Evaluation of salinity and Sodicity of different water sources used for irrigation in Yamaltu Deba, Gombe State, Nigeria

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Abstract

The unpredictable pattern of rainfall coupled with population increase has encouraged farmers to cultivate more farmlands through irrigation to meet food demand. But the prevalence of soluble salts in water is a threatening factor for soil fertility as a result of an increase in soil salinity and sodicity causes land degradation due to the rise in soluble salts in water. This study evaluates salinity and sodicity from different irrigation water sources in areas of Yamaltu-Deba: Zambuk, Kunuwal and Yamautu east. Samples were collected from eight irrigation water sources in each selected area and analyzed for physicochemical, major cations (K^+, Ca^{2+}, Mg^{2+}, and Na^+) and anions (Cl^-, HCO^{3-}, CO_3^{2-}, NO_3^-, and SO_4^{2-}). pH, electrical conductivity (EC) and temperature of water samples were measured in situ. pH, temperature, and alkalinity were in the ranges 5.2-7.4, 20.1-30.2ºC and 4.0-58.0 mg/L, respectively were within FAO permissible limits for irrigation purposes, except pH in some samples. The cations ions except K^+ were within acceptable limits in the studied samples. Nitrate was high in all water sources as a result of farming activities close to those water sources. The high concentration of K^+ in the samples may attribute to the same EC, with values ranging from 8.33 to 480 µS/cm. The results imply that the content of water sources in these study areas is not at the level to cause drastic salinity and sodicity to the soil of the area even when used for irrigation and other farming activities.

Keywords: Salinity, Sodicity, Ions, dissolved salts, cations, anion, permissible limit

Introduction

Water is the most important natural resource which forms about 80% constituent of the ecosystem (Sulaiman *et al*, 2018) [27], and It is essential for the survival of all living beings and plays an important role in our life (Adebo and Adetiyinbo, 2009) [1]. The water sources may be in the form of rivers, lakes, glaciers, rainwater and groundwater. It is essential for various activities and is the most valuable and vital resource for the sustenance of life and also for any developmental activity (Kumar *et al*., 2010; Sulaiman *et al*., 2018) [27]. Water resource sustainability largely depends onthe proper management and efficient utilization of agricultural water such as rain and irrigation farming (Fasakhodi *et al*. 2010) [12].

Irrigation water quality is a key environmental issue faced by the agricultural sector as well as it is very important for every agricultural use, passing through such activities as irrigation to livestock watering (Shainberg and Oster, 1978) [25]. As crop yield is directly related to the quality of water used for irrigation, an assessment of water sources' suitability for irrigation is essential for the growth of food production and poverty eradication. Previously, water quality concerns have often been neglected because good-quality water supplies have been plentiful and readily available (Islam and Shamsad 2009) [16]. However, salinity increase has been one of the major problems for traditional agricultural practices and the number of non-saline areas attacked by the salinity problem had increased within the last few decades and the agricultural production of those areas is also affected (Shammi *et al*., 2016) [26].

Salinization and Sod citification of water sources are major processes of water degradation threatening both human and animal health, land productivity and global food security at large. They not only influence the physical and chemical characteristics of arable soils but also affect the biochemical and microbial properties of the soil, this, in turn, poses a great effect on the yield of crops (Rietz and Haynes, 2003) [23]. Anjum *et al*. (2005) [5] have reported a decrease in the yield of crops as a result of soil degradation from water salinization and sodification. The risk of salinization is defined as a measure of the probability and severity of the salinization/sodification due to human activities which adversely affect one or more soil functions. Tavakkoli *et al*. (2010) [28] acknowledged the fact that the presence of multiple factors contributes to subsoil constraints including salinity, sodicity and high chloride ion concentrations present in many rain-fed farming-bound areas.

Several studies conducted in North-eastern Nigeria were mainly concentrated on the salinity and sodicity of the arable land around this region, little knowledge or research was carried out concerning these processes in water sources around the region (Daba and Qureshi, 2021) [7]. The effect of salt and sodium contents on the water sources is very important to ascertain the level of impact of these ions on water quality health and farming purposes. Therefore, this study aims to evaluate water salinity and sodicity parameters from Zambuk, Kunuwa and Yamautu east of Yamaltu-deba LGA of Gombe state for the main purpose of achieving water quality in these areas for maximum irrigation for crop production and utilization purposes.

