Spring Water Sources Assessment and Forest Area Dynamics in Roshi and Melamchi Watersheds

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ABSTRACT

Spring-water sources mapping was carried out in eight wards of Dhulikhel and four wards of Melamchi Municipality and forest area dynamics in Roshi and Melamchi Watersheds. Ward number 9 and 10 of Dhulikhel Municipality were rich in water sources. Whereas ward number 6 of Melamchi Municipality has a good amount of water sources compared to other wards. The major spring types were depression, fractured, and contact in both the Municipalities.The percentage of forest areas in the Roshi and Melamchi watersheds seems to be fluctuating with the data compared in 2010 and 2020. There is an increase in forest areas in both municipalities in 2020. Also, the perennial spring sourceswith good discharge are prominent in having a good forest area and large watershed recharge area.

Keywords: Watersheds, Springs, Geographic Information Systems (GIS), Discharge, Forest Dynamics

1. INTRODUCTION

Springs generally form in impermeable and sloping ground intersecting with the groundwater table and yield water during rainy and non-rainy seasons, which is affected by rainfall and the recharge area characteristics (Negi & Joshi 2004). The demand for freshwater increases due to urbanization and the increased population (FAO 2011). Villagers have been using these groundwater springs since time immemorial to meet their basic domestic needs, irrigation, and for livestock (Ghimire *et al.* 2019). Due to widespread depletion of groundwater, surface water pollution, and climate change, freshwater sustainability has a question mark (Gleeson *et al.* 2012). Most people depend on the spring water in the hilly region for daily household purposes. Springs are the main source of domestic water supply for rural communities (Poudel & Duex 2017; Vashisht & Sharma 2007).

Moreover, in the context of the springs in Nepal Himalaya, they also depend upon the monsoon rainfall (Sharma *et al.* 2016) and seem to be vulnerable (Gurung *et al.* 2019).Water is a critical natural resource upon which all social and economic activities and ecosystem functions depend (World Water Assessment Programme 2012). Global water demand is largely influenced by population growth, urbanization, food, and energy security policies (Nations 2016). The land use and land cover on the earth's surface is subjected to dynamic changes (Bose *et al.* 2010). Aerial and Landsat satellite images are frequently used to evaluate the land cover distribution and update existing geospatial features (Rwanga & Ndambuki 2017). Land use change also plays an important role in groundwater recharge (Adhikari *et al.* 2021). The density of forest cover upstream of the spring plays a vital role in the spring's discharge. Therefore, studying forest coverage in the watershed is important to restrict its depletion to make the springs sustainable in the future. Water sources and Forest dynamics were studied in wards of Dhulikhel and Melamchi Municipalities which lie in the Melamchi and Roshi watersheds.

2. MATERIALS AND METHODS

The Global Positioning System (GPS) was used to collect the data on existing springs. With the help of the local government and the local people, the coordinates of the different springs were collected. The discharge of the corresponding spring was taken. Spring type classification was done on the site. The rocks around the springs and watershed were studied too. Finally, the database of different springs in the Roshi and Melamchi watershedswas prepared. The coordinates of collected springs were plotted in GIS, and the forest cover was determined using Satellite data. The GIS platform was used to analyze the forest area dynamics. The spring recharge area was delineated based on topography, geological unit boundaries, and Landscape mapping on Google Earth.

3. GROUND WATER SOURCES DATABASE

3.1 Dhulikhel Municipality

The different location of groundwater sources was collected and made a database that could be beneficial to the local government for yearly planning to preserve these sources and utilize them for local communities. These water sources data were plotted in GIS as shown in Fig. 1.

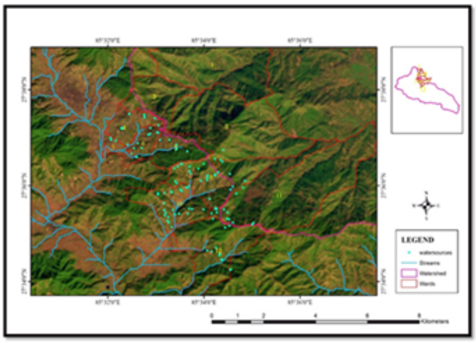


Fig. 1. Water sources of dhulikhel (ward number 4, 5, 6, 7, 9, 10, 11 & 12)

Wards 4, 5, 6, 7, 9, 10, 11, and 12 in the Dhulikhel Municipality have 55 spring boxes and 21 wells. The wards rich in groundwater sources are 9 and 10. Ward number 9 has 22 spring boxes and fourwells. Similarly, Ward number 10 has 15 spring boxes and tenwells as shown in Fig. 2.

