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Urbanization-Driven Land Use Shifts, Diminished Traditional Water Ponds, and Their Impacts on Water-Dependent Livelihood: A case of Panchkhal Municipality, Kavre District

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Abstract

The escalating trend of urbanization is reshaping land use patterns, impacting the hydrological cycle, and giving rise to issues like intensified floods and prolonged droughts. Concurrently, Traditional Water Ponds, essential for sustaining surface and ground hydrology, flood control, and livelihood water access, are rapidly declining. In the Panchkhal Municipality of Kavre District, the dependency of households on water for vegetable cultivation, and effective land and watershed management is imperative. This prompted a comprehensive study to analyze changing land use, the status of traditional water ponds, and their repercussions on water-dependent livelihoods. Presently, a concerning 73% of traditional water ponds are either completely abandoned or repurposed for construction. Urbanization has surged dramatically, with a 1662.5% growth rate in the past two decades, reshaping the landscape. This transformation directly affects supplementary water sources that support livelihoods. Notably, traditional spring sources (*kuwas*) have dried up, with 60 % of the respondent experiencing a decrease in water availability in *kuwas* which has been fulfilled by the construction of wells, tap, and water pumps.

Keywords— Traditional Water Ponds, Land-Use Land-Cover, Sources of Water, Water Dependent livelihoods, Water Availability

1. Introduction

With the rise in population, human activities such as agriculture, industrialization, and land-management practices have significantly altered the global environment, affecting land, water, and ecosystems worldwide (Clark, et al., 1986). Studying land use helps comprehend how changing human needs have reshaped land utilization, and analyzing these changes reveals their underlying motives. Land is a resource used for various purposes, encompassing natural elements like forests, grasslands, agriculture, and urban areas, each serving distinct human requirements such as habitat, production, recreation, and more (Briassoulis, 2020).

Effects of land-use change on the decrease in flow discharge and increase in contamination in stream flow has been a common global phenomenon, especially for the water-limited regions of developing countries. Many researchers have found a strong relationship between land use and water quantity as well as quality (Tang, et al., 2011). In response to dwindling water sources, rural communities in Laos have adjusted their traditional high-water demanding rice-focused agricultural practices, and have transitioned to economically viable pursuits with lower water requirements, a shift highlighted by (Vongvisouk, et al., 2014). Similarly, an investigation conducted in Ghana's Atwima Nwabiagya District revealed the adverse influence of land-use and land-cover changes on people's livelihoods, manifested through diminished forest cover and heightened accommodation costs; this trend was aggravated by urbanization due to increased immigration, leading to elevated land prices, as observed by (Kullo, et al., 2021). With the variation in utilization of the land in the catchment of streams, the quality and

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quantity of surface and groundwater are highly affected. An increase in urbanization and ground sealing have reduced the groundwater recharge and increased the surface runoff (Anderson & Burt, 1998). A separate research endeavor conducted in the Bagmati Basin highlighted the encroachment of open spaces due to urbanization, which accounted for 10.4% of the total basin area from 2010 to 2018. Furthermore, this study made a forward-looking estimation, predicting that by 2050, approximately 21.4% of the open area would undergo transformation from fertile and permeable agricultural land to developed zones. This shift has significantly impacted both surface and subsurface hydrology within the Bagmati River basin, converting 6% of rechargeable land into impermeable surfaces (Lamichhane & Shakya, 2019). The alteration in land use within the Chure hills commenced in the 1950s after malaria eradication in the Terai region, driven by government policies that encouraged deforestation to increase land revenue. This period also saw the initiation of a resettlement program for the economically disadvantaged and individuals affected by natural disasters (Joshi, et al., 2016). A study carried out in Kamala Watershed, Sindhuli showed that agricultural land had increased by 11.41% from 1995 to 2014 and the river terrace had decreased by 26.50% by modifying to agricultural land (Dhakal & Neupane, 2017).

Apart from land use, there are other factors that influence water availability. For instance, Nepal receives most of its rainfall during the four monsoon months, resulting in a significant imbalance in precipitation throughout the year (WCG, 2018). This uneven distribution of rain, with excessive and scarce rainfall, poses challenges during dry periods. In the winter season, many regions in the country face insufficient rainfall, leading to prolonged droughts and the depletion of small rivers and streams (MoFALD, 2013). As soon as the monsoon rain ends, groundwater reserves begin to decline, causing springs to gradually dry up, starting from higher elevations and moving to lower areas, ultimately affecting the livelihoods of people living in the surrounding regions (Patel, et al., 2020). Traditionally, people have recognized the imbalanced rainfall pattern and devised methods to bolster water resources in aquifers during the dry season through the use of earthen ponds. These age-old ponds have served a vital role by collecting rainwater during the monsoon and gradually releasing it during drier times, thereby ensuring consistent groundwater levels throughout the year. However, in recent times, these valuable traditional ponds are rapidly disappearing due to changes in land use, often being repurposed for construction purposes such as roads, buildings, and recreational spaces. This decline in traditional ponds not only disrupts surface hydrology but also has far-reaching effects on sub-surface hydrology and the availability of water from springs during periods of low rainfall (Ferk, et al., 2020). Enhancing the rate of infiltration, traditional recharge ponds (natural/man-made) are some easy and low-cost methods of augmenting groundwater sources. Ponds are an appropriate and practical means for collecting, storing and later replenishing water towers in the hills and mountains (MoFALD, 2013). Recharge ponds not only enhance groundwater resources but also serve various water-dependent livelihoods, including irrigation, animal bathing, and construction activities. Traditionally, in the mid-hills of Nepal, animal husbandry and agriculture were primary income sources. Farmers constructed ponds to facilitate regular wallowing of animals, particularly buffaloes, which in turn led to increased animal product yields, like milk. However, in recent years, the disappearance of many ponds has led to a decline in livestock populations, with buffalo being replaced by cows (Sharma, et al., 2016). A study conducted by ICIMOD in Tinpiple (now within Panchkhal Municipality, Kavre), Dapcha, and Daraune Pokhari (both currently within Namobuddha Municipality, Kavre) revealed that 14 ponds in Tinpiple, 9 out of 43 ponds in Dapcha, and 8 out of 16 ponds in Daraune Pokhari have dried up. Moreover, not only have the ponds dried up, but also 14%, 29%, and 30% of spring sources have dried up in Tinpiple, Dapcha, and Daraune Pokhari, respectively. This study establishes a correlation between the presence of ponds and spring discharge (Sharma, et al., 2016).

Following preliminary observations and a comprehensive literature review, it came to light that Panchkhal Municipality having 13 number of wards with total area of 103 square kilometer in Kavre District is currently witnessing the swift decline of traditional ponds and a concurrent rise in urbanization, highlighting the urgency of this research to explore the repercussions of these transformations on water resources and local livelihoods; thus, the principal aim of this study is to scrutinize the fluctuations in LULC, assess the present condition of ponds, and analyze their collective influence on the essential water sources that sustain water-dependent livelihoods within Panchkhal Municipality.

