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Spatial Distribution of Spring Water Resources: A Study of Waling Municipality, Nepal

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Abstract

Spring water resource is a natural source of freshwater that emerges to the land from the underground of the Earth has been a source of drinking water in the hilly region of Nepal. The Waling Municipality covers 128.4 square kilometers and comprises 14 wards located in the Syangja district, Nepal. The study applied a mixed method comprising quantitative and qualitative approaches, where the information was gathered through field observation and key informant interview with 14 individuals of respective wards having knowledge about water sources. The study provides the spatial distribution of the spring water resources using remote sensing and GIS tools. 73 permanent (perpetual for round the year) spring water resources have been identified in the Waling Municipality. The elevation range of 800–1100 meters exhibits the highest availability of spring water resources, containing 35 springs.

Keywords: *Spring water, Spatial distribution, Waling Municipality, Remote Sensing, GIS*

Introduction

A spring is the natural flow of groundwater to the surface of the earth. People believe that water is the most important and valuable natural resource that all life on Earth depends on. Water is essential for the growth of many parts of the economy, such as agriculture, raising cattle, forestry, generating electricity for industry, fishing, and other new activities (Soraya et al., 2017). Spring water comes from a known and accepted underground source, just like natural mineral water. It has to come straight from the source, without any chemicals or disinfection, and it has to be safe and healthy to drink. Spring water is originated below the ground. Basically, spring water sources are found in the hilly region. Spring water is one of the main sources of drinking water in the remote area of mountain. Springs are distinct and diverse because they are formed by a natural process involving the complex interaction of ground and surface water (Gornakov et al., 2002).

The Nepal Himalayas are famous for their stunning scenery, water towers, and rich culture. Nepal is one of the least developed countries in the world, even though there is enough fresh water over the Himalayas. There isn't much fresh water available for each person. The Himalayas are the highest mountain range in the world. They are also a natural wonder and a major source of water that keeps people alive. Nepal has many different sources of water, but the Himalayan springs stand out because they collect rain, snow, and ice. Their huge peaks and glaciers make them a natural reservoir. Snow falling down the mountains and filling underground aquifers makes the cleanest spring water (Century-Foods, 2023). Most rural villages get their water from boreholes, community standpipes, rivers, and springs because they don't have access to piped-in drinking water in their homes (Sharma et al., 2016). Springs are very important in rural areas because almost 80% of the 13 million people who live in hills and mountains rely on them for their main water needs (NSO, 2012).

Rising atmospheric temperatures and unpredictable precipitation patterns are unmistakable indications of climate change, particularly affecting the foothills of the Nepal Himalayas (Khatri et al., 2025). It can be stated that climate change and human activity make Himalayan springs vulnerable since such phenomena as temperature change, precipitation, and snowmelt might seriously influence the volume and quality of water from springs. Permanent water level in the central Himalaya region (Koshi river basin and Kumaon) declined in three springs yearly and increased in one spring yearly during the period outside the monsoon season. The high concentration of nitrates, chloride, sulfate, and coliform bacteria found in the spring water indicates a serious vulnerability of shallow aquifers to non-point source contamination (Panwar, 2020). Climate change is causing disappearance and vulnerability of the springs of the Mid-hills of Nepal, as the water-dependent community has witnessed different patterns of weather changes in their environment, consistent with the historical vulnerability of climate in terms of rainfall and temperature with vulnerability index ranging between 0.10 and 0.67 (Chettri et al., 2020).

Eight wards in Dhulikhel and four wards in Melamchi Municipality were assessed for spring water sources and forest areas where ward numbers 9 and 10 of Dhulikhel and ward number 6 of Melamchi Municipality were found abundant with water resources. The coordinate data of springs collected using GPS technology were mapped in GIS while changes in the forest areas were analyzed using satellite data obtained from remote sensing technologies. Forest areas have been increased in both the municipalities in 2020. More specifically, it is evident that there is an increase in the discharge rate of perennial spring sources, and they are known to have significant forest cover and large recharge areas (Chaudhary et al., 2021).

Although many studies have assessed the quality of spring water and origin of spring water resources in the mid- hills of central Nepal (Gurung et. al., 2019). Many studies have been made on analyzing physicochemical features and quality of water for human consumption in different regions of Nepal (Thapa et al., 2020), limited attention has been given towards the identification of spring water resources in Waling Municipality. So this study is focused on identification and distribution of spring water resources in Waling Municipality.

