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Effect of Continuous Long-term Tea Cultivation in Water Quality index under Deep, Fine Loamy, Very Deep, Course Loamy and Very Deep, Fine Loamy Well Drained Soil

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Authors' contributions

This work was carried out in collaboration among all authors. Author NB designed the experiment, laboratory analysis and preparation of manuscript. Author BKM designed the experiment and helped in preparation and finalization of the manuscript. Authors JK, PB and BB helped in statistical analysis and preparation of manuscript. All authors read and approved the final manuscript.

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ABSTRACT

For this investigation, three different types of soil were chosen: very deep, coarse loamy, well-drained soil; deep, fine loamy, well-drained soil; and deep, coarse loamy, well-drained soil. Ten water samples were taken from the ring well, ponds, drains, and existing shallow tube wells (hand and mark tube wells) for each category of soil types. The minimal dada set, which include all variables, was chosen on the basis of the significant correlation discovered by correlation analysis. Very deep, coarse loamy, well-drained soil had the lowest water quality index (10.34), whereas very deep, fine loamy, well-drained soil had the highest (15.38).

Keywords: Water quality index; agricultural activity; aquatic biodiversity; urbanization.

1. INTRODUCTION

The impact of agriculture on surface and ground water quality as well as aquatic biodiversity is a growing concern for scientists, consumers, and even the agricultural community (Katak et al., 1994). Tea cultivation is a major agricultural activity in Assam, N.E India that provide livelihood to a large number of people. However, the tea business also uses a lot of pesticides and fertilizers, which end up being washed into streams and other freshwater systems by surface runoff. This harms the aquatic biodiversity and water quality. In Malaysia, it has been discovered that increased agricultural activities, notably the growing of tea, causes nitrates to seep into surface and ground water. In tea gardens, a lot of agrochemicals are used to increase its productivity. Consequently, contamination of the soil and water becomes obvious. Thus, it is crucial to keep an eye on the sources of drinking water in the tea gardens region [1].

One of the best techniques for informing concerned individuals and decision-makers about the condition of the water is the water quality index. The World Health Organization estimates that water is the primary cause of around 80% of human ailments. It is not possible to restore the quality of groundwater once contamination has occurred by removing the pollutants from their source [2-4]. As a result, it becomes crucial to constantly check the quality of groundwater and devise strategies and tactics to safeguard it. Consequently, it turns into a crucial factor in the evaluation and maintenance of groundwater [5]. A grade that reflects the combined influence of several water quality measures is known as the Water Quality Index. It is estimated concerning groundwater's appropriateness for human consumption. By normalizing values to arbitrary rating curves, it is a dimensionless number that integrates several water quality parameters into a single number (Miller et al., 1986). WQI factors are subject to change based on local preferences and the water body's defined usage. Dissolved oxygen (DO), pH, chemical and biological oxygen demands (BOD and COD), temperature, bacteria, and nutrients (nitrogen and phosphorus) are a few of the variables. These parameters have various ranges of measurement and units of expression. These parameters have various ranges of measurement and units of expression. Because of population growth, industrialization, and urbanization, there is an enormous increase in the demand for fresh water, which is measured by the Water Quality Index (WQI), which synthesizes complicated scientific data about these variables into a single number. Additionally, a major issue facing the tea sector is the degradation of water quality brought on by the prudent use of pesticides and agrochemicals in the gardens.

