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Assessment of Potential of Groundwater Yield for Domestic and Dry Season Irrigation in North-East Region of Ghana

Yussif Seidu[1], Nicholas Kyei-Baffour[2], Agyare Wilson Agyei[2] and William Amponsah[2]
[1]Agricultural Engineering Department, Engineering Faculty, Tamale Technical University, Northern Region-Ghana.

[2]Agricultural and Biosystems Engineering Department, Mechanical and Chemical Engineering Faculty, Kwame Nkrumah University of Science and Technology, Kumasi-Ghana.

Corresponding email: yussifseidu20@gmail.com

ABSTRACT

This paper investigated the potential of groundwater yield for domestic and dry-season vegetable irrigation in East Mamprugu, West Mamprugu, Muagduri, Nakpanduri-Bunkpurgu, Yunyoo and Cheriponi districts of the North-East Region of Ghana. In this study, a simple random sampling technique was used to select respondents for the questionnaires. The cluster sampling method was used to select four communities from each district. A sample size of 480 households from twenty-four communities was used for the study. Groundwater yield test was carried out on all the water facilities (Boreholes and Hand-dug wells) in each of the studied communities in the six districts of the region. It compared the total domestic water demand per day (m^3) with that of the total available yield of groundwater facilities per day (m^3). Results indicated that groundwater demand for all domestic purposes is low compared to available groundwater yield in most of the communities in the region. There was surplus groundwater available over a dry period of six (6) months with Kulguduri in East Mamprugu district having the highest surplus groundwater. This could be used for dry-season vegetable irrigation. The study also revealed that by using the combined water availability-demand measure some communities out of the twenty (24) studied communities in the districts of the region would become vulnerable to water stress by 2050. The potential of groundwater for dry season irrigation can be expanded if more of the broken boreholes in the study areas are repaired.

Keywords: *Potential, groundwater yield, domestic and dry season irrigation*

INTRODUCTION

The well-being of humans in any community requires substantial quantities of potable water for domestic, agricultural and industrial purposes (Falowo et al., 2019; Shrikant et al., 2020). Groundwater has been estimated to provide almost half of all drinking water worldwide with 2.5 billion people depending solely on this resource to satisfy their daily water needs (UNESCO, 2012). Groundwater is used by about 2 billion people worldwide making it the single most used natural resource (Tirkey et al., 2013). Groundwater also delivers water for domestic, industrial and agricultural demand applications and also assists many regions in the world in maintaining ecological standards.

According to (Koncagül and Tran, 2022), groundwater proportion for agricultural, domestic, and industrial purposes is estimated to be 69%, 22%, and 9%, respectively globally. These percentages vary between the continents. It therefore can be implied that groundwater is a very significant and critical source of freshwater in satisfying the increasing demands for domestic, agricultural, and industrial activities.

Agriculture accounts for an estimated 70% of groundwater withdrawals worldwide, with the domestic sector responsible for just over 20% and industry just under 10% (based on 2010 data) (Margat and van der Gun 2013). Groundwater plays an increasingly significant role in domestic, industrial and agricultural water supply in Sub-Saharan Africa region. In a recent report, the British Geological Survey estimated that the groundwater potentials of aquifers in Africa are 100 times the amount found on the surface (MacDonald et al., 2011; McGrath, 2012). Currently, more than half of the continent‘s populations depend directly on this natural resource for their daily water needs. Some regions of the world have room for further development of groundwater to fully reap the economic benefits associated with its use (Margat and van der Gun 2013). Rain-fed agriculture is the main source of food for the better part of the population of Sub-Saharan Africa, which yields cereals and roots of "limited nutritional content and low market value" (Domenech 2015). Meanwhile, the potential for groundwater development in this region is considerable. The total area that can be irrigated with renewable groundwater in Sub-Saharan Africa is estimated between approximately 20 and 50 times the present groundwater-irrigated area (Altchenko and Villholth 2015).

