Austin Environmental Sciences

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Austin Publishing Group

Research Article

Assessment of Surface and Underground Water Quality for Irrigation in Some Selected Parts of Makurdi Metropolis

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Received: August 23, 2024
Accepted: September 17, 2024
Published: September 24, 2024

Abstract

Ensuring food security has become an issue of key importance due to the increase population accompanied with high demand for food. It has therefore become necessary to produce food all year round to cope with the increasing population. For this reason, farmers both in arid and semi-arid areas have adopted irrigation agriculture. Irrigation water quality can have a profound impact on crop production. However, sources of these irrigation waters are hardly checked to determine whether they promote crop yield or not. Thus, this study assesses the quality of water sources for irrigation purpose in some selected areas of Makurdi. A total of six (6) water samples were taken at random across some selected parts of Makurdi metropolis. The samples were group into surface (river) and underground (borehole) waters with each group containing three samples. For each sample, four (4) parameters (pH, EC, TDS, and Cl^-) were analysed. These parameters were analysed and subjected to descriptive statistics. The result shows a pH mean value of 7.4 for all the surface water samples, EC mean values range from 0.06 dS/m - 0.07 dS/m, TDS mean values ranges from 27.40 mg/L - 30.33 mg/L, Cl^- mean values range from 0.96 meq/L - 1.35 meq/L for the surface water. On the other hand, pH means values range from 7.2 - 7.9, EC mean values range from 0.32 dS/L - 0.36 dS/L, TDS values range from 95.00 mg/L – 129.60 mg/L and Cl^- mean values range from 1.12 meq/L -2.09 meq/L for the underground water samples. From the parameters measured, the result shows that, the sampled water has good quality and can be used for irrigation. However, the EC of surface water posed a threat to crops growth and yield. This result can be used to preferentially grow crops around Makurdi metropolis to enhance maximum yield.

Keywords: Irrigation; Food Security; Underground and Surface water

Introduction

Ensuring food security has become an issue of key importance to countries with different degrees of economic development. Agricultural sector plays a strategic role in improving food availability. However, while there is general agreement on the increased global demand for food to be expected in the coming decades, there is uncertainty surrounding global agriculture's capacity to service this demand through an expansion in the food supply [22]. Better food provision ensured by increasing the productivity of agriculture and expanding the range of agricultural land use seems to be a possible method to eradicate food insecurity [62]. Agriculture is concerned with the husbandry of crops and animals for food and other purposes. It is the foundation upon which the development of stable human communities such as villages and towns depend in many parts of the world, [12]. It embraces all the activities involved in crops and livestock production starting from preparatory stages through the production, processing, and marketing or consumption stages. The importance of agriculture, according to Asogwa and Nongugwa, [12] include the provision of food, shelter, timber, employment opportunities, generation of income amongst others. In the production of crops, water is one of the major factors required for crops growth and productivity. The water needed by crops is provided by natural sources such as rainfall, dew, ground water etc. But where the natural sources of water are inadequate to support crop production, the need then arise for irrigation agriculture. Irrigation is defined as an artificial applica-

Citation: Asemave K, Iorhemen TC. Assessment of Surface and Underground Water Quality for Irrigation in Some Selected Parts of Makurdi Metropolis. Austin Environ Sci. 2024; 9(2): 1110.

tion of water to soil for the purpose of supplying the moisture essential in the plant root-zone to prevent stress that may cause reduced yield and/or poor quality of harvest of crops [50]. Sahadrabudhe, [53] maintained that, irrigation is a systematically developed knowledge based on handling of available water resources for economic growth resulting in bumper harvest. The author observed irrigation practices to include; trapping and taping of sources of water supply, conveying stored water effectively to the field, drainage of surplus and using the supply of water economically for the bumper crop production. The author also stated that irrigation can be divided into two phases, namely: engineering phase and agricultural phase. The agricultural phase is concerned mainly with the use of water economically for bumper crop production. [52] identify various types of irrigation methods to include; surface irrigation, subsurface irrigation, drip irrigation and smart irrigation. Irrigation has long played a key role in feeding the expanding world population and is expected to play a still greater role in the future. Irrigated agriculture shows significant improvement over rain fed agriculture productivity. It provides improved resilience against climate variability, improves food security and enhances intensification. Advantages of irrigation as identified by [30] include; provision of control over the water as of when to apply and method of application, improves people's standard of living, yield of crops and make farmers prosperous. A farmer, in the view of [46], is someone who is involved in agricultural production and management of the entire crop or animal farm. Different sources of water for irrigation include; rivers, lakes, dams, wells, boreholes, streams to mention but a few. Irrigated agriculture has expanded significantly over the past five decades [73]. It seems to be a general consensus improving agriculture and enhancing agricultural productivity and remains a key strategy for rural poverty alleviation in most developing countries like Nigeria [13].

