

INTRODUCTION

Water and soil are precious natural resources in the environment, hence constant monitoring and evaluation must be done regularly in order to conserve and manage the resources properly. Due to the identification of inadequacy of knowledge regarding the distribution of chemical species in groundwater and soil quality, several selected important soil and well water quality parameters were determined and mapped in this study. This work supports the current context of the environment and the prevailing environmental condition while introducing a data bank of the selected area, for the determined parameters.

Another important aspect of this research is to demonstrate the importance of a chemical data bank of chemical parameters of well water and soil for a country, or a given area. Construction of a map from the area of study simplifies the data and depicts an overall picture of the determined parameters of groundwater and soil, which can be used as a reference for future work, and to interpret the environmental changes which may occur in the future.

According to available literature, such a study has been last published on the topic “Hydro geochemical atlas of Sri Lanka” CB Dissanayaka, SVR Weerasooriya considering groundwater quality parameters (1993) (Figure 1). In work mentioned above, 500 samples have been collected from dug wells covering the whole island, and the work has covered contouring maps for 15 water quality parameters (Dissanayake, 1993). As any other work has not been reported within a considerable period this study suggests the importance of carrying out monitoring environmental resources in a timely manner.

In the present study, using the area of study was limited at a time gradually covering the whole district to give a descriptive picture of the district; this study suggests carrying out sampling at the smallest administrative unit, which is the *Grama Niladhari* unit. This study helps to address the scope of variations in quality parameters even within a small area and

gives detailed maps due to having a higher number of sampling sites, which can be more helpful to construct a representative map in the study area.

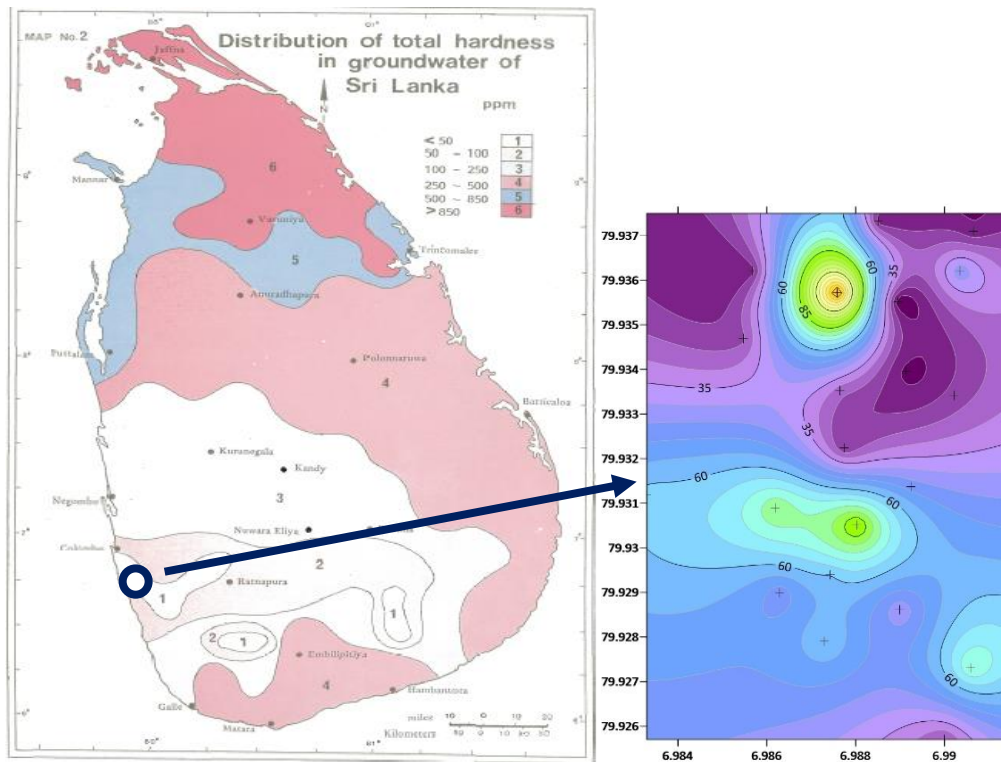


Figure 1: .Map produced by “Hydro geochemical atlas of Sri Lanka”(Dissanayake, 1993) for the total hardness of Sri Lanka (left) and map produced by present study for the total hardness of well water in Thalawathuhenpita North Grama Niladhari division (right).

METHODOLOGY/MATERIALS AND METHODS

KOH (85%), NaCl (99.5%), Sulfanilic acid (99%), and Sodium acetate (99%) were purchased from Lobachemie (Mumbai, India). EDTA (98.5%), Salicylic acid (100%), $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 12\text{H}_2\text{O}$ and $\text{FeSO}_4 \cdot (\text{NH}_4)_2 \cdot 6\text{H}_2\text{O}$ (98.50-101.50%) were purchased from HIMEDIA (Mumbai, India) KNO_3 (99%), and Concentrated H_2SO_4 (95-97%) were purchased from Riedel de haen (Germany, Seelze). HCl (35%), Conc. NH_4OH , glacial acetic acid was purchased from Merck (Mumbai, India) Zn dust, and $\text{K}_2\text{Cr}_2\text{O}_7$ (99.9%) were purchased from Central drug house (India, Delhi). NH_4Cl (99.5%), and FeCl_3 (99%) were purchased from Srlchem (Mumbai, India). H_2O_2 , $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$, and Phosphoric acid (85%)

were purchased from Daejung (South Korea, Siheung-si). KCl (99%), and Diphenylamine were purchased from Fluka (Switzerland, Buchs) NaF (97%) was purchased from Fischer Scientific (USA, New Jersey) and KCN was purchased from BDH (England, Poole).