1.1 Roles of Traditional Water Ponds

Water, a perishable resource, can result in substantial losses due to poor management and inefficient usage, primarily through floods and evaporation, underscoring the crucial need for effective water channelization and storage; In this context, Traditional Water Ponds have served as significant reservoirs, and further contributing to groundwater recharge, rainwater harvesting offers an additional avenue for storage facilitated by these ponds (Studer & Linger, 2013). The drinking and irrigation water supply technology was used over 2000 years ago when water ponds were used to feed the water canals and stone spouts through groundwater recharge, which mostly depends on the geological and surface conditions. In a community in Patan, Nepal, a study conducted by UN-Habitat and the Center for Integrated Urban Development (CIUD) revealed that channelizing rainwater into a recharge pit led to an observed rise in flow-through water spouts and an increase in groundwater levels in dug wells (Shrestha, 2009). Similarly, a noteworthy initiative was undertaken in Salang Rural Municipality of Dhading District, Nepal, where a mountain-top pond was constructed to replenish previously depleted springs in the aftermath of an earthquake, yielding positive outcomes (Adhikari, 2019). In a similar vein, a practical trial carried out in Dabhu, Central Mehsana, India, showcased that the creation of recharge ponds notably enhanced infiltration rates in shallow aquifers, achieving a remarkable rate of 0.5 meters per day; during the 60 days recharge phase, a significant uplift of 4.13 meters in water level was observed within a 5 meter radius of the recharge pits (GoI, 2000).

1.2 LULC Change on Water Availability

Land Use and Land Cover (LULC) profoundly influence the hydrological cycle and stream volumes. Urbanization, a key driver of LULC changes, significantly affects urban environments by accelerating runoff and amplifying the peak discharge of stream flow, thereby exacerbating the occurrence of urban floods. A meticulous examination of urbanization in Beijing, China, conducted over several decades, unveiled substantial consequences on surface runoff dynamics, revealing a noteworthy 25% surge in surface runoff and an associated 11.4% decline in the infiltration rate (Sun, et al., 2011). The intricate LULC patterns profoundly influence the dynamic shifts within the catchment's flow patterns. Embarking on a journey to Sub-Saharan Africa, specifically Tanzania, a study employing the tandem of Land Change Modeler (LCM) and Soil and Water Assessment Tool (SWAT) unveiled a nuanced narrative: a projected decrease of 6-8% in low flows due to future land-use changes, yet a striking increase of up to 84% ascribed to the reverberations of LULC transformations, peering into the horizon of 2030 (Naschen, et al., 2019).

More than four million people in Kathmandu Valley depend on groundwater as a major source of water supply. 19 % and 31 % of dry and wet demands respectively of Kathmandu Valley is fulfilled by Kathmandu Upatyaka Kahanepani Limited (KUKL) through groundwater. Rapid urbanization of the catchment area has resulted in increased runoff and a decrease in groundwater recharge (Thapa, et al., 2018). Earlier studies show that groundwater recharge in Kathmandu Valley was in the range of 4.6 to 14.6 million cubic meter per year but due to the combined effect of LULC change and excessive pumping groundwater level is depleting (Lamichhane & Shakya, 2019).

2. Research Design

LULC change specifically impacts the natural coverage, water bodies, and hydrological cycle. A comprehensive approach involved on-site GPS surveys and detailed questionnaire assessments to assess the condition of traditional water ponds. For delving into LULC changes, a treasure trove of secondary data was harnessed — the LULC map spanning the Hindu Kush Himalayan region from 2000 to 2019, seamlessly integrated into a sophisticated GIS platform and tailored to our study's specific area. This transformation from raster to vector gave a distinct LULC classification, meticulously curated to align with our research goals. Exploring the diverse water sources that sustain livelihoods in Panchkhal Municipality, we blended questionnaire surveys and thoughtful data analysis to validate our outcomes and gain insights into water availability. As we unveil the results of this analytical journey, the data's intricacies are closely examined, allowing us to draw conclusions and craft recommendations that address any uncovered gaps.

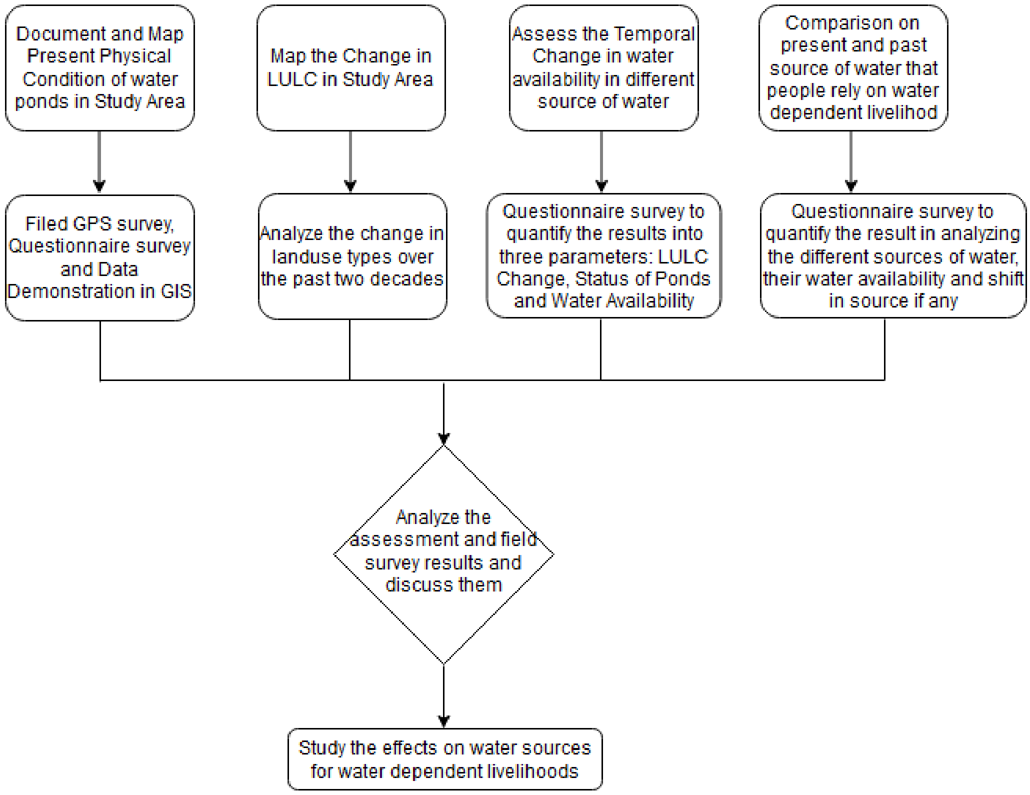

Figure 1 Flow Chart

3. Results and Discussion

3.1 Physical Status of Traditional Water Ponds

During the field study, a total of 112 traditional water ponds were identified within the boundaries of Panchkhal Municipality, each of which had been functional and actively utilized until 2000 A.D. These ponds exhibited varying surface areas ranging from 20 to 730 square meters. Within the expanse of Panchkhal Municipality, characterized by its diverse topography, encompassing elevations spanning from 597 meters to 1606 meters above mean sea level, the preponderance of these water ponds nestled within higher elevations beckons intriguing possibilities. The elevation gradient hints at their potential to serve as reservoirs for irrigation and domestic purposes in corresponding lower elevations, a spatial dynamic vividly portrayed in Figure 2. Beyond their immediate functional roles, these ponds have woven a tapestry of contributions to the holistic watershed management of Jhiku Khola playing pivotal roles in groundwater recharge dynamics and spring discharge processes.

