride and convenience of having water tap at home made the community easily swift from the traditional water supply system [8]. This left the spouts unattended and poorly managed. However, due to the uncertainty of municipal water, Hiti was still used of washing clothes and taking bath, more so for the urban poor.

3. Research Design

As the research is consisting of both qualitative and quantitative in nature, with the qualitative aspect being dominant, a mixed method approach is used. Owing to this, the research has been conducted in pragmatic paradigm, employing case study research method. The case study area was chosen to be two locations namely Alko Hiti and Pimbahal pond of Patan. The Valley has three major systems of Hiti viz. The Kathmandu System, the Bhaktapur system and the Patan system. Out of all these systems Patan has a comparatively better maintained Hiti system. As the study entails assessing the features of Hiti system, which can be better assessed on a well-functioning Hiti system these two cases of Patan namely, Alko Hiti and Pimbahal pond were chosen. A mixture of field observations, key informant interview and semi structured interview was used in data collection. For the case of Alko Hiti, field observation relating to physical aspects, key informant interviews with the management committee, and semi structured questionnaire survey with the users group was conducted. For the semi structured questionnaire survey, 20 samples were collected based on convenient sampling, considering the availability of the people. For the case of Pimbahal pond, field observations were carried about to assess the physical attributes, while key informant survey with the management committee was conducted to assess the socio-cultural aspects. As mentioned, the research being mostly qualitative, having a descriptive quantitative aspect, so the study has been presented in a narrative review. The

flowchart for this is referred to in Figure 1.

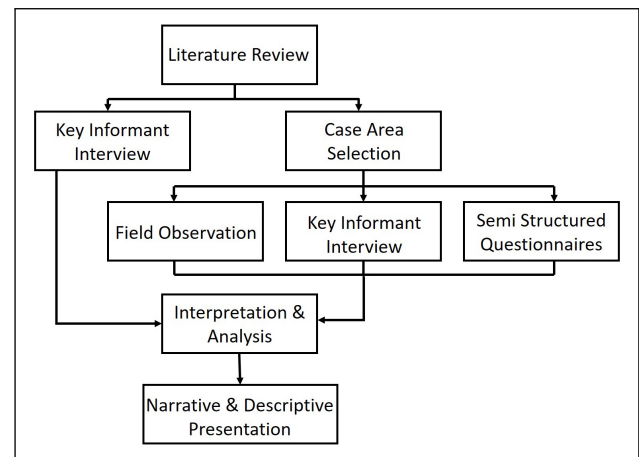


Figure 1: Methodology

4. Study Context

The research is based on the study of water security issues of Kathmandu valley, which is the largest urban agglomeration of Nepal. Then the two case areas of Alko Hiti and Pimbahal pond, which are two successful examples of restoration of Hiti system within the Kathmandu Valley is studied, with the aim of assessing its features and drawing out results which may aid regenerating Hiti system in addressing water security of the Valley.

4.1 Kathmandu Valley

The water security context of Kathmandu Valley can be classified as,

Water Stress and affordability As per the annual report(2079) of Kathmandu Upatyaka Khanepani Limited(KUKL), which is the responsible organization for the operation and management of water and wastewater services in the valley, out of the total demand of 472 Million Litres per day, KUKL has an average production of only 101.24 MLD (including losses)[16]. Even with the introduction of Melamchi Water Supply project in 2021, which introduced 170 MLD (excluding losses) to the valley, the supply has not been reliable enough and the distribution has not been accessible to all. However, if we are to add Melamchi Water Supply Project including losses and present KUKL supplies, there would still be a deficit of 234.76 MLD in the present context, which is expected to grow steadily. To cover this gap, the population of the valley have been relying on different sources such as wells, tube wells, stone spouts, jar, tanker etc. According to census (2021), only 45.7%, 44.3%, 50.2% of the households in Kathmandu, Lalitpur and Bhaktapur respectively, identify taped water within their compound as their main source of drinking water. From the same report, it can be inferred that there is a high dependence upon water tankers and jar water in the Valley, which is 21 and 155 times more expensive than KUKL water respectively. In instances, hitis are still the only source of water for many; especially for the urban poor.

