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Assessment of Groundwater Suitability for Irrigation in Dadin-Kowa, Yamaltu Deba LGA, Gombe State, Nigeria

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ABSTRACT

In semi-arid regions, the quality of irrigation water and soil salinity were the main factors limiting agricultural yield in irrigation schemes. The increasing salinity of groundwater used in hot, dry regions with limited rainfall limits the variety of crops that can be produced. Therefore, it is crucial to ascertain the quality of the irrigation water. This study examined the physicochemical composition of the groundwater at the Dadin-kowa irrigation site and determined if it was suitable for irrigation. Using 1.5 liter sterilized bottles, four (4) water samples were taken from boreholes. The samples were then tested using conventional protocols for key physicochemical quality parameters, such as pH, ECw, TDS, Ca++, Mg++, Na+, HCO-3, CI-, SO-4, NO3-, K+, SAR, and SSP. The Food and Agriculture Organization (FAO) standard recommendations were followed in the quality evaluation of each parameter of the water samples for irrigation suitability. The findings of the study revealed that most of the tested parameters, including CI-(385.8 ± 104.3 mg/l), K+(5.5 ± 2.9 mg/l), Na+(70.2 ± 26.8 mg/l), Mg++(24.2 ± 5.05 mg/l), Ca++(32.0 ± 2.83 mg/l), and Na+(70.2 ± 26.8 mg/l) were found to be higher than the FAO threshold level for irrigation. This led to the conclusion that there are now a lot of risks connected to using groundwater for irrigation in the research region. Therefore, stress the necessity of using the area's water quality as a reference for suitable management methods in irrigated agriculture in order to preserve the soil's current productivity and reap the benefits of a high crop yield.

Keywords: Dadin-Kowa, FAO Standard, Groundwater, Irrigation, Quality, Suitability.

INTRODUCTION

Irrigation refers to the artificial application of water to land to assist in the growing of crops and pastures or to maintain vegetation growth (Sule, Musa, & Maina, 2017). Water is the most fundamental and important necessity for human survival, making it one of the most desired urban and rural utilities (Gupta & Gupta, 2021). Water exists substantially either as surface or groundwater. Groundwater is defined as water present in every pore inside a geologic layer (Sule, Abashiya, & Musa, 2019). Groundwater is crucial for the survival of all living things on Earth (Bari *et al.,* 2021). It is a major source of water for a variety of uses (Jamshidzadeh, 2020), such as industrial, domestic, and irrigation water supply (Oinam *et al.,* 2012). Due to its perceived superiority over surface water for irrigation, it makes up 43% of the world's irrigation water use (Adagba, Kankara, & Idris, 2022). Groundwater contains some level of dissolved minerals (Mirabbasi *et al.,* 2008). These dissolved minerals split into ions, which are known as cations and anions, respectively. The ions are positively and negatively charged (Rubini *et al.,* 2020). This describes the chemical composition of a water source. According to Okunlola & Afolabi (2015), a water source's chemical composition influences its quality and, consequently, its suitability for various uses (Nagaraju *et al.,* 2016).

According to Eldaw, Huang, Mohamed, & Mahama (2021), toxicity, infiltration, and salinity are the main issues with irrigation water quality. The primary sources of these problems include major cations, water anions, and total dissolved solids (Tiwari *et al.,* 2017). Salinity problem arises when there is an accumulation of salt in the root zone of the plant, which reduces productivity (Hao *et al.*, 2017; Merouche *et al.,* 2020). According to Mostafazadeh-Fard *et al.* (2008), the infiltration problem arises when water either remains on the soil's surface or infiltrates the root zone at a rate that is not high enough to sustain acceptable yields. When specific ions, such as sodium, chloride, or boron, are absorbed by crops and build up to high quantities that inhibit plant growth and, as a result, lower yields, toxicity issues arise (Singh et al. 2018). Among the various issues are those pertaining to irrigation water quality, which reoccur and ultimately lead to a reduction in the rate of water infiltration (Sule, Abashiya, & Musa, 2021). However, issues related to irrigation water quality are quite complicated, and multiple issues can have a greater detrimental effect on the crop than one issue alone. In order to address this problem, there is a need to find out the quality of water used for irrigation, as that will serve as a guide in monitoring, planning, and maintaining water resources (Bauder *et al.,* 2011).