Some studies in Ghana have proclaimed that over 80% of rural dwellings, characterising almost 70% of the total population count on groundwater as a source of water supply for domestic needs (Gibrilla, Anornu, and Adomako, 2018). Lately, groundwater demand for domestic industrial and agricultural intents in the North-East Region has seen an inclination, a scenario that has critically culminated in the exploitation of groundwater. With a flourishing population and its associated demand for water for domestic and agricultural use to support food security due to the promotion of dry season small-scale farming using shallow wells, groundwater resource sustainability is becoming a principal concern to water resource managers and the usage of groundwater generally. This study, therefore, sought to investigate the groundwater resource potential for domestic, dry season irrigation and the impact of population growth on domestic groundwater demand in the North-East Region of Ghana.

MATERIALS AND METHODS

Study Area

The study was conducted in the North-East Region of Ghana. The region is one of the sixteen regions of Ghana. It is located in the north of the country and was created in December 2018 after a referendum was voted upon to break it off of the Northern region. The region's capital is Nalerigu. The Region is bordered on the north by the Upper East region, on the east by the eastern Ghana-Togo international border, on the south by the Northern region, and the west by the Upper West region. North- East region is made up of 6 districts. The region covers an area size of 9,072 km^2.

The Region is characterized by a gently rolling topography with the Gambaga escarpment, which marks the northern limits of the Voltaian sandstone basin. The scarp stretches from East-West and peaks at Nakpanduri, with waterfalls presenting its beauty. Important drainage features in the region include the White Volta, which enters the region in the northeast and is joined by the Red Volta near the Gambaga escarpment with the Nawonga and Moba rivers also draining the South-Western part.