Groundwater Depletion According to KUKL(2021) report, out of the average production of 126.55 MLD of KUKL, an average of 40MLD is supplied through ground water source. Reports, suggests that nearly half of the valley's total water supply during the wet season, and 60%–70% during the dry season, comes from groundwater sources supplied by KUKL [17]. The Kathmandu Valley consists of a shallow aquifer which is easily replenished and confined aquifer system which is not a renewable source of water. In confined aquifers [18], atleast 20 times the amount of recharge is being pumped and the groundwater will be depleted below present extraction levels in 100 years. The KUKL(2021) is mostly dependent upon deep tube wells for its ground water and this coupled with the trend of private entities and businesses to construct private boring facilities has led to serious depletion of ground water.

Urban Pluvial Flooding Through satellite images, it has been observed that in the last thirty years(1990 to 2020), the Kathmandu valley has witnessed an alarming increase of 206.88 km²(368.06%) in built up area[19]. This transformation limits water infiltration and increases the speed and the amount of water run-off on the ground [4]. Causing urban pluvial flooding. Urban pluvial flooding, a product of inadequate management of the urban drainage system and strongly correlated with built-up areas and climate change, has become more evident in urban areas of Nepal, especially Kathmandu Valley. According to a study done by [4], based on the urbanization and climate change conditions for the case of Kathmandu Metropolitan City, there will be a 40% increase in the flooding amount considering the current and future climate for a 25 year return period. So, with increasing water stress and unaffordability, decreasing ground water levels and increased risk of urban flooding, the water security of Kathmandu Valley is under serious pressure.

4.2 Case Area: Alko Hiti

Alko Hiti Complex is situated in Ikhachhen tole, which is a historic Newar tole in Patan, presently lying in Ward 11 of Lalitpur Metropolitan City of Kathmandu Valley. The inscription in the Hiti complex states that the Hiti was established in in 535 Nepal Sambat (1415 AD) by the forefathers of Bajracharya family living nearby the Hiti complex.

Alko Hiti Water Management System About 20 years back, the locals were faced with severe water scarcity, and they united to form Aalok Hiti Conservation and Water Supply Users' Committee in 2003. This committee created a water collection system by harvesting water from the Hiti and distributing it via pipes to individual households. Water is collected from the Hiti through a pipe leading to a collection drum. This water is then pumped upwards to an overhead tank reservoir of ten thousand litres and then distributed to individual houses through underground pipe lines to 180 households at present.

4.3 Case Area: Pimbahal Pokhari

Pimbahal Pond or Jagmadu Pukhu in local language was built around 14th century nad lies in Ward no. 19 of Lalitpur



Figure 2: Alko Hiti

Metropolitan City of Kathmandu Valley. Before 2017 A.D, the situation of the pond was quite poor. All sorts of pipes carrying the dirt drained into it as a result of this situation was that people there suffered from mosquito infestation. So there were proposals coming in to convert the pond into a shopping center, park and only a small portion to a pond. However, with the active efforts of the community led by Mr. Shailendra Shrestha, and financial aid from World Bank PURPP, (Pro-Poor Urban Regeneration Pilot Project) in 2017, things took a different turn for the good. The restored pond is one of the most successful Urban regeraration project of World Bank in Nepal.

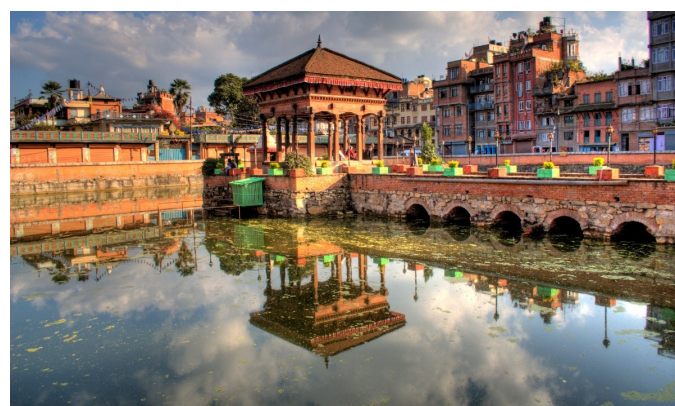


Figure 3: Pimbahal Pond

5. Results and Discussion

5.1 Alko Hiti

The findings from field observations, semi structured interviews and key informant interview from Alko Hiti are listed as,