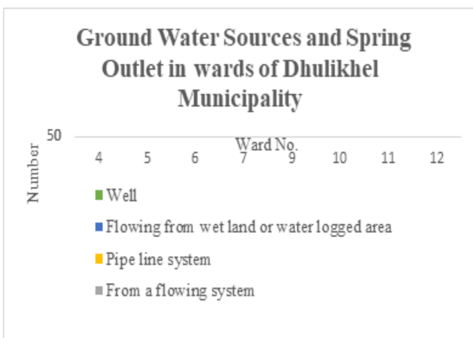


Fig. 2. Ground water sources and spring outlet in wards of Dhulikhel Municipality

3.2 Soil & Rock types and springs of Dhulikhel Municipality

The area is entirely covered with residual, colluvial soils and mostly weathered to fresh Lesser Himalayan rocks. The geological features and conditions within the project area are reflected in the geomorphological characteristics. Geological structures and lithology control the main geomorphic features of the area. Steep slopes are observed along the phyllite and meta-sandstone cliffs and the cut bank of the gullies, whereas gentle slopes with smooth ridges are seen on the residual soil deposits area. The major geomorphic features of the area include active gullies, small soil slides, residual soils, and colluviums. There are no major rivers; however, the dendrite drainage pattern is the most common in the area. The existing springs are on the 69% residual, 19% colluvium, 8% rocky, and little alluvium deposits. In most cases, the depth of the deposit is 1-3m. Residual soil made by in-situ weathering is the major group of a deposit followed by colluvial soil with depths of 0-5 m. Generally, steep slopes (>35^{o}) have only 0.3 - 0.75 m thickness of soil, whereas, on a gentle slope, the thickness is up to 3m. In addition, the lower hill slope generally consists of a thick colluvial deposit compared to the upper hill slope. Based on theUnified Soil Classification System (USCS), the soil can be classified as Organic Clayey Silt to Organic Clay (OL-OH). The materials are generally compacted and dry on the southern slope whereas moist on the Northern and Eastern.

Springs are located on most slopes with residual and colluvial soil. The gullies and stream valleys are the major locations for the spring sources. It includes the location of various water sources like springs and streams and geological formations. The major saturated zones depend upon the fractures present in rocks. Therefore, the intensity of fractures in calcareous metamorphic rocks governs the presence of groundwater in the rock. The area is composed of fractured metamorphic rock and overburdens residual and colluvial soils act as aquifers with three types of springs

3.2.1 Depression Springs

This type of spring occupied 51%, and it is situated almost parallel to landform/surface (Topography) on residual and colluvial soils. The water level and discharge vary on a seasonal basis concerning the amount of precipitation. This spring-type generally appears along with the water table because of a slope. The overburdened soil is overlain on the impermeable layer or less permeable layer. The level fluctuates as per the quantity of the recharge water. The study area is the most prominent shallow water source as a form of well. Ward no 4, 5, 7, 10, and 12 are the most dependent on these types of springs.

3.2.2 Fracture Springs

This type of spring occupied 22%, and it is generally developed by permeability along the discontinuities of the rocks or water movement through joints/bedding contact fractures. The discharge appears through the opening of the rocks in a suitable landform where the slope cut the water-bearing fracture rock. It also depends on the precipitation indirectly. However, the level fluctuation does not exist in most cases. In the study area, a water source is a spring tap (Dhara). Ward no 11 is mostly dependent on this type of spring.

3.2.3 Contact Springs

This type of spring occupied 19%, and it is generally developed on a boundary between two different permeability: especially lower layer underlies, i.e., contact between soil/deposit/debris with rock. It is also a major abundant type in the study area. It is situated almost parallel to landform/surface (Topography) on residual and colluvial soils. The water level and discharge vary on a seasonal basis relevant to the precipitation. The level fluctuates as per the quantity of the recharge water. The study area is the most prominent shallow water source as a form of well and Kuwa. Ward no 6, 7, and 10 are mostly dependent on this type of springs. The different types of springs, soil, and rocks of ward number 4, 5, 6, 7, 9, 10, 11, and 12 of Dhulikhel Municipality are shown in Fig. 3-5.