Benue state which is regarded as the food basket of the nation is the leading state in terms food production. It is an agrarian zone that produces food all year round both during raining and dry seasons to ensure constant food supply to the nation. During dry season, farmers indulge in irrigation system of farming to ensure food productivity. Most farmers in Benue state who practice irrigation agriculture live in rural or/and riverine areas. Makurdi local government which is the capital city of Benue state has river Benue pass through it. This has attracted most farmers here to engage in irrigation agriculture and used the river as their source of irrigation water. However, others used underground waters (boreholes and Wells) for the irrigation.

Notable food crops and vegetables irrigated includes; tomatoes, pumpkins, green leaves, rice, maize, groundnut, tobacco, pepper, garden eggs, Okro, etc. Most farmers depend on irrigated agriculture yet get minimum yield in return. This is attributed to the use of crude tools such as watering cans for water supply, untimely of water supply, wrong pattern of water supply to the crops, and majorly, the use of unsuitable water for irrigation. Unsuitable in terms of pollution, salinity nature of the waters, which lead to low yield. Chemical quality of water is a significant factor to evaluate the suitability of water for irrigation [1]. The composition and concentration of dissolved constituents in water determine its suitability for irrigation use. Suitability of water for irrigation depended on the effect of mineral constituents of water on both the soil and the plant. Irrigation water contains dissolved mineral salts, but the concentration and composition of the dissolved salts vary depending on the source of the irrigation water [33]. The total concentration of soluble salts in irrigation water (salinity) can be expressed in terms of electrical conductivity for purposes of diagnosis and classification. Dissolved salt could result from natural phenomenon (eroded rocks, deep sea vocanoes) and anthropogenic activities (application of fertilizers, industrial effluents). Dissolved salts in irrigation water form ions. The most common salts in irrigation water are table salt (sodium chloride, NaCl), gypsum (calcium sulfate, $CaSO_4$), Epsom salts (magnesium sulfate, $MgSO_4$), and baking soda (sodium bicarbonate, $NaHCO_3$) (Grattan 2022). Salts dissolved in water forms positive ions (cations) and negative ions (anions). The most common cations are calcium (Ca^{2+}), magnesium (Mg^{2+}), and sodium (Na^{+}) while the most common anions are chloride (Cl^{-}), sulfate (SO_4^{2-}), and bicarbonate (HCO_3^{-}). Dissolve salt (saline water) has adverse effect (toxic) to some fruit trees, vegetables and other cultivations. Salinity reduces the plants' water uptake, increasing the osmotic potential and the force to absorb water, decrease the plants' growth rate, photosynthesis rate, and stomatal conductance [25]. The increase in salinity level reduces the photosynthesis rate due to the lower stomatal aperture [57], the depression in specific metabolic processes in carbon uptake, the inhibition in photochemical capacity or a combination of these phenomena. Too much salt can reduce or even prohibit crop production while too little salt can reduce water infiltration, which indirectly affects the crop productivity [33]. Other related toxic ions present in irrigation water include; Chloride, sodium and boron. These are absorbed by the roots and transported to the leaves where they accumulate in much quantity resulting into leaf burn and leaf necrosis. Also, direct contact during sprinkling of water drops with a high chloride content may cause leaf burn in high evaporation condition [48]. Thus, alongside other factors, most irrigation water may contribute to low yield of farm produce unless ascertained. Hence this calls for the assessment of surface and underground water quality for irrigation in some selected parts of Makurdi metropolis.

Materials and Methods

Study Area

Makurdi is located in Benue state north central Nigeria. It is bounded by latitude 7^0 43' 55.7472''N and longitude 8^0 32' 20.9184''E. It is located within the middle Benue trough and covers an area of about 370 km^2. It is accessible by Makurdi Rafia road and intra state road such as Makurdi Otukpo road, Makurdi Gboko road. The annual rainfall depth ranges from

Table 1: Physicochemical parameters of surface water.

Samples	pH	Parameters EC (dS/m)	TDS (mg/L)	Cl- (meq/L)
Sample A	7.4±0.20	0.07±0.0013	30.33±0.38	1.35±0.25
Sample B	7.4±0.21	0.07±0.0008	29.53±0.25	1.28±0.25
Sample C	7.4±0.19	0.06±0.0006	27.4±0.33	0.96±0.29

Key
Sample A- River water behind Wadata
Sample B- River water behind BSU
Sample C- River water opposite Air force Base

Table 2: Physicochemical parameters of underground water.