Method and Materials

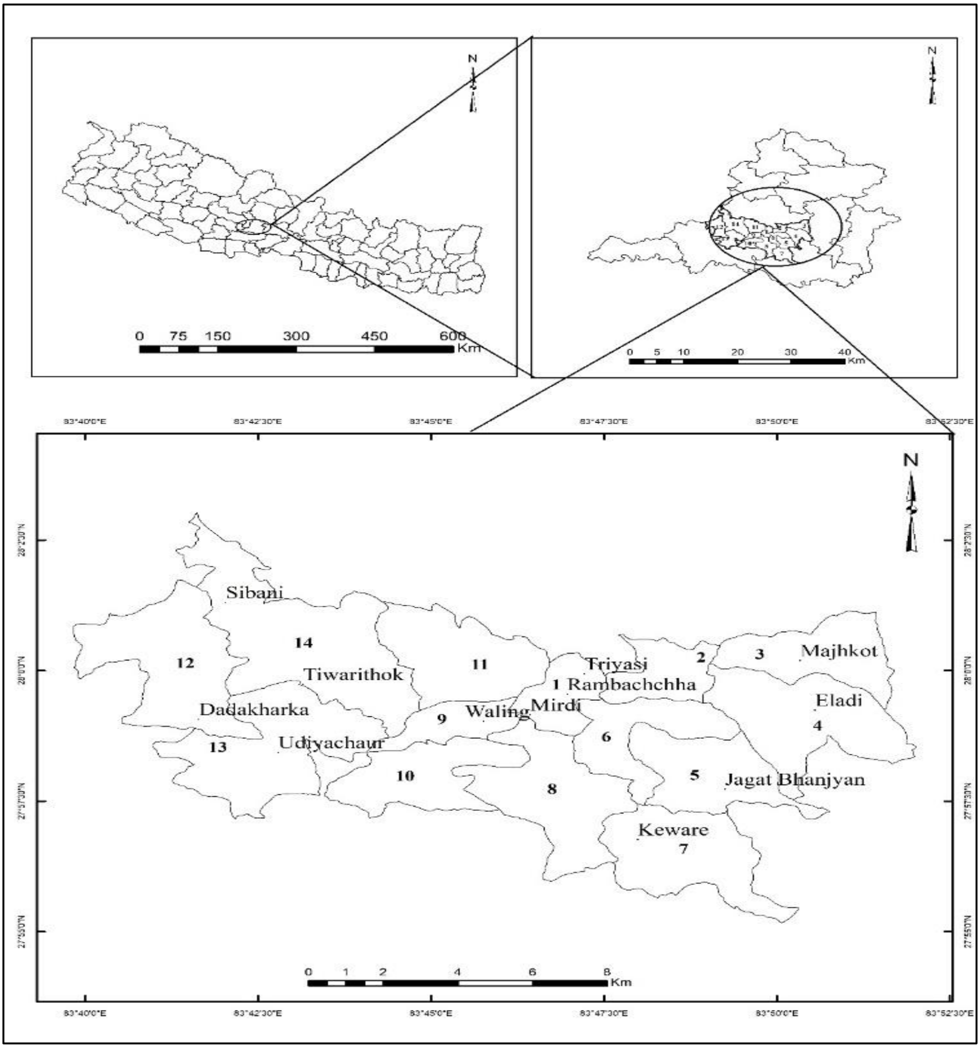
The Study Area

The study was conducted in Waling Municipality, Syangja district of Gandaki province. Waling Municipality was announced on 2053/10/11 BS by the Government of Nepal by joining the areas of Village Development Committees Dhanubans, Pekhu Baghkhor, and Waling. In 2015, the Federal Government System's administrative reform, the municipal boundaries were expanded to integrate multiple previously distinct administrative units, including Waling Municipality and various VDCs (Figure 1).

As the result of this restructuring, which modified the existing 14 wards, total land area increased by approximately 128.4 km². The incorporated VDCs comprised Majhkot Shiwalaya, Yeladi, Jagat Bhanjyang, Keware Bhanjyang, Sirsekot, Thumpokhara, Chhangchhangdi (Ward Nos. 1, 4–6), Malyangkot (Ward No. 4), Tindobate (Ward Nos. 2–5), Kalikakot (Ward Nos. 1, 2, 9), Pelakot (Ward Nos. 5–6), and Sworek (Ward Nos. 2, 4–8).