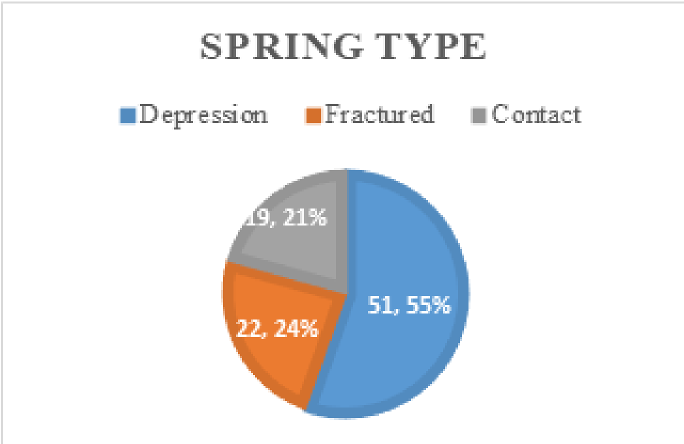


Fig. 3. Spring type of Dhulikhel Municipality

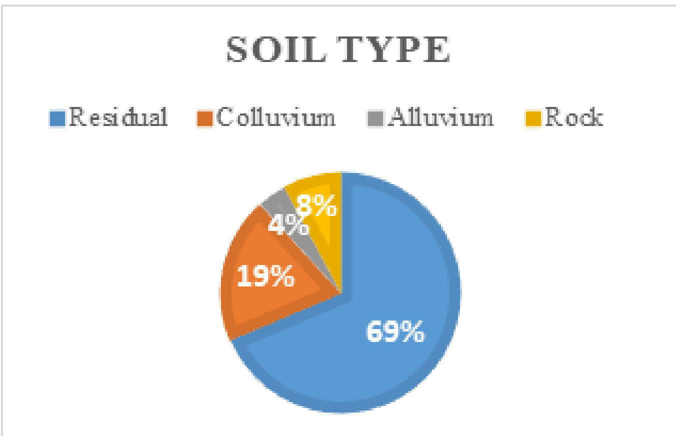


Fig. 4. Soil type of Dhulikhel Municipality

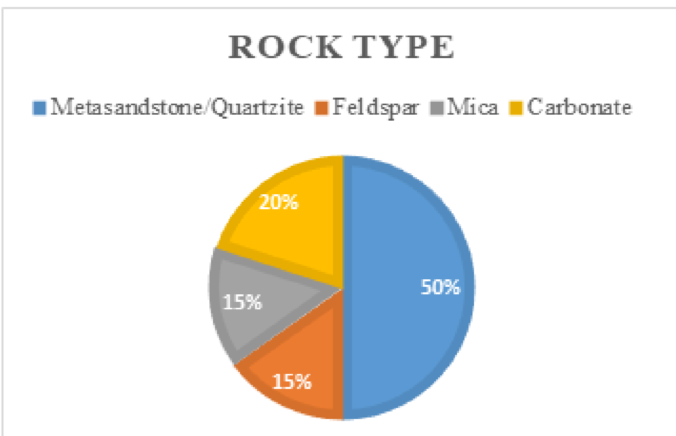


Fig. 5. Rock-type of Dhulikhel Municipality

3.3 Melamchi Municipality

Similarly, different locations of ground-water sources were collected, and these water sources data were plotted in GIS as shown in the Fig. 6.

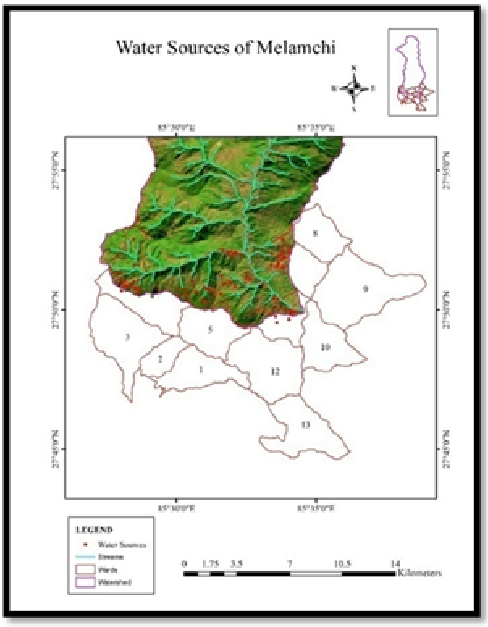


Fig. 6. Water sources of Melamchi Municipality (ward number 4, 6, 7 & 11)

In the Melamchi watershed, wards 4, 6, 7, and 11 have 26 spring boxes. The wards rich in ground-water sources are 4 and 6 (Fig. 7.).