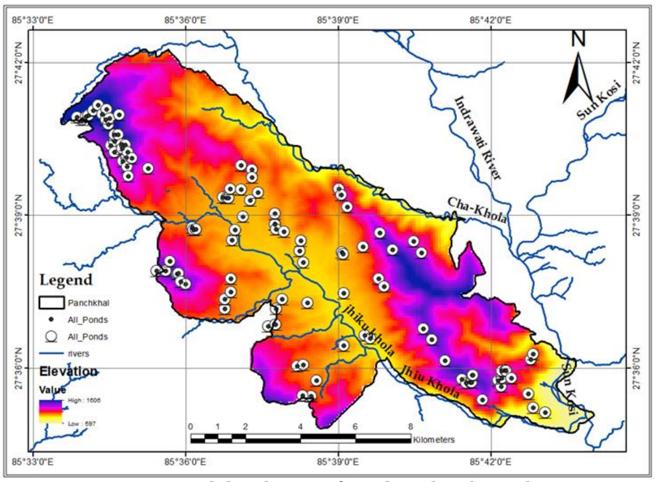

Figure 2 Spatial distribution of ponds within the study area

With the change in land-use patterns and urbanization, the status of Traditional Water Ponds has changed. Over the past two decades, a notable transformation has unfolded, with over one-third of the traditional water ponds within Panchkhal Municipality transitioning into conduits for construction purposes, accommodating public buildings, schools, health posts, and road infrastructure. Concurrently, another one-third of these ponds now stand desiccated, overtaken by swathes of grass, while a mere 22% endure as tangible vestiges of their original form within our study's confirms. This stark reality paints a vivid picture: more than two-thirds of the once-existing ponds have now been engulfed by the annals of time, vanishing from the landscape of Panchkhal Municipality. The comprehensive spectrum of changes encompassing the physical facets of these traditional water ponds, spanning the course of the past two decades, is documented in Table 1 and Figure 3.

Table 1 Present Physical Status of Earthen Ponds (as of 2022)

Total Number of Ponds			112
S.N	Present Status of Ponds	Number of Ponds	Change Percentage
1	Available	25	22.32%
2	Land Reclaimed for Constructional Purpose	38	33.93%
3	Seasonally Available	6	5.36%
4	Completely Dry	22	19.64%
5	Covered by Grass	21	18.75%

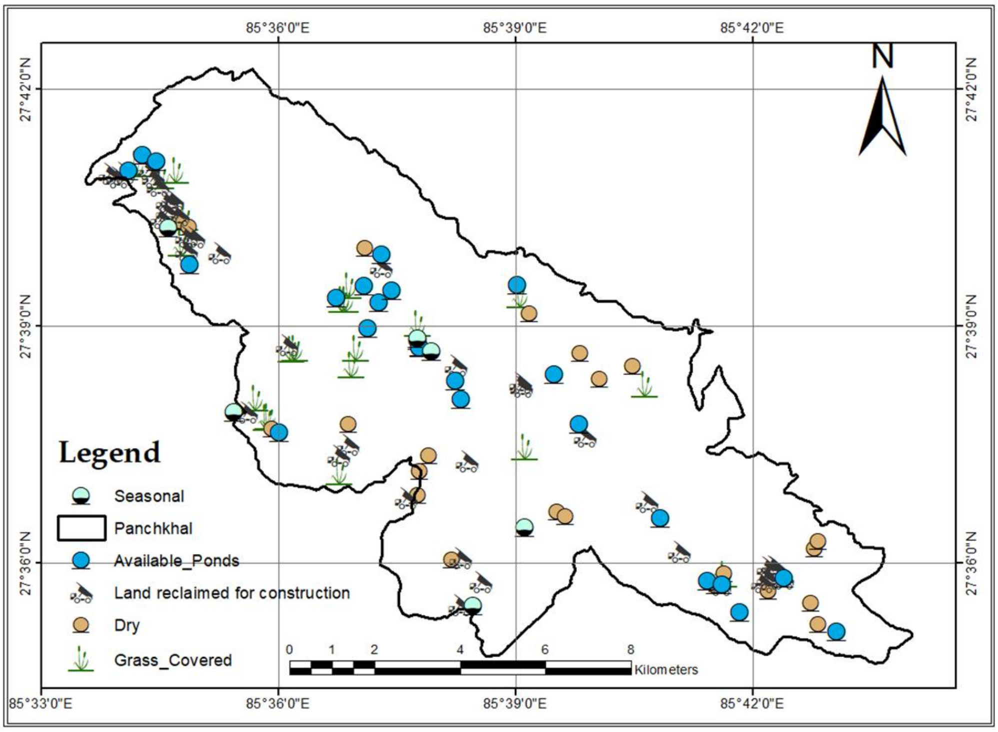

Figure 3 Ponds status quo as of 2022

In Table 2, we delve into similar findings. All the wards except 4 and 8 in Panchkhal Municipality, have seen ponds being used in various construction projects. A striking example is ward number 1, where 11 ponds have been incorporated into construction activities. This trend extends to ward number 11 as well, where the sole pond has also been utilized in construction. Likewise, one pond each in wards number 5, 7, and 10 has been part of the construction work. In ward number 13, 7 ponds have dried up and the same number of ponds in ward 3 has been covered by grass. Ward numbers 7 and 13 stand out with 5 available ponds each, while wards number 5, 10, and 11 have no ponds left. Notably, in 5 out of the 13 wards, more than the average of 8 ponds have vanished.