Since the kind of dissolved salts that are present in the groundwater supply mostly determine the quality of the groundwater (Okunlola & Afolabi, 2015). According to Fallatah & Khattab (2023), when evaluating groundwater quality for irrigation, there are a few fundamental standards to follow. For instance, estimates of the sodium-adsorption ratio (SAR), which measures the relative proportion of Na^+ to Ca^{2+} and Mg^{2+} ions, are used to address the salinity hazard; estimates of the residual sodium carbonates (RSC), which account for the HCO_3^- and CO_3^{2-} anions and Ca^{2+} and Mg^{2+} cations in irrigation water, are used to address the alkalinity (ALK) hazard (Fallatah & Khattab, 2023). In light of the aforementioned, the purpose of this study is to evaluate the study area's groundwater suitability for irrigation. The parameters used were Acid/Basicity (pH), Calcium (Ca^{++}), Magnesium (Mg^{++}), Sodium (Na^+), Bicarbonate (HCO^-_3), Chloride (Cl^-), Sulphate (SO^-_4), Nitrate–Nitrogen (NO_3^-), Potassium (K^+), Electrical conductivity (EC_w), Total Dissolved solids (TDS), Sodium Adsorption Ratio (SAR), and Soluble Sodium Percentage (SSP). This will offer the essential water quality knowledge needed to use the appropriate irrigation management techniques for sustainable agriculture.

STUDY AREA

Yamaltu-Deba Local Government Area is located on latitudes 10^0 00’ to 10^0 30’ N and longitudes 11^0 15’ to 11^0 45’ E. It covers an area of 1,981km^2 and has the population of 255,726 according to population census 2006 (NPC, 2006). The irrigated area is located at Dadin-Kowa, Yamaltu-Deba LGA, Gombe State. It lies between latitude 10° 10' 0 " to 10° 25' 0 " N and longitudes 11° 11' 26" to 11° 40' 0” E. (Fig. 1). The climate of the area is characterized by two distinct seasons (Dry and wet seasons), with an average annual rainfall of 850mm (Wanah & Mbaya, 2012). Temperature is between 35 – 40°C in the month of March and April, while minimum temperature is recorded during the harmattan period (Baminda & Dabi, 2011). The vegetation is characterized by scattered shrubs and thorn bushes which fall within the open Sudan savannah vegetation zone of Nigeria (Mbaya, 2016). Gombe formation is the main outcrop in the study area and its hydrology consists of numerous seasonal streams, however, there is a perennial river known as

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Gongola which has been dammed at Dadin-kowa and was use for irrigating over a total of about 20,000 hectares of land.