5.1.1 Semi Structured Interview

There were a total of 185 households connected to the Alko Hiti Distribution Network. Amongst them, semi structured interview was conducted in 20 households. The study included 60% females and 40% males. Likewise, 15% of the people surveyed were aged more than 50, 35 % were aged between 40

to 50, 25% were aged 30 to 40 and 25% were aged 20 to 30. Also, efforts were made to include all the ethnic groups present such as Shakya, Maharjan, Shrestha, Tandukar, Bajracharya and Bhramin. The results are,

1. The households used the distributed piped water from the project for various domestic purposes such as drinking, cleaning, washing, sanitation etc., however even with piped supply, all of them also used water fetched directly from Hiti on a regular basis.

Analysis: The water fetched directly from Hiti is believed to be “pure water”. For other domestic activities such as cooking, washing etc. people use the piped supply water, but for the purpose of drinking, most people revere to Hiti water collected in traditional vessels as being better for the body. Though there are people who are reverting to other sources such as jar water, for drinking but the linkages to religious activities remain even stronger. For the purpose of religious offering, pure water is required, which is believed to be flowing water from the Hiti. This water is called as “Nhi La:” and people come to the Hiti to fetch it for daily religious activities or during puja in festivals or important events.

2. When the respondents were asked to rate their satisfaction on a five-point scale of the project, ranging from highly unsatisfied to highly satisfied, 75% responded with highly satisfied and the remaining with satisfied.

Analysis: Even though the provided water by the project is below the per capita water supply requirements of 135 lpcd, people still responded with satisfaction. This can be attributed to the relative water security with other toles in Patan and the water culture from place to place. One respondent when inquired that they are getting less water than the per capita requirement, they simply said “There will never be enough of water. It depends upon how you use it.” A point that was frequently raised when answering this question was the consistency of the Hiti supply sytem. For e.g. in the KUKL system there might be problems in the pipe line in the locality and maintenance cost might be high, but in the Hiti system there are no such maintenance issues in the pipeline.

5.1.2 Hiti Usage Data

The data of usage of Hiti was collected in the peak hours of morning(6 a.m. to 7 a.m.) and evening(5:30 p.m. to 6:30 p.m.) for three days on July 14,16 and 18, 2023 and an average of the data is shown in Table 1.

Table 1: Hiti Usage Data

Time	Native		Non Native	
	Male	Female	Male	Female
Morning	21	41	12	19
Evening	7	5	15	10

Analysis: The data shows that the Hiti water is used predominantly by the local community in the morning, while it is used predominantly by the non-native community in the evening. The usage characteristic is also somewhat different. The local community perform their morning religious rituals

in the Hiti and also take water for drinking purpose, while the non-native people take water for drinking and other domestic purposes. In case of the local community, two thirds of the ones arriving in the Hiti were women. This time is also seen as being distinctly utilized by women for social bonding. So it serves a threefold purpose of religious rituals, social bonding and water usage. The non-native community can be seen using the Hiti water to fill up mostly 15l to 20l jars for domestic purposes. Of the total nonnative community users, 60% were found to be male. This might be attributed to the male student renters living in nearby communities.

5.2 Jagmadu Pukhu or Pimbahal Pond

The findings from field observations and key informant interviews with Jagmadu Pukhu Chhetra Bikas Samiti are as follows.

5.2.1 Rainwater Harvesting

The project has a well-functioning system of inlet providing for year round availability of water to the pond and the outlet system to the municipal drain which is used minimally. For this, surface drain is laid from about 167m from the pond. The rain water is allowed to flow in these drains with adequate slope and enters the main drains, and then sent to the collection chamber, and discharged to the pond after primary sedimentation. Rain water also enters from secondary drains laid around the pond. There are in total 9 secondary drains and an outlet drain located in the North East corner.

5.2.2 Water collection

The depth of the pond is approximated to 5.5 ft and the surface area is 3235 sq. metres (Source: Google Earth Pro). The Jagmadu Pukhu Area Development Committee steered the redevelopment of the ponds, and the committee members stated that they had constructed the pond to a level of 5.5 ft, and a minimum level of 3 ft is maintained in all seasons which means that a level of 1.5ft(0.46m) is filled during the monsoon, which amounts to 1488 cubic meters.