Table 2 Ward-wise Data Analysis on Ponds Present Status

Ward No	Ward-Wise Data Analysis					
	Physical Status (2020)					
	Available	**Land Reclaimed for Constructional Purpose**	**Seasonally Available**	**Completely Dry**	**Covered by Grass**	**Total (2000 A.D)**
1	3	11	1	1	4	20
2	1	4	0	1	1	7
3	4	2	0	1	7	14
4	2	0	0	0	0	2
5	0	1	1	0	1	3
6	1	2	0	2	3	8
7	5	1	2	0	1	9
8	2	0	0	2	2	6
9	1	2	0	2	0	5
10	0	1	0	3	0	4
11	0	1	0	0	0	1
12	1	6	2	3	1	13
13	5	7	0	7	1	20
Total	**25**	**38**	**6**	**22**	**21**	**112**

In the span of the past two decades, a wave of development and urbanization has swept across our nation. Between 2000 and 2018 A.D., the road network expanded by a substantial 8653.62 km (Gautam, et al., 2018), while urbanization surged at a pace exceeding 4.5% (CBS, 2011). Within this tide of progress and urban expansion, the hallowed land of Traditional Water Ponds has been encroached upon. Our study underscores a poignant reality: over 33% of the pond's land has been reclaimed for construction endeavors.

3.2 LULC Change

The LULC change map provides a visual representation of how land is used in a specific area over time. In our study, we crafted this map to span two decades, capturing snapshots at five-year intervals (2000, 2005, 2010, 2015, and 2019 A.D.). The data for this map was sourced from ICIMOD SERVIR-HKH and offers a comprehensive insight into the evolving landscape of our study area throughout these years. Following Figure 4, 5, 6, 7, and 8 shows the change in LULC over two decades.

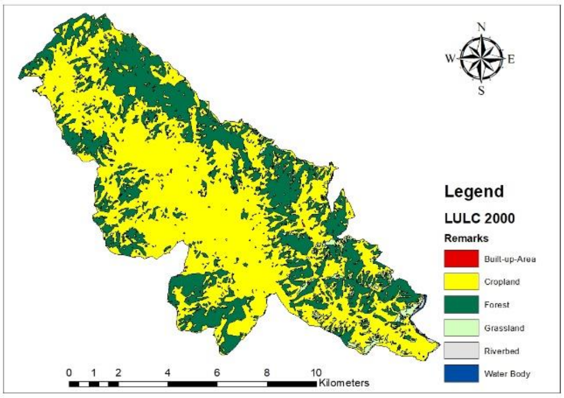

Figure 4 LULC Map 2000 A.D.

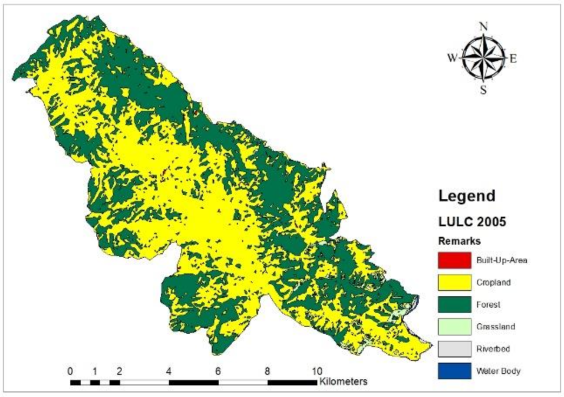

Figure 5 LULC Map 2005 A.D.

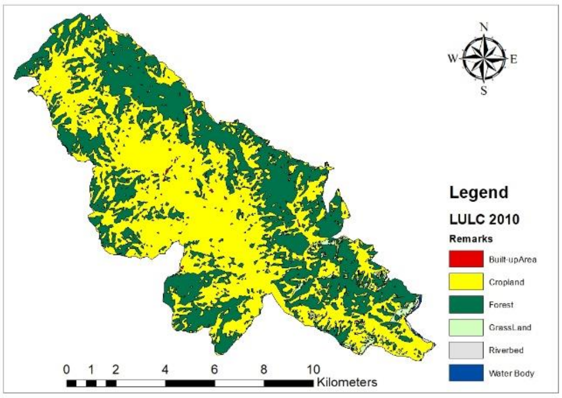

Figure 6 LULC Map 2010 A.D.

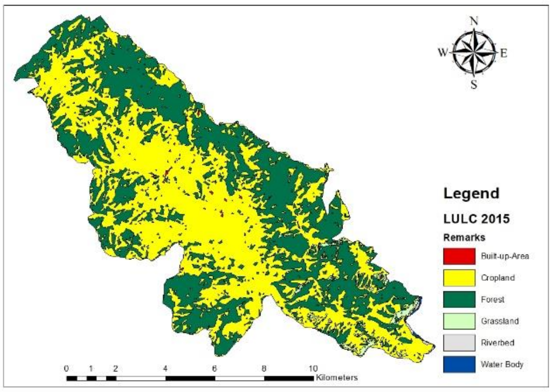

Figure 7 LULC Map 2015 A.D.

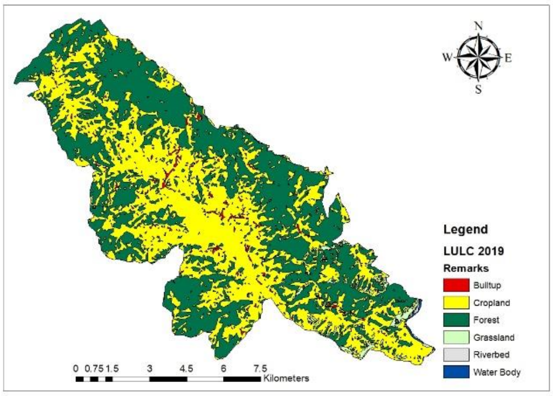

Figure 8 LULC Map 2019 A.D.

3.2.1 Change in Forest Cover

Upon scrutinizing the LULC map across various years, a notable surge in forested areas emerges as a significant finding. In 2000, the total forest coverage within Panchkhal Municipality stood at 34.94 square kilometer, which remarkably escalated to 49.97 square kilometer in 2019, signifying an impressive growth rate of 43.02%. This remarkable expansion owes its origins to the practice of community-based forest management, which has catalyzed the augmentation of forested landscapes.

The percentile change matrix, encapsulated within Table 3, vividly elucidates the evolving forest cover in relation to each interval year. A discernible shift is particularly evident between 2000 and 2005 A.D., underscoring a pivotal epoch of transformation.

Table 3 Percentile Change Matrix for Forest Cover Area

Year	**2000**	**2005**	**2010**	**2015**	**2019**
2000	NA	25.33%	23.24%	29.82%	43.02%
2005	NA	NA	-1.67%	3.59%	14.11%
2010	NA	NA	NA	5.34%	16.05%
2015	NA	NA	NA	NA	10.16%
2019	NA	NA	NA	NA	NA

3.2.2 Change in Cropland

When delving into the LULC map data, a significant shift comes to light: the area of cropland has decreased by 23.49% between 2000 and 2019 A.D. This change becomes even more apparent when looking at the percentile change matrix in Table 4, showcasing noticeable shifts primarily between 2000 to 2005 and 2015 to 2019 A.D.