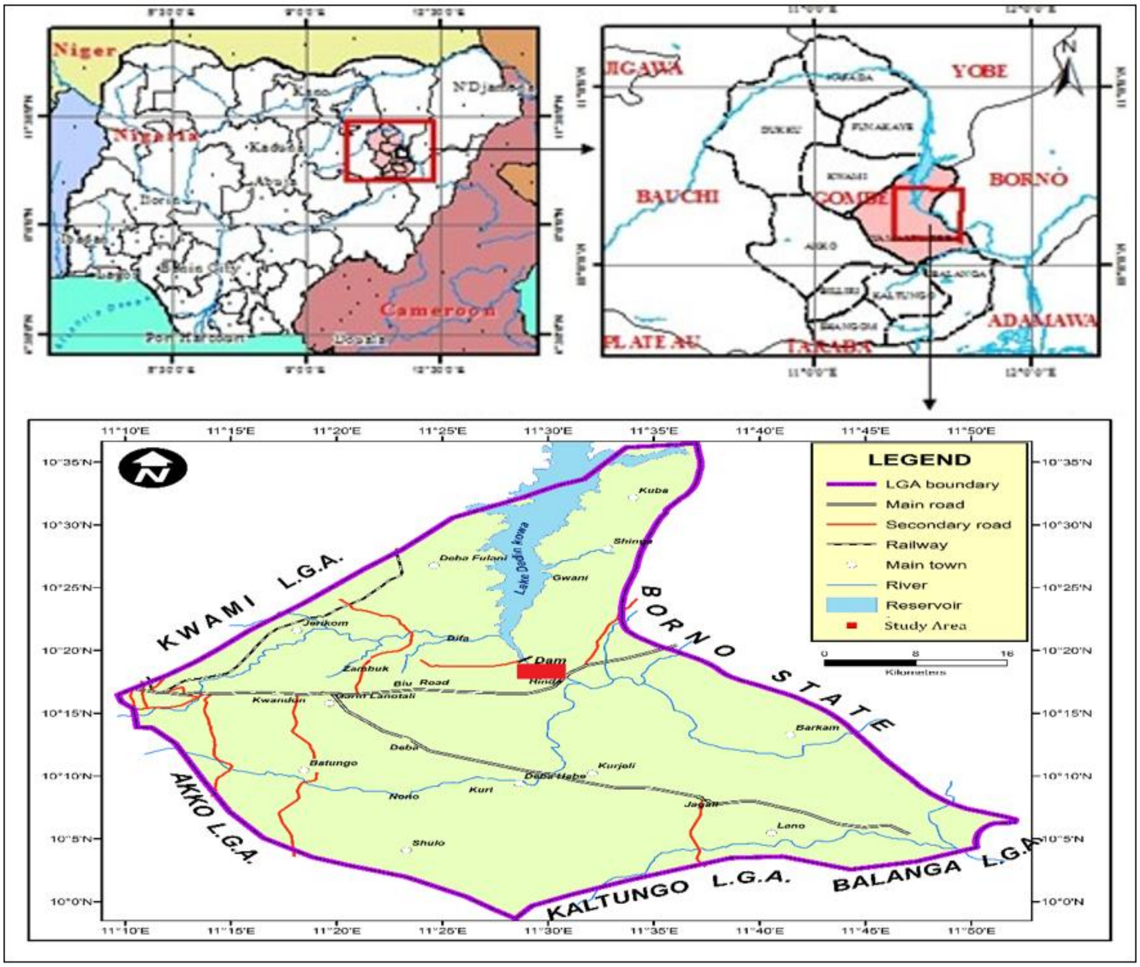

Figure 1. Map of study area.

Source: Authors' GIS Analysis, 2023

MATERIAL AND METHOD

Water samples were collected from four (4) different boreholes in the irrigated site using standard procedures from the field (two samples from each side of the road). The samples were collected in 1.5 liters sterilized bottles and were sealed and stored in a low temperature and transported to the Federal Ministry of Water Resources Department of Water Quality and Sanitation for laboratory analysis using the following instruments and methods: EC and pH measurements were made using EC and pH Meters which were calibrated prior to taking readings. Calcicol and Magnicol test methods were used to determine Ca^{++} and Mg^{++} respectively. A flame photometric method was used to determine Na^+ and K^+. Cl^- was analyzed using argentometric titration method. HCO^-_3 was measured by calculation from titration method of alkalinity determination using 0.01M HCl, Phenophtherlien and methyl orange indicators. While $NO3^-$ was measured by colorimetric method.

The results obtained from the laboratory water quality analysis were statistically analyzed

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using descriptive statistics such as relative frequencies, mean and standard deviation. While the non-parametric ANOVA was applied to examine whether the water quality from the several boreholes utilized for irrigation in the research area differed significantly from one another. 0.05 significant threshold was used to test the outcome.

RESULTS AND DISCUSSION

Table 1 displayed the analytical findings for the quality parameters of the irrigation water samples from Dadin-kowa irrigation site as well as the FAO standards for interpreting the water quality for irrigation.