2. MATERIALS AND METHODS

For this investigation, three different types of soil were chosen: very deep, coarse loamy, well-drained soil; deep, fine loamy, well-drained soil; and deep, coarse loamy, well-drained soil. Ten water samples were taken from the ring well, ponds, drains, and existing shallow tube wells (hand and mark tube wells) for each category of soil types. The substantial association found by correlation analysis was used to pick the minimum dada set, which represents all of the variables [6]. For every statistically significant variable, standardized Principal Component Analysis (PCA) was carried out using SPSS-15 software, and component-wise MDS were chosen in the following stage. It was considered that variables with high factor loading and principal components with high eigen values better described the qualities of the system. The principal components that best describe the system were chosen based on the breaking point, which is where the steady reduction in eigen values appears to uniform towards the right part of the graphical principal components. We will only lookat PCs that explained at least 10% of the variation in the data [7] and those with eigenvalues >1 [8] Only highly weighted factors were kept for MDS inside each PC. Absolute values within 10% of the highest factor loading were considered highly weighted factor loadings. Multivariate correlation matrices were also utilized to assess the strength of the correlations between the variables in order to eliminate duplication and rule out erroneous groupings among the highly weighted variables inside PCs. Only one well-correlated variable was taken into account for the MDS since other variables considered superfluous. The remaining ones were removed from the dataset. Each highly weighted variable was considered significant and kept in the MDS if there was no correlation between them. Following the identification of the MDS indicators, a linear scoring approach was applied to each observation of the MDS indicators [6]. The order of the indicators was determined by categorizing a greater value as "good" or "bad" for soil function. Each observation was divided by the greatest observed value for "more is better" indications, resulting in a score of 1 for the highest observed value. In the case of "less is better" indicators, each observation (in the denominator) was divided by the lowest observed value (in the numerator) to give the lowest observed value a score of 1. Following transformation, the PCA findings were used to weight each observation's MDS variables. A specific percentage (%) of the variation in the entire data set was explained by each PC.

$$WQI = \sum_{i=1}^{n} Wi.Si$$

where Wi is the weighted factor obtained from the PCA and Si is the subscripted variable's score. Here, it was assumed that higher index scores corresponded to either improved soil function or better soil quality [9].

3. RESULTS AND DISCUSSION

The correlation matrix among the observed variables was examined in order to evaluate the compatibility of correlation values with the hypothesized factor structure. Four out of the thirteen pairs of water properties for the deep, fine loamy, well-drained soils in the Jorhat district showed significant correlations (P<0.01).There were notable positive associations found for pH and HCO_3^{-}(0.755**), TDC (1.00**), and Ca (0.897**) in EC. Ca showed significant negative correlations with SO_4^{2-} (-0.836**). Using the Cattel scree test, the 13 water quality attributes that were taken into consideration for the principal component analysis were classified into components (Table 1) for the purpose of grouping water quality indicators. The components were plotted as the X-axis and the associated eigen values as the Y-axis (Fig. 1). The first three main components were kept for interpretation since they had eigen values >1 and explained 72.20% of the variance in the whole data set. The six components described more than 90% of the variation in EC, TDS, and Ca; more than 80% in F; more than 70% in pH, Mg, CO_3^{2-}, HCO_3^-, NO_3^-, SO_4^{2-}, and more than 60% in PO_4^{3-}; more than 30% in Cl^-, and more than 10% in As, according to the communities for the soil parameters. 31.76 percent of the variation was explained by the first principal component. It loaded positively for TDS (0.942), Ca (0.967), and EC (0.942). Based on the absolute values within 10% of the highest factor loading, these soil parameters were selected. The second major component demonstrated positive loading for pH (0.813), CO_3^{2-}(0.848), and HCO_3^{-}(0.8850), accounting for 24.81 percent of the variance. The third principal component exhibited a positive loading for F-(0.904) and explained 15.63% of the variance. Just 3 PCs with an eigen value greater than one were identified by a PCA of 13 variables, which accounted for 72.20% of the variance in the total data set. Separate runs of a correlation matrix were conducted for the highly weighted variables under various PCs (Table 2). F-was kept for MDS in PC2, pH, and PC3, while EC and TDS were retained in PC1. Four variables in total—EC, TDS, pH, and F—were selected as MDS. The MDS variables were transformed by using scoring functions. The WQI was calculated by using weighing factors for each scored MDS variable according to the formula:

$$WQI = \Sigma(0.439\ EC + 0.439\ TDS + 0.344\ pH + 0.216\ F^-) = 14.44$$

If all four MDS were considered to be responsible for contributing ideal (100%) water quality index for deep, fine loamy, well drained soil then the relative soil quality explained would be 42.47% for TDS, 23.9% for EC, 22.23% for pH and 11.37% F^- for MWD (Fig. 2).

3.1 Water Quality under Very Deep, Fine Loamy, Well Drained Soils

The correlation matrix among the observed variables was examined in order to evaluate the compatibility of correlation values with the proposed factor structure. Four out of the thirteen pairs of water properties for the deep, fine loamy, well-drained soils in the Jorhat district showed a significant connection (P<0.01). Significant positive correlations were observed for pH with CO_3^{2-} and HCO_3^- (0.0.826** and 0.849**) and EC with TDC (1.00**) and Ca (0.913**) ; CO_3^{2-} with SO_4^{2-} (0.746**).