Materials and Methods

Study Area

Yamaltu-deba L.G.A occupies a land mass of 1,981km and is located 7km east of Gombe town with an approximate population of 255,726 (NPC, 2007) [20]. Areas under study within Yamaltu-Deba located at the latitude of 110 30N, longitude 100 20E and latitude of 24m above the sea level, the area received a total annual rainfall of about 760-1100mm per annum and temperature ranges between 240ºC to 480ºC. The area predominantly has two seasons; the rainy season commencing in April-October and the dry season from October-March. Sources of water for irrigation, agricultural and other domestic purposes in the study area include ponds, taps, streams, rivers, boreholes, shallow well, water pans, reservoirs and dams.

Sample collection

Sampling techniques based on Environmental Protection Agency. Samples were collected three times from a pond, tap, stream, river borehole, shallow well, water pan, and dam. A total of seventy-two (72) samples were collected for this study. The sampling bottles were washed with detergent and rinsed with tap water, and then soaked in 10% nitric acid and finally rinsed with deionised water (Akan *et al*., 2010) [2]. At each sampling points the bottles were rinsed thrice with water being sampled before samples were collected. Samples were filtered in the field using Sartorius polycarbonate filtering apparatus and 0.45µm cellulose acetate filter membranes. Each bottle was filled to the brim with the sample water and tightly sealed as early as possible to avoid exposure to air and labelled in a field book with a unique number and exact sampling location. The samples were kept in the ice box and transported to Gombe State University, Biochemistry laboratory and stored in the refrigerator at 4ºC before analysis.

Determination of chemical parameters

The relative proportion of some cations that include Ca^{2+},K^{+}, Mg^{2+} andNa^{+}, were determined by Ionic chromatography methodology as described by APHA (1998) [3] while the relative proportion of some anions notably Cl^{-}, HCO_3^{-}, CO_3^{2-}, NO_3^{-},$NO_2^{-}$and SO_4^{2-},as reported elsewhere (Fipps, 2004; Shahinasi and Kashuta, 2008) [13, 24].

Determination of Electrical conductivity (EC) and Sodium Absorption ratio (SAR)

Electrical conductivity (EC) was determined using EC meter (Hanna HI8032) by the method described by APHA (1998) [3]. FAO (1985) described sodium hazard expressed as the Sodium Adsorption Ratio (SAR) and quantifies the proportions of concentration of sodium to that of calcium and magnesium and expressed as;

$$\mathrm{SAR} = \frac{Na^{+}}{\sqrt{1/2(Ca^{2+} + \mathrm{Mg}^{2+})}}$$

Statistical Analysis

The data obtained were subjected to simple descriptive statistics (mean and standard deviation) and analysis of variance (ANOVA) was used to test for a significant difference in the mean of the salinity and sodicity parameters among the three study sites and Turkey's multiple comparisons with SPSS version 25 for a window.

Results and Discussion

Physico-chemical parameters

The mean pH value ranges from 5.2-7.4 with an average of 6.31.The highest pH was obtained from a borehole in yamaltu east while the lowest was from a stream in kunuwal in Figure 1b. The pH of sampled waters in the study area was slightly acidic in some study samples. However the average pH (6.31) of water used for irrigation in the study area is less than the lower limits of both FAO standards, it will not have any significant effects on the soil's pH in the short term since soils are high buffer systems. The results in Figure 1abc showthe mean temperature ranges from 20.1 - 30.2^{O}C with an average of 24.82^{O}C. This revealed that all the temperatures of water sources fall within the FAO (5-30 ºC) recommended temperature for irrigation. Alkalinity of water sources used for irrigation in the study area ranged from 4.0-58.0mg/Lwith an average of 17.83 mg/L (Figure 1abc). The highest alkalinity was obtained at yamaltu east borehole. This indicates that all the samples are within the FAO limit (200mg/L) and will have no significant effect on soils and plant growth in the study area.

