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Factors controlling the variation in physicochemical parameters of springs in Melamchi area, Nepal

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ABSTRACT

Understanding the factors controlling the spatial and seasonal variation of physicochemical parameters of groundwater are important for quick water quality assessment and for a better planning of the water quality management strategies. This study evaluated spring's five physicochemical data (pH, EC, TDS, DO and temperature) for 75 springs in two seasons (pre and post monsoon). The aim of the research presented in this paper is to assess physicochemical parameters of spring water, understand their seasonal and spatial variation and the factors controlling the variation. Physicochemical parameters were correlated with each other to understand the processes and an attempt has been made to understand groundwater processes studying the physicochemical parameters.

Groundwater is slightly acidic to slightly alkaline with pH ranging from 5.5 to 7.5 and is weakly to very weakly mineralized with EC range of 21.6–234.0 µS/cm in pre-monsoon and 10.5–189.8 µS/cm in post-monsoon. TDS ranged between 5.3–116.9 mg/l and 10.8–94.9 mg/l, DO between 3.1–9.4 mg/l and 2.4–7.3 mg/l and groundwater temperature between 18.4–27.9°C and 19.2–27.4°C in pre-monsoon and post monsoon season respectively. TDS and EC are noted to be higher in pre-monsoon whereas pH, DO and temperature are comparatively higher in post-monsoon. The south-east region of the study area shows minimum groundwater temperature. Minimum concentration of EC and TDS were observed in south-east and north-west part of the study area with values increasing towards the river valley. Groundwater temperature shows inverse relation with elevation, pH and DO while correlated with EC and TDS of groundwater in the region. The measured parameters were seasonally and spatially variable.

The results indicate difference for measured physicochemical parameters mainly caused due to results generated by cumulative interactions of monsoonal rain, atmospheric temperature, rock-groundwater interaction, residence time of groundwater and seasonal influences. The change in parameters with respect to elevation and relation between different parameters shows shallow aquifer-related groundwater processes.

Keywords: Groundwater, physicochemical parameters, seasonal variation, spatial distribution, springs

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INTRODUCTION

Groundwater, the largest available source of fresh water can also be assessed when it occurs in the form of springs. A spring is a location where groundwater discharges from the aquifer creating visible flow on the land surface (Kresic and Stevanovic, 2010). Springs are the principle source of water for many communities residing in mid hills of Nepal. Limited studies have been conducted related to spring water quality in the mountainous region. Monitoring of groundwater quality provides important information for determining the suitability of water for diverse purposes such as drinking, domestic, irrigation, fisheries and also aid in management of groundwater (Abel, 1996). Furthermore, understanding the spatial and temporal variation of physicochemical parameters of spring water is essentially important in the growing context of climate change and when groundwater resources are depleting rapidly.

Groundwater quality depends on various physicochemical parameters which is a result of various natural as well as anthropogenic activities in an area. It depends on the total amounts and kinds of dissolved minerals which is influenced by several factors such as local geology, land use and climate. Physicochemical parameters such as pH, EC, TDS, DO and temperature can be measured in-situ and yield important information on water quality aspects. Depending on geological variations of the area; the rock type through which water moves after infiltration and changes with season (Kale, 2016)**.** The importance of temperature in water quality is derived mainly due to its effect on other water quality parameters (physical, chemical and biological activities). Temperature is one of the important parameters as it affects rate of chemical reactions, solubility of ions and microbial activities in groundwater. Increase in temperature leads to speeding of chemical reactions and reduction in the solubility of gases (Trivedy and Goel, 1986). The pH indicates hydrogen ion concentration in water and is important in determination of water quality since it affects other chemical reactions including the solubility and toxicity of metals in the water (WHO, 2011). The pH is affected by temperature and also by photosynthetic activity. EC is a measure of water capacity to pass the electric current which is related to the concentration of ionized substances present in water. It depends upon temperature, type of ions and its concentration (Hem, 1985; Boyd, 2000). TDS is a measure of all chemical constituents dissolved in the water and considered as an indicator of general water quality as it directly affects the water by increasing the turbidity. It is an important parameter to classify groundwater for determining the suitability of water for various uses (Davis and De Weist, 1966; Freeze and Cherry, 1979). The concentration of dissolved ions depends on groundwater flow path and rock-water interactions (Hem, 1985). Thus, TDS is often used to estimate the relative residence time of groundwater. DO contents in water are closely related to the partial pressure of oxygen in the atmosphere and the water temperature. The concentration of DO in water is affected by photosynthetic activity, water temperature, decaying organic matter in water, stream flow and altitude/atmospheric pressure (Kale, 2016).

The aim of the research presented in this paper is to assess the level of some physicochemical parameters, understand the factors controlling the seasonal and spatial variation and study the relation between different parameters. This study presents comparative analysis of some physicochemical properties (pH, EC, TDS, DO, temperature) of springs in dry and wet seasons. Springs were studied to understand various aspects of groundwater quality. The study is entirely based on field measurement data of spring's physicochemical parameters in two seasons. The evaluation of groundwater quality is important to establish database for water resources planning and development. The increased knowledge of seasonal variation in the properties of water can aid in effective and sustainable management of these groundwater resources.

STUDY AREA

The study area lies in central Himalayan region of Nepal between 26°49'30" N to 27°53'00" N latitude and 85°32'30" E to 85°38'00" E longitude. It is located in Sindhupalchok district which lies northeast of Kathmandu. The study area incorporates two villages: Jyamire and Dubachaur of Melamchi municipality. The major rivers of the study area are Indrawati River and Melamchi Khola. The map of the study area with major drainage network and studied spring's location is shown in Figure 1.

METHODOLOGY

Determination of physicochemical parameters

A total of 75 perennial springs were studied for five physicochemical characteristics of spring water in two seasons. For the primary data collection, field study was conducted in two phases: May and October 2017 representing pre- and post-monsoon season. Physicochemical parameters of springs were measured in both seasons to understand the behavior and characteristics of springs. The physicochemical parameters investigated include pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO) and temperature which was determined in-situ using Mettler Toledo field kit (Model SevenGo, US manufacturer).