Samples	pH	Parameters EC (dS/m)	TDS (mg/L)	Cl- (meq/L)
Sample D	7.2±0.19	0.36±0.003	129.6±0.43	2.09±0.09
Sample E	7.7±0.14	0.32±0.0005	95±15.80	1.12±0.09
Sample F	7.9±0.99	0.35±0.003	129±0.82	1.96±0.25

Key
Sample D- underground water in Wadata settlement
Sample E- underground water behind St. Thomas Anum
Sample F- underground water opposite Air force Base

about 1200 mm to1500 mm with an average depth of about 1350mm. Temperature are generally very high during the day, particularly in March and April. Makurdi records average maximum and minimum daily temperature of 35 ^{0}C and 21 ^{0}C during the rainy season and 37 ^{0}C and 16 ^{0}C during the dry season, respectively [9].

Sample Collection

Water samples (surface and underground) were collected at six (6) different locations within Makurdi metropolis with a total of six (6) samples, in the month of May, 2023. The surface water was collected along river Benue within Makurdi metropolis; behind Wadata settlement (point A), behind Benue state university campus (point B), and after air force base (point C). While underground water was collected at; Wadata market (point D), behind St Thomas Anum, (point E) and after Air force base (point F). All the samples were fetched and stored in the plastic sample containers. The sample containers were pre-washed with ordinary water, and then with dilute hydrochloric acid HCl, and finally with distilled water. Prior to fetching the sample, the sample containers were washed twice with the water to be sampled. It was then filled to overflow and tightly sealed. The samples were taken to the laboratory and subjected to various analyses.

Sample Analysis

pH

The pH of the samples was analyzed using a digital pH meter (Eutech Instrument, pH 700). A 400 ml beaker was first rinsed with distilled water and finally with the sample to be analysed. The probe of the pH meter was inserted in the beaker containing the sample to be analyzed and stable pH value was read. The experiment was performed three times and average with standard deviation reported.

Table 3: Combined results for the physicochemical parameters of surface/underground water and FAO Standard.

Samples	pH	Parameters Surface EC (dS/m)	water TDS (mg/L)	Cl- (meq/L)
Sample A	7.4±0.20	0.07±0.0013	30.33±0.38	1.35±0.25
Sample B	7.4±0.21	0.07±0.0008	29.53±0.25	1.28±0.25
Sample C	7.4±0.19	0.06±0.0006	27.40±0.33	0.96±0.29
		Underground	**water**	
Sample D	7.2±0.19	0.36±0.003	129.60±0.43	2.09±0.09
Sample E	7.7±0.14	0.32±0.0005	95.00±15.8	1.12±0.09
Sample F	7.9±0.99	0.35±0.003	129.00±0.82	1.96±0.25
		FAO Standard		
Potential irrigation problem	**unit**		**Degree of restriction**	
		None	Slightly to moderate	Severe
EC	dS/m	<0.7	0.7-3.0	>3.0
TDS	mg/L	<450	450-2000	>2000
Cl-	meq/L	<4	10-Apr	>10
pH			Normal range	
			6.5-8.4	

Key
Sample A- River water behind Wadata
Sample B- River water behind BSU
Sample C- River water opposite Air force Base
Sample D- Underground water in Wadata settlement
Sample E- Underground water behind St. Thomas Anum
Sample F- Underground water opposite Air force Base

Electrical Conductivity (EC)

Electrical conductivity of the sample was determined using electrical conductivity meter (Primo 5 electrical conductivity meter). A 250 ml beaker was properly rinsed with distilled water and finally rinsed with the sample to be analysed, it was then filled with the analyte, the probe of the EC meter was inserted in the beaker containing the analyte and stable EC value was read. This was repeated three times and average with standard deviation reported.

Total Dissolve Solid (TDS)

In determination of total dissolve solid, a watch model TDS meter was used. The probe of the meter was inserted in a 250 mL beaker containing the sample to be analyzed, after the beaker was rinsed with distilled water, and a stable value was read. The experiment was done three times and the mean as well as the standard deviation were reported.

Chloride (Cl^-)

Chloride was determined using silver nitrate titrimetric method where potassium chromate was used as an indicator. 10 mL of the sample to be analysed was measured into a beaker, and 1 ml of potassium chromate (K_2CrO_4) was added into the beaker containing the sample. A portion of silver nitrate $AgNO_3$ was titrated against the solution, drop by drop, until a colour change was observed which indicate the end point of the titration. The average volume of silver nitrate used was recorded.

Equation for the reaction $2AgNO_{3(aq)} + K_2CrO_{4(aq)}$ $Ag_2CrO_{4(aq)} + 2KNO_{3(aq)}$

Hence the value of the chloride was calculated using the expression;

$$Cl^- = \frac{VxMx\ 35.45\ x\ 1000}{S}$$

Where V= volume of titrant

M = molarity of the titrant and

S = volume of sample used.