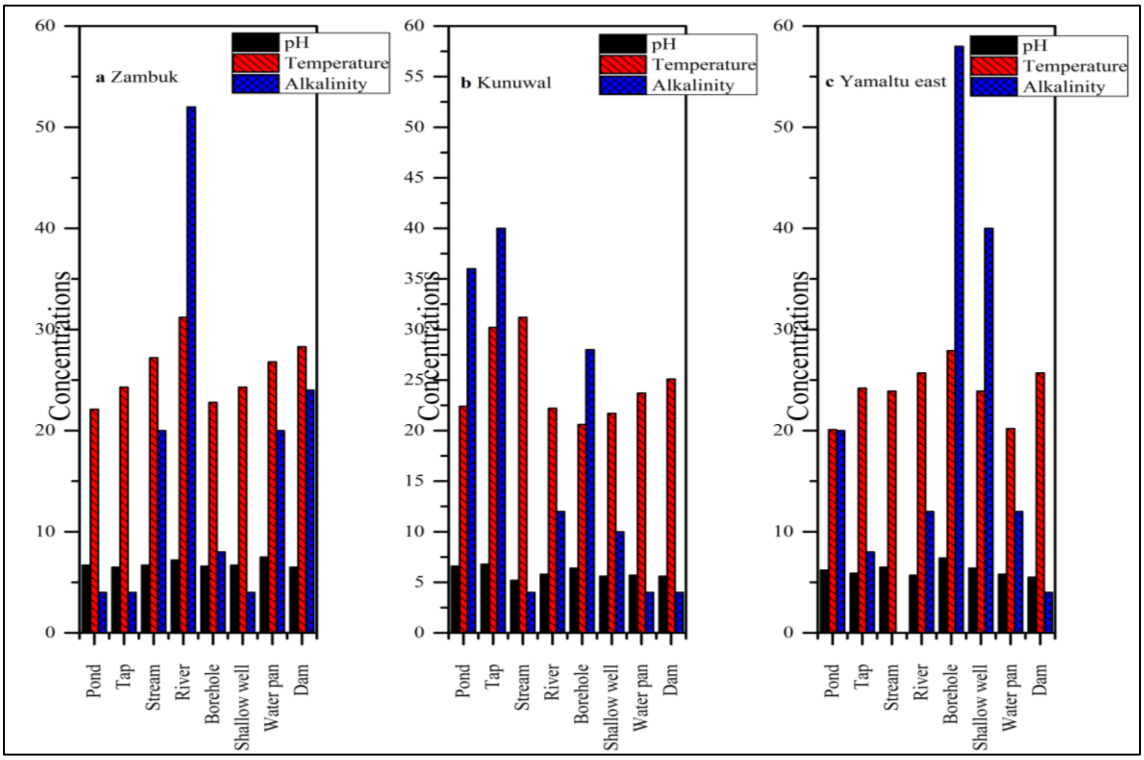

Fig 1: Physico-chemical properties of water samples from Zambuk, Kunuwa and Yamaltu east

Concentrations of cations in the water sources

Toxicity occurs of ions in irrigation water accumulate within the soil and or plant at concentrations that causes dent and decreased the yield of farm produce. This depends on the concentrations of ions present in water in the soil.Table 1 present the mean concentration of cations in the selected areas of Yamaltu-deba local government area of Gombe state. The mean values of sodium ions found within these areas of Zambuk, Kunuwal and Yamaltu east showed a significant difference at $p< 0.05$, though water sources from Zambuk showed a higher concentration of the sodium ions with 13.3±4.26 mg/L while Gwani with the least concentrations with 0.26±1.14 mg/L but falls within the lower range of safe limits. The amounts of Na^+ in these areas provide a core basis for the utilization of water from the area for irrigation and other agricultural purposes as it did not exceed the permissible limit of 50mg/ L by FAO and proved no risk of sodification across the arable lands in these areas but a great risk deficiency with time. This agrees with the observations of Nata *et al.* (2009) [19] that until there is a prolonged use of modern farming inputs such as fertilizer then rise in Na^+.

Calcium ions are an essential element in determining the hardness of water, calcium ions were found to be higher in Zambuk with 49.74± 4.85 mg/L while the lowest mean value below the detectable limit was recordedin some samples from Zambuk, and yamaltu east. The mean values from the three sites of Zambuk, Kunuwal and Yamaltu east showed a significant difference at $p< 0.05$. The mean concentrations of calcium ions obtained in this study did not exceed the maximum permissible limit by FAO but were within the permissible range, which favours the use of water sources within the study area for crop production. It's reported that calcium ionsdeficiency can affect plant growth (Weng *et al.*, 2022) [22].