5.2.3 Well Recharge

Further, the pond may have aided in the recharge of the surrounding wells. The ponds in Kathmandu Valley, which are mostly man made are constructed through the use of specific technology, using a soil called “gathucha”. This construction technique allows for the recharge of nearby sources. A representative statement by Mr. Shailendra Shrestha, is stated as, “During the reconstruction of the pond in 2017, the water had to be drained out. When this happened, the people from the nearby toles asked the committee to fill the water in the pond as water levels in their wells had gone down”. Also, previous researches too point that the pukhu in fact worked as a water recharging body [8]. To compliment this notion, the water level of a well lying 56m North from the pond was measured. The water level was found to be 1.9m from the ground level.

5.2.4 Analysis

The Jagmadu Pukhu development model uses rainwater harvesting as a means to sustainably store rain water. This does not require any artificial refilling of the pond. The system of dedicated inlets and outlets, charged through rainwater of this model, are the shortcomings for many recent pond development failures. Besides this, the pond water has also been used for firefighting purposes. Also, this model has eliminated the need for storm water drainage works in the service area. It stores a tentative amount of 1488 cubic metres in the monsoon, which aids to dampen the pluvial urban flooding. To add to it, the pond might have aided in increased level of water levels in the surrounding wells.

5.3 Findings and Analysis from Key Informant Interview

The key informant interviews were mostly focused on the socio-cultural aspect of the study. The interviewees unanimously agreed that Hiti system can be a solution to our water security issues, but the essence of its sustainability lies in its "Community Based Management Approach". As stated by Mr. Shailendra Shrestha, who led Jagmadu Pukhu Development Area project,

"The reason why Hiti system survived more than 1500 years, is because of its integration with the community through Guthi System and the process of Ritualization, creating a sense of ownership. So, if we are to go forward with engaging Hiti system as a Nature Based Solution, the mechanism for community engagement of Hiti system must be a crucial component."

An example of this has been given by Hiti expert, Mr. Padma Sunder Joshi as,

"The Machhindranath Jatra is an excellent example of ritualization. The jatra happens during the dry period, and all the strategic ponds have to be filled before the commencement of the jatra. This is possible only when the state canals (rajkulo) are well maintained. So, before the starting of jatra, the state canals are maintained every year, establishing a ritual, and to carry out the jatra different ethnic groups have their management institutions in the form of different guthi, which delegates roles and responsibilities needed for the functioning of Machhindranath Jatra."

But, this sense of ownership is not limited solely to volunteerism. Most Guthi systems have land endowments vested in them which act as financial mechanism. This institutional backing which has socio-cultural linkages through ritual mediation has been effective in bringing about the sense of community ownership, and also establishing financial resource for generations. However, at present there has been massive decline in guthi land, the state owned guthi sansthan is not being able to cater to localized customs and traditions and the economy has moved on from an agricultural economy. In the case area of Alko Hiti, the surrounding 9.25 ropanies was said to be Guthi Land, and owned by the Bajracharya family living nearby. The land is believed to be entrusted for the operation and management, and rituals of the Hiti. However, the land rights do not lie with the Guthi now. Mr. Sushil Srestha, who led the Alko Hiti restoration said,

"There was a Guthi of Alko Hiti, which also had 9 ropanies of the nearby land, belonging to the Bajracharya family, but we don't know what they did with the land. The Bajracharya family does conduct puja 2 to 3 times a year, but are not involved in its maintenance. Now, the responsibility of Hiti is with the tole committee, and we will work for its betterment."

In case of another case area, Jagmadu Pukhu, if it weren't for local involvement, the pukhu might have been transformed into a shopping mall. Mr. Shailendra Shrestha says that,

"The local authorities did not care much about the pond, and were waiting for the world bank project of urban regeneration to finish. If it weren't for our intervention they would have given the project away, but we persisted, and the construction of the project was completed in 6 months. We situated that maximum local participation happened, by forming smaller commit for construction, and engaging as many people as possible."