The laboratory instruments used in the research were; Electrical balance (KERN EW 2200-2NM), Analytical balance (Kern, ALJ 250-4AM, Germany), Flame photometer (Jenway-pfp7, UK) for accurate measurements, Microplate reader (MULTISKAN GO, Thermo Scientific), colorimeter (IndiaMART, India) for absorbance readings, Orbital shaker (mrc, UK) for homogenizing samples, pH meter (Eutech pH 700, Thermo Scientific) to measure pH, hot plate (Gallenhamp) were used for heating.

In this study, sampling was done in one of the selected grama niladhari division “Thalawathuhenpita north” in the Gampaha district. 23 sampling sites were selected depending on the availability of well water sources. Two representatives well water samples (~500 mL each) were collected on each sampling site into polyethylene/polypropylene bottles. Bottles were rinsed with HCl (2 M), distilled water and air-dried. While collecting the sample the bottle was rinsed with sample water. Bottles were filled entirely with the samples including the screw cap (Buurman, Lagen, & Velthorst, 1996).

A clean plastic spade was used to collect soil samples from the sites. A V-shaped cut was made with a spade to remove a 1–2 cm slice of soil. The sample (~250 g each) was collected on the blade of the spade and packed in labeled polythene zip-lock bags. Air-dried samples were ground gently using a mortar so that the soil aggregate was crushed but the soil particles did not break down and the soil was screened through a 2 mm sieve and used for analysis (Buurman et al., 1996).

pH meter was used to measure the pH of well water. The pH meter (Eutech pH 700) was switched on and kept for 10 minutes until it warmed up. The electrode was cleaned with distilled water and wiped with a tissue. pH meter (Eutech pH 700) was calibrated using

standard buffer solutions of pH=4, pH=7, and pH=10. The electrode was cleaned again with distilled water and dipped in the sample and the readings were recorded. The same procedure was carried out for all the samples. Readings were duplicated and reported as means \pm standard deviation (Buurman et al., 1996).

The total hardness and Calcium content of well water samples were measured using EDTA titrations. Initially the EDTA solution was standardized against standard Calcium solution (25.00 mL). Then sample (50.00 mL) was placed in a conical flask. Ammonium chloride-ammonium hydroxide buffer (pH=10, 2.00 mL), and EBT (0.10 mL) were added to the conical flask titration and titrated against EDTA solution until the wine-red color changed to blue. The above procedure was carried out for all the samples. Titrations were duplicated and the volume of EDTA used was reported as means \pm standard deviation. A blank solution (with all reagents containing deionized water) was run (n=3) (Vogel & Arthur, 1917).

The calcium content of well water samples was measured using EDTA titrations. The sample (25.00 mL) was pipetted to a conical flask and KOH (8 M, 4.00 mL) was added and swirled. KCN (30 mg) was added to the flask and stirred until the solid was dissolved. Patton reeder indicator (0.5 g) was added to the flask and titrated with EDTA (0.01 M) until the color changed from red to blue. A blank solution (with all reagents containing deionized water) was run (n=3) (Vogel & Arthur, 1917).

Nitrate content was measured using colorimetric analysis Nitrate stock solution (500. mg/L) aliquots (5.00, 10.00, 15.00, 20.00, 25.00 mL) were transferred separately into volumetric flasks (100.00 mL) and diluted up to the mark. Solutions were transferred into Erlenmeyer flasks (250.0 mL). HCl (25% v/v, 2.00 mL), and sulfanilic acid (2.00 mL) were added to each flask and mixed thoroughly. Zn/NaCl (2.00 g) granular mixture was added into each and swirled for 7 minutes and then the solutions were filtered under a vacuum.

Mapping of well water and soil parameters

1-naphthylamine (2.00 mL) reagent was added into each flask and mixed well. Sodium acetate solution (2 M, 2.00 mL) was added into each flask, mixed well, and allowed to stand 5 minutes for color development. The absorbance (n=3) was measured at 520 nm using a microplate reader ((Multiskan go, Thermo Scientific), blank (n=3) was also carried out. A graph was plotted for absorbance against concentration(mg/L) (Beevers & Hageman, 1980).

The well water sample (10.00 mL) was transferred into a volumetric flask (100 mL) and diluted up to the mark. The solution was transferred into an Erlenmeyer flask (250.0 mL). HCl (25% v/v, 2.00 mL), and sulfanilic acid (2.00 mL) were added to the flask and mixed thoroughly. Zn/NaCl (2.00 g) granular mixture was added and swirled for 7 minutes and then the solution was filtered under a vacuum. 1-naphthylamine (2.00 mL) reagent was added into the flask and mixed well. Sodium acetate solution (2 M, 2.00 mL) was added into the flask, mixed well and allowed to stand 5 minutes for color development and the absorbance (n=2) was measured at 520 nm using a microplate reader (Multiskan go, Thermo Scientific), blank (n=3) were also carried out.(BEEVERS & HAGEMAN, 1980).A correction for nitrite was carried out simultaneously for the sample without the reduction by Zn/NaCl mixture. The nitrate content of the samples was calculated using the standard curve and expressed as mg/L.