Table 4 Percentile Change Matrix for Cropland Area

Year	**2000**	**2005**	**2010**	**2015**	**2019**
2000	NA	-11.79%	-10.70%	-14.42%	-23.49%
2005	NA	NA	1.24%	-2.98%	-13.26%
2010	NA	NA	NA	-4.17%	-14.33%
2015	NA	NA	NA	NA	-10.60%
2019	NA	NA	NA	NA	NA

3.2.3 Change in Grassland

The observation reveals a substantial decline in grassland, notably plummeting by 45.58% within the initial five years. This overarching transformation spanning the study's duration is meticulously examined in Table 5, wherein a percentile change matrix crystallizes these alterations. Over the past two decades, the total expanse of grassland has experienced a noteworthy shift, dwindling by 40.64%. Specifically, an area that encompassed 2.83 Square kilometer in 2000 has contracted to 1.68 Square kilometer by 2019.

Table 5 Percentile Change Matrix for Grassland Area

Year	**2000**	**2005**	**2010**	**2015**	**2019**
2000	NA	-45.58%	-44.88%	-42.76%	-40.64%
2005	NA	NA	1.30%	5.19%	9.09%
2010	NA	NA	NA	3.85%	7.69%
2015	NA	NA	NA	NA	3.70%
2019	NA	NA	NA	NA	NA

3.2.4 Change in Built-up Area

Upon meticulous analysis of the LULC data spanning the study periods, a striking narrative unfolds: the built-up area has surged dramatically by 1662.50%. This transformative trajectory finds eloquent representation in Table 6, where a percentile change matrix masterfully encapsulates the nuanced shifts in each study year from 2000 to 2019. Particularly noteworthy is the pronounced change observed during the final four years of the study, during which the built-up area experienced a remarkable surge of 571.43%. This surge could likely be attributed to reconstruction efforts post the Gorkha Earthquake in 2015. Commencing the decade with a mere 0.08 Square kilometer of built-up expanse, Panchkhal Municipality has witnessed a remarkable expansion to 1.41 Square kilometer by the year 2019 A.D.

Table 6 Percentile Change Matrix for Built-up Area

Year	2000	2005	2010	2015	2019
2000	NA	75.00%	112.50%	162.50%	1662.50%
2005	NA	NA	21.43%	50.00%	907.14%
2010	NA	NA	NA	23.53%	729.41%
2015	NA	NA	NA	NA	571.43%
2019	NA	NA	NA	NA	NA

3.3 Perceived Change in LULC

The evolving needs and aspirations of humanity wield substantial influence over the natural earth's surface. Trends such as escalating urbanization and the dwindling expanse of forests, grasslands, and agricultural land collectively shape the ever-changing landforms. In this landscape of transformation, LULC changes serve as a lens to comprehend the prevailing pattern of land use, shedding light on the underpinning factors of specific alterations (Wubie, et al., 2016). In a parallel vein, a meticulous examination of the LULC map of Panchkhal Municipality has unveiled profound shifts. To fathom the experiences of the local populace and corroborate the insights gleaned from the map, a comprehensive questionnaire survey was conducted. The respondents' firsthand experiences were encapsulated through multiple-choice responses, documenting their encounters with various LULC changes. The intricate tapestry of changes experienced by these respondents is richly illustrated in Table 7. Among the findings, it emerges that over 79% of respondents have witnessed a reduction in cropland, while 61% have observed an expansion in built-up areas. Significantly, 51% of respondents noted a decline in water bodies, echoing the decrease in Traditional Water Ponds within Panchkhal Municipality. The confluence of data derived from LULC change map analysis and the firsthand experiences of the community yield strikingly congruent outcomes.

Table 7 Type of Land-Use Change Experienced in Panchkhal Municipality

S.N.	Particular	No. of Respondent	Percentage of Respondent
1	Decrease in Cropland	319	79.75%
2	Increase in Forest Areas	48	12.00%
3	Increase in Built-up Areas	245	61.25%
4	Decrease in Water Body	205	51.25%

3.4 Major Source Livelihoods and Perceived Water Availability in the Different Sources of Water

The economic backbone of Panchkhal Municipality rests upon agriculture, livestock, and a diverse array of services including remittances, private and government jobs, and entrepreneurial ventures. A study conducted in Tinpiple, a part of Panchkhal Municipality, underscores the dominance of agriculture as the primary income source, contributing to a significant 97% of earnings (Sharma, et al., 2016). In the quest to unravel the intricate impacts of changing LULC patterns and the diminishing Traditional Water Ponds on water sources crucial for livelihoods, a comprehensive examination of respondents' core livelihoods was undertaken. This insightful analysis finds its expression in the detailed tableau presented in Table 8, providing a window into the multifaceted livelihoods of the respondents. Impressively, a substantial 91% of respondents are directly engaged in water-dependent livelihoods, spanning activities like vegetable cultivation and animal husbandry. The diminishing Traditional Water Ponds and the concurrent expansion of built-up urban areas could potentially have far-reaching consequences for those whose livelihoods are intricately woven into water-dependent activities.

Table 8 Livelihood of the Respondent

S.N	Particulars	Number of Respondents	Percentage
1	Vegetable Farming	325	81.25%
2	Animal Husbandry	43	10.75%
3	Other Services	32	8.00%
4	**Total Number of Respondent**	**400**	**100.00%**

To provide a tangible grasp of the diverse water sources and their corresponding quantities, a perceptive study was conducted with meticulous attention. Within this study, six distinct water sources—namely *Kuwa* (traditional spring sources), river, Traditional Water Ponds, well, tap water, and pump—emerged as pivotal contributors to water-dependent livelihoods. Illustrated succinctly in Table 9, this compilation deftly captures the spectrum of water sources and their utilization patterns within the study area. What is remarkable is that the majority of these water sources seamlessly serve both domestic and agricultural needs. Offering a more intricate insight, the ensuing breakdown unveils the water availability as perceived by respondents, thereby painting a comprehensive and insightful picture.

Table 9 Sources of Water and their Utilization

S.N	Source	Utilization
1	Kuwa	Domestic Purpose, Agriculture
2	River	Agriculture
3	Traditional Water Ponds	Agriculture
4	Well	Domestic Purpose, Agriculture
5	Tap Water	Domestic Purpose, Agriculture
6	Pump	Domestic Purpose, Agriculture

3.4.1Water Availability in Kuwa

Historically, *kuwas* have held a significant place as essential water sources in Nepal's hilly regions. They have served both domestic and agricultural needs. This narrative is poignantly illustrated in Figure 9, which together depicts the firsthand experiences of respondents regarding water availability in *kuwas*. A striking shift is evident as respondents report a decline in water availability compared to the past. Impressively, a staggering 76% of respondents express that water has become markedly scarce in *kuwas*. In stark contrast, a majority, 85% of respondents recall that water availability in water spouts was ample in the past.