One thing, which is common to these cases, is that the sustained revival of Hiti system, has to come from the community level and mechanisms have to be identified to integrate financial resources to it. With the declining state of guthi system, in both the study context, "Tole Sudhar Samiti", which is an elected body of representatives from the community, backed by a degree of local government, are working to fill the institutional gap in the Hiti system as evident in the two successful case study of Hiti system. An important feature for their success is that in both the case studies, the restoration projects have also been financially feasible. In Alko Hiti financing has been through monthly user's fee, while in Pimbahal it has been through fish farming, boating and users fee.

These cases can provide a framework for approach for future actions. Most Guthi's relating to Hiti have become dysfunctional, mainly due to their inaccessibility with land rights. Also, the population dynamics and societal structure is changing, which urges the need for greater participation from youths and the diversifying community. As, in both cases, empowering "Tole Sudhar Samiti" with co-ordination from local government can be a viable way of moving forward with the management of Hiti system. It can ensure participation from youths and all castes and as it is an elected body of the people who live in the same area, the institution can be held the most accountable for the preservation of Hiti. The Tole Sudhar Samiti can finance the operation through internal revenue, and from the budgets of the 3 tier government and agencies. For this, if we can add the notion of Nature Based Solutions to the notion of cultural preservation to Hiti system, then this can work to create newer possibilities of financing. In this way functional integration of the system can be made as shown in Figure 4.

However, even in dysfunctional Guthi's, the act of performing religious rituals still remain, and in those where it is has been disregarded, efforts should be made to promote them to perform such rituals. In this way, by inspiring both cultural and functional aspects, the sense of community ownership can be revived to the Hiti system, which in turn adds to the water security. This way of protecting the ecosystem, by engaging the community, can be Nepal's own version of Nature Based Solution.

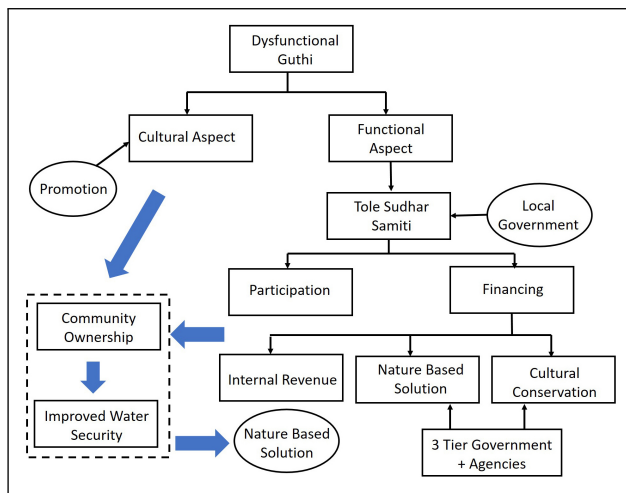


Figure 4: Proposed Institutional Structure

6. Discussion

6.1 Hiti as a Nature Based Solution

In accordance to the first sub objective, the planning of Hiti system has been studied in this research through literature reviews, key informant interviews and case study approach, and the salient features of the system have been identified. These salient features have then been identified with concept of Nature Based Solution, to fulfill the second sub objective. This can be summarized as below.

Protection, management and enhancement of Natural Ecosystem The conservation of Hiti system, naturally amounts to conservation of ecologically water sensitive areas. These areas are generally the underground shallow aquifers and wetlands, which are essential in maintaining the underground water storage. These sources are renewable sources of water, which get replenished every monsoon, and its judicious use can bring about sustainable usage of water which is evident through the case area of Alko Hiti.

Localized Solution Hiti system is a local solution which is coherent with the principles of Environmental Justice. It is not right that Kathmandu Valley wastes its water, and then uses a different watershed for filling its need. This has been causing issues for the Melamchi watershed. Most of the water needs of Kathmandu could be met with only 6% of the rainwater (Domènech et. al, 2013). Also, it has been earlier stressed that Melamchi Water Supply has not been reliable yet and is prone to disasters in monsoon. So, in order to build water resilience, we should be working on better utilizing our local resources.

Community Based Management The Hiti system is based upon the community and its beliefs. Its management engulfs community involvement and ownership. It carries a history of socio-cultural linkages with the community. Traditionally, these aspects along with the financial mechanisms were catered through the guthi system, but our interventions have weakened the system. However, the socio-cultural ties with the community still remain strong and if appropriate financing mechanisms are established these systems can once again run in perpetuity. This is the case with both Alko Hiti and Pimbahal bond, where the community ownership

remains and financial mechanisms have been established.