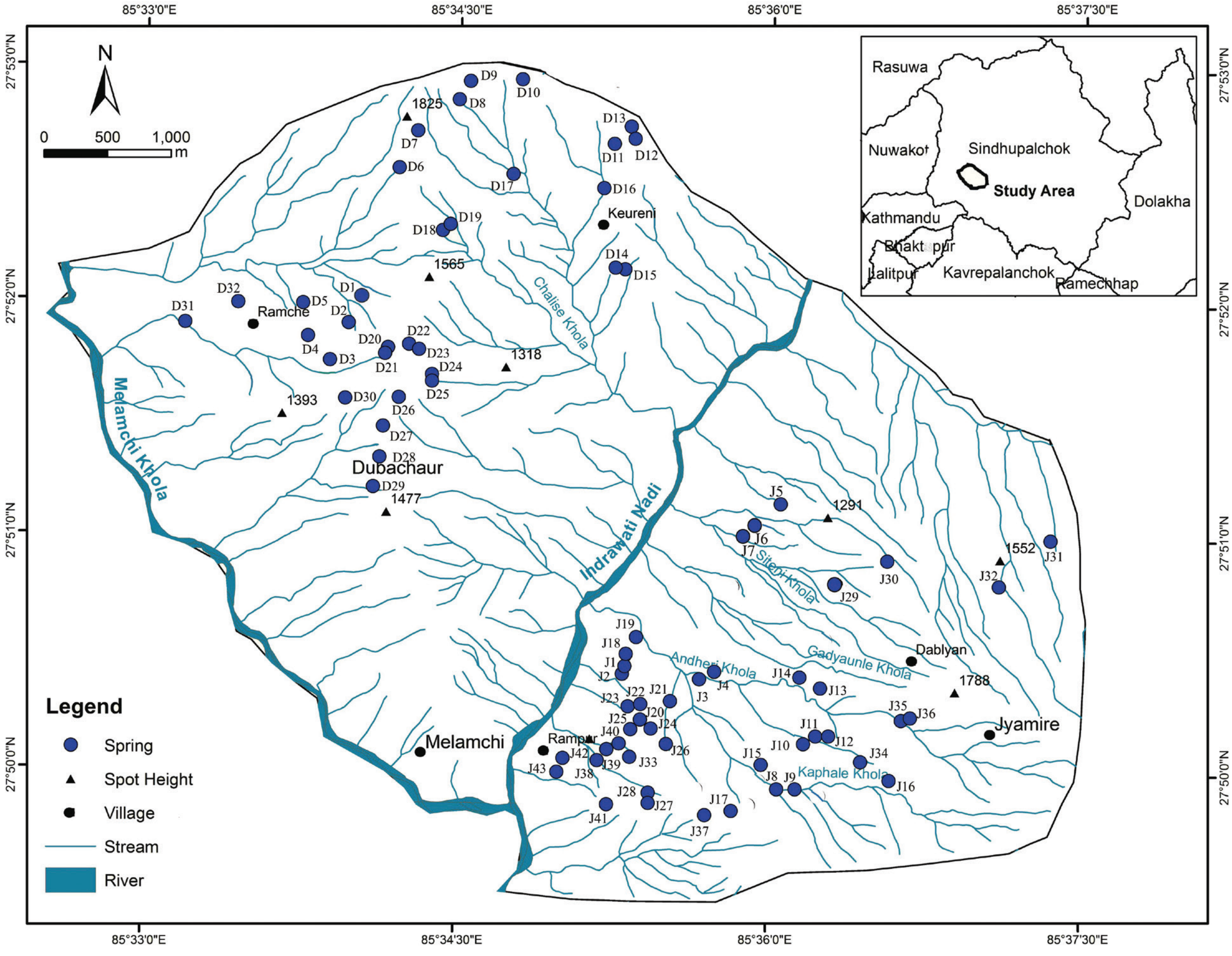

Fig. 1: Study area with location of observed springs.

RESULT AND DISCUSSION

Seasonal and spatial variation of physicochemical parameters

Physicochemical characteristics of 75 spring water samples were investigated for EC, TDS), pH, DO and temperature in both seasons. Table 1 presents the statistically analyzed results of the insitu physicochemical parameters of spring water samples. The parameters are plotted in graph to study the seasonal variation (Fig. 2). Spatial distribution maps of measured parameters were generated to better visualize and understand the spatial distribution pattern (Figs. 3–7).

Temperature

In the pre- and post-monsoon season, the temperature of spring water ranges from 18.4°C to 27.9°C and 19.2°C to 27.4°C respectively. The temperature values show that there is slight change with increase in temperature of water during post-monsoon. According to Gupta and Roy (2012), changes in the temperature of groundwater may be attributed to seasonal influences. The spatial distribution map of groundwater temperature of the study area shows that the temperature is minimum in the south-east region of the map with values increasing towards the valley (Fig. 3).

pH

The pH of the groundwater in the study area ranges from 5.5 to 7.5 in pre-monsoon and 5.7 to 7.5 in post-monsoon season. In general, the pH of spring water fluctuates between 5.5 and 7.5 implying that the groundwater in the study area is slightly acidic to slightly alkaline in nature. The WHO approved pH range for drinking water is 6.5 to 8.5, and most of the samples have values lower than these limits. In this study, pH values of water show slight variation between two seasons changing to slightly basic in the post-monsoon. The slight increase in the average pH in post-monsoon could be attributed to the dilution effect of monsoon rain. As illustrated in the spatial distribution map of pH levels in groundwater, the area mostly has pH of water ranging between 6–6.5 (Fig. 4).

Electrical conductivity (EC) and total dissolved solids (TDS)

In the present study, the value of EC ranges from 21.6 µS/cm to 234.0 µS/cm in pre-monsoon and 10.5 µS/cm to 189.8 µS/cm in post-monsoon. Similarly, the value of TDS in spring water samples was recorded between 5.3 mg/l to 116.9 mg/l and 10.8 mg/l to 94.9 mg/l in the pre-monsoon and post-monsoon seasons, respectively. Higher values of EC and TDS were recorded in the pre-monsoon than post-monsoon. This is possibly due to more residence time of groundwater in pre-monsoon resulting rock-water interaction, thus more ions are acquired whereas after the monsoon, there is significant groundwater recharge reducing residence time and lowering dissolved ions. The spatial distribution map shows that EC and TDS values are minimum at south-east and north-west region of the map (hilltop regions of the area elevation ranging from 1500 to 1800 m) which increases towards the river valley (Figs. 5, 6).