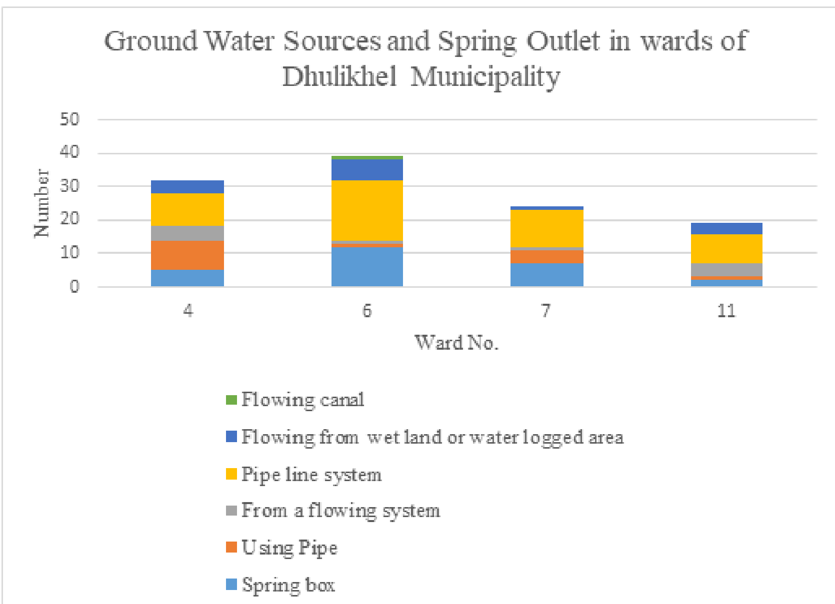


Fig. 7. Ground water sources and dpring outlets in wards of Melamchi Municipality

3.4 Soil, Rock Types and Springs of Melamchi Municipality

Geologically the project area lies in the Higher Himalayan Zone, the upper part of the Main Central Thrust (MCT) that passes through the southern part of the study area along with the Northwestern to Southeastern direction. The regional geology indicates that both sites belong to crystalline rocks with higher schists in the Southern section and gneiss. There are rock exposures in and around the study area, and most of the rock exposures are noticed along the Indrawati and Melamchi rivers and other tributaries and gullies of Southern and Northern facing slopes. The rocks around the project are weathered to fresh metamorphic with three major sets of discontinuities. The soil in the project site comprises residual and colluvium. The soil thickness around the area is about 1-4 m, followed by the weathered rock after the regolith.

Steep slopes are observed along the river and streams. The gentle slopes with smooth ridges are seen in the thick colluvial debris deposits and residual soil deposits. The major geomorphic features of the area include residual soils, talus deposits, active gullies, and colluviums. The Indrawati & Melamchi rivers and their tributaries are the major drainages of the area, and the dendritic drainage pattern is the most common in the area.

Springs water is the main source of drinking water in the study area. These are located on most slopes with colluvial soil, residual soil, and fractured rock. The gullies and stream valleys are the major locations for the spring sources. It includes the location of various water sources like spring sand streams and geological formations. The major saturated zones depend upon the fractures present in rocks. Therefore, the intensity of fractures in metamorphic rocks governs the presence of groundwater in the rock. The area is composed of fractured metamorphic rock and overburdens residual and colluvial soils act as aquifers with three types of springs.

3.4.1 Contact Springs

This type of spring occupied 28%, and it is generally developed on a boundary between two different permeability: especially lower one underlies, i.e., contact between soil/deposit/ debris with rock. It is the most abundant type in the study area. It is situated almost parallel to landform/surface (Topography) on colluvial and residual soils. The water level and discharge vary on a seasonal basis relevant to the precipitation. The level fluctuates as per the quantity of the recharge water. The study area is the most prominent shallow water source as a form of well Dhara and Kuwa. Ward no 4 and 6 are mostly dependent on these types of spring.