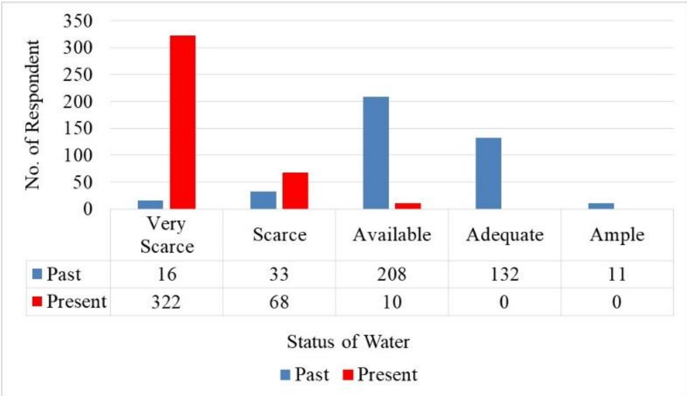

Figure 9 Water Availability in Kuwa

3.4.2 Water Availability in River

Water stands as an irreplaceable cornerstone of farming. Among the prevalent sources of irrigation, rivers hold a paramount position. In the context of Panchkhal Municipality, Jhiku Khola serves as the principal water source for irrigation purposes. This dynamic is succinctly encapsulated in Figure 10, which collectively portrays respondents' perspectives on water availability in the river. Notably, historical experiences indicate that none of the respondents had encountered water scarcity from the river within the study

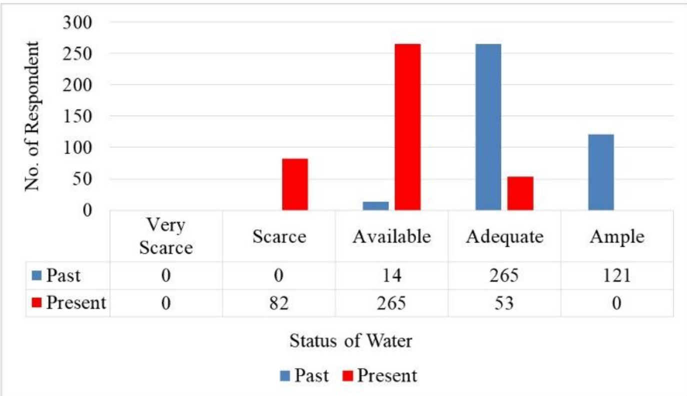

Figure 10 Water Availability in River

area. However, the present scenario reveals a noteworthy shift, with 20% of respondents now reporting a decline in river water availability—a change reflective of the current context.

3.4.3 Water Availability in Traditional Water Ponds

Traditional Water Ponds, a prominent hallmark of the hilly landscape, have historically underpinned water-dependent livelihoods, particularly in the realms of animal husbandry and surface irrigation. A dual advantage of these ponds in hilly terrain was not only their support to livelihoods but also their recharge potential (Sharma, et al., 2016). Figure 11 synergistically unravels the past and present water availability experienced by the inhabitants of Panchkhal Municipality. An evident decline is discernible in the availability of water within these earthen ponds, as a substantial 86% of respondents report water scarcity. During the field survey, a mere 25 earthen ponds were identified out of a total of 112, illustrating a marked reduction in their numbers in the study area. This diminution has directly affected water availability in the municipality. Delving deeper into the perception of water availability in ponds, a significant 94% of respondents recollect an ample water supply in Traditional Water Ponds in the past. However, in the current context, 51% of respondents find water to be exceedingly scarce—a perceptual shift likely influenced by the depletion of these earthen ponds.

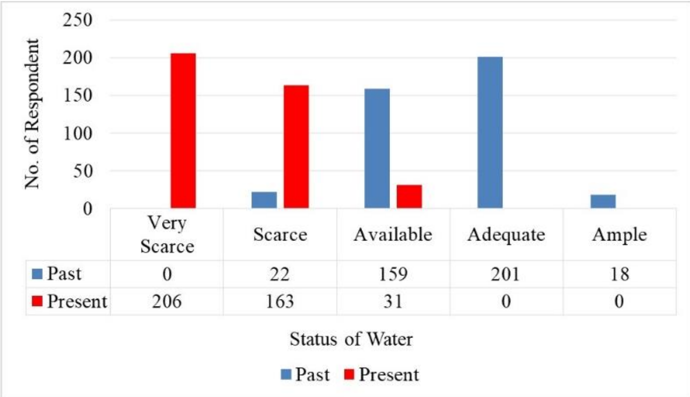

Figure 11 Water Availability in Traditional Earthen Ponds

3.4.4 Water Availability in Wells

Wells have long served as pivotal groundwater sources in the plains adjacent to the mid-hills, often catering to both domestic and agricultural needs (Sharma et al., 2016). This trend is vividly depicted in Figure 12, which offers a detailed glimpse into the water availability within wells. Intriguingly, in the past, the construction and utilization of wells were not commonplace within our study area; a mere 23 respondents had employed wells for water-dependent livelihoods. However, in the present, this landscape has dramatically shifted, with the number of wells surging to 232. This surge in well construction signifies a reduction in naturally available water sources like Kuwa, rivers, and ponds. This transformation is not merely numerical; it is indicative of broader changes in water accessibility. As usage increases, so too does the proportion of respondents, 19% to be precise reporting water scarcity in wells. This scarcity could be indicative of dwindling groundwater resources, raising concerns about sustainability.

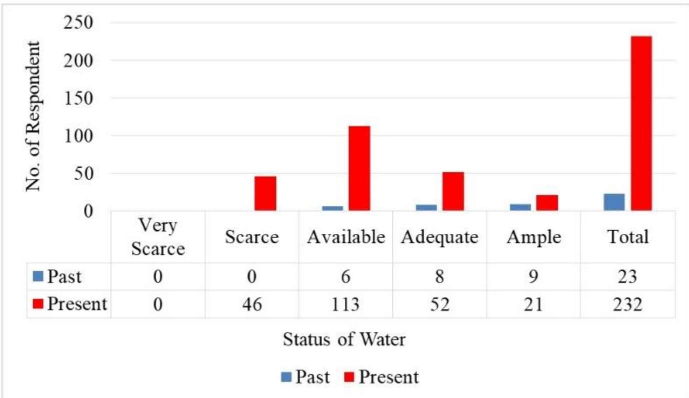

Figure 12 Water Availability in Wells

3.4.5 Water Availability in Tap Water

For domestic uses, water is sourced from springs, groundwater, and rivers, channeled through pipelines to either public taps or private connections commonly referred to as tap water (GoN, 2021). While tap water is predominantly utilized for domestic needs, a surplus of this resource also contributes to activities such as kitchen gardening and livestock maintenance (Zalichin, et al., 2007). As depicted in Figure 13, the accessibility of tap water has seen significant enhancements due to the implementation of various water supply initiatives within our study area. According to respondent experiences, the availability of tap water has progressed notably. What was once deemed scarce has now witnessed a turnaround, with 55% of respondents acknowledging a substantial improvement in tap water availability. This noteworthy improvement could potentially serve as a compensatory measure for the depletion of water from surface sources.