Dissolved oxygen (DO)

The DO of the spring water ranges from 3.1 mg/l to 9.4 mg/l and 2.4 mg/l to 7.3 mg/l in pre and post monsoon respectively. DO is supplied to water through direct diffusion of oxygen from the atmosphere, and photosynthesis. The levels changes depending on factors including water temperature, time of day, season, depth, altitude, and rate of flow (Kale, 2016). During summer, high temperature accelerates photosynthetic activity giving off oxygen and increasing the DO contents (Krishnamurthy, 1990). This possibly accounts for high DO values for springs in May (such as D23 and J8 with 9.4 mg/L and 8.4 mg/L respectively). The spatial distribution map of DO values of water shows the area mostly has DO of water ranging between 5 to 7 mg/l (Fig. 7).

Variation in physicochemical parameters with respect to elevation

In general, the temperature of groundwater in the area decreases with increasing elevation in both the seasons (Fig. 2). This is also presentable in the spatial distribution map which shows that the groundwater temperature decreases as altitude increases. This indicates that the springs are fed by aquifer at shallow depth and are affected by the atmospheric temperature (Moore et al., 2008).

Further analyzing EC and TDS values of springs with respect to elevation, the results show decreasing trend with increase in elevation. High altitude springs have shown low change in EC and TDS values in both seasons indicating shorter groundwater flow path, shorter residence time probably being located near to the recharge zone. The change of these values is different for different springs that explain its characteristics related to its type (the geological conditions in which spring occur), aquifer properties, flow path and residence time.

Relation between the physicochemical parameters

In this present study, groundwater temperature shows inverse relation with pH and DO, while correlated with EC and TDS values of groundwater. This suggests shallow aquifer groundwater processes. This is also supported by study conducted in the region by Tiwari et al. (2020).

Warmer water seems to have comparatively lower pH in the study. This is because water molecules have a slight tendency to break down into their constituents as temperature increases

Table 1: Statistics of insitu physicochemical parameters of pre and post monsoon spring water samples.

Season		Temperature (°C)	pH	EC (µS/cm)	TDS (mg/l)	DO (mg/l)
Pre-monsoon	Minimum	18.4	5.5	21.6	5.3	3.1
	Maximum	27.9	7.5	234.0	116.9	9.4
Post-monsoon	Minimum	19.2	5.7	10.5	10.8	2.4
	Maximum	27.4	7.5	189.8	94.9	7.3

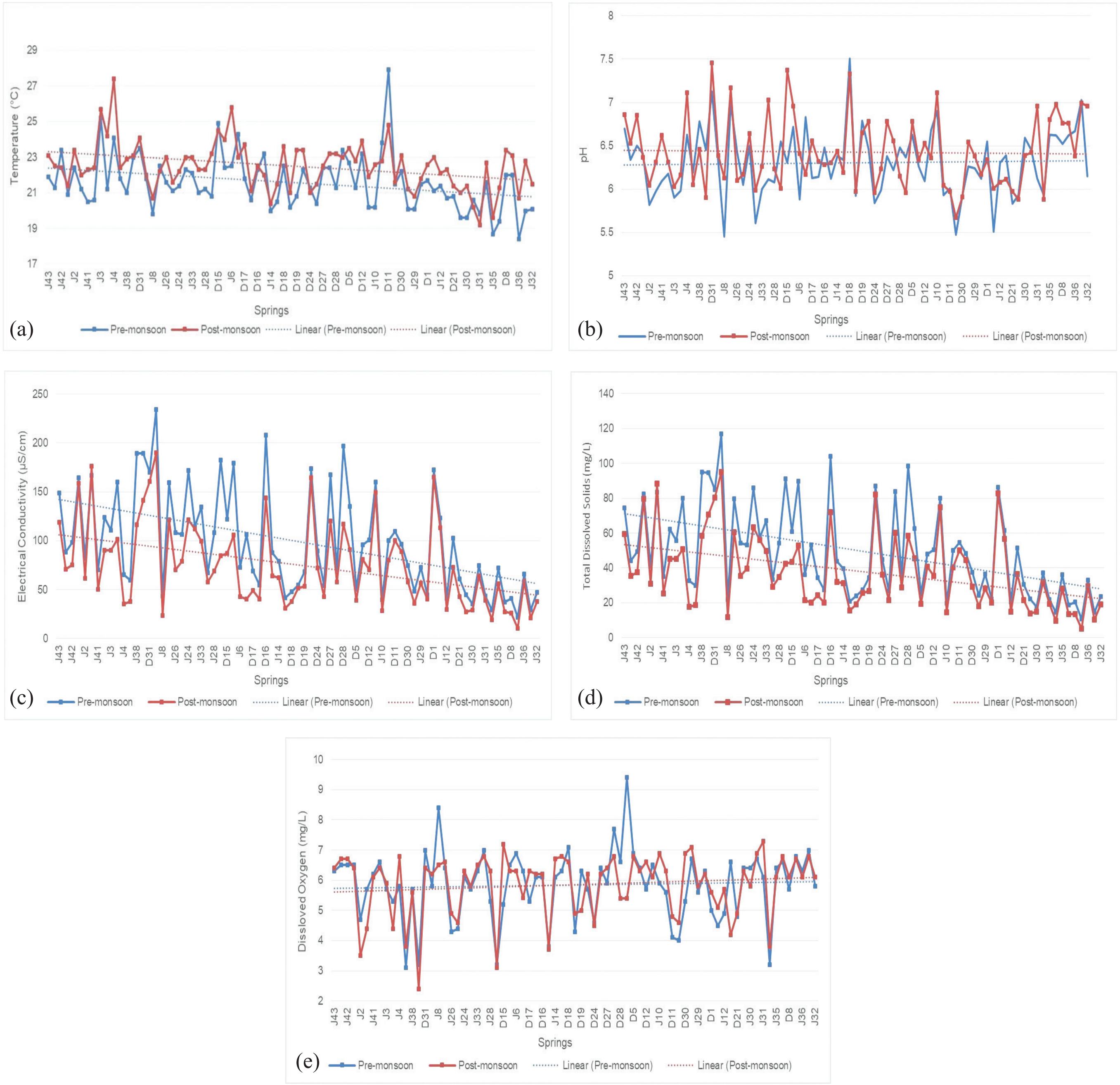

Fig. 2: Seasonal variations of insitu-physical parameters of spring water (a) temperature, (b) pH, (c) EC, (d)TDS, (e) DO. [Note: The springs have been arranged based on elevation; increasing from left]

releasing more hydrogen ions decreasing the pH (Holman et al., 2012).