Results and Discussion

Results

Result of assessment of surface and underground water is shown below in Table 4.1 and 4.2.

The table above shows the result of some physicochemical parameters for the surface water. All the results were obtained following systematic analysis using different methods and analytical instruments as explained in the previous chapter. From the table above it can be seen that the pH for the surface water is constant with a value of 7.4 for all the samples. In a similar way EC is also constant with a value of 0.07 dS/m except for sample ‘C’ which has a value of 0.06 dS/m. Finally, the values for TDS decreases gradually from sample ‘A’ to ‘C’ and the same trend can be seen in the values of Cl^-.

The table above shows the results of some physicochemical parameters of underground water. All the results were obtained following systematic analysis using different methods with different analytical instruments as explained in the previous chapter. From the table, it can be inferred that, the pH increases from sample ‘D’ to ‘F’ while EC, TDS and Cl^- does not follow a particular trend.

Table 4: Different crops with their optimum pH, EC, TDS, and Cl-.

Crops	pH	EC (dS/m)	TDS (mg/L)	Cl- (meq/L)
Onion	6.0 7.0	0.8	900 -1200	3.94 -4.93
Garden egg	5.5 -7.5	0.7	900 -1000	3.45 -4.00
Beans	6.0 -6.5	0.7	1400 -2800	3.45 -4.93
Carrot	5.5 -6.5	1	1120 -1400	3.45 -4.00
Okro	6.0 -7.5	2.00-2.40	1400 -1600	9.86 -11.83
Sugar cane	6.0 -7.0	1.7	900 -1100	8.38 -9.86
Spinach	6.5 -8.0	1.4 -1.8	<335	6.89 -8.87

The table above shows some selected crops with their range of values for pH, EC, TDS, and Cl^-, within which they produced maximally, [4,20,33,38,67].

FAO- Food and Agricultural Organization

The table above shows a comparative result for both surface and underground water. From the table it can be seen that, pH values for the underground water are slightly higher than those of surface water except for sample D with a lesser value of 7.2. All other parameters for underground water have higher values compare to surface water.

Discussion

pH

The pH concentration in all the sampled point of the surface water has the same mean value of 7.4. The mean pH value indicates that the river across the points of collection is not acidic but slightly alkaline. This value falls into the acceptable standard range (6.5-8.4) of irrigation water set by FAO. In a similar way the mean pH value for underground water ranges from 7.2-7.9. The pH values indicate that the underground water across the point of collection is slightly alkaline. However, the values also fall within the acceptable range of 6.5-8.4 set by FAO for irrigation. A comparism of the pH between surface and underground water showed that, the underground water has a pH concentration slightly above the surface water though both falls within the acceptable range. Thus, the result obtained shows that, both the surface/underground water from the sampled points is suitable for irrigation. This result is in agreement with that of Bing, *et al* [17] with a mean value of 7.93 for surface water and 7.21 for underground water, but different from that of Adeyemi *et al* [6] with a mean value of 6.89. For the range of pH obtained from the above result, crops such as Okro (pH 6.0 -7.5), Spinach (6.5 -8.0) and garden egg (pH 5.5 -7.5) as can be seen in table 4.4 above, are most suitable to be grown in other to produce maximum yield.

Electrical Conductivity (EC)

The electrical conductivity EC of the surface water has mean values of 0.06 S/m 0.07 S/m and 0.07 S/m for sample A, B, and C respectively. The EC can be said to be fairly constant. This implies that, the salt concentration at the various points is fairly uniform. This value fall into the acceptable limit base on the degree of restriction as recommended by FAO. However, the EC still posed adverse effect on plant, this is because according to Grattan, (2022) low EC values of less than 0.3 dS/m are likely to cause infiltration problems. Low EC may severely affect plant health and yield [37], under such circumstances it is not possible to maintain good crop development conditions and obtain high yield. The low EC values may mean that, the river is a fresh water source. Again, the time in which the research was carried out could also contribute, since the salt ions could get diluted with increased in water volume of the river. On the other hand, the EC of underground water have mean values of 0.32dS/m, 0.35dS/m, and 0.36dS/m increasing from sample D< E< F respectively. This could be attributed to the soil formation which adds salt ions in the water progressively from point D to F. This value falls into the acceptable range of < 0.7 dS/m prescribe by FAO. This shows that the underground water is more suitable for irrigation compare to surface water. Thus, following the result above, it is advisable that the underground water should be used for irrigation instead of the river water in other to achieve maximum yield. The range of values of the above EC is most suitable to irrigate crops such as carrot (EC=0.7 dS/m), beans (EC= 0.7 dS/m), and garden egg (EC= 0.7 dS/m) to obtain a maximum yield in reference to table 4.4 above.