Figure 1

The study area.



The municipality is located along the Sidhartha Highway with geographical locations from 27°55’02” to 28°03’11” N latitude and 83°40’04” to 83°52’07” E longitude ranging from 731m to 1596 meter above the mean sea level. According to the census 2021, total population of the municipality is 50,488 (46.7% Male and 53.5% Female) with the population density of 393 having sex ratio of 86.95 male per 100 females.

Methods

The primary data collection comprises of field observation, KII and Photograph along with GPS to identify the spatial location of spring water resources. The field survey was carried out by thoroughly visiting each ward office of Waling Municipality for KII and with guidance of key respondents, the inventory for springs water was accounted for using knowledge of local people along fields observation and Topographical map 1998 (sheet no.2783 03D, 2783 04A, 2883 15D and 2883 16C).

The secondary data consists of various sources, the base map, digital boundary and toposheet of Waling Municipality were taken from Survey Department of Nepal. To generate the topographical parameters (Elevation and Slope) was taken from ASTER Digital Elevation Model 2014 with 30m spatial resolution.

Spring distribution was investigated by overlaying spring locations on elevation and slope maps generated from DEM in GIS. Springs were classified based on elevation and slope, and their frequency distribution was investigated to uncover advantageous zones and spatial patterns. The spatial pattern was analyzed with average nearest neighbor in ArcGIS 10.4 which is a statistical tool for showing the pattern of distribution of spring water sources, whether the pattern is random, cluster or dispersed through the equation created by Clark and Evans (1954). Average Nearest Neighbor is as follows:

$$ANN = \frac{\bar{D}_0}{\bar{D}_E} \qquad \textit{(equation i)}$$

Where $\bar{D}_0$ shows the average distance of each feature with its nearest neighbor.

$$\bar{D}_0 = \frac{\sum_{i=1}^{n} \mathrm{d}i}{n}$$

and $\bar{D}_E$ depicts the expected average distance for the feature, which is in a random pattern.

$$\bar{D}_E = \frac{0.5}{\sqrt{n / A}}$$

On the above equation, di represent the distance between feature i and its nearest neighbor, where n is the sum of feature count, and A is minimum area of surrounding rectangle.

And, the calculation for average nearest neighbor z-score for the statistic is:

$z = \frac{\bar{D}_0 - \bar{D}_E}{SE}$ *(equation ii)*

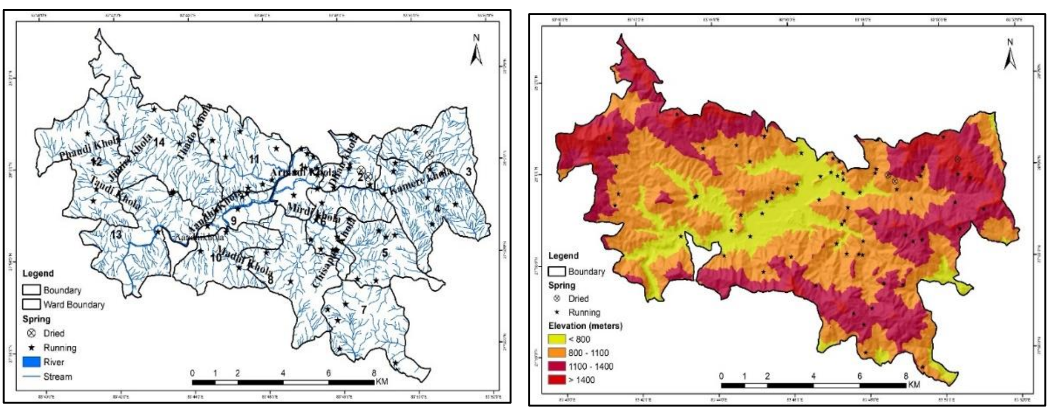
Given that, $SE = \frac{0.26136}{\sqrt{n^2/A}}$

Result and Discussion

All the spring water resources available in Waling Municipality have been developed through the natural process. According to the experiences of the locals, the establishment of the reservoir tank around the locality has made the spring water resources available until today. In the study area, there are 73 spring water resources. Figure 2 illustrates how water sources are distributed geographically in terms of active and inactive springs within the study area. Water sources are highly unequally distributed, implying large variation in the accessibility of groundwater geographically. The springs that running are mostly found in the middle and northern parts of the study region. Such locations may be characterized by hydrogeological advantages such as high rates of infiltration, sufficient zones for recharge, and minimal anthropogenic interference. The existence of extensive stream networks in such sections is indicative of continuous groundwater recharge.