The mean concentrations of Mg^{2+} and K^+a showed a significant difference at $p< 0.05$ among the values obtained and were not above the permissible limit but fall within the range for good water quality for crop production but soil requirements for these ions have to be increased by other sources such as the used manure. The highest concentration for Mg^{2+} and K^+were 5.97±1.88 mg/L for Kunuwal and 5.97±4.52 mg/L for Zambuk, respectively. The lowest mean concentration of Mg^{2+} and K^+were0.80mg/L and 0.46mg/L obtained from Zambuk and Kunuwal, respectively. It's reported that a deficiency of Mg^{2+} causes acidic soils which might lead to low levels of essential plant nutrients such as phosphorus and molybdenum. This result obtained in this agrees with the reports of Gupta (2005) [14] that rise in sodium ions above calcium and potassium ions can cause the replacement of these ions thus affecting soil permeability and texture. The cation trend in water samples of the study area were $K^+ > Na^+ > Ca^{2+} > Mg^{2+}$.

Table 1: Mean Concentrations of cations (mg/L) in water samples from Zambuk, Kunuwa and Yamaltu east

	Water sources	Na^+	Ca^{2+}	Mg^{2+}	K^+
Zambuk samples	Pond	13.30	1.84	1.98	17.20
	Tap	9.06	0.79	2.12	6.47
	Stream	0.69	1.32	4.21	3.96
	River	4.99	49.74	5.53	9.74
	Borehole	9.51	BDL	0.80	5.48
	Shallow well	2.16	1.32	3.52	3.12
	Water pan	5.22	0.26	3.51	4.81
	Dam	3.26	8.16	4.90	6.49

Kunuwal samples	Pond	3.68	3.16	5.97	3.16
	Tap	3.98	0.49	5.28	0.46
	Stream	9.18	7.06	1.59	7.06
	River	8.90	3.25	3.64	3.50
	Borehole	0.26	2.06	5.23	2.06
	Shallow well	2.98	3.85	3.60	3.85
	Water pan	7.94	6.59	3.73	6.59
	Dam	7.20	5.64	1.99	5.64
Yamaltu east samples	Pond	4.80	2.37	4.37	10.47
	Tap	6.91	2.37	4.37	3.91
	Stream	4.58	BDL	4.08	4.79
	River	4.01	BDL	1.92	4.29
	Borehole	4.92	4.47	5.28	4.92
	Shallow well	6.67	11.84	5.21	6.67
	Water pan	4.35	BDL	0.60	4.35
	Dam	3.99	BDL	1.92	3.99
	FAO	50.00	120.00	50. 00	2.00

Concentrations of anions in the water sources

Table 2 present the results ofanions obtained from Zambuk, Kunuwal and Yamaltu east. The concentrations of Cl^- show any significant difference $p< 0.05$ within sampling sites. Yamaltu east with 33.33 mg/L has the highest followed by 8.33mg/Lin the pondwhereas5.56mg/Lin Tap from Zambuk and lowest was recorded in the river, borehole and water pan from Zambuk, Kunuwal and Yamaltu east, respectively. The lowest chloride ions are anions effective in the formation of saline soils and are highly water soluble and thereby possess severe toxicity (Banderi *et al.*, 2012) [6]. These anions cannot be precipitated at concentrations usually present in water but are readily transported through plants' roots and conveyed to the leaves where they accumulate (DWAF, 1996) [9]. These values are extremely below FAO (1985), this result is in agreement with khan *et al* (2013) [17] and therefore cannot cause toxicity to arable soils and injury to plants. The mean concentrations of bicarbonates in water samples across these sites showed no significant difference $p< 0.05$ between Zambuk, Kunuwal and Yamaltu east. The highest range for HCO_3 is from Kunuwal with a value of 106.75mg/L while the lowest is 3.05mg/L from Yamalltu east with the lowest.