TDS

The Total Dissolve Solid (TDS) of the surface water range from 27.4 mg/L-30.33 mg/L. The higher value (30.33 mg/L) for sample 'A' could be as a result of residential (urban) runoff which could deposit organic and inorganic substances in the river water. It could also be attributed to the interaction of water with rocks found within the sampled area [1]. These values fall within the permissible limit of <450 mg/L recommended by FAO, and they have no restriction to use for agriculture. This value is related to that of Adeyemi, (2019) with a TDS of 38.80 mg/L but different from Kundu [41] with a TDS mean value of 523.23 mg/L. The large different is attributed to the higher concentration of the dissolved organic and inorganic content in the surface water of the later. On the other hand, underground water has the TDS mean values range 95.00 mg/L- 129.60 mg/L. The highest value 129.60 mg/L recorded at point 'D' could means that high rate of geochemical reactions takes place at this point [8] (Yetiş *et al.*, 2019). These values also fall within the acceptable range of <450 mg/L recommended by FAO for irrigation purpose. These values here disagreed with that of Abbasnia, [1] with a TDS of 300 mg/L- 6310 mg/L attributed to high enrichment of salts in the water. A comparison of the surface and underground result shows that, underground waters have higher TDS than surface water. This could be as a result of the geological formation/weathering of the underlining rocks or dissolution of soil across the sampled point generating ions in the water [8] (Yetiş et al., 2019). Even though underground water has higher TDS value compare to surface water, both can be conveniently used for irrigation. With the result above, Spinach (TDS of<335mg/L) as can be seen in table 4.4 is the suitable crop that can produce maximally with such range of TDS.

Chloride (Cl^-)

From the table above, the mean values of chloride ranges from 0.96 meq/L - 1.35 meq/L. This shows that there is low concentration of chloride ions in the river water. These values fall within the acceptable limit of <4 meq/L base on the degree of restriction proposed by FAO. In a similar way, underground water recorded results with the range of values from 1.12 meq/L - 2.09 meq/L. This also falls within the acceptable limit recommended by FAO. The chloride concentration in the underground water is slightly above that of surface water this could be as a result of salt trapped in the underlining parent material. Both results are similar to the findings of Bing *et al.,* [17] with a mean value of 1.55 meq/L but contrary to Kundu [41] with a mean value of 7.01 meq/L. This result shows that, both the surface and underground water in the sampled areas can be conveniently used for irrigation. Suitable crops that should be irrigated with such water for maximum yield include; carrot (3.45 meq/L - 4.93 meq/L), beans (3.45 meq/L – 4.93 meq/L), and Onion (3.94 meq/L -4.93 meq/L), see table 4.4.

Conclusion

The assessment of surface and underground water quality in some selected parts of Makurdi metropolis was successful carried out. This was to ascertain the quality of surface and underground water used for irrigation in the stated area, and to see whether the water is suitable for irrigation, leading to maximizes yield, thus, tackling the problem of food security arising as a result of increasing population. In respect to the measured parameters, the result shows that the sampled water has good quality as of the time of this research and can be used effectively for irrigation. However, the EC of surface water posed a threat to crops which may cause infiltration problem, reduce crops growth and yield if not properly managed. Thus, it becomes important to routinely check these sources of water to ensure their good quality and suitability for irrigation, for this will maximum food production, cut down poverty rate, generates employment opportunities, boost the economy of the farmers and increase the GDP of the country.

Recommendations

In respect to the research carried out, the following recommendations are made and if considered, will help to maximize food production in other to cope with the increasing population.

This research should be carried out in other parts of the state, nation and worldwide to ascertain the quality of irrigation water to enhance maximum food production. The research should be routinely carried out at least every quarter of the year to understand the variation in the physicochemical parameters of the water. When parameters in one source of irrigation water is found above the thresh hold limit, it should be treated before use, or other sources of water should be explore. Farmers should ensure growing appropriate plant species that can tolerate ambient water salinity. Industries should ensure proper treatment of their effluent before disposing it into water bodies.

Author Statements

Acknowledgements

My most profound gratitude goes to God almighty for his infinite mercy upon my life. I extend my appreciation to my supervisor Dr. K. Asemave whom within his tight schedules created time for me, instructed me accordingly, to ensure the actualization of this research work. My appreciation also goes to the lab attendant's, chemistry department Benue State University. Thanks to my beloved parents Mr/Mrs Iorhemen Gbagam for their great support.