The 13 water quality attributes taken into account in the main component analysis were divided into components (Table 3) for the purpose of grouping the soil quality indicators. The components were plotted as the X-axis and the associated eigen values as the Y-axis (Fig. 3) using the Cattelscree test. Retaining the first three principal components for interpretation, they accounted for 74.91 percent of the total variance in the entire data set and had eigen values >1. Communalities for the soil properties indicate that the six components explained >90% of the variance in pH, EC, TDS and Ca; >80% in Cl^- and CO_3^{2-} ,>70% in HCO_3^- , PO_4^{3-} , SO_4^{2-} , >60% in As, > 50% in F and NO_3^- and >20% in Mg. The greatest negative loading was observed for pH (-0.815) and HCO_3^- (-0.815). Based on the absolute values within 10% of the highest factor loading, these soil parameters were chosen. Positive loading for SO_4^{2-}(0.779), As (0.756), and 18.48 percent of the variation was explained by the second principal component. The third principal component had a positive loading for HCO_3^-(0.656) and explained 14.99% of the variation. Only three PCs with eigen values > 1 were retrieved by a PCA of 23 variables, which accounted for 74.19 percent of the variance in the total data set. A correlation matrix for the highly weighted variables under different PCs was run separately (Table 3). In PC1, Ca; in PC2, pH and SO_4^{2-}; in PC3, HCO_3^- were chosen as MDS. The MDS variables were transformed by using scoring functions. The WQI was calculated by using weighing factors for each scored MDS variable according to the formula:

$$WQI = \Sigma(0.437\ Ca + 0.372\ pH + 0.372\ SO_4^{2-} + 0.192\ HCO_3^-) = 10.34$$

If all four MDS were considered to be responsible for contributing ideal (100%) water quality index for continuous tea cultivation, then the relative water quality explained would be 32.94% for pH, 28.22% for Ca, 23.47% for SO_4^{2-} and 15.35% for HCO_3^- for MWD (Fig. 6).

Table 1. Rotated Component loadings and communalities of water properties in deep, fine loamy, well drained soil of Jorhat district, Assam

Water properties	Component			Communalities
	PC1	PC2	PC3	
pH	0.100	0.813	-0.270	0.744
EC	0.942	0.178	0.114	0.932
TDS	0.942	0.178	0.114	0.932
Ca	0.967	-0.047	-0.054	0.939
Mg	0.733	-0.376	-0.345	0.798
F^-	0.049	0.068	0.904	0.824
Cl^-	-0.267	-0.371	-0.396	0.366
CO_3^{2-}	-0.024	*0.848*	0.193	0.757
HCO_3^-	0.022	*0.850*	0.109	0.734
PO_4^{3-}	0.230	-0.264	0.708	0.624
NO_3^-	-0.072	-0.740	0.459	0.764
SO_4^{2-}	-0.779	0.339	0.255	0.787
As	0.365	0.202	0.108	0.186
Eigan values	4.130	3.225	2.032	Total
% variance	31.76	24.81	15.63	72.20

Table 2. Correlation matrix for highly weighted variables of water analysis under PC's with deep, fine loamy, well drained soil of Jorhat district, Assam

PC1	EC	TDS	Ca
EC	1	1.000**	0.897**
TDS	1.000**	1	0.897**
Ca	0.897**	0.897**	1
Correlation sum	2.897	2.897	2.794
PC2	pH	CO32-	HCO3-
pH	1	0.516	0.755**
CO_3^{2-}	0.516	1	0.585*
HCO_3^-	0.755**	0.585*	1
Correlation sum	2.271	2.101	2.24
PC3	F		
F-	1		

***Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level*

Table 3. Rotated component loadings and communalities of water properties in very deep, fine loamy, well drained soil of Jorhat district, Assam