3.4.2 Fracture Springs

This type of spring occupied 22%, and it is generally developed by permeability along the discontinuities of the rocks or water movement through joints/bedding contact, fractures. The discharge appears through the opening of the rocks in a suitable landform where the slope cut the water-bearing fracture rock. It also depends on the precipitation indirectly; however, the level fluctuation does not exist in most cases. In the study area, a water source is a spring tap (Dhara). Ward no 11, 7, and 4 mostly depend on this spring type.

3.4.3 Depression Springs

This type of spring occupied 14%, and it is situated almost parallel to landform/surface (Topography) on residual and colluvial soils. The water level and discharge vary ona seasonal basis relevant to the precipitation. This spring-type generally appears along with the water table because of a slope. The overburdened soil is overlain on the impermeable layer or less permeable layer. The level fluctuates as per the quantity of the recharge water. The study area is the most prominent shallow water source as a form of well and Kuwa. Ward no 7, 6, and 11 are the most dependent types of spring. The different types of springs, soil, and rocks of wards number 4, 6, 7, and 11 of Melamchi Municipality are shown in Fig. 8-10.

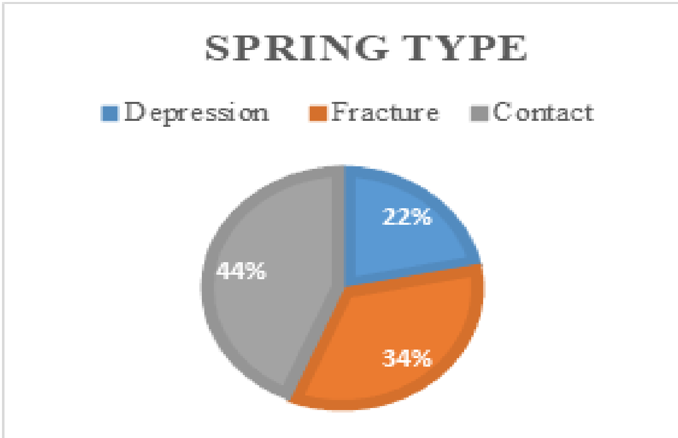


Fig. 8. Spring type of Melamchi Municipality

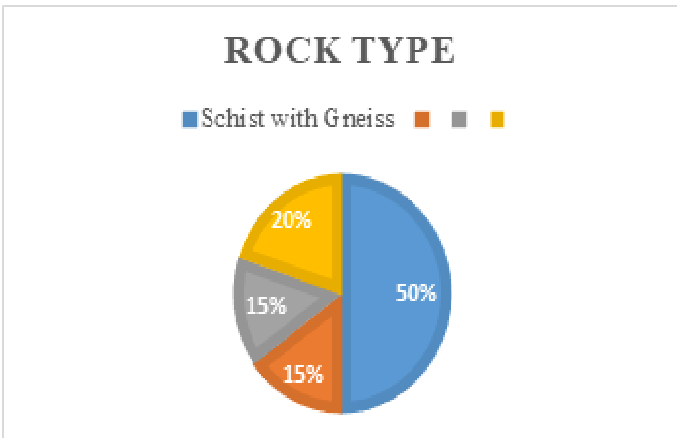


Fig. 9. Rock-type of Melamchi Municipality

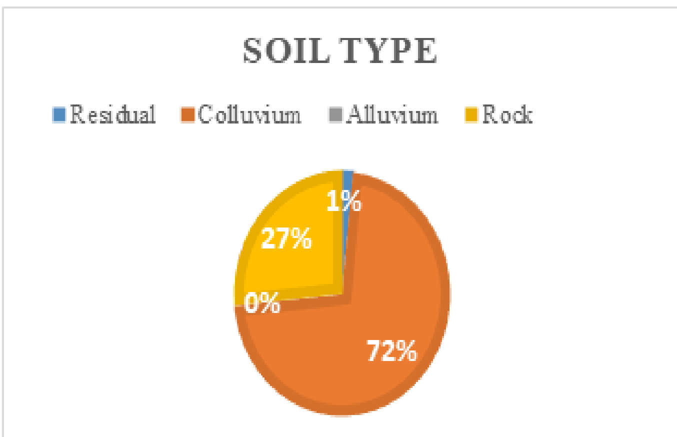


Fig. 10. Soil type of Melamchi Municipality

4. RESULTS AND DISCUSSION

4.1 Forest Dynamics

In the preliminary study, Roshi and Melamchi watersheds were studied from Google Earth. Data such as Topographic sheets 278503 C and 278507 C were collected and studied. The digital elevation model of the project site was acquired from the USGS site. The two DEMs were joined to form a mosaic using tools in GIS. The watershed was delineated using the GIS software separately for Roshi and Melamchi watersheds.