The results show that all the water sources have bicarbonate levels lower than the FAO (150 mg/L) upper limit but below the mid value of FAO (1985) permissible level. The low bicarbonate content of all the water samples accounted for the low alkalinity and pH levels in the study area and this indicates that bicarbonate levels from these areas are favourable for use by farmers for irrigation purposes. Nitrate (NO_3^-) mean concentration varied within the study area and ranged between 5-30 mg/L safety range, the highest was 42.70mg/L from Kunuwal and the lowest was 4.65fromZambuk. There was a significant difference $p< 0.05$ between Zambuk, Kunwal and Yalmatu eat. The higher values of Nitrate at Kunuwa for the river (42.70 mg/L) and dam (36.81 mg/L), were above the limit (30 mg/L) for irrigation and other farming activities (FAO, 1985). USEPA (1999) [29] reported groundwater contamination by nitrate is a result of agricultural practices in most cases fertilizer or manure applications on farms. There was a significant difference $p< 0.05$ between the mean values of nitrite. Dikeogu *et al.* (2021) [8] reported several control measures against a rise in permissible limits of anions in the groundwater such as leaching, reduced evaporation and improved drainage systems effectively utilized for irrigation purposes. Sulfate (SO_4^-) showed a significant difference of $p<0.05$ among mean values from the study sites but mean values showed variations with the highest concentrations of 9.26mg/L from Kunuwal, and the lowest value of 2.19 mg/L from Zambuk. Sulphate is a major anion in many water sources. Its toxicity is not much of a problem; however, extremely high concentrations may interfere with the uptake of other nutrients by the plant. However, the permissible limit by FAO (1985) of 0-20mg/L is considered safe indicating that the water samples concerning sulphate are safe for irrigation purposes without restriction.

Table 2: Mean Concentrations of anions (mg/L)in water samples from Zambuk, Kunuwa and Yamaltu east

	Water sources	Cl^-	HCO_3	CO_3	NO_3	SO_4
Zambuk samples	Pond	1.67	30.50	BDL	6.36	2.71
	Tap	5.56	36.6	BDL	15.64	5.66
	Stream	2.22	27.45	BDL	5.01	2.19
	River	1.67	76.25	BDL	4.65	7.46
	Borehole	2.78	15.25	BDL	11.50	4.79
	Shallow well	2.78	15.25	BDL	4.52	3.52
	Water pan	3.33	54.90	BDL	4.88	2.61
	Dam	2.22	45.75	BDL	8.26	6.49
Kunuwal samples	Pond	8.33	143.35	BDL	25.69	9.26
	Tap	2.78	106.75	BDL	26.81	4.37
	Stream	2.78	39.65	BDL	22.40	3.50
	River	6.11	42.70	BDL	42.70	7.35
	Borehole	1.67	36.60	BDL	30.39	4.72
	Shallow well	2.22	61.00	BDL	24.57	2.87
	Water pan	3.33	6.10	BDL	24.49	4.05
	Dam	3.89	140.3	BDL	36.81	8.35

Yamaltu east samples	Pond	33.33	42.7	BDL	26.66	3.24
	Tap	6.11	6.10	BDL	20.69	4.90
	Stream	1.67	36.6	BDL	18.60	2.83
	River	2.22	30.50	BDL	30.09	2.88
	Borehole	1.67	103.7	BDL	16.36	2.54
	Shallow well	2.22	91.50	BDL	15.31	2.30
	Water pan	1.67	3.05	BDL	24.57	4.38
	Dam	2.78	36.60	BDL	34.04	6.82
	FAO	350.00	150.00	3.00	30.00	20.00

Assessment of salinity hazards or restriction on the use of water sources

Salinity hazard is used to determine the concentration of salts in water and the risks it causes to the soil when used for irrigation. EC is a measure of salt concentration in water in the form of ions (Laluraj *et al.*, 2005) [18]. Water with high EC or TDS is detrimental to plants and causes soil degradation and therefore must be controlled. The EC value of irrigation water sources ranges from 202.00 to 777.00 µS/cm in Zambuk with a mean of 293.725 µS/cm (Islam and Shamsad, 2009) [16] falls within the irrigation water quality standard 'excellent to good'. The EC value of irrigation water sources ranges from 8.33 to 861 µS/cm in Kunuwal with a mean of 240.016 µS/cm (Table 3). The EC value of irrigation water sources ranges from 76.7 to 480 µS/cm in Yamaltu east with a mean concentration of 212.5125 µS/cm. The EC is less than 700 µS/cm signifies none or less salinity.