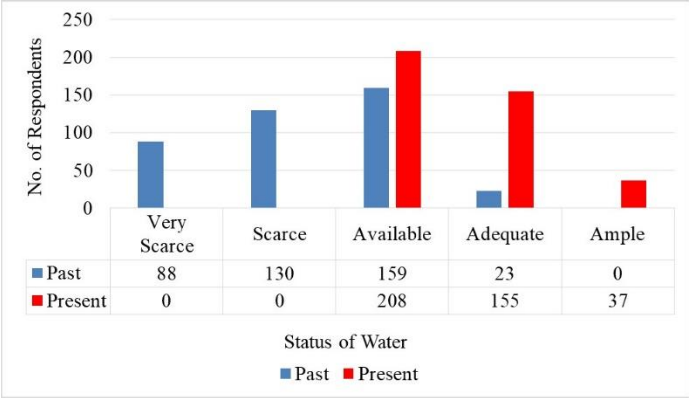

Figure 13 Water Availability in Tap Water

3.4.5 Water Availability in Pump

Another valuable water resource catering to both domestic and agricultural needs involves the utilization of electro-mechanical pumps to extract water from either rivers or underground sources (GoN, 2021). Figure 14 provide a comprehensive view of pump water utilization over a defined timeframe within the study area. Remarkably, in the past, pump water usage was non-existent among respondents. However, a perceptible shift has transpired due to the diminishing availability of surface water sources such as *Kuwas*, rivers, and Traditional Water Ponds. Respondents, now facing these constraints, have embraced electro-mechanical pumps as an alternative solution for securing water. Interestingly, a mere 26% of respondents have resorted to pump water extraction, a notable reflection of the escalating costs associated with water harvesting for water-dependent livelihoods. This transition not only signifies a financial shift but also underscores a shift in water utilization dynamics, moving from readily available surface water to a reliance on groundwater and technologically assisted water retrieval mechanisms.

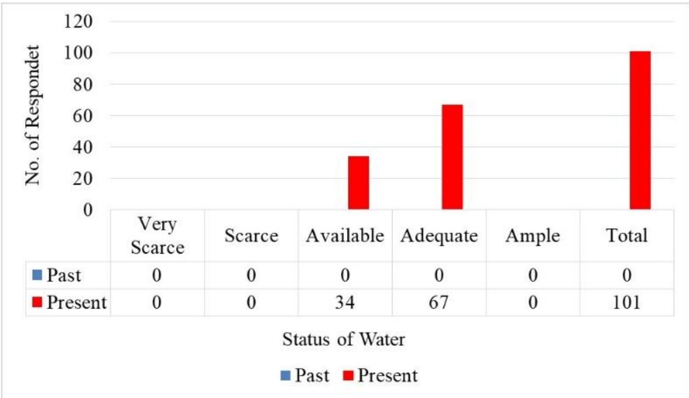

Figure 14 Water Availability in Pump

3.5 Shift in Water Sources for Water-Dependent Livelihood

Throughout the study period, respondents have witnessed significant shifts in the availability of water from various sources crucial for their water-dependent livelihoods. The quantity of water in sources like *Kuwas*, rivers, and Traditional Water Ponds has dwindled, whereas the tap water supply has improved. Within Panchkhal Municipality, a perceptible trend has emerged wherein people are transitioning their reliance on water sources to incorporate more technically efficient and economically viable means of water harvesting. Notably, more respondents have opted to construct wells or install pumps to secure their water supply.

A study conducted by ICIMOD between 1998 and 2005 A.D. within the Jhiku Khola Watershed echoed similar findings, indicating a 33% of respondents reported water shortage for irrigation during that period. Furthermore, the study showcased a substantial increase in the number of wells, with figures surging from a modest count in 1998 A.D. to over 200 by 2005 A.D. (Zalichin, et al., 2007). Capturing this evolving landscape, Figure 15 visually illustrates the dynamic shift in respondents' preferred water sources over the study duration.

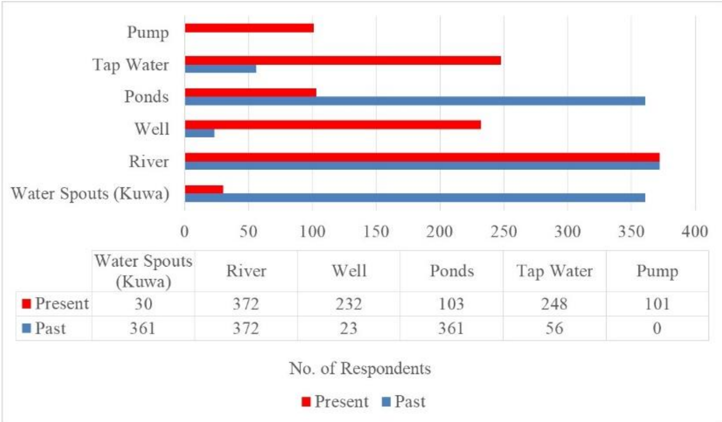

Figure 15 Shift in Source of Water Utilization

Interestingly, over 90% of respondents once deemed *Kuwas*, rivers, and ponds as their primary water sources for water-dependent livelihoods. However, at present, this preference has transitioned towards well water, tap water, and pump water. Notably, river utilization for irrigation has remained consistent over the two decades, reflecting its continued significance in the community. The surge in well construction, surpassing a 50% increase, coupled with a quarter of respondents resorting to pumps for water extraction, underscores this shift in reliance towards newer sources. On the contrary, kuwa and ponds have seen a steep decline of over 60% in their utilization compared to the past.

3.5 Possible Implication of Depletion of Traditional Water Ponds

During the comprehensive field survey conducted to assess the physical status of Traditional Water Ponds in Panchkhal Municipality, a total of 112 ponds were recorded up until the year 2000 A.D. However, over the past two decades, a concerning trend has emerged, with the majority of these Traditional Water Ponds disappearing. Their fate has been either complete desiccation or repurposing for construction purposes. Given the context that more than 90% of the surveyed respondents are engaged in water-dependent livelihoods, which primarily involves activities like vegetable farming and animal husbandry, and with approximately 82% of respondents directly involved in agricultural practices, for them the dwindling number of Traditional Water Ponds could potentially yield adverse impacts on both productivity and production costs. The vital role these ponds played in enhancing water availability and supporting the local agricultural landscape cannot be overlooked. Hence, this phenomenon warrants careful consideration due to its potential to reshape the dynamics of livelihoods and agricultural practices within the municipality.