Table 1: Quality parameters of the irrigation water samples and FAO Standard

Water parameter	Symbol	Unit	Point A	Point B	Point C	Point D	Min	Max	Mean	Std. Dev	FAO
Acid/Basicity	pH	1-14	6.33	6.18	6.25	5.75	5.75	6.33	6.12	0.25	6.0-8.5
Electrical conductivity	EC_W	dS/m	1.10	0.84	1.25	1.05	0.84	1.25	1.06	0.17	0-3
Total Dissolved solids	TDS	mg/1	356	268	403	339	268.00	403.00	341.50	55.97	0-2000
Calcium	CA^{++}	mg/1	31	29	35	33	29.00	35.00	32.0	2.83	0 – 20
Nitrate	NO_3^-	mg/1	1.96	0.94	2.80	2.08	0.94	2.80	1.94	0.76	0-10
Sulphate	$SO\text{-}_4$	mg/1	0.94	3.46	5.01	2.13	0.94	5.01	2.88	1.75	0-20
Chloride	CI^-	mg/1	371.88	243.92	455.85	471.85	243.92	471.85	385.88	104.30	0-30
Sodium	Na^+	mg/1	96.93	40.48	87.06	56.37	40.48	96.93	70.21	26.28	0-40
Potassium	K^+	mg/1	9.9	4.6	3.73	3.64	3.64	9.90	5.46	2.98	0-2
Magnesium	Mg^{++}	mg/1	23	30	26	18	18.00	30.00	24.25	5.06	0-5
Bicarbonate	HCO^-_3	mg/1	46	108	96	222	46.00	222.00	118.00	74.35	0-10

Source: Field Survey, Laboratory Analysis (2023) and FAO (2005)

The quality of water sampled from four different locations within the Dadin-kowa irrigation site was examined, and to test the hypothesis that "the quality of irrigated water sample from different boreholes in the study area does not varies," the laboratory analysis of the irrigation water results were statistically analyzed using one way analysis of variance (ANOVA) (table 2).

Table 2: ANOVA for association between parameters of Boreholes water

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2123547.727	13	163349.825	64.784	.000
Within Groups	105901.394	42	2521.462		
Total	2229449.121	55			

Source: Authors' Analysis, 2023

As the ANOVA test result in Table 2 indicates that the P value is 0.00 and is less than the alpha level 0.05, we accept the null hypothesis, which states that there are no variations in the water quality from the several boreholes used for irrigation at the Dadin-kowa irrigation site.

Parameters' relationship with FAO standards

The sample's pH indicates how acidic (or alkaline) it is. A pH of 7.0 or above is alkaline, whereas 7.0 or less is acidic. According to Mukiza *et al.* (2021), the pH of the soil and water cannot adversely affect plant growth. However, the effectiveness of the coagulation and flocculation processes is significantly impacted by pH (Hossain & Patra, 2021). Water utilized in the irrigation system at Dadin-kowa ranged in pH from 5.75 to 6.18, with a mean and standard deviation of 6.12 ± 0.25. The minimum and maximum values measured fell within the acceptable FAO permitted limits for irrigation water (6.0 - 8.5),

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which meant they couldn't potentially harm the nearby crops. However, the appropriate balance of main nutrients and trace elements available for plant uptake may be impacted by the minimum pH of 5.75, which is slightly acidic. Reducing the use of chemical fertilizer can solve low pH issues (Merouche *et al.*, 2020).

The ability of water to transfer electric current is referred to as electrical conductivity (ECw). According to Bryan, Chase & Schulte (2019), it is an effective estimator of the total amounts of mineral salts dissolved in water. High EC water indicates a high ion concentration in the water, which also has an impact on plant growth. The total electrical conductivity of the water sampled from the boreholes at the Dadin-kowa irrigation site ranged from 0.84 to 1.25 ds/m, with a mean and standard deviation of 1.06 ± 0.17. The FAO allowed limits of 0 to 3 ds/m were met by the minimum and maximum values of EC measured, which means no crops in the area are in danger.

Total Dissolved Solid (TDS) is a measure of the salinity behavior of water. TDS alters the appearance and characteristics of water, aids in the reduction of photosynthesis, combines with heavy metals and hazardous substances, and raises water temperature (Nematollahi *et al.,* 2016). Even if the soil is sufficiently moist, plants can wilt because their roots are not absorbing enough water relative to the water lost through transpiration. To avoid issues with plugs and other plant-growing conditions, TDS levels should be below 640 mg/L and 960 mg/L, respectively (Swistock, 2016). The computed TDS levels in all of the borehole water samples taken at the irrigation site ranged from 268 to 403 Mg/L, falling within the FAO's allowed range of 0 to 2000 Mg/L as well as below the 640 mg/L thus, plugs and other plant-growing conditions at the site are not problematic for crops output.