Table 3: Electrical Conductivity (µS/cm) as measured on the Field

				Salinity degree of restriction		
					EC (µS/cm)	
				< 0 – 700	**700– 3000**	**> 3000**
Water sources	Zambuk	Kunuwal	Yamaltu east	**None**	Slight/moderate	**Severe**
Pond	124.6	298	226.4			
Tap	355	121.2	127.6			
Stream	777	165.7	131.5			
River	173.8	8.33	76.7			
Borehole	124.4	861	480			
Shallow well	202	200.1	444			
Water pan	358	129.1	125			

Assessment of sodicity hazards in water sources

Irrigation water with sodicity hazard implies sodium replacing calcium and magnesium in the soil through the cation exchange process when used for irrigation eventually damaging soil permeability and structure (Gupta, 2005) [15]. The values of SAR for irrigation water in the study area range from 0.29 to 1.35meq/L with an average of 0.86 meq/L in Table 4. The maximum and minimum values occurred for streams at Kahuguni and Gatitu respectively. The SAR values for all the samples are below FAO limits and therefore may not cause any sodicity hazards to the soil or plant when used for irrigation. The low level of SAR is a result of the dominant levels of calcium in all the water samples.

Table 4: SAR values (meq/L) of water samples from Zambuk, Kunuwa and Yamaltu east

Parameters	**Zambuk**	**Kunuwal**	**Yamaltu east**
Pond	0.13	0.14	0.12
Tap	0.11	0.13	0.15
Stream	0.14	0.1	0.09
River	0.12	0.13	0.11
Borehole	0.13	0.1	0.09
Shallow well	0.09	0.13	0.15
Water pan	0.09	0.11	0.16

Conclusion

The presence of different metal ions notably sodium, magnesium, calcium and potassium and their salts in higher concentrations in water aid the process of salinization and sodification that results in soil deterioration, especially if control or management methods are not practised. In this research, results have shown that the limits of these ions in water samples collected from different sources are not in a large concentration to cause salinization nor sodification but the rise in Na^+ ions and its salts above Ca^{2+} and Mg^{2+} can lead to salinity and sodicity if not checked and these may be due to some factors low organic matter decomposition, the effect of leaching, government policies on farming, adequate drainage system and biotic factors. Thus, water samples from Zanbuk, Kunuwal and Yamaltu east of Yamaltu-deba LGA present a choice for selection of water for irrigation and other agricultural purposes as the ion content can add up to the normal limit of the soil and cannot exceed the maximum permissible limit to be toxic to plants. Other ions with values less than the minimum permissible limits can be remedied by soil water quality improvement practices.

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Competing Interest

The authors have declared that no competing interest of any kind exists concerning the publication of this manuscript.