When we compare the historical water utilization patterns with the present scenario in Panchkhal Municipality, the repercussions of the declining number of earthen ponds become apparent. In the past, over 90% of respondents viewed *kuwa*, rivers, and ponds as primary water sources for their water-dependent livelihoods. However, at present, merely 7.50% of respondents still consider *kuwa* to be a viable water source for their needs. This drastic shift is attributed to the reduction in the number of earthen ponds from 112 to 25, resulting in a significant decline in water availability in *kuwa* as perceived by over 80% of respondents. This underlines a noticeable correlation between the presence of earthen ponds and water availability in *kuwa*. Likewise, an examination of well water availability reveals an interesting trend. In the past, none of the respondents reported water scarcity in wells. However, in the current context, about 20% of well users indicate a decrease in water availability. This suggests a potential interrelation between groundwater resources and earthen ponds. Furthermore, while none of the respondents faced river water scarcity in the past, around 95% of them perceived the river as sufficiently abundant. However, the present scenario reflects a different story, with roughly 80% of respondents experiencing a reduction in river water availability. This shift can be attributed to the diminishing water availability in kuwa and earthen ponds, prompting increased reliance on river water.

At present, only 25% of respondents rely on earthen ponds for their water-dependent livelihoods, marking a 65% decline compared to the past. Conversely, the construction of wells and utilization of pump water have increased by more than 50% and 25%, respectively. This transformation underscores a clear shift in water sources, with a notable rise in the cost of acquiring water for water-dependent livelihoods. This shift reflects the changing landscape of water resource utilization within the municipality. In the global context, ensuring sufficient water resources to sustain the current population has emerged as a significant challenge in the 21st century. The scope of water utilization has expanded beyond traditional consumption patterns. Notably, agricultural irrigation constitutes a substantial portion of total water consumption, ranging from 60% to 70% depending on regional economic development and climate conditions (López-Felices, et al., 2020). The historical solution to meeting the demands of both agricultural and domestic water needs has been the construction of water ponds. These ponds, ranging in size from 1 to 50000 sq. m, whether naturally formed or human-made, serve as vital reservoirs for irrigation water on a global scale (Ce´re´ghino, et al., 2008). The construction of earthen ponds for irrigation has proven effective, with a single pond capable of supplying water to a command area spanning 1.5 to 50 hectares. These ponds harness monsoonal water, providing a crucial source of water during the dry season (Gunnell & Krishnamurthy, 2003). Beyond their roles in agriculture and domestic usage, earthen ponds play a pivotal role in groundwater recharge and mitigating excessive groundwater extraction. An on-site study in Albuquerque, New Mexico demonstrated that about 30% to 50% of on-site precipitation is recharged into groundwater by capturing it within recharge ponds (Miller, 2006). These water ponds offer an array of ecosystem services, encompassing contributions to biodiversity, water supply and storage, enhancement of watershed water quantity, flood control, and the regulation of greenhouse gas emissions (López-Felices, et al., 2020).

3.5 Possible Implication of LULC Change

Upon scrutinizing the LULC attribute map of Panchkhal Municipality over the period from 2000 to 2019 A.D., several significant alterations in the land-use pattern have come to light. Notably, the most pronounced change is the expansion of the built-up area, an observation shared by more than 60% of the respondents. The key LULC changes encompass a surge in built-up area (1662.50%), an upswing in forest cover (43.02%), a decline in cropland (23.49%), and a reduction in grassland (40.64%). Additionally, a prominent transformation highlighted by the respondents is the decrease in water bodies, as indicated by 51.25% of them. This decline in water bodies might be a contributing factor to the reduction in cropland. In the past, kuwa stood as a significant water source, but in the current context, its prominence has waned due to increased urbanization and forest expansion. This decline could potentially stem from *kuwa* being repurposed for construction activities. Despite the observed 43.02% rise in forest cover, respondents' experiences reveal a decrease in water availability in both kuwa and river, underscoring that elevated forest cover does not necessarily equate to heightened water availability in the watershed.

LULC changes have notably impacted Traditional Water Ponds, with 36% of ponds having desiccated, 33.75% being repurposed for construction, and 12.75% being engulfed by grass. These changes, such as increased built-up areas and expanded forest cover, exhibit a discernible link with the decline in the number of ponds. In conjunction with the LULC map attributes, 79.75% of respondents have noted a decrease in cropland. In contrast, the total number of households has risen to 9321 in 2018 (PMun, 2018) compared to 7457 households in 2011 A.D. (CBS, 2011). This dynamic could potentially bear adverse implications for water-dependent livelihoods and agricultural productivity, considering that agriculture constitutes a primary occupation in Panchkhal Municipality. LULC changes exert substantial influence on water resources, as well as other vital natural assets like forest cover, grasslands, wetlands, agriculture, and surface drainage. Alterations in land usage, including both tillage and deforestation, impact infiltration rates, runoff characteristics, ground recharge, water yield, and evapotranspiration (AGI, 2022). A pertinent study conducted in the Mula and Mutha Rivers Basin in Pune, India showcased the ramifications of LULC changes on agricultural patterns. The research revealed that the conversion of grasslands and croplands into urban areas led to diminished groundwater availability, compelling farmers to shift from water-intensive crops like rice and sugarcane to less water-demanding alternatives such as maize and cotton (Wagner, et al., 2013). Further evidence emerges from the Upper Basin of Bhima River in India, where urbanization has wrought notable changes in surface runoff dynamics. Specifically, the region has experienced an augmentation in water yield within the river system during the monsoon season (Samal & Gedam, 2021). This highlights how the shifting LULC patterns can profoundly alter hydrological behaviors and water availability in a given area.

4. Conclusion

The comprehensive analysis conducted on three distinct parameters LULC changes, the status of Traditional Water Ponds, and people's perceptions of water utilization and availability—yields several significant conclusions. Firstly, the disappearance of Traditional Water Ponds in Panchkhal Municipality is striking, with a considerable 73% of these ponds either lost entirely or repurposed for construction purposes. Secondly, the LULC dynamics within the municipality present a compelling narrative of rapid urbanization, as evidenced by the exponential growth of the built-up area from a mere 0.08 square kilometer in 2000 to a substantial 1.14 square kilometer in 2019, reflecting an astounding 1662.5% rate of change.

Furthermore, the shifting water availability perceptions among the local population are noteworthy. The shift from abundant to scarce water availability in primary sources like *kuwa*, traditional water ponds, and rivers underscores the evolving water landscape. Encouragingly, tap water availability has improved, serving as a means to counter water deficits essential for water-dependent livelihoods. Consequently, respondents have adapted their water utilization strategies to match the changing scenario. The transition towards more intricate and financially demanding water harvesting techniques, such as well construction and pump utilization, highlights the community's resilience in securing water resources amidst evolving conditions. This multi-dimensional analysis reveals the intricate interplay between land use, water availability, and the actions taken by local residents to navigate these shifting dynamics.

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