Soil properties	Component			Communalities
	PC1	PC2	PC3	
pH	-0.815	0.066	0.484	0.902
EC	0.874	-0.019	0.382	0.910
TDS	0.874	-0.019	0.383	0.910
Ca	0.848	0.109	0.429	0.915
Mg	0.239	-0.462	0.146	0.292
F-	-0.507	-0.314	-0.485	0.590
Cl-	0.877	0.321	-0.145	0.894
CO_3^{2-}	-0.815	0.312	0.226	0.813
HCO_3^-	-0.694	0.070	-0.656	0.791
PO_4^{3-}	0.289	0.464	0.552	0.730
NO_3^-	0.152	0.688	0.251	0.559
SO_4^{2-}	-0.373	0.779	0.175	0.776
As	0.026	0.756	-0.285	0.654
Eigan values	5.387	2.402	1.950	Total
% variance	41.44	18.48	14.99	74.91

Table 4. Correlation matrix for highly weighted variables of water analysis under PC's with very deep, fine loamy, well drained soil of Jorhat district, Assam

PC1	Cl^-	CO_3^{2-}	Ca	TDS	EC	pH
Cl-	1	-0.643*	0.712*	0.664*	0.664*	-0.690*
CO_3^{2-}	-0.643*	1	-0.596*	-0.553*	-0.553*	0.826**
Ca	0.712*	-0.596*	1	0.913**	0.913**	-0.467
TDS	0.664*	-0.553*	0.913**	1	1.000**	-0.542
EC	0.664*	-0.553*	0.913**	1.000**	1	-0.542
pH	-0.690*	0.826**	-0.467	-0.542	-0.542	1
Correlation sum	1.707	-0.519	2.475	2.482	2.482	-0.415
PC2	SO42-	As				
SO_4^{2-}	1	0.327				
PC3	HCO_3^-					
HCO_3^-	1					

***Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level*

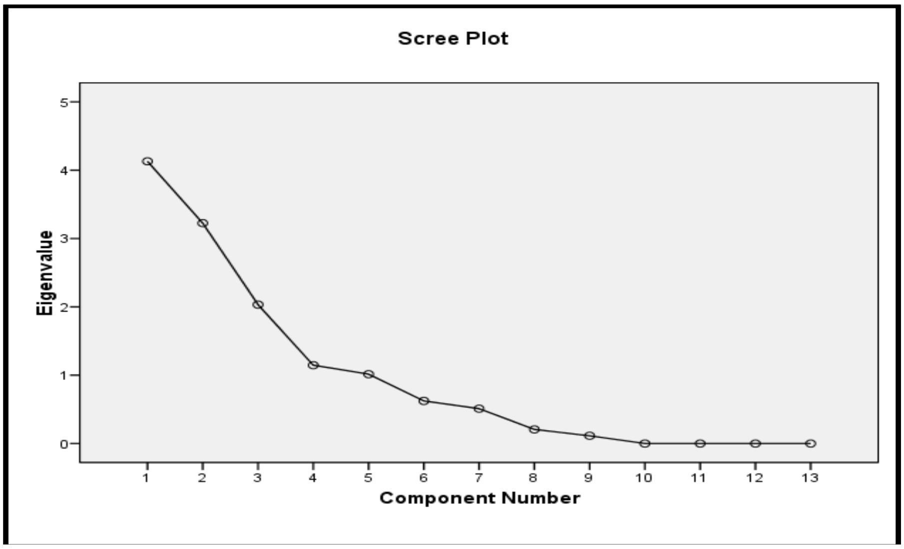

Fig. 1. Scree plot for selecting principal components under deep, fine loamy, well drained soil