References

1. Abbas A, Nader Y, Amir H, Mahvia RN, Majid R, Mahmood Y, et al. Evaluation of Groundwater Quality using Water Quality Index and its Suitability for Assessing Water for Drinking and Irrigation Purposes: Case study of Sistan and Baluchistan province (Iran). Human and Ecological Risk Assessment. 2018; 34: 45-56.
2. Abbas A, Nader Y, Amir HM, Ramin N, Majid R, Mahmood Y, et al. Human and Ecological Risk Assessment. 2018.
3. Abdul KM, Sylvia L. Cytosolic Calcium and pH Signaling in Plants Under Salinity Stress. Plant Signaling & Behavior. 2010; 5: 233-238.
4. Aberta Ministry of Agric and Forestry. Salt tolerance of plant. 2001: 250–252.
5. Adamu GK. Quality of Irrigation Water and Soil Characteristics of Watari Irrigation Project. American Journal of Engineering Research (AJER). 2013; 2: 59-68.
6. Adeyemi AG, Aluko DM, Aludare AT. Assessment of the Suitability of Water Quality for Irrigation in Ogbomoso, Oyo state''. GSC Biological and pharmaceutical sciences. 2019; 9: 21-31.
7. Aditya R, Ankita G, Neha G, Sameer SB. Effect of Water TDS, on the Growth of Plant (Phaseolus vulgaris) International Journal of Plant & Soil Science. 2023; 35: 131-136.
8. Akakuru OC, Akudinobi BE, Nwankwoala HO, Akakuru OU, Onyekuru SO. Compendious Evaluation of Groundwater in parts of Asaba, Nigeria for Agricultural Sustainability. Geosciences Journal. 2021a; 3: 25-36.
9. Akuh TI, Alagbe SA, Ibrahim AA. Evaluation of Ground Water Suitability for Drinking, Domestic and Irrigation Purpose. A Case Study of Makurdi Metropolis and Environs, Benue State, North Central Nigeria. African Journal of Environmental science and technology. 2014; 8: 610-622.
10. Ali AM. Rice to shrimp: Land use/Land Cover Changes and Soil Degradation in Southwestern Bangladesh, Land Use Policy. 2009.
11. Andreas P. Handbook on Pressurized Irrigation Techniques. Food and Agriculture Organization of the United Nations publisher. 2007.
12. Asogwa VC, Nongugwa DT. Strategies Adopted by Famers for Enhancing Irrigation Agriculture for Sustainable Livelihood in Benue State. Journal of Vocation Education & Training Research (JVETR). 2014.
13. Awulachew S, Merrey D, Van Koopen B, Kamara A. Roles, Constraints and Opportunities of Small-Scale Irrigation and Water Harvesting in Ethiopian Agricultural Development. 2010.
14. Ayers RS, Westcot DW. Water quality for agriculture. Food and Agriculture Organisation (FAO) of the United Nation. 1985.
15. Bazihizina N, Barrett-Lennard EG, Colmer TD. Plant Growth and Physiology under Heterogeneous Salinity. Plant Soil. 2012; 354: 1–19.
16. Bernstein L, Francois LE. Effects of Frequency of Sprinkling with Saline Waters Compared with Daily Drip Irrigation. Agron J. 1975; 67: 185.
17. Bing Z, Xianfang S, Yinghua Z, Dongmei H, Changyuan T, Yilei Y, et al. Hydrochemical Characteristics and Water Quality Assessment of Surface Water and Groundwater in Songnen plain, Northeast China. Elsevier, water research. 2012; 46: 2737-e2748.
18. Bolanos L, Lukaszewski K, Bonilla I, Blevins D. Why Boron? Plant Physiol. Biochem. 2004; 42: 907–912.
19. Bortolini L, Maucieri C, Borin M. A Tool for the Evaluation of Irrigation Water Quality in the Arid and Semi-Arid Regions. Agronomy. 2018; 8: 23.
20. Canadian Council of ministry of Environment. Canadian Water Quality Guidelines, Water Quality Branch, Inland Water Directorate, Environment Canada Ottawa. 1987.
21. Cavallaro V, Maucieri C, Barbera AC. Loliummultiflorum Lam. Germination under Simulated Olive Mill Wastewater Salinity and pH Stress. Ecol Eng. 2014; 71: 113–117.
22. Cook DC, Fraser RW, Paini DR, Warden AC, Lonsdale WM, DeBarro PJ. Biosecurity and Yield Improvement Technologies Are Strategic Complements in the Fight against Food Insecurity. Plos One. 2011; 6: e26084.

23. Cseko G, Hayde L. Danube Valley: History of irrigation, drainage and flood control. New Delhi, India: International Commission on Irrigation and Drainage. 2004.