The temperature of water is an important factor which determines DO contents in water. In general, low DO values coincide with high temperature of water in the area. This is because solubility of oxygen in water decreases with higher temperature. In general, higher the temperature, the lower is DO content and vice-versa (Zhai et al., 2011; Ali et al., 2016).

The EC and TDS values are lower in higher altitudes where the groundwater temperature is also low. A similar pattern was observed by Thapa et al. (2020). This is because temperature increases the mobility of ions increasing the conductivity. Low temperature caused lower dissolved solutes in water. Groundwater with higher temperature can dissolve more minerals from rocks increasing the EC values (Raut et al., 2015; Akpe et al., 2018).

TDS content of spring water is generally low (excluding hot springs) as the solute contents are closely related to the groundwater flow path and the rock-water interaction depending upon the residence time (Edmunds, 2009). The low TDS contents in water in this study too supports shallow groundwater processes with shorter groundwater residence time (Zhai et al., 2011).

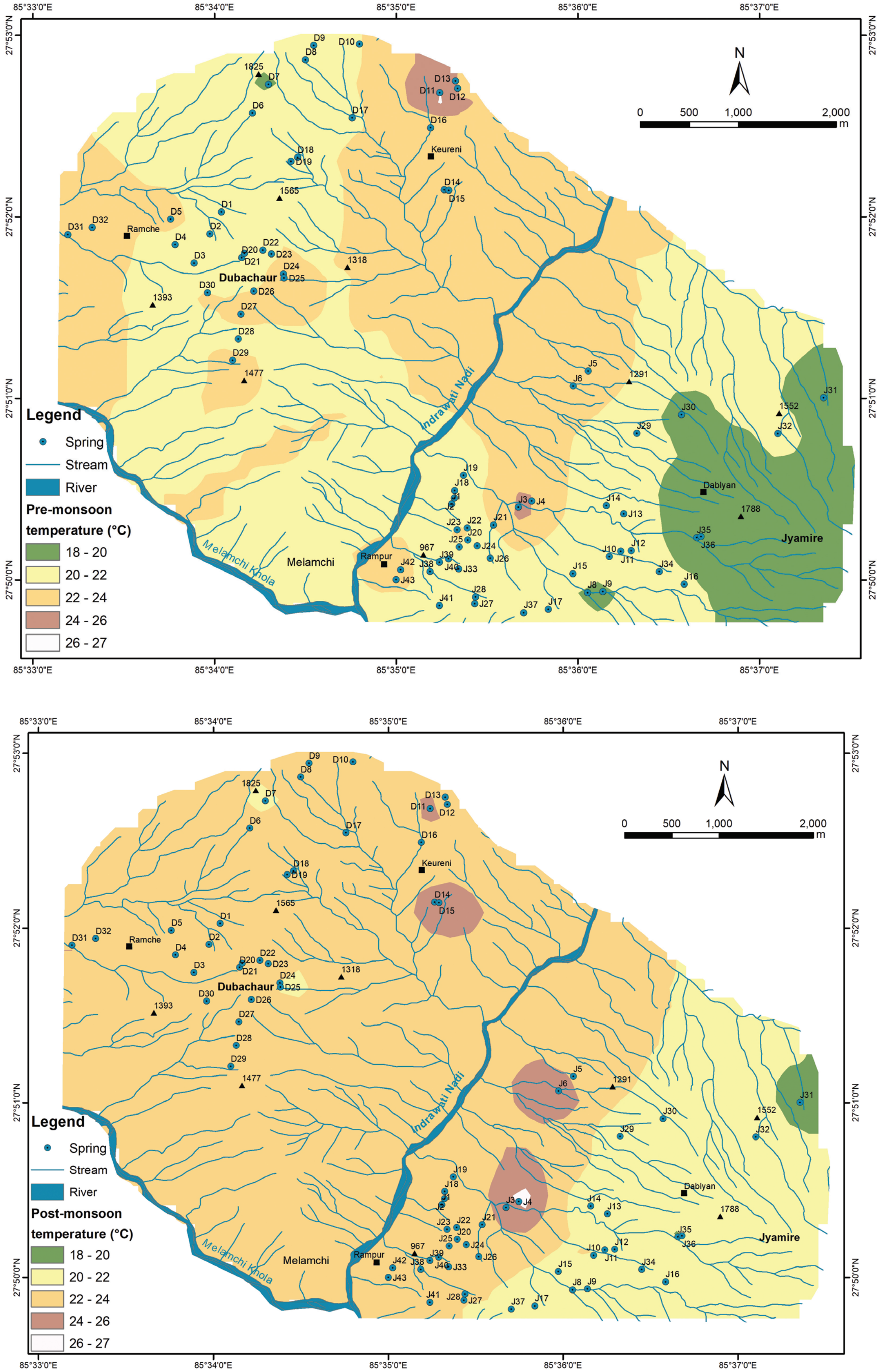

Fig. 3: Spatial distribution map of pre- and post-monsoon temperature of groundwater.