The iron content of the well water samples was determined using colorimetric analysis. Ferric stock solution (1000. mg/dm³) aliquots (1.00, 2.00, 3.00, 4.00, 5.00 mL) were transferred into a volumetric flask (100.00 mL). H₂O₂ (30%, 1.00 mL), salicylic acid (1%, 2.00 mL), and sodium acetate (0.2M, 1.00 mL) reagents were added into each flask, diluted up to the mark with deionized water and mixed well. Each flask was allowed to stand 5 minutes for color development and the absorbance (n=3) was measured at 525 nm using the colorimeter, blank (n=3) was also carried out. A graph was plotted for absorbance against concentration (mg/dm³) (Rajendraprasad & Basavaiah, 2016).

The well water sample (10.00 mL) was transferred into a volumetric flask (100.00 mL). H₂O₂ (30%, 1.00 mL), salicylic acid (1%, 2.00 mL), and sodium acetate (0.2M, 1.00 mL) reagents were added and diluted up to the mark with deionized water into each flask and mixed well. Each flask was allowed to stand 5 minutes for color development and the absorbance (n=2) was measured at 525 nm using a colorimeter, blank (n=2) was also carried out (Rajendraprasad & Basavaiah, 2016). Iron content was determined using the calibration curve plotted as mentioned above.

The active pH of the soil samples was measured using a pH meter. Soil sample (10.00 g) was placed in a beaker (50.0 mL), and CaCl₂·2H₂O (0.01M, 20.00 mL) was added. The soil sample was allowed to absorb CaCl₂·2H₂O for 30 minutes without shaking and then stirred for 10 seconds. The suspension was stirred for 30 minutes and the pH (n=2) was recorded using the calibrated pH meter (calibration of pH meter was done as explained in the determination of pH of water) (Buurman et al., 1996).

Water-soluble cation solution was made by weighing an air-dry soil (2.50 g) into an Erlenmeyer flask (250.0 mL) and deionized water (100.00 mL) was added and shaken in the orbital shaker (mrc, UK) for 1 hour. The solution was filtered and Na⁺, and K⁺ ions were determined separately using the Flame photometer (Motsara & Roy, 2008).

Extractable cation solution was made by weighing an air-dried soil sample (10.00 g) in an Erlenmeyer flask (250.0 mL) and NH₄OAc solution (1 N, 50.00 mL) was added to it and shaken in an orbital shaker (mrc, UK) for 30 minutes. The solution was filtered using Whatman No.1 filter paper in a gravity filter. The final volume was brought up to 50.00 mL using NH₄OAc solution (1 N). Na⁺, and K⁺ ions were determined separately using the Flame photometer (Jenway-pfp7, UK) (Motsara & Roy, 2008).

The nitrate content of soil samples was determined as mentioned above for water samples. Air-dried soil (5.00 g) was placed in an Erlenmeyer flask (250.0 mL) and nitrate

extracting solution (25.00 mL) was added and shaken for 10 minutes in an Orbital shaker (mrc, UK). Nitrate-extracted soil solution(10.00 mL) was transferred into a volumetric flask (100.00 mL) and diluted up to the mark. Solutions were transferred and colorimetric analysis was carried out.

The extractable iron content of the soil samples was also determined as mentioned above for water samples. The organic matter of the soil was measured by a titrimetric method. Air-dried soil (1.00 g) was placed in an Erlenmeyer flask (500.0 mL) and $K_2Cr_2O_7$ (0.1667 M, 10.00 mL) and concentrated H_2SO_4 (20.00 mL) was added to it and mixed for 30 minutes in an Orbital shaker (mrc, UK). The solution was diluted to 200.0 mL and H_3PO_4 (80%, 10.00 mL), NaF (10.00 mL), and Diphenylamine (2.00 mL) were added, and the solution was titrated against $FeSO_4 \cdot (NH_4)_2 \cdot 6H_2O$ (0.5 M) to brilliant green color. A blank was run simultaneously without the soil sample (Motsara & Roy, 2008).

RESULTS AND DISCUSSION

The pH values of the well water samples analyzed in this study lie between 4.61 ± 0.02 and 7.98 ± 0.03 . According to the United States Environmental protection Agency (EPA)(American Public Health Association, 2017), the acceptable pH for public water systems lies between 6.5-8.5. Nearly 70% of the samples analyzed have an acidic pH and a trend of increasing acidity is present in the urbanized area (Figure 2). Acidic groundwater may result from natural processes such as flowing ground water through noncarbonate rocks such as granite, or from pyrite oxidation, or pollution (Huang, 2014).

According to Sawyer and McCarty's classification for hardness, more than 75% of the analyzed samples are categorized as soft water, 20% are classified as moderately hard and only one well water sample was classified in the category of hard water. Total hardness in the site varies in a range of 10-145 mg/L in $CaCO_3$ (Figure 3). According to the study, most of the study area has soft water, which is verified by measuring pH values. Because

most acid waters soft waters and associated Calcium and Magnesium deficiencies may also be involved (Bowen, 1979).