In most natural waters, calcium (Ca^{++}) can be found. Soils are friable and typically allow for easy water drainage when they are sufficiently supplied with exchangeable calcium. Ca^{++} concentrations were varyingly higher in all the boreholes water samples in Dadin-kowa irrigation site. The irrigation site's Ca^{++} concentrations, which had a minimum and maximum range of 29 to 35 Mg/L-1 with a mean and standard deviation of 32.0 ± 2.83 Mg/L-1, respectively, were beyond the permissible FAO limits of 0 to 20 Mg/L-1 and may pose a threat to the area's capacity to grow veggies. However, it has been demonstrated that raising the calcium content of potatoes, onions, apples, and pears improves crop quality, lessens the effects of environmental stress and plant disease, and prevents the development of sick tissue during storage (Egbueri *et al.,* 2021).

Magnesium (Mg^{++}) can be used in conjunction with calcium to determine the link between total salinity and sodium danger. The term "water hardness" refers to the combined calcium and magnesium contents. The Mg^{++} content found in the water samples taken from the irrigation site's boreholes ranged from 18 to 30 Mg/L. The average levels measured were 24.25 ± 5.06 Mg/L, which were deemed to be beyond the FAO's permissible threshold of 0 to 5 Mg/L and could limit vegetable production due to the site's increased pH and nutrient deficiency. High quantities of magnesium can also create scale, which may need to be softened (Bryan, Chase & Schulte, 2019).

Sodium (Na+) is highly soluble and is frequently found in natural fluids. Sodium problems are frequently linked to chloride (Cl) and sulphate (SO4) issues. Because sodium has an adverse effect on soil, it is especially dangerous for irrigation water to contain high levels of Na^{+}. The range of Na+ concentrations found in the borehole water sources at the Dadin-kowa irrigation site was 40.48 to 96.93 Mg/L. The average Na^+ concentration in the area was 70.21 ± 26.28 Mg/L, which is higher than the FAO's permitted range of 0 to 40 Mg/L and may present a sodium hazard.

Nitrate (NO_3^-) levels in water sampled from boreholes in Dadin-kowa irrigation site were range between 0.94 to 2.80 Mg/L with the mean concentration of 1.04 ± 0.76 Mg/L and was within the acceptable threshold of the FAO 0 – 10 Mg/L and pose no threat to the vegetable production in the area. The Sulphate (SO^-_4) concentrations recorded were range between 0.94 to 5.01 Mg/L with the mean value of 2.88 ± 1.76 Mg/L and were within the acceptable threshold of the FAO 0 – 20 Mg/L and pose no threat to the vegetable production in the site.

Chloride (Cl^-) is an anion that is frequently present in irrigation water. The total salt (salinity) concentration of soils is influenced by chlorides, in tiny amounts, essential for plant growth; in high doses, poisonous to certain plants or inhibiting plant growth. The water from the boreholes had Cl^- values ranging from 243.92 to 471.85 mg/L, with a mean and standard deviation of 385.88 ± 104.30 mg/L. These concentrations were higher than the FAO allowed threshold. Excess chloride content can increase the TDS in water which is easily absorbed by the plants and accumulated in plant tissue and changes the osmotic pressure of the cell sap resulting in decrease in uptake of essential nutrients from the soils (Mukherjee, Das, & Ghosh, 2022).

Potassium (K^+) cations are typically found in trace concentrations in natural streams and exhibit similar soil behavior to salt. The water sampled from boreholes at the Dadin-kowa irrigation site had minimum and maximum levels of K^+ ranging from 3.64 to 9.90 mg/L. The mean and standard deviation of the sample were 5.46 ± 5.06 mg/L, which is higher than the FAO's acceptable limits of 0 to 2 mg/l. This could potentially be dangerous for crop productivity in the designated area. However, high potassium levels, according to Bryan, Chase & Schulte (2019), typically don't harm plant growth, but they can be a sign of water contamination from fertilizers or other artificial sources.