ICIMOD has prepared Nepal's first and most complete national land cover database using public domain Landsat TM data of 2010 and replicable methodology (Bajracharya & Uddin 2013). Similarly, Esri released the first-ever high-resolution (10 m) 2020 global land cover map. The map was built using European Space Agency (EAS) Sentinel – 2 satellite imagery and developed using a new machine learning workflow. These two data sets were clipped with the delineated area used to analyze forest cover in Roshi and Melamchi Watersheds, and the analysis of forest cover was done. The forest land has occupied 45% in Melamchi and 50% in the Roshi watershed (Chaudhary *et al.* 2019). The LULC maps of the Roshi and Melamchi watershed in different time frames are shown in Fig.11-18.

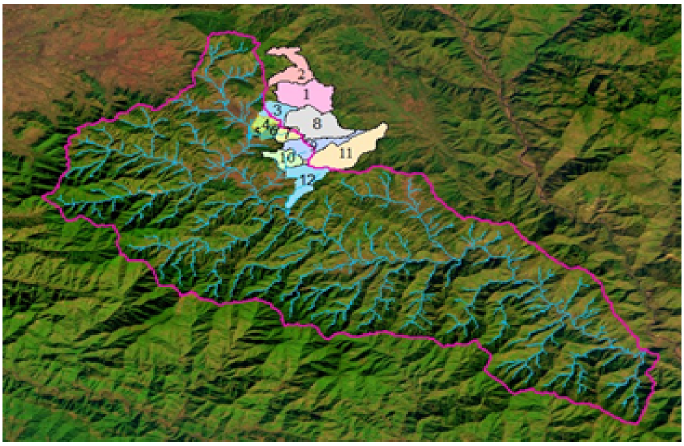


Fig. 11. Roshi watershed (Google earth image)

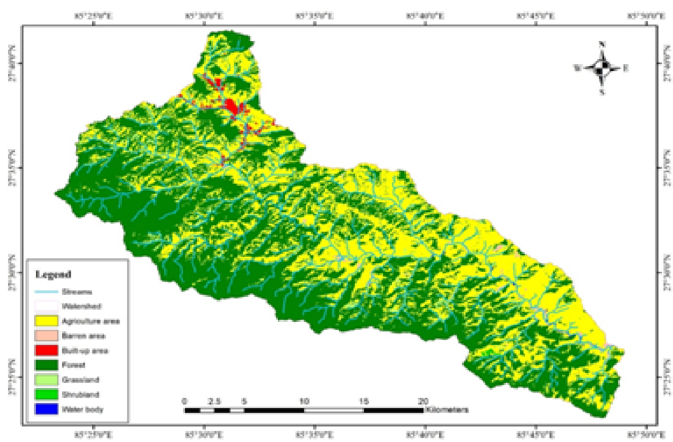


Fig. 12. LULC map of Roshi watershed (ICIMOD 2010)

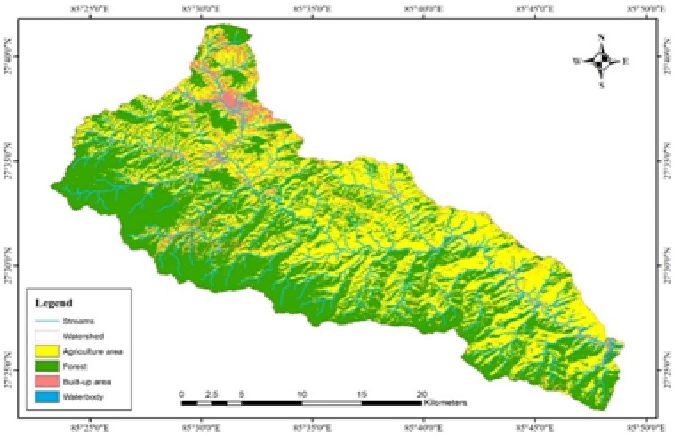


Fig. 13. LULC map of Roshi watershed (Chaudhary *et al.* 2019)