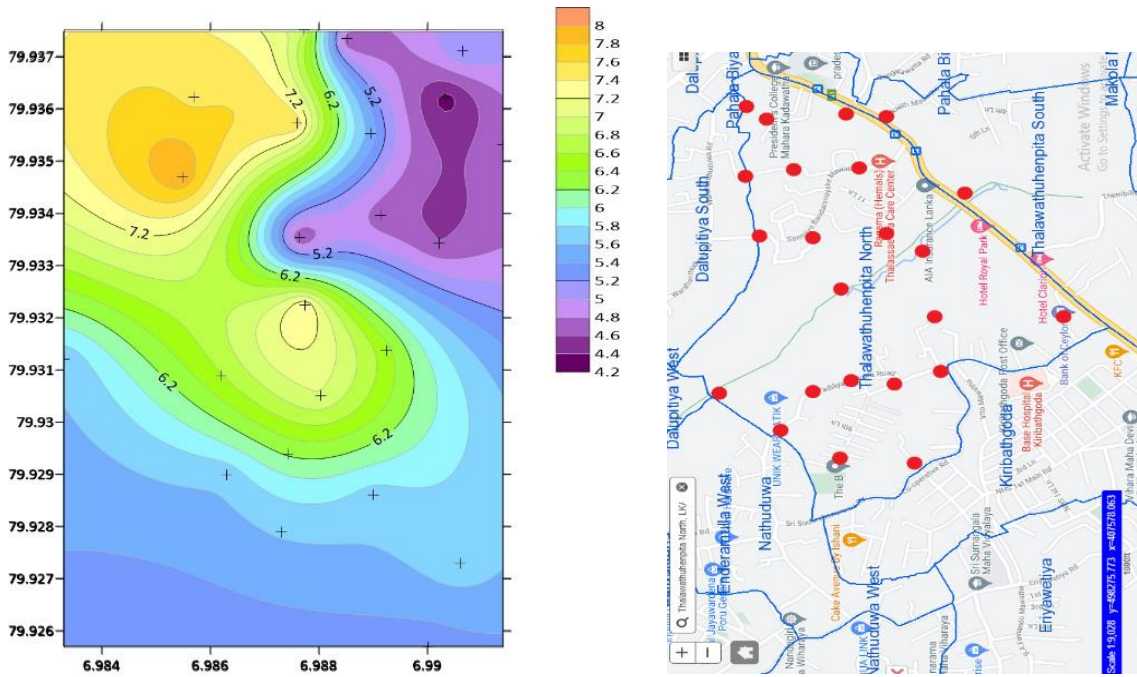


Figure 2: Spatial distribution of pH in well water in Thalawathuhenpita North (left) and reference diagram for sampling sites (right) ("Grama Niladari Boundary Map of Sri Lanka," n.d.)

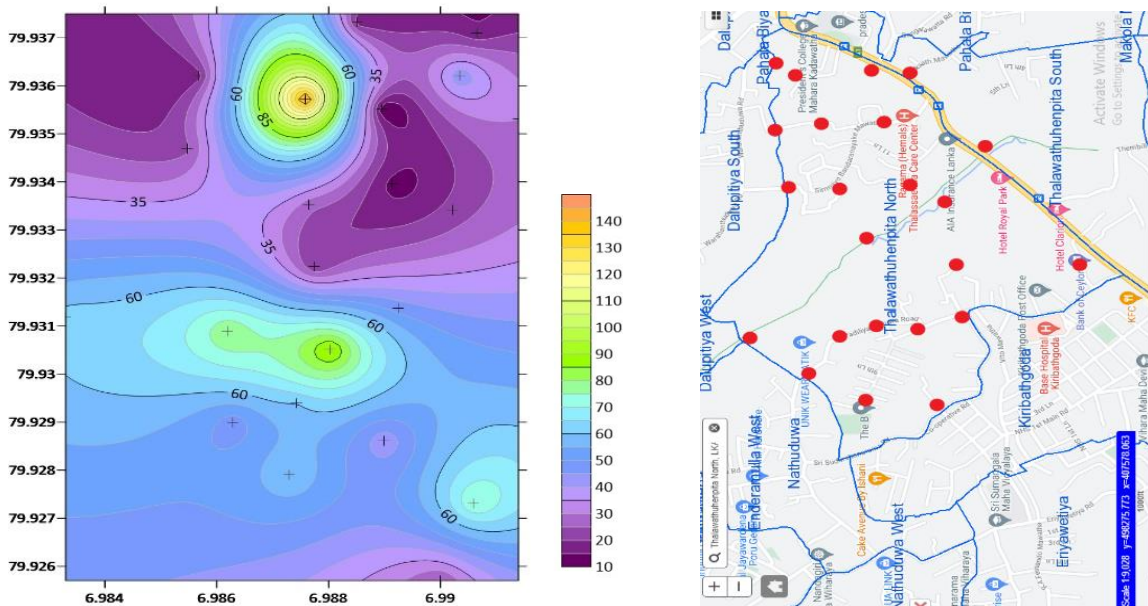


Figure 3. Spatial distribution of total hardness of well water in Thalawathuhenpita North (left) and reference diagram for sampling sites (right) ("Grama Niladari Boundary Map of Sri Lanka," n.d.)