Figure 2

Spatial distribution of existing spring water resources of Waling Municipality, 2024



(a) (b)

Source: Spring point distribution (a) Drainage network from the Department of Survey, Nepal, and (b) Elevation from ASTER DEM satellite image.

The presence of spring water depends upon the altitude, the higher the altitude, the fewer are the springs of water found. The topography of Waling consists of rugged areas that help form spring water.

As shown in Table 1, the accessibility of spring water resources depends on the altitudes because there are more springs (35) within the altitudes of 800 meters to 1100 meters even though one spring has dried out. The next higher altitudes, from 1100 meters to 1400 meters, have 18 springs while above 1400 meters have less springs (5). Only three springs have dried out so far among 73 springs. Nevertheless, the dried-out springs appear to be within the altitudes of 800 meters to 1100 meters and above 1400 meters. As shown in Figure 2, the abundance of spring water resources is found within the altitude of 800 meters. Thus, in high altitudes, spring water resources are not abundant; therefore, spring water resources are found mostly in low altitudes.

Table 1

Distribution of spring water resources on the basis of altitude

Elevation (meter)	No. of spring	No. of dried
< 800	15	0
800 – 1100	35	1
1100 – 1400	18	1
> 1400	5	1
Total	73	3

Source: Field survey, 2024

For steep slopes, its ability to retain water resources is relatively low depending on how much influence the anthropogenic factor had on it. Slope degree ranging from 15^o to 30^o had a total of 36 spring water resources, slope degree from 30^o to 45^o had 19 springs while the slope degree of greater than 45^o had just two springs. In addition, the slope degree of less than five also had minimal number of springs present. Human interference has greatly affected the water resources due to the ongoing developments. From Figure 3, dried springs are mostly found on the slope degrees from 30^o to 45^o, thus confirming that steep slopes do not suit spring water.

Figure 3

Distribution of spring water resources based on slope

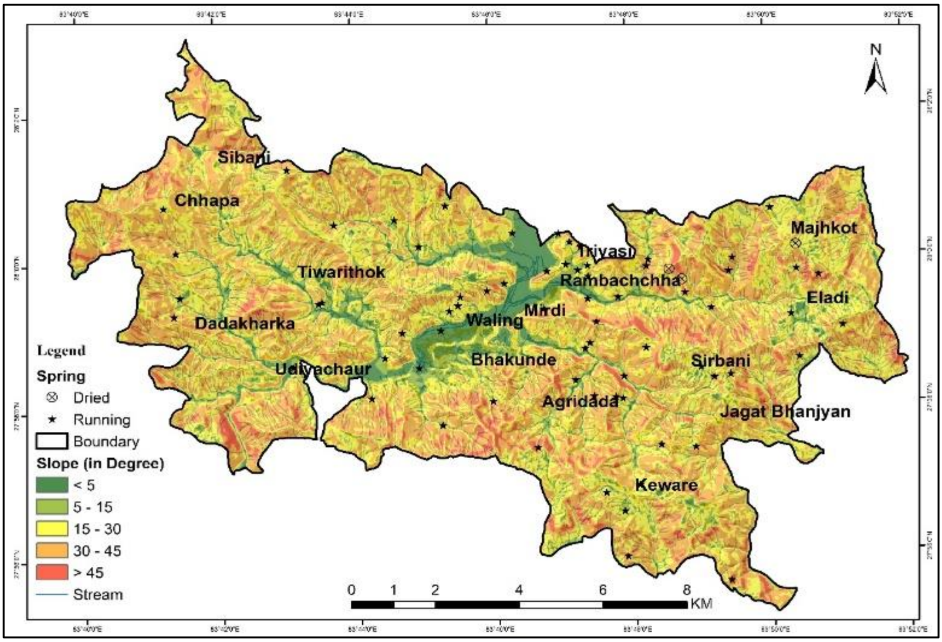


Table 2

Distribution of spring water resources based on slope

Slope (degree)	No. of spring	No. of dried
< 5	3	0
5 – 15	13	0
15 – 30	36	2
30 - 45	19	1
> 45	2	0
Total	73	3