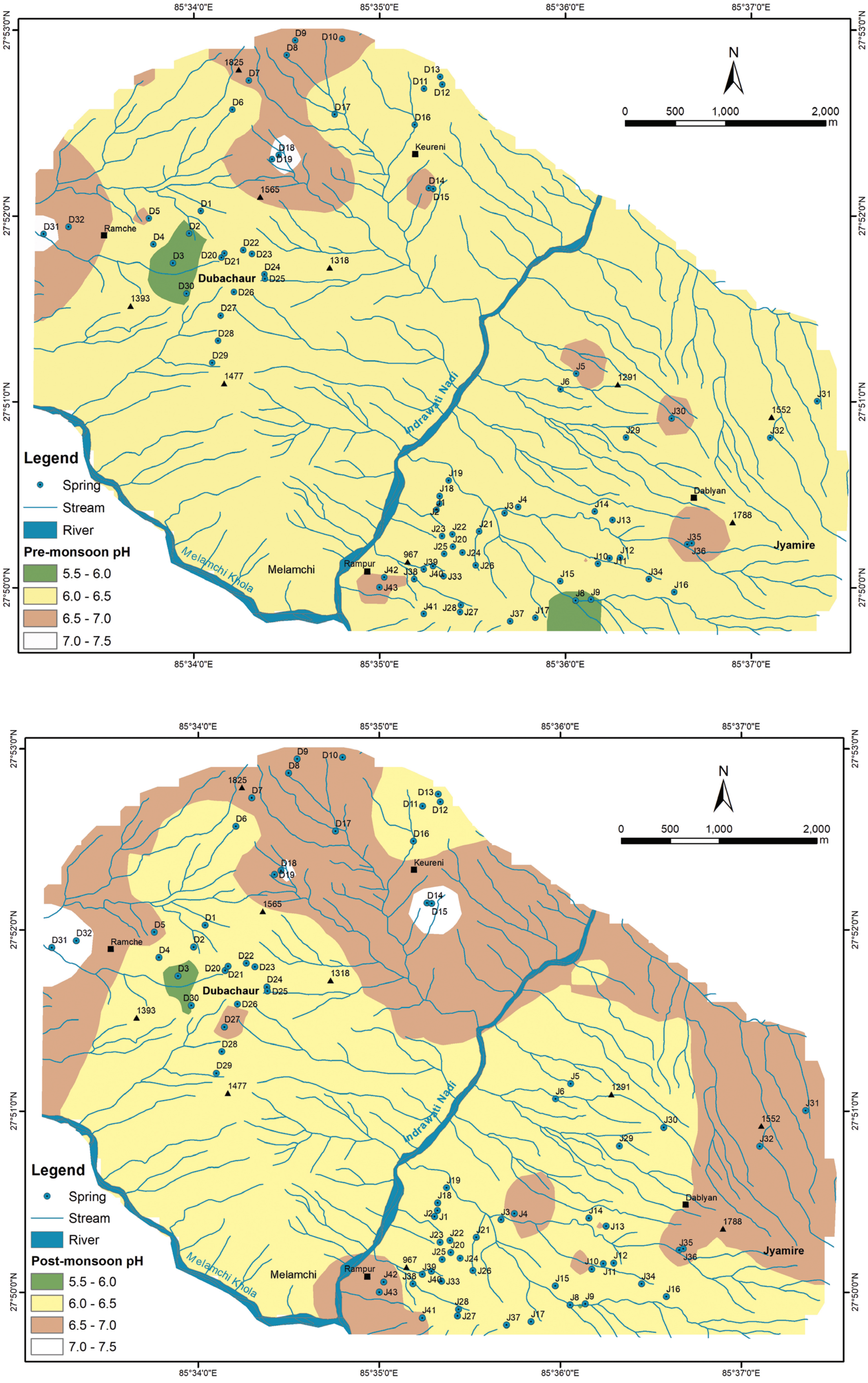

Fig. 4: Spatial distribution map of pre- and post-monsoon pH of groundwater.