In this study Calcium, concentration varies between 0.60 ± 0.00 and 134.60 ± 2.83 mg/L while Calcium, magnesium and total hardness in the groundwater are interrelated (Figure 4). Calcium hardness and total hardness maps in this study show a comparable region indicating that Calcium is the primary cause of hardness (Zaalishvili, Dzhgamadze, Gogichev, Dzeranov, & Burdzieva, 2018).

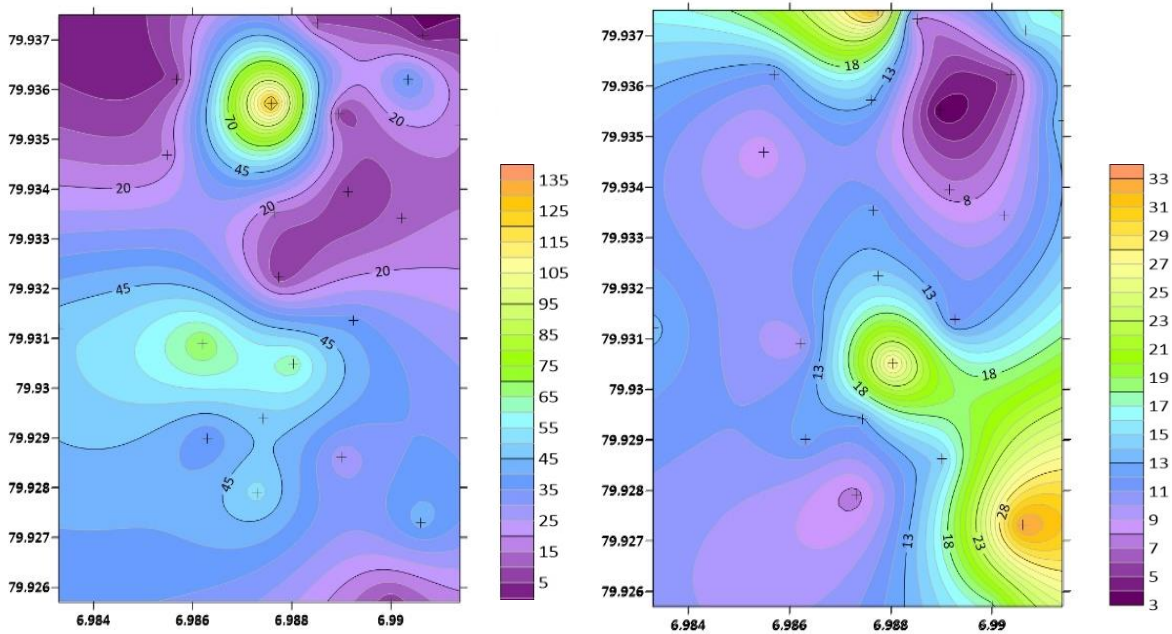


Figure 4: Spatial distribution of Calcium content in well water in Thalawathuhenpita North (left) Magnesium content (right)

Dissolution of magnesium-rich minerals is slow and calcium is more prevalent in the earth's crust; magnesium is commonly found in lower concentrations than calcium which may be the reason for the lower levels of Magnesium in the study site (Zaalishvili et al., 2018). According to the analysis, nitrate was not detected or may not be present in most samples (Figure 5). The method was validated, and the percentage recovery was 97.10%, which shows that the method can be used to determine nitrate. The detection limit was detected which was 18.00 mg/L. Hence, the samples may contain nitrate levels lower than 18.00 mg/L or nitrate may be absent. Factors such as rainfall, and the depth of the

groundwater table may have been contributing to lower levels of nitrate (Dissanayake, 1993).

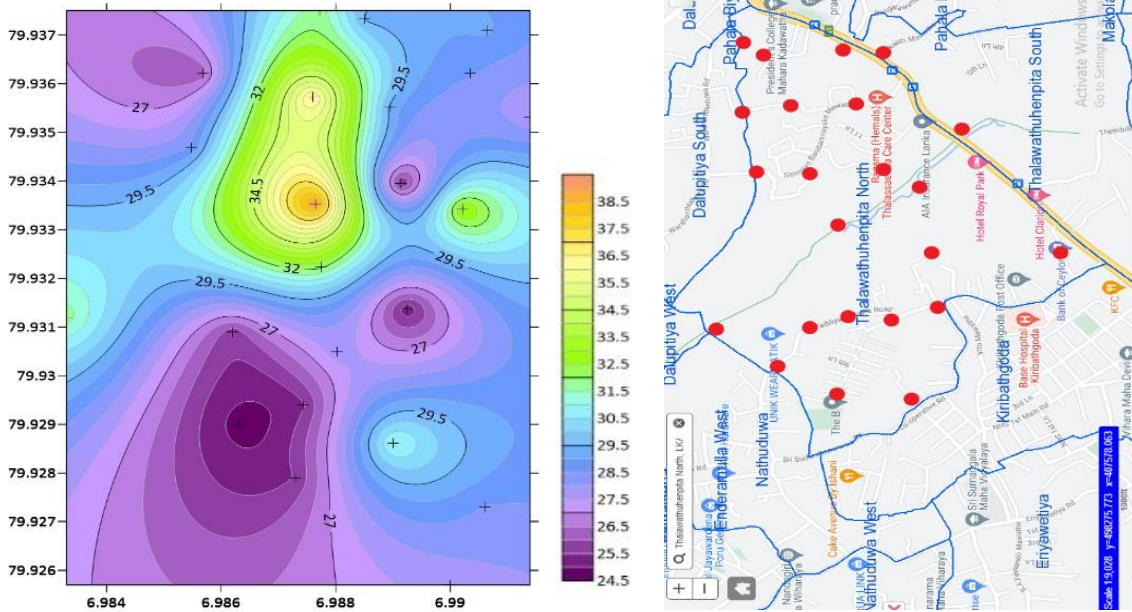


Figure 5. Spatial distribution of nitrate of well water in Thalawathuhenpita North (left) and reference diagram for sampling sites (right) ("Grama Niladari Boundary Map of Sri Lanka," n.d.)