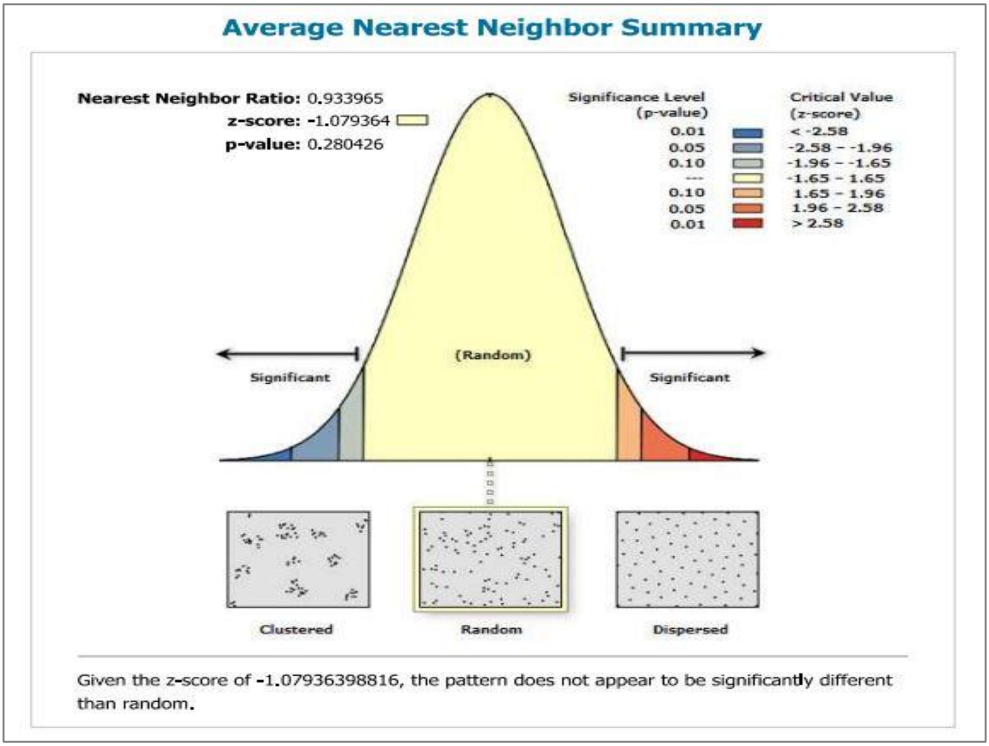
Source: Field survey, 2024

Table 2 shows that the distribution of spring waters is very much dependent on slope gradient. The highest occurrence of springs, which totals 36, exists in the 15°-30° slope zone. This shows that the conditions are favorable for the existence of spring water. The moderate slope category, which is 30°-45°, supports many springs; however, some of the springs are dried (1). Springs in the gentle slope category are fewer, with none being dried out. The total occurrences of dried springs are only three, with most being dried in higher slope zones.

The spatial pattern of spring water resources shows a random distribution of spring in Waling Municipality (Figure 4). There is an uneven distribution across Waling that has been sharing with neighboring wards.

Figure 4

NNI analysis of spring water resources in Waling, 2024



Overall, there are 70 spring water resources are prevalent in Waling Municipality and three of spring are inactive, most of them are identified in the elevation range between 800m to 1100m (35 spring), resulting slope between 15 degrees to 30 degrees suitable (36 springs) for availability.

Conclusion

Sources of spring water are the natural sources of water that come out from beneath the earth surface to the land. Talking about spring water sources in the country of Nepal, it is the primary source of drinking water for people living in the hilly areas. Waling Municipality nestled in the hilly region of central Nepal, has adequate spring water resource. Altogether 73 spring water resources are identified in Waling Municipality where three of them are dried up due to earthquake, haphazard road construction, and climate change.

The study's outcomes are mainly based on the information responded to by key informants of Waling. The information obtained from KII helps in find out the spatial distribution of spring water resources. Waling Municipality, a rapidly growing urban area has the higher concentration of people around the administrative offices, indicating the significance of administrative offices in pulling the people towards a specific area. Further, with the administrative offices, the development activities also revolve around it, attracting the people to in-migrate from the rural hilly regions. The study was focused on the spatial distribution of spring water resources in Waling Municipality, identifying a total of 73 springs, where three of the springs have been totally dried, which makes 70 active springs. The spatial distribution of the spring is randomly distributed. In the elevation from 800 meters to 1400 meters, there are 35 springs. And on the slope from 15 to 30 degrees, there are 36 springs present.

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