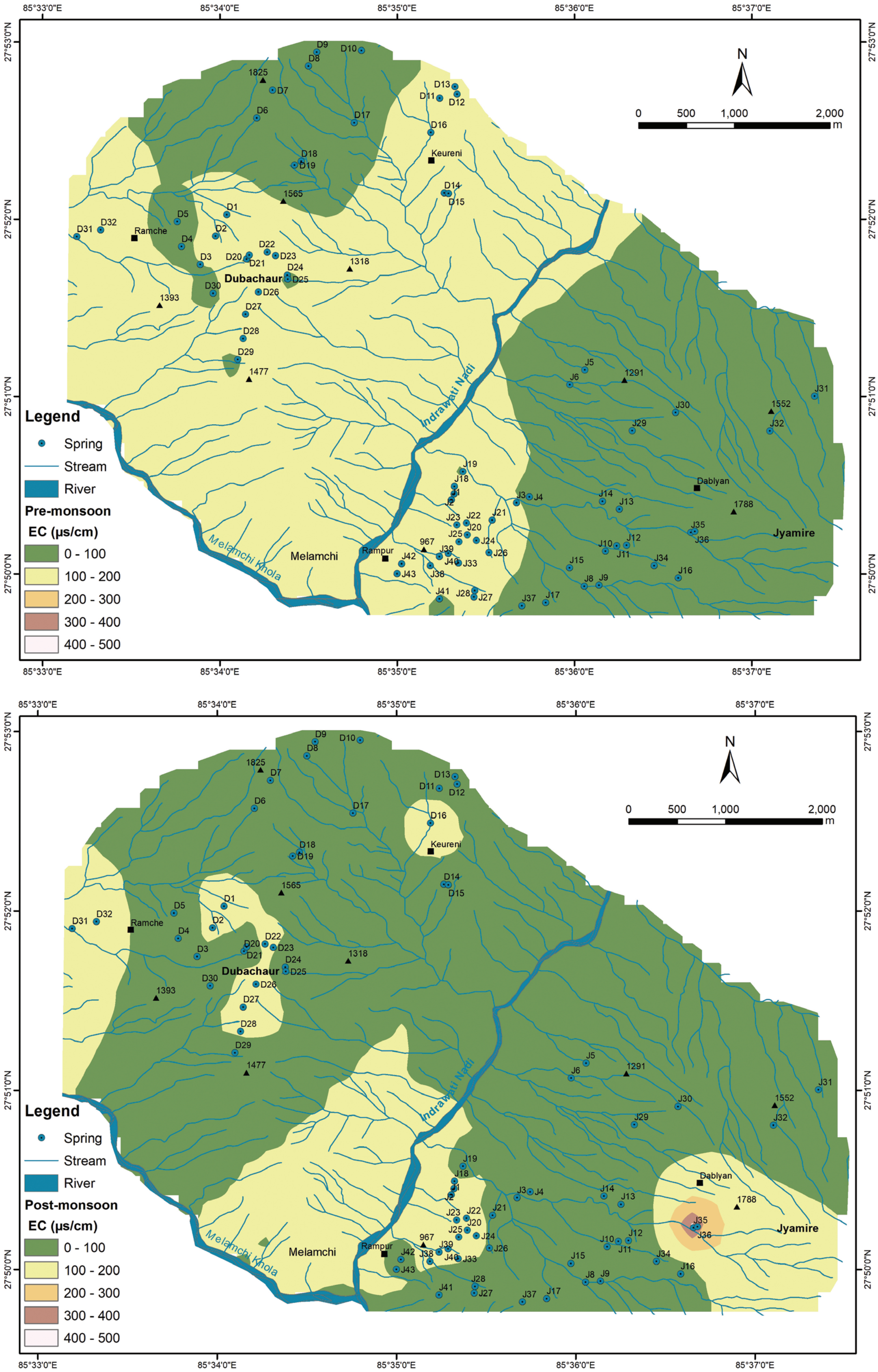

Fig. 5: Spatial distribution map of pre- and post-monsoon EC of groundwater.

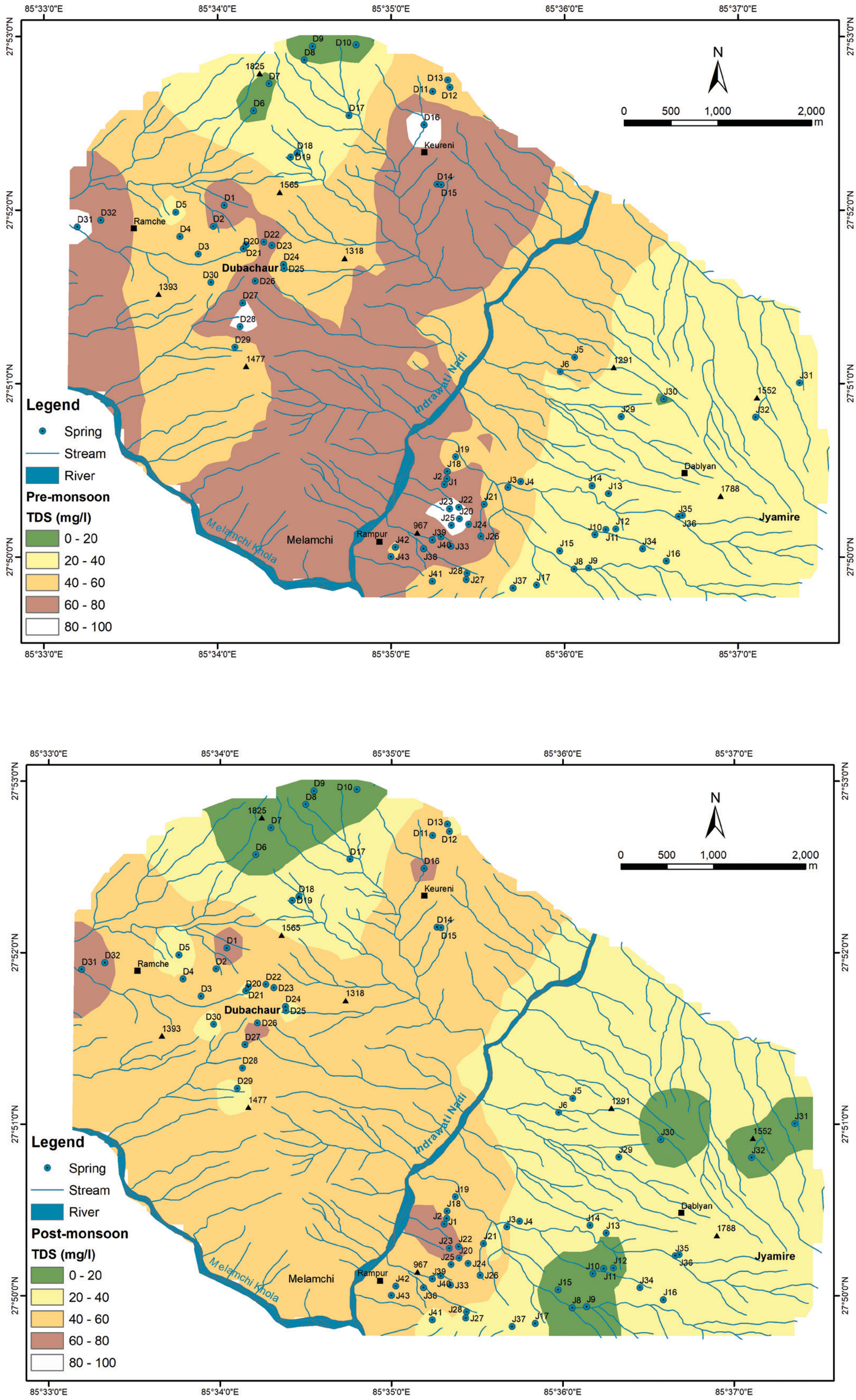

Fig. 6: Spatial distribution map of pre- and post-monsoon TDS of groundwater.