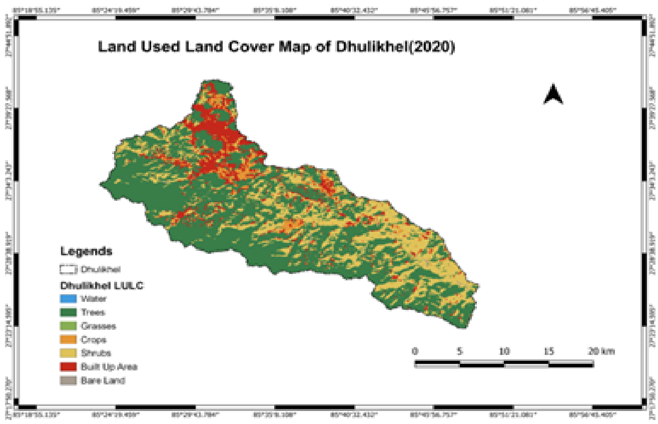


Fig. 14. LULC map of Roshi watershed (2020)

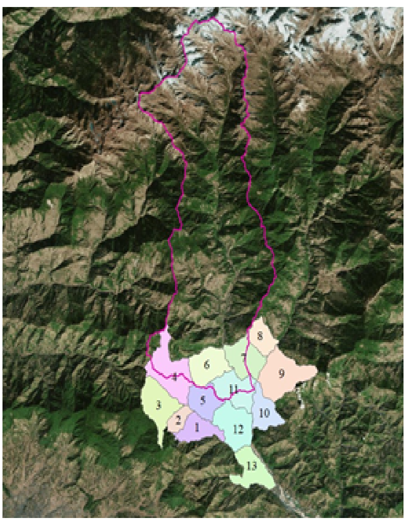


Fig. 15. Melamchi watershed (Google earth image)

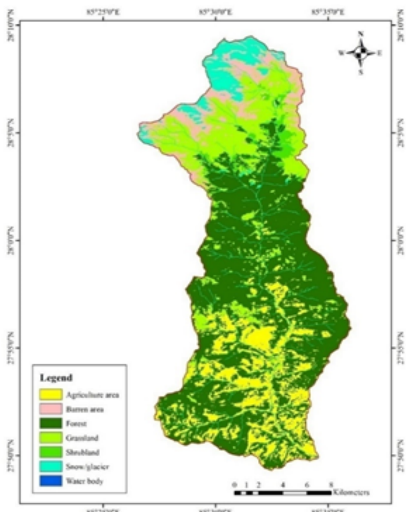


Fig. 16. LULC map of Melamchi watershed (ICIMOD 2010)

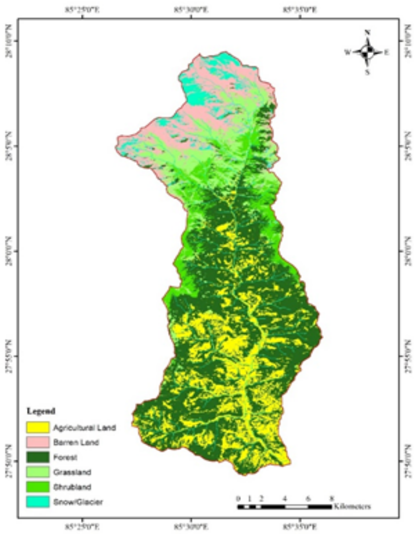


Fig. 17. LULC map of Melamchi watershed (Chaudhary *et al.* 2019)

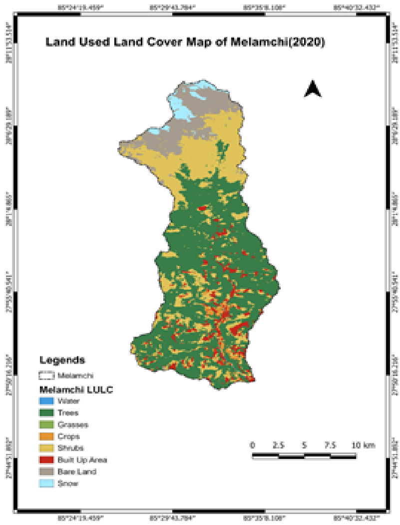


Fig. 18. LULC map of Melamchi watershed (2020)

Forest constitutes the major portion of the Melamchi and Roshi watersheds. The percentage of forest in Roshi and Melamchi watersheds is shown in Fig. 19 in the years 2010 and 2020.