Bicarbonate (HCO^-_3) levels in deep aquifer water are frequently high. In areas that are irrigated, bicarbonates can build up. Elevated bicarbonate concentrations cause calcium to be drawn out of solution and lessen its availability at soil exchange sites. The minimum and maximum HCO^-_3 values observed were 46.00 and 222.00, respectively. The mean HCO^-_3 concentration measured in borehole water samples taken from the Dadin-kowa irrigation site was 118.00 ± 74.38 Mg/L, higher above the FAO's allowable limit of 0 to 10 Mg/L. Consequently, it might lead to a sodium-dominant soil, which would decrease soil gas exchange and water infiltration rates. Additionally, it frequently causes problems since it can raise the pH of the growth environment, which can result in a variety of nutrient issues such an imbalance in calcium and magnesium and an iron and manganese deficit (Bryan, Chase & Schulte, 2019).

Sodium Adsorption Ratio (SAR):

The sodium adsorption ratio, also known as SAR, is a common unit of measurement for sodium hazard. It gauges how much sodium, calcium, and magnesium are present in the water. The SAR measures the risk of salt permeability as water permeates the soil. The biggest issue with high sodium levels is their impact on the physical characteristics of soil. SAR is determined using the formula:

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$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \text{…………………………..(1)}$$

According to the FAO (2013), water with a SAR of 10 or less is of exceptional quality, 10 to 18 is of good quality, 18 to 26 is of medium quality, and water with a SAR of 26 or more is of poor quality and consequently not appropriate for irrigation. At the Dadin-kowa irrigation location, the computed SAR of water samples from four boreholes (Points A, B, C, and D) were 18.65, 7.45, 15.76, and 11.16, respectively, indicating that the irrigation water quality met the Food and Agriculture Organization's (FAO, 2013) standards, falling between medium and good quality.

Soluble Sodium Percentage (SSP):

Assessing sodium hazard also makes use of the SSP. The ratio of sodium in epm (equivalents per million) to all cations in epm is known as SSP, and it is calculated by multiplying that ratio by 100. Utilizing a formula taken from Todd (1959), the SSP was determined. Where all cation concentrations are listed in meq/L.

$$\mathrm{SSP} = \frac{(Na^{+} + K^{+}) \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \quad \text{……………………….(2)}$$

Good quality water is indicated by Soluble Sodium Percent (SSP) readings less than or equal to 50%; values greater than 50% indicate that the samples are unsuitable for irrigation. A water with an SSP of more than 50% may lead to sodium buildups that degrade the physical characteristics of the soil (Eldaw, Huang, Mohamed, & Mahama, 2021). The calculated values of SSP of the water sampled from four boreholes (Point A, B, C & D) in Dadin-kowa irrigation site were 67%, 43%, 60% and 54% respectively and were higher than the 50% in three location. Thus, indicating a sign of sodium hazard in the area. According to Feizi *et al.* (2010), salts have two main effects on plants: first, they slow down their ability to absorb water, which results in slower development; second, they may enter the transpiration stream and damage leaf cells, which further slows down growth.

CONCLUSION AND RECOMMENDATIONS

Crop productivity, soil physical characteristics, irrigation system performance, and soil fertility can all be impacted by the quality of irrigation water. Farmers are being compelled to use lower-quality water and change their irrigation techniques due to the ongoing reduction of water resources worldwide, and in arid regions specifically. This study assessed the physicochemical composition of groundwater in Dadin-kowa irrigation site and evaluate its suitability for irrigation purpose. The results of the investigation and assessments of the groundwater quality from different boreholes at the Dadin-kowa irrigation site, which were conducted in accordance with the FAO recommendations for the interpretation of water quality for irrigation, proved that the water from boreholes was unfit for irrigation. Therefore, different corrective actions concerning irrigation water ought to be implemented in order to lessen the likelihood of salinity issues. To ensure that the aquifers

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are sufficiently protected, environmental measures including rigorous quality control and the implementation of a water abstraction plan are essential. Since runoff can contaminate both surface water and groundwater due to their significant overlap, restrictions should be put in place to control the excessive use of pesticides and fertilizers in agriculture. The quality of groundwater in the vicinity of this location must also be conserved and preserved, which requires rigorous data analysis and ongoing monitoring.

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