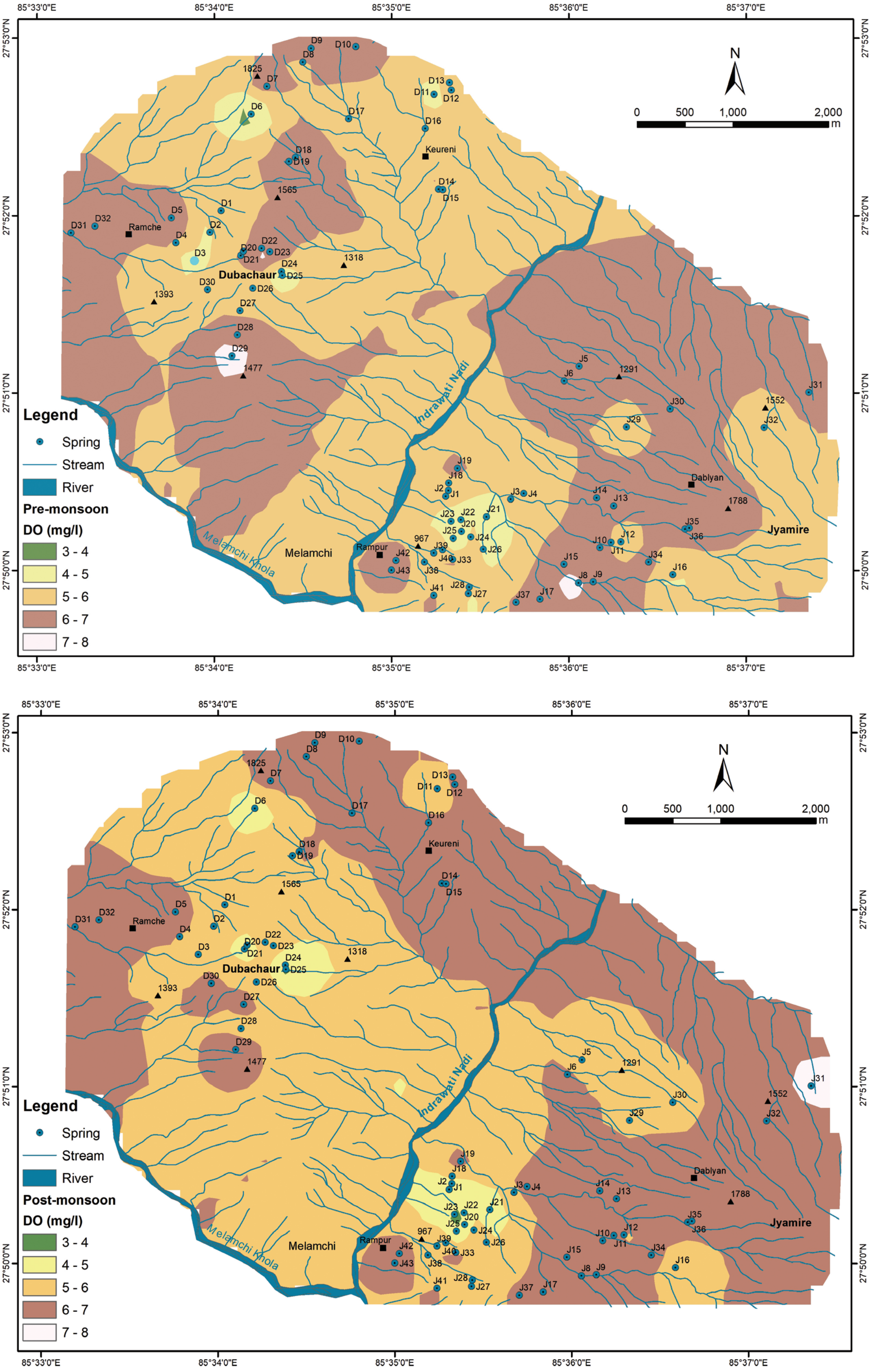

Fig. 7: Spatial distribution map of pre- and post-monsoon DO of groundwater.

EC-TDS relationship

TDS values can be approximately calculated from EC values by mathematical equations (Hem, 1991). The EC and TDS relationship can be obtained with statistical approach with EC values on x-axis and TDS values on y-axis is shown in Figure 8. The results show that the correlation coefficient (R^2), value close to 1, indicating strong relation between EC and TDS for the both seasons showing linear correlation.

Geological control on variation of physicochemical parameters

Geologically, the study area comprises of schist and gneiss of the Talamarang Formation (Khadka and Rijal, 2020) (Fig. 9). The seasonal variation in the physico-chemical parameters is mainly due to rock-water interactions. The longer the groundwater is in contact with rock, the larger the effect of the rock is on the water chemistry. As observed, after the monsoon, the EC and TDS values are lower which is mainly due to the shorter groundwater residence time resulting shorter interactions between groundwater and rock. This indicates that the underlying rocks are the source of dissolved ions in the groundwater. The change in EC and TDS values is different for different springs in two seasons which explains the complexity of springs characteristics related to its type (the geological conditions in which spring occur), aquifer properties, flow path and residence time. Even within the similar geological condition, the unique characteristics of each spring can differ the groundwater properties.