In this study the pH of soil samples vary between 3.98 to 7.50 (Figure 6). Acceptable levels for soil pH are given as a range between 6-7 by the National resources conservation service in the United States department of agriculture. Nearly 30% of the samples analyzed lay within the range while most of the samples analyzed showed alkaline nature. Several points have been identified to have an acidic nature in soil. Factors such as climate, mineral content, and soil texture affect soil pH and caused fluctuation in average values of soil pH. The percentage of organic matter in the study varied between 0.55 %-6% (Figure 6), which lies within the normal range of 2-10%. Most of the productive agricultural soils contain 3-6% organic matter. Hence, 50% of the soil samples may be categorized as productive agricultural soils containing 3-6% organic matter (Johnston & Poulton, 2018).

Mapping of well water and soil parameters

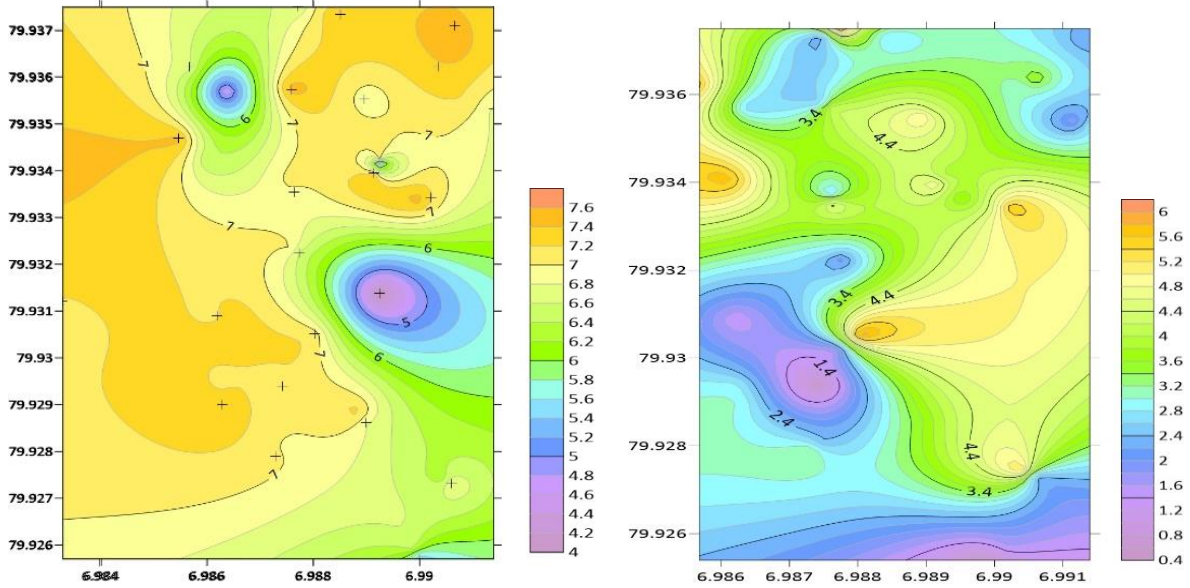


Figure 6: Spatial distribution of pH in the soil in Thalawathuhenpita North (left) and organic (right)

In the present study amount of nitrate varied from 2.66- 132.34 mg/L of nitrate in which the majority of the concentrations were determined to be at the acceptable level (45 mg/L) (Figure 7). Nitrate concentrations may vary from site to site and from time to time. Factors such rate of mineralization to nitrate, and transportation of nitrates may have influenced fluctuations in nitrate levels.