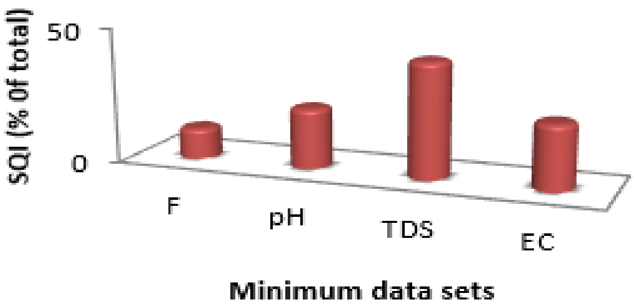

Fig. 2. WQI under deep, fine loamy, well drained soil

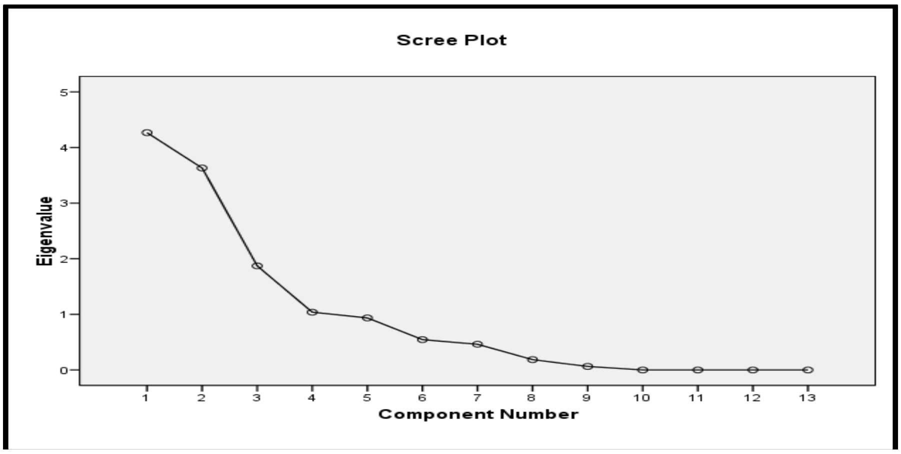

Fig. 3. Scree plot for selecting principal components under very deep, fine loamy, well drained soil

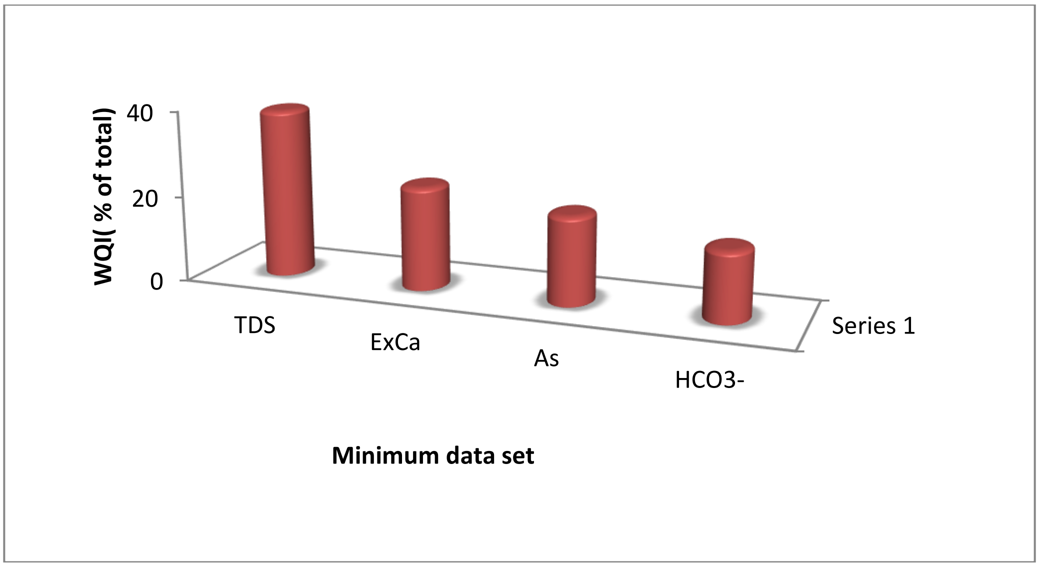

Fig. 4. WQI under very deep, fine loamy, well drained soil

Table 5. Rotated component loadings and communalities of water properties in very deep, coarse loamy, well drained soil of Jorhat district, Assam

Soil properties	Component			Communalities
	PC1	PC2	PC3	
pH	-0.431	*0.674*	0.412	0.809
EC	0.776	0.392	0.421	0.934
TDS	0.776	0.392	0.421	0.934
Ca	*0.939*	0.059	0.209	0.930
Mg	0.521	0.347	*-0.724*	0.917
F^-	0.068	0.529	-0.426	0.466
Cl^-	0.171	*-0.683*	-0.003	0.496
CO_3^2	-0.686	0.522	0.096	0.753
HCO_3^-	-0.594	0.546	*0.656*	0.938
PO_4^{3-}	-0.191	-0.422	0.412	0.881
NO_3^-	0.718	-0.034	0.052	0.519
SO_4^{2-}	0.412	*0.679*	0.063	0.634
As	0.379	-0.539	0.353	0.559
Eigan values	4.267	3.631	1.871	Total
% variance	32.82	27.93	14.39	75.15