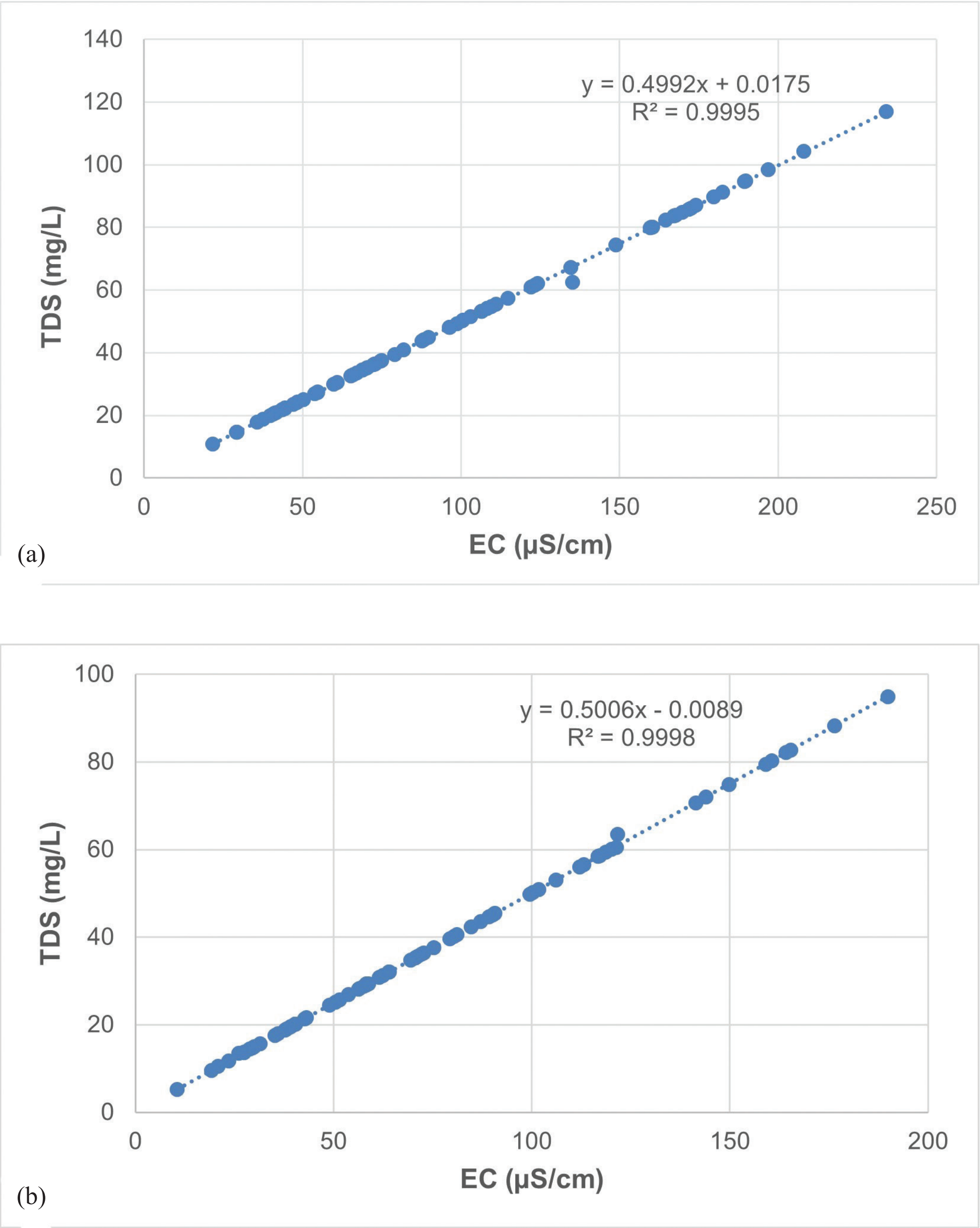

Fig. 8: EC-TDS relationship for (a) pre-monsoon (May), (b) post-monsoon (October).

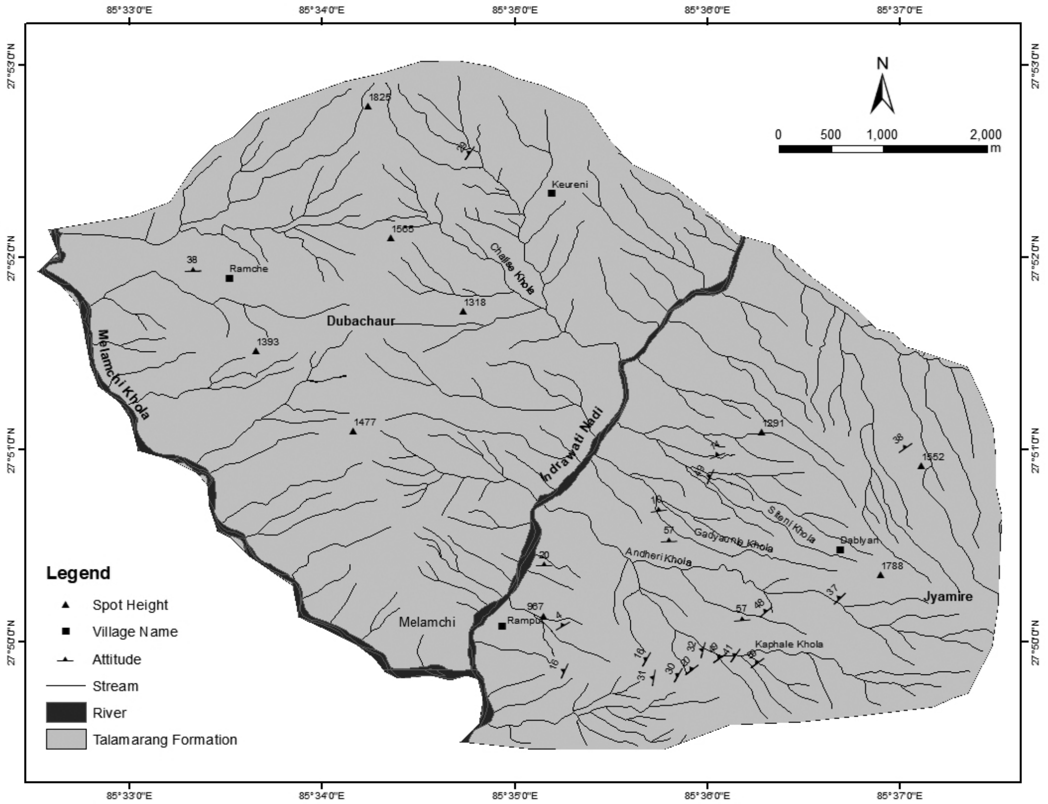

Fig. 9: Geological map of the study area (modified after Khadka and Rijal, 2020).

CONCLUSION

In this study, an attempt has been made to study the seasonal variation and spatial distribution of the physicochemical characteristics of groundwater in the region for understanding the factors controlling the variation in the parameters.

Measured physicochemical parameters are spatially and temporally variable. Parameters such as TDS and EC, are noted to have higher concentration in the pre-monsoon season while pH, DO and temperature values are comparatively higher in post-monsoon season. Increase in EC and TDS values after monsoon suggest rock-water interaction processes responsible for dissolved ions in water. Findings reveal that the seasonal variations with respect to measured physical and chemical parameters of groundwater were observed mainly due to the influence of air temperature, monsoon rainfall infiltrating through the earth's surface, groundwater temperature, and rock-water interaction. Furthermore, groundwater temperature shows inverse relation with elevation, pH and DO while correlated with EC and TDS of groundwater in the region. The analysis of groundwater temperature, and TDS values, of springs indicate that the majority springs are fed by aquifers at shallow depth.

This research study shows that how basic physicochemical parameters can be used to understand the groundwater processes. However, further research related to detailed chemical and microbiological analysis would give a broader picture of water quality in the region and better understanding of groundwater processes involved. Besides, monitoring of groundwater is essential to understand the change in quality and quantity of groundwater and respond accordingly related to the treatment and uses of water.

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