24. Dean EE, Derrel LM, Derek MH, Glenn J Hoffman. Introduction to Irrigation. Published by the American Society of Agricultural and Biological Engineers. 2019.

25. Eisa S, Hussin S, Geissler N, Koyro HW. Effect of NaCl Salinity on Water Relations, Photosynthesis and Chemical Composition of Quinoa (Chenopodium quinoa Willd.) as a Potential Cash Crop Halophyte. Aust J CropSci. 2012; 6: 357-368.

26. Elferink M, Schierhorn F. Global Demand for Food is Rising. Can We Meet It? Harvard Business Review-7. 2016.

27. Evans, R.G. and E.J. Sadler. Methods and Technologies to Improve Efficiency of Water use. Water Resources Res. 2008; 44: 1–15.

28. Foley JA, Ramankutty N, Brauman KA, Cassidy ES, Gerber JS, Johnston M, et al. Solutions for a Cultivated Planet. Nature. 2011; 478: 337–342.

29. Food and Agriculture Organization of the United Nations Statistical Database. Annual Population.

30. Freddie RL. Advantages and Disadvantages of Subsurface drip irrigation. Academia edu. 2002.

31. Fukase E, Martin WJ. Economic Growth, Convergence, and World Food Demand and Supply; Policy Research Working Paper 8257; World Bank Group, Development Research Group Agriculture and Rural Development Team: Washington, DC, USA. 2017.

32. Gattward JN, Almeide AA, Souza JO, Gomes FP, Kronzucker HJ. Sodium-potassium Synergism in Theobroma cacao: Stimulation of Photosynthesis, Water-use Efficiency and Mineral Nutrition. Physiol Plant. 2012; 146: 350–362.

33. Grattan SR. Irrigation Water Salinity and Crop Production. Agriculture and Natural Resources. 2022.

34. Gulhati ND, Kovda C, Vanden B, Hagan RM. Irrigation/Drainage, and Salinity. London: Hutchinson. 1973: 1-14.

35. Hakim MA, Juraimi AS, Begum M, Hasanuzzaman MK, Uddin ST, Islam MM. Suitability Evaluation of Groundwater for Irrigation, Drinking and Industrial Purposes. American Journal of Environmental Sciences. 2009; 5: 413-419.

36. Hatfield JL, Sauer TJ, Prueger JH. Managing Soil to Achieve Dreater Water use Efficiency: A review. Agron J. 2001; 93: 271–280.

37. Haydon MJ, Roman A, Arshad W. Nutrient homeostasis within the plant circadian network. Front Plant Sci. 2015; 6: 299.

38. Hector PG. Relationship between Chloride Concentration and Electrical Conductivity in Ground water and its Estimation from vertical Electrical Sounding in Sinaloa, Mexico. Cien Inv Agr. 2012; 29: 229-239.

39. Hillel D. Rivers of Eden: The Struggle for Water and the Quest for Peace in the Middle East; Oxford University Press: New York, 1994; 355.

40. Junko N. Food and Agriculture Organization of the United Nations and the Sustainable Development Goals. e-Bulletin. 2018: 22.

41. Kundu S. Assessment of Surface Water Quality for Drinking and Irrigation Purposes: A Case Study of Ghaggar River System Surface Waters Bulletin of Environment, Pharmacology & Life Sciences. 2012; 1: 01-06.

42. Kuros GR. Qanats-A 3000-year-old Invention for Development of Groundwater Supplies. Proc. Special Session, Int. Committee on Irrigation and Drainage. 1984.

43. Lu YB, Qi YP, Yang LT, Lee J, Guo P, Ye X, et al. Long-term Boron Deficiency Responsive Genes Revealed by cDNA-AFLP differ between Citrus sinensis Roots and Leaves. Front. Plant Sci. 2015; 6: 585.

44. Luo WT, Nelson PN, Li MH, Cai JP, Zhang YY, Zhang YG, et al. Contrasting pH Buffering Patterns in Neutral-alkaline Soils Along a 3600 km Transect in northern China. Biogeosciences. 2015; 12: 7047–7056.

45. Maas EV. Salt Tolerance of Plants. In: The Handbook of Plant Science in Agriculture. CRC Press, Boca Raton. Flori. 1984.

46. Michael AM. Irrigation; Theory and Practice. New Delhi, Starndard Publishers. 2008.

47. Modi PN. Water engineering and water power engineering. New Delhi Press. 2000; 339-360.

48. Paranychianakis NV, Chartzoulakis KS. Irrigation of Mediterranean Crops with Saline Water: from Physiology to Management Practices. Agriculture, Ecosystems and Environment. 2005; 106: 171–18.