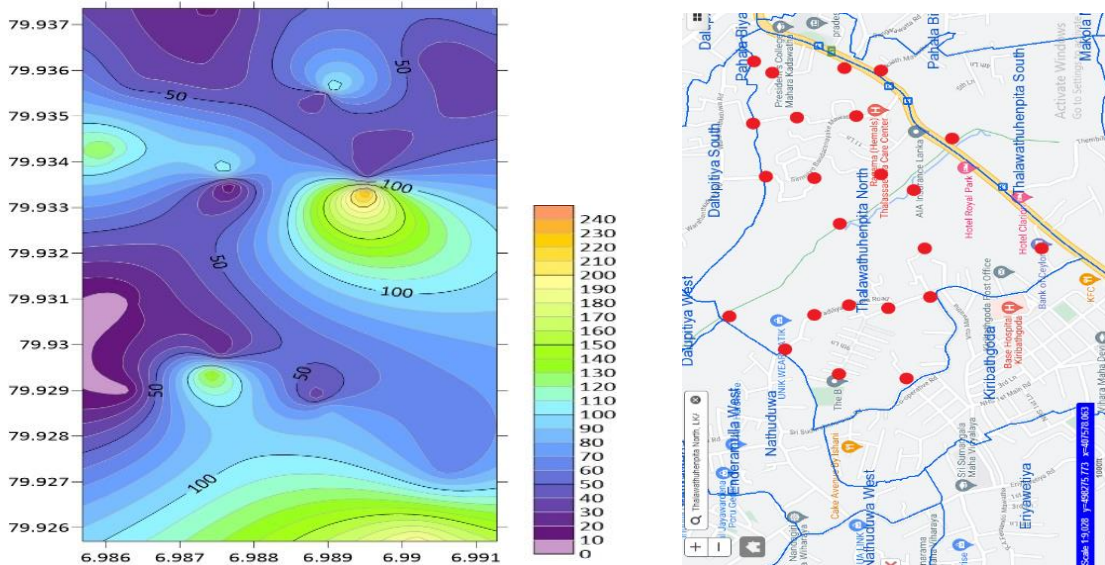


Figure 7: Spatial distribution of nitrate in the soil in Thalawathuhenpita North (left) and reference map (right) ("Grama Niladari Boundary Map of Sri Lanka," n.d.)

According to the results, this area contains water-soluble calcium in the range of 240.00-720.00 mg/L and extractable calcium in the range of 35.00-240.00 mg/L (Figure 8). Calcium levels may be greater as a result of recent limestone applications or due to the parent rocks with high content of Calcium (Sharpley, 1989).

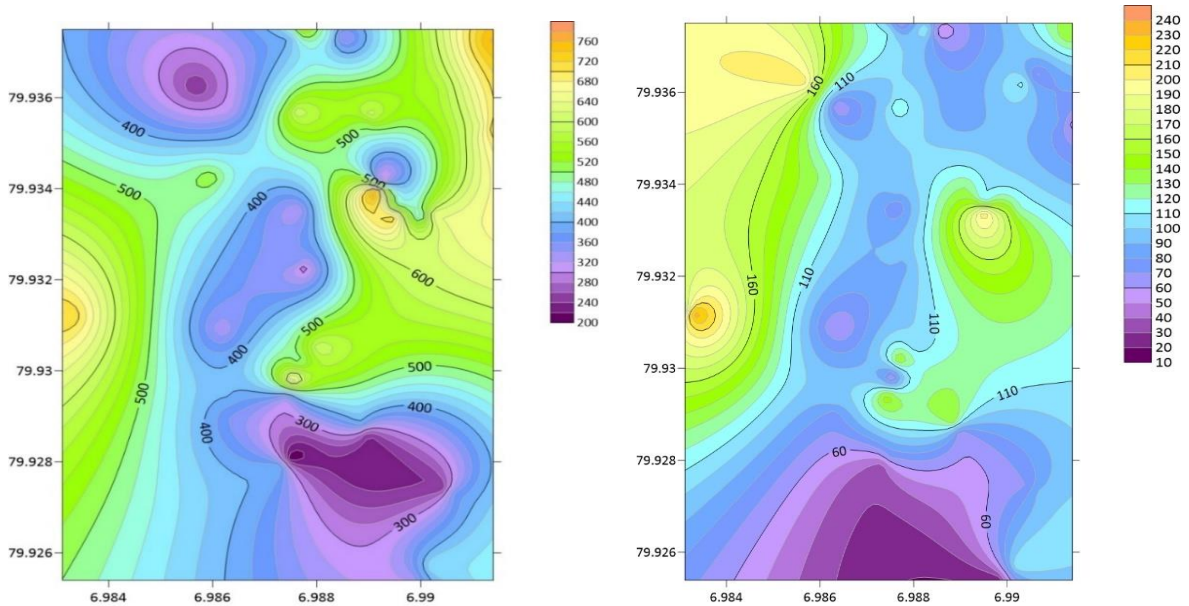


Figure 8: Spatial distribution of water-soluble Calcium content (left) and extractable Calcium content (right) in the soil of Thalawathuhenpita North

According to the results this area contains water-soluble Sodium in a range of 120-440 mg/L and extractable Sodium in the range of 60-110 mg/L (Figure 9). Many minerals contain sodium, which is released when they break down over time. Concentrated runoff of pesticides, fertilizers, and other soil amendments causes the majority of salt pockets in the soil. The high salt content in soils can also be caused by fossil salt discharge (Kronzucker, Coskun, Schulze, Wong, & Britto, 2013).

According to the results, this area contains water-soluble potassium in the range of 40-360 mg/L and extractable potassium 35-240 in the range of mg/L (Figure 10). According to studies the minerals feldspar and mica are the primary suppliers of potassium in soils.

Mapping of well water and soil parameters

According to the results, this area contains water-soluble potassium in the range of 40-360 mg/L and extractable potassium 35-240 in the range of mg/L (Figure 10). According to studies the minerals feldspar and mica are the primary suppliers of potassium in soils.