References

1. Adebo AB, Adetiyinbo AA. Scientific Research and Essay. 2009;4(4):314-319.

2. Akan JC, Abdurrahman FI, Yusuf E. Physical and chemical parameters in abbatoir waste water sample. Maiduguri metropolis. Nigerian Pacific Journal of science Technology. 2010;11(1):640-647.
3. American public health association. Standard methods for examination of waters and wastewaters, 20th edn, Washington, DC, USA; c1998.
4. Anikwe MAN, Ofoke PE, Mbah CN. Relationship between irrigation water quality and salinization of selected irrigated soils in Abakaliki, South Eastern Nigeria. Nigeria Journal of Soil Research. 2002;3:58-62.
5. Anjum R, Ahmed A, Rahmatullah A, Jahanghir M, Yousaf M. Effects of sol salinity and sodicity on the growth and yield of different cotton varieties. International journal of Agricultural Biology. 2005;7(4):606-608.
6. Banderi A, Mohammad MS, Hamdi H, Shomeli M, Ali SD. Water quality assessment of Amir Kabir sugarcane agro-industry with respect to agricultural and drinking views. Journal of Environment and Ecology. 2012;3(1):11-28.
7. Daba AW, Qureshi AS. Review of Soil Salinity and Sodicity Challenges to Crop Production in the Low land Irrigated Areas of Ethiopia and Its Management Strategies. Land. 2021;10(12):1377. https://doi.org/10.3390/land10121377.
8. Dikeogu TC, Okeke OC, Nwachukwu HGO, Agbo CC. Salinization and Water logging In Agricultural Lands: Causes, Effects and Mitigation. International Journal of Innovative Environmental Studies Research. 2021;9(1):45-57.
9. DWAF (Department of water affairs and forestry). South African Water Quality Guidelines (second edition): Agricultural Use: Irrigation. c1996;4:123-7.
10. Ezlit YD. Modelling the change in conductivity of soil associated with the application of saline-sodic water, A dissertation submitted for the award of doctor of Philosophy University of Southern Queensland Faculty of Engineering and Surveying, c2009.
11. FAO. Advanced in the assessment and monitoring of salinization and status of biosaline agriculture, World soil resource report, Report of an expert consultation held in Dubai, UAE; c1985.
12. Fasakhodi AA, Nouri SH, Amini M. Water resources sustainability and optimal cropping pattern in farming systems; a multi-objective fractional goal programming approach. Water; c2010.
13. Fipps G. Irrigation water quality standards and salinity management strategies, Texas cooperative extension, Texas, USA; 2004;234-5.
14. Gupta PK. Methods in Environmental Analysis: Water, soil and air. Published by Agrobios (India), Jodhpur; c2005;1-127.
15. Gupta PK. Methods in Environmental Analysis: Water, soil and air. Published by Agrobios (India), Jodhpur, c2005, 1-127.
16. Islam MS, Shamsad SZKM. Assessment of irrigation water quality of Bogra District in Bangladesh. Bangladesh Journal of Agricultural Research. 2009;34(4):597-608.
17. Khan MA, Khan TA, Muhammad SK, Saeed UT, Daulat K. Evaluation of salinity and sodicity parameters; Bannu Scarp Pakistan. Journal of Agricultural Science and Soil Science. 2013;3(10):343-352.
18. Laluraj CM, Gopinath G, Dineshkumar PK. Groundwater Chemistry of Shallow Aquifers in the Coastal Zones of Cochin, India. Applied Ecology and Environmental Research. 2005;3(1):133-139.
19. Nata T, Bheemalingeswara K, Berhane A. Groundwater suitability for irrigation: a case study from DebreKidane Watershed, Eastern Tigray, Ethiopia. Momona Ethiopian Journal of Science. 2009;1(1):36-58.
20. NPC. Population Census results for Gombe state. NPC Abuja, Nigeria; c2007.
21. Rahman MM, Zaman MW. Quality assessment of river and ground waters for irrigation at Shahzadpur in Bangladesh, Progress Agric. 1995;6(2):89-96.
22. Rengasamy NS. Diagnosis and management of sodicity and salinity in soil and water in the Murray Irrigation region, The University of Adelaide, SAP p 421-3. Resour Manage. 2010;24(15):4639-4657.
23. Rietz DN, Haynes RJ. Effects of irrigation-induced Salinity and sodicity on Soil Microbial Activity. Soil biology and Bio-chemstry. 2003;35:845-54.
24. Shahinasi E, Kashuta V. Irrigation water quality and its effects upon soil, Tirana Agricultural University, Tirana, Albania. Balwois-OHride, Republic of Macedonia; c2008.
25. Shainberg I, Oster JD. Quality of irrigation water. I.I.I.C. Publication No. 2. (International Rice Research Institute); c1978.
26. Shammi M, Rahman R Rahman, Md. Moniruzzaman M, Md, Bodrud-Doza, Md, Karmakar M and M. K Assessment of salinity hazard in existing water resources for irrigation and potentiality of conjunctive uses: a case report from Gopalganj District, Bangladesh. Sustain. Water Resour. Manag. 2016;2:369-378.
27. Sulaiman MB, Maigari AU, Ringim SA. Quality Index of Drinking Water from Different Sources in Gombe town, Northern Nigeria. Journal of Chemical Society of Nigeria. 2018;43(4):752-758.
28. Tavakkoli E, Jones B, Coventry S, Rengasamy P, McDonald G. On-farm assessment of sub-soil salinity and sodicity constraints to barley production in southern Australia. Proceedings of 15th Agronomy conference 2010, 15-18 Nov, 2010. Lincoln New Zealand; c2002.
29. USEPA. Guidance manual for conducting sanitary surveys of public water systems; surface water and groundwater under the direct influence (GWUDI) USEPA, Washington; c1999.
30. Weng X, LiH, Ren C, Zhou Y, Zhu W, Zhang S, Liu L. Calcium Regulates Growth and Nutrient Absorption in Poplar Seedlings. Frontiers in Plant Science. 2022;13:887098. doi:10.3389/fpls.2022.887098