49. Rashid MM, Hoque AKF, Iftekhar MS. Salt Tolerances of Some Multipurpose Tree Species as Determined by Seed Germination. J Biol Sci. 2004; 4: 288-292.

50. Reddy RN. Irrigation Engineering. Gene-Tech Books. 2010.

51. Richards LA. Diagnosis and Improvement of Saline and Alkali soils. Soil Sci. 1954; 78: 154.

52. Rohan S, Sagar K, Adesh G, Sagar T, Adesh P. A review on different irrigation methods. International Journal of Applied Agriculture Research. 2019; 14: 49-60.

53. Sahasrabudhe SR. Irrigation Engineering. New Delhi, Starndard publishers. 2000.

54. Samarakoon UC, Weerasinghe PA, Weerakkody AP. Effect of Electrical Conductivity (EC) of the Nutrient Solution on Nutrient Uptake, Growth and Yield of Leaf Lettuce (Lactuca sativa L.) in Stationary Culture. Trop Agric Res. 2006; 18: 13–21.

55. Schulze LM, Britto DT, Kronzucker HJ. A Pharmacological Analysis of High-affinity Sodium Transport in Barley (Hordeumvulgare L.): a 24N+/42K+ study. J Exp Bot. 2012; 63: 2479–2489.

56. Seth K, Aery NC. Boron Induced Changes in Biochemical Constituents, Enzymatic Activities, and Growth Performance of wheat. Acta Physiol. Plant. 2017; 39: 244.

57. Shabala S, Munns R. Salinity Stress: Physiological Constraints and Adaptive Mechanisms in Plant Stress Physiology. Oxfordshire, UK. 2012; 59–93.

58. Sibhatu KT, Qaim M. Rural Food Security, Subsistence Agriculture, and Seasonality. PlosOne. 2017; 12: e0186406.

59. Signore A, Serio F, Santamaria P. A targeted management of the nutrient solution in a soilless tomato crop according to plant needs. Front Plant Sci. 2016; 7: 391.

60. Silva G. Feeding the World in 2050 and Beyond–Part 1: Productivity Challenges. Michigan State University Extension-part-1. 2018.

61. Singh SK, Srivastava PK, Gautam SK, Pandey AC. Integrated assessment of groundwater influenced by a confluence river system: occurrence with remote sensing and geochemical modelling. Water Resource Management. 2013; 27: 4291–4313.

62. Smyth SJ, Phillips PW, Kerr WA. Food Security and the Evaluation of Risk. Glob. Food Secur. 2015; 4: 16–23.

63. Sonneveld C, Voogt W. Plant Nutrition of Greenhouse Crops, Springer, ISBN 9048125316, New York, USA. 2009.

64. Subbarao GV, Ito GW, Berry WL, Wheeler RM. Sodium-A Functional Plant Nutrient. Critical Reviews in Plant Sciences. 2013; 22: 391-416.

65. Tilman D, Balzer C, Hill J, Befort BL. Global Food Demand and the Sustainable Intensification of Agriculture. Proceedings of the National Academy of Sciences USA. 2011; 108: 20260–20264.

66. USDA. Irrigation and water management survey. Washington, DC: USDAvol.3. Part1.AC-17-SS-1. 2019.

67. Wade WM. The pH Preference of a Plant. College of Tropical Agriculture and Human Resources University of Hawaii. 1980.

68. Wallace JS. Increasing agricultural Water use Efficiency to Meet Future Food Production. Agr. Ecosystem Environ. 2000; 82: 105–119.

69. Wallace JS, Gregory PJ. Water resources and their use in Food Production System. Aquat Sci. 2002; 64: 363–375.

70. Wimmer MA, Abreu I, Bell RW, Bienert MD, Brown PH, Dell B, et al. Boron: An essential element for Vascular Plants. New Phytol. 2019; 2: 144–160.

71. Xiaotao D, Yuping J, Hong Z, Doudou G, Lizhong H, Fuguang L, et al. Electrical conductivity of nutrient solution influenced photosynthesis, quality, and antioxidant enzyme activity of pakchoi (Brassica campestris L. ssp. Chinensis) in a hydroponic system. Plos One. 2018; 13: e0202090.

72. Yishai N, Moshe S, Amnon S. Effects of Irrigation using Treated Wastewater on Table Grape Vineyards: Dynamics of Sodium Accumulation in Soil and Plant Springer-Verlag Berlin Heidelberg. 2004.

73. Zewdie M, Moti J, Ascimelis G. Assessment of WendoWesha irrigation scheme in AwassaZuria. Proceedings of Research Project Completion Workshop. 2007; 1-2.