6.2 Hiti system in solving water security

The research has gone to fulfill the third sub objective of assessing the role of Hiti system in addressing water security through case studies and practical examples. This can be summarized as follows,

Water Stress The case of Alko Hiti shows that how the combination of Hiti and piped system can relieve water stress. It has been observed that only Melamchi will not be enough, so a localized mechanism of water supply should also be sought.

Water affordability Most Hiti systems have been delivering water free of cost, if not minimally. Considering the case when, jar water is 155 times the cost of piped water supply, and piped supply is only catering to 25% of the population, the affordability aspect of the system has been useful, especially to the urban poor. Further, it is based on gravity flow, which does not require pumping costs, and the filtration process is based on natural filtration methods.

Water Resilience Locals are often seen complaining of the maintenance issues in piped supply, and its fixation might not be done by the community alone, but in case of Hiti system, the community can move forward to fix its own problems. Hiti system is a low maintenance system. It has been functioning properly for the last 1500 years with little maintenance. In case of Alko Hiti, there have been very few issues regarding maintenance, thus ensuring reliability. In case of disaster related events, for e.g. in earthquake 2072, piped supply faced numerous issues, while Hiti system served as an important source during that time. The system has also been helping to combat disasters, through the protection of open spaces, and water for firefighting purpose.

Urban Pluvial Flooding The case study of Pimbahal shows that, an alternative storm water drainage through the process of rainwater harvesting can prove to be beneficial. Ponds served multiple functions in the Hiti planning and a major function is the control of urban pluvial flooding, which was calculated to be 1488 cubic metres in a season in case of Pimbahal. This offsets the peak in flooding time, and also has the simultaneous benefit of aiding in water recharge. This principle has also been duly implemented in the sponge cities of China. For e.g. Mangrove Ecological Park in the city of Shenzhen, China.

Sustainable Usage of Water The system is based upon usage of replenishable source of water i.e. shallow aquifers. It uses rainwater harvesting in the form of ponds, wetlands, and aquifer storage. The principle of the system bases upon allowing percolation of rainwater and protecting ecologically sensitive areas. All this is done by motivating the people to look after their own ecosystem through the delicate act of religion and social ties. Protection and groundwater Recharge

In this way, the research has been positioned to fulfill the three sub objectives which add up to fill the main objective of the research.

7. Conclusion and Recommendation

As with major cities around the world, the Kathmandu Valley is facing serious issues of water security. The learnings from studies around across the globe is that built infrastructures alone is not being able to solve water security in the long run and that is why to combat this a combination of anthropogenic as well as Nature based solutions must be in place. These Nature Based Solutions have been observed to be based on traditional knowledge of water management, and as Hiti system is an indigeneous system of water management in the Valley, which is deeply connected to the community, this research has strived to showcase Hiti system as the Nepalese version to Nature Based Solutions. In this research the salient features of Hiti system as a Nature Based Solution has been assessed which encompasses protection of ecosystem, local watershed usage and community engagement. This works to reducing water stress and increasing water affordability, water resilience, checking urban flooding and enhancing sustainable usage of water, all adding to the water security of the Valley. In this way, the sub objectives of the research, to understand the Hiti system, assess its salient features as a Nature Based solution and investigate how it addresses water security have been studied, with the intention of fulfilling the larger objective of assessing Hiti system as a Nature Based Solution in addressing water security in the Kathmandu Valley.

The research advocates that, the protection and enhancement of Hiti system be not limited to the notion of cultural preservation only. It should be seen as providing essential service of addressing water security. This view makes Hiti system an important mechanism to achieve sustainability. Consequently, the system can be viewed through the lens of SDG's and Climate Change Mitigation, which opens up newer possibilities for related agencies and the government to work to invest and conserve the Hiti System. With this shift in perspective the importance of Hiti system as an urban planning tool for the present and the future can be realized.

Further, the system of Hiti, is a community based system. The research also proposes an institutional model as shown in Figure 4, for the Hiti system having dysfunctional management systems, so as to reinvigorate the community relationship, which is essential to the functioning of the system.

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