Table 6. Correlation matrix for highly weighted variables for water analysis under PC's with very deep, course loamy, well drained soil of Jorhat district, Assam

PC1	Ca		
Ca	1		
PC2	pH	Cl^-	SO_4^{2-}
pH	1	-0.690*	0.410
Cl^-	-0.690*	1	-0.143
SO_4^{2-}	0.410	-0.143	1
Correlation sum	0.72	0.167	1.267
PC3	Mg	HCO_3^-	
Mg	1	-0.109	
HCO_3^-	-0.109	1	

***Correlation is significant at the 0.01 level, *Correlation is significant at the 0.05 level*

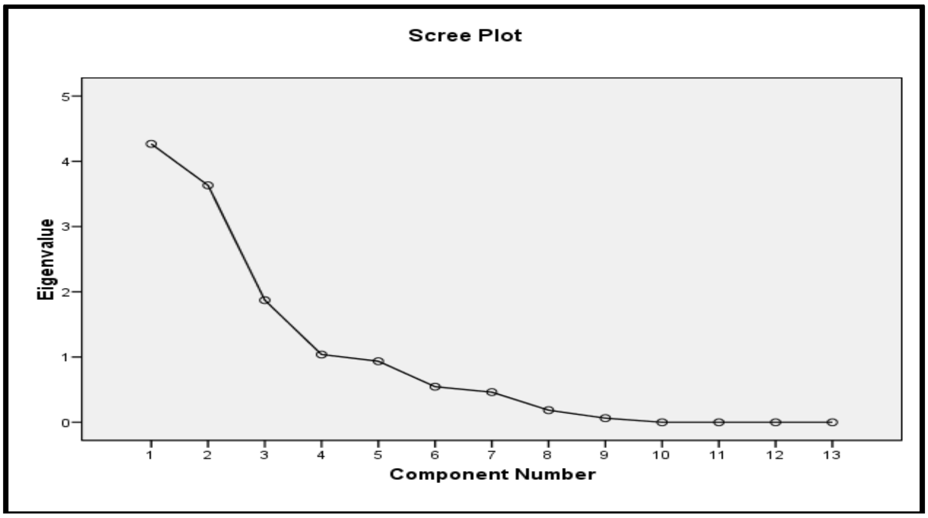

Fig. 5. scree plot for selecting principal components under deep, coarse loamy, well drained soil

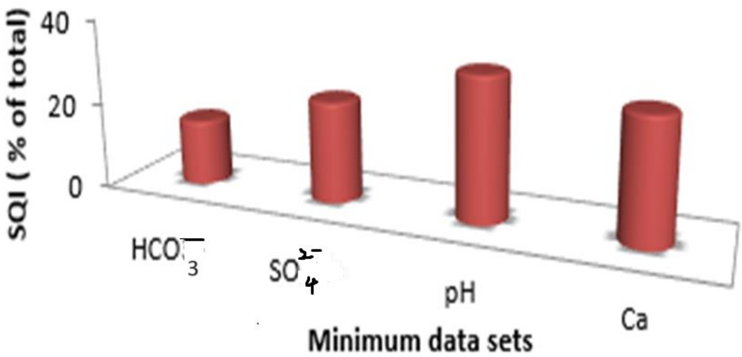

Fig. 6. WQI under deep, coarse loamy, well drained soil

3.2 Water Quality under Very Deep, Coarse Loamy, Well Drained Soils

The correlation matrix among the observed variables was examined in order to evaluate the consistency of correlation values with the proposed factor structure. Four out of the thirteen pairs of water properties for the very deep, coarse loamy, well-drained soils in the Jorhat district showed a significant connection (P<0.01). pH and CO_3^{2-} and HCO_3^- (0.781** and 0.786**), EC and TDC (1.00**) and Ca (0.876**), and TDS and Ca (0.876) showed significant positive correlation. Mg and PO_4^{3-} showed significant negative correlations (-0.732**).