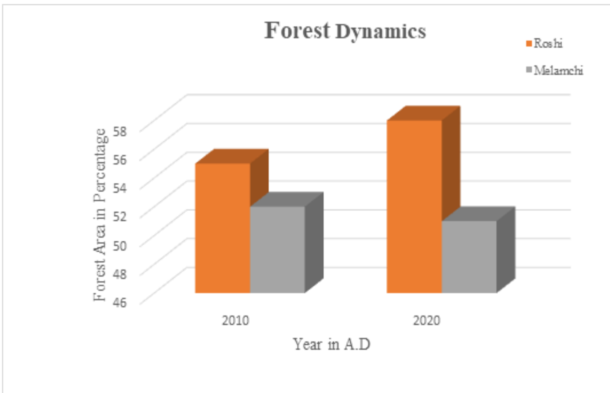
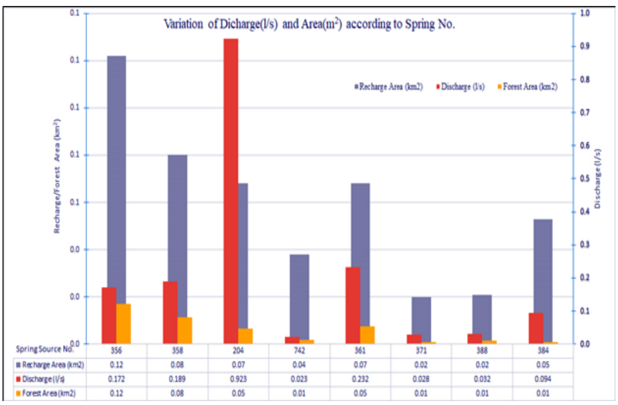


Fig. 19. Forest area in the different time frame

Recharge area (km^2), Forest Area (km^2), and Discharge of groundwater sources (l/s) were analyzed and found that the places having good forest cover had good discharge in spring sources (Fig. 20-21).



Spring Source No.	356	358	204	742	361	371	388	384
Recharge Area (km2)	0.12	0.08	0.07	0.04	0.07	0.02	0.02	0.05
Discharge (l/s)	0.172	0.189	0.923	0.023	0.232	0.028	0.032	0.094
Forest Area (km2)	0.12	0.08	0.05	0.01	0.05	0.01	0.01	0.01

Fig. 20. Discharge according to forest and recharge area in Dhulikhel Municipality

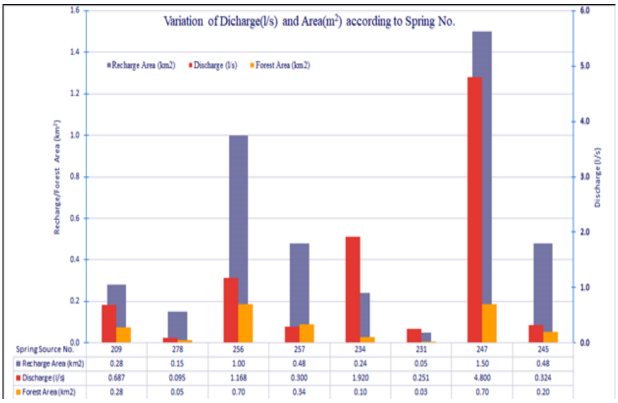


Fig. 21. Discharge according to forest and recharge area in Melamchi Municipality

4.2 Water Sources

4.2.1 Water Sources in Dhulikhel and Melamchi Municipalities

It was found that most of the water sources were located in Ward No. 9 and 10 of Dhulikhel Municipality and Ward Number 6 of Melamchi Municipality. The spring types are depression, fractured, and contact and occupied by 55%, 24%, and 21%, respectively, with variation in the area of recharge watersheds in Dhulikhel Municipality. Similarly, the spring types are depression, fractured, and contact and occupied by 22%, 34%, and 44%, respectively, with variation in the area of recharge watersheds in Melamchi Municipality.

5. CONCLUSION

Most water sources are located in Ward No. 9 and 10 of Dhulikhel Municipality and Ward No. 6 of Melamchi Municipality. The majority of spring types are depression and fractured in both watersheds. Moreover, the land cover in the study areas has been continuously changing due to natural and anthropogenic activities. From the analysis of recharge area, forest area, and discharge of respective spring sources, it is found that the spring sources having good forest and recharge have a good amount of discharge, and it is independent of types of springs. The groundwater resources can be preserved by studying spring water sources and forest mapping. Preparing its database will be helpful for the sustainable management of the spring recharge watershed and for efficient use of this spring water in the local community.

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