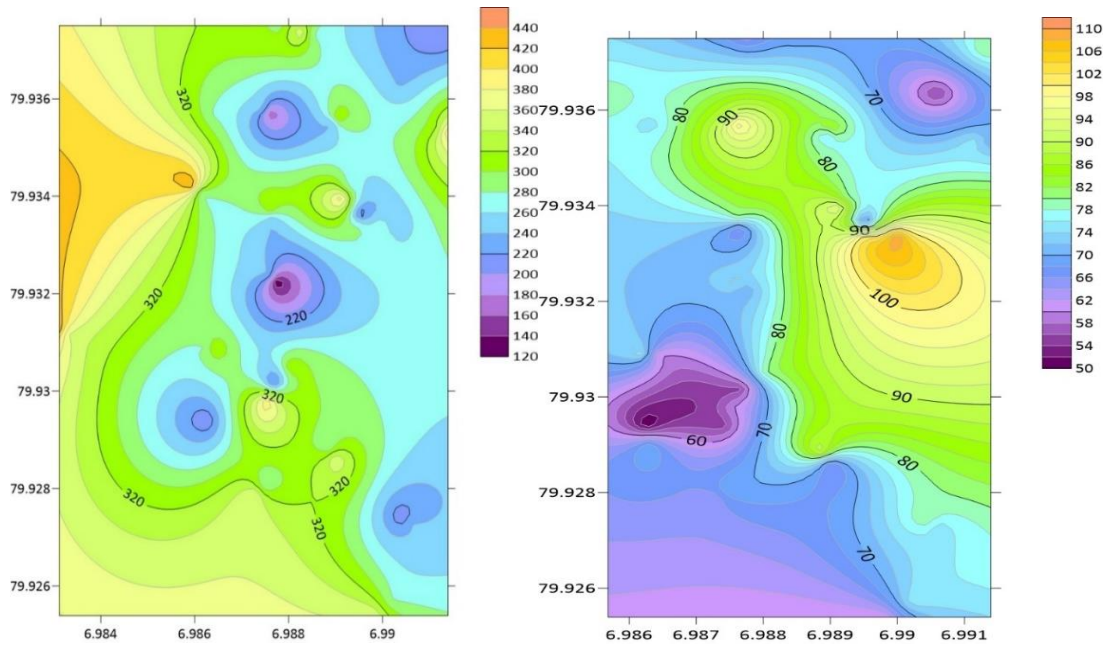


Figure 9: Spatial distribution of water-soluble Sodium content (left) and extractable Sodium content (right) in the soil of Thalawathuhenpita north

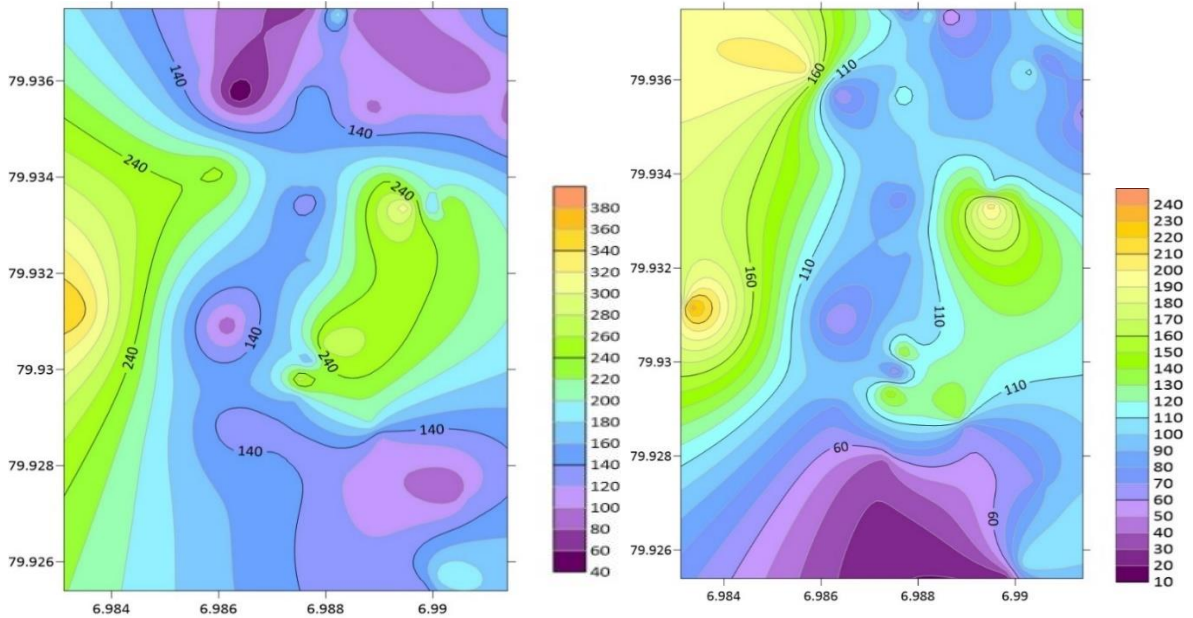


Figure 10: Spatial distribution of water-soluble Potassium content (left) and extractable Potassium content (right) in the soil of Thalawathuhenpita north

Potassium levels will be high in natural soils built over ions from these minerals (Schlegel & Grant, 2015). As Iron was not detected in any of the well water or soil samples, therefore it can be suggested that Iron may not be present in this area or Iron may be present in concentrations lower than 5 mg/L.

CONCLUSION

The study successfully illustrates the possibility of clearly and comprehensively, mapping water and soil parameters in a selected area. The mapping of the entire country on a fixed and regular basis will give environmentalists, scientists and policymakers information about a given environment and thus lead to easy monitoring and policy making of an area.

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