3.3 Grouping of Water Quality Indicators

Using the Cattelscree test, the 13 water quality parameters taken into account for the Principal component analysis were divided into components (Table 5). The components were plotted as the X-axis and the associated eigen values as the Y-axis (Fig. 5). The first three main components were kept for interpretation since they had eigen values greater than 1 and explained 75.15% of the variance in the whole data set. The six components accounted for over 90% of the variation in EC, TDS, Ca, Mg, and HCO_3^-; >80% in pH and PO_4^{3-}; >70% in CO_3^{2-}; >60% in SO_4^{2-}; >50% in NO_3^-, As; and >40% in F and Cl^-, according to the communities for the soil parameters. 32.82 percent of the variation was explained by the first principal component. For Ca, it demonstrated positive loading (0.939). Based on the absolute values within 10% of the highest factor loading, these soil parameters were chosen. The second principal component, which showed positive loading for SO_4^{2-}(0.679) and pH (0.674), explained 27.93 percent of the variation. The third main component, which had the maximum negative loading (-0.724) for magnesium and a positive loading (0.656) for HCO^{3-}, explained 14.39% of the variation. Only three PCs with eigen values > 1 were retrieved using a PCA of 23 variables, which accounted for 75.15% of the variance in the total data set. Separate runs of a correlation matrix under various PC settings were conducted for the highly weighted variables (Table 6). In PC1, Ca; in PC2, pH and SO_4^{2-}; in PC3, HCO_3^- were chosen as MDS. The MDS variables were transformed by using scoring functions. The WQI was calculated by using weighing factors for each scored MDS variable according to the formula:

$$WQI = \Sigma(0.437\ Ca + 0.372\ pH + 0.372\ SO_4^{2-} + 0.192\ HCO_3^-) = 10.34$$

If all four MDS were considered to be responsible for contributing ideal (100%) water quality index for continuous tea cultivation, then the relative water quality explained would be 32.94% for pH, 28.22% for Ca, 23.47% for SO_4^{2-} and 15.35% for HCO_3^- for MWD (Fig. 6).

4. DISCUSSION

In deep, fine-loamy, well-drained soil, the water quality index was found to be 14.44. Since there is a strong correlation between Ca and EC, EC and TDS were kept for MDS in PC1, while Ca was removed. Because CO_3^{2-} and HCO_3^- were linked with pH, they were removed from MDS in PC2, while pH was kept in place. F- was kept for PC3 in the MDS. Ultimately, for MDS, four variables EC, TDS, pH, and F—were kept. We can conclude that TDS is the primary indicator of water quality if all four MDS are thought to be important for contributing to the ideal (100%) water quality index. The leaching of ions from agricultural fields and the soils and rocks of tea gardens could be the cause of the high TDS value. TDS shows how salinity behaves in water. According to Dutta et al. [10], it is typically the primary component that restricts or determines the use of ground water for any purpose. According to Dutta et al. [10], in small tea estates in the Sonitpur district, almost 13% of the water samples had TDS levels over the allowable limit of 500 ppm.TDS content is usually the main factor, which limits or determines the use of ground water for any purpose. Dutta et al. [10,11] found that more than 13 per cent of the water samples were exhibited TDS values outside the permissible limit 500 ppm in small tea gardens of Sonitpur district. In PC1, Ca was retained for MDS. In PC2, pH and SO_4^{2-} were retained and Cl- was dropped from MDS as it showed the lowest correlation sum In PC3, HCO_3^-. Finally, Ca, pH, SO_4^{2-} and HCO_3^{2-} were retained for MDS. Finally four parameters viz., Ca^{2+}, pH, SO_4^{2-} were retained for MDS. The water quality index in deep, fine loamy, well drained soil was found to be 10.34. If all four MDS were considered to be responsible for contributing ideal (100%) water quality index, the we could conclude that pH was the key indicator of water quality. The guideline value of pH in drinking water set by WHO (World Health Organistion) is 6.5 to 8.5. Dutta *et al.,* 2013 reported that pH was an important factor of of water quality in the tea growing areas of Sonitpur district, Assam.

5. CONCLUSION

The long-term, continuous cultivation of tea has a considerable impact on water quality index. As tea growing practices change, it is imperative to monitor and manage any potential effects on water quality issues, such as fertilizer runoff, pesticide residues, and soil erosion. In tea-growing locations, implementing sustainable farming practices can assist in maintaining water quality with routine monitoring and mitigation actions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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