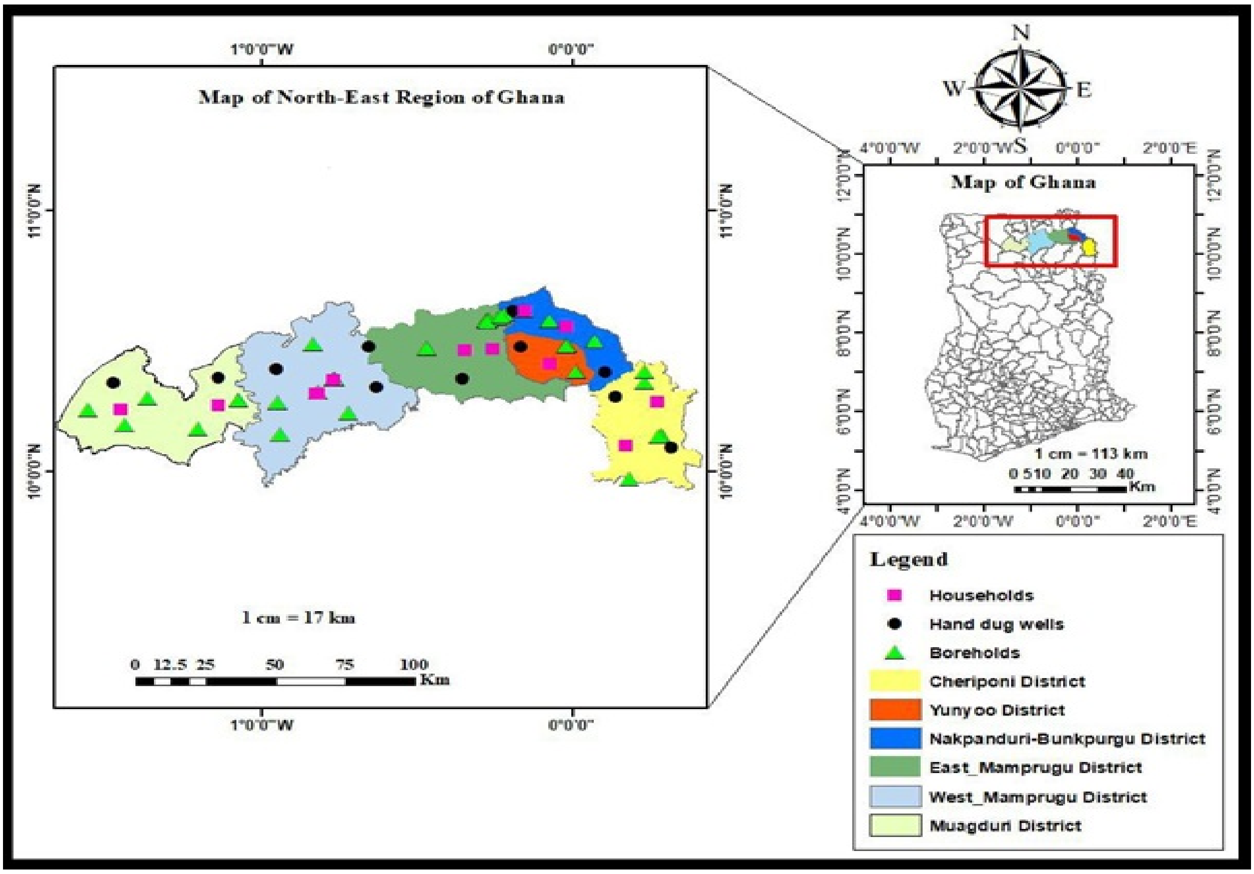

Figure 1: *A map of Ghana showing the location of Muagduri, West Mamprugu, East Mamprugu, Nakpanduri-Bunkpurgu, Yunyoo and Cheriponi Districts with water facilities and households*

Materials
The materials used for the study include; a 15 15-litre bucket, a stopwatch, a tape measure, GPS**,** and a personal computer for data entry and storage.

Methods
Data for this study were from both primary and secondary sources. Both qualitative and quantitative were used including a literature survey and discussions with local communities and stakeholders of the rural water supply schemes in the six districts. In addition, field surveys and experiments were conducted together with interviews using questionnaires. In this study, a simple random sampling technique was used to select respondents for the questionnaires. The cluster sampling method was used to select four communities from each district. A sample size of 480 households from twenty-four communities was used for the study.

In West Mamprugu District (Loagri, Kukua, Banawa and Gagbeni were chosen), in East Mamprugu District (Kulgu-duri, Zaratinga, Namasim and Sakugu were selected), in Muag-duri.District (Prima, Sakpaba, Kuba and Loagri were selected). Bombila, Kpemale, Dukluatuk and Naabtinga were also selected in the Nakpanduri-Bunkpurgu District, Yunyoo, Danduri, Jimbali and Sitik were selected in the Yunyoo District and Adari, Mansawusi, Garinkuka and Banjani were selected in the Cheriponi District.

The case-control method was used such that the water situation in the six districts can be compared with one another to identify vulnerable district(s) to water sources. Twenty-four (24) communities were randomly selected so that the information acquired would be representative of the six districts. To ensure that the information obtained is a true representation of the situation, 20 households were sampled in each community.

Sample Size

Yamane's (1967) Formula.

$$n = \frac{N}{1+N(e)^2}$$ ....[1]

n = $n = \frac{658946}{1+658946(0.0456)^2} = 480$

n = Sample size

N = Population size and

e = Level of precision

Crop Data

Crop data which included crop coefficient (K_C) and reference evaporation (ET_O) derived from 30 years of mean monthly climatic data to compute crop evapotranspiration (ET_C) were also obtained from the Savanna Agricultural Research Institute (SARI), Tamale (Nyankpala). These were also used in the estimation of the irrigation water requirement.

Available Yields of the Groundwater Systems

Available groundwater yield tests were conducted on groundwater facilities in the study communities. These included boreholes and hand-dug wells. This data is required to establish whether the supply yields were capable of meeting domestic and small-scale industrial water needs.

Available Yield of Hand Dug Wells

In this study, a recuperation test was considered in determining the yield of the wells. In this method, the water level in the well was depressed by pumping to any level below the normal level. Then the pumping was later stopped and the time taken by the percolating water to fill the well to any particular level was noted. The total quantity of water flowing into the well was calculated by knowing the cross-sectional area and the rise in the water level after the stoppage of pumping. The yield of the well was determined by dividing the quantity of water by the time. All yield tests were carried out in the driest period (January, February and March) for two (2) years (2021 and 2022) so that the worst conditions will be taken into account.

Available Yield of a Borehole

Since the boreholes in these rural communities are fitted with hand-pumps, the yields would be dependent on human power, hence the available yield was measured based on human power. The following steps were used:

- Ten (10) different people fill a 15-litre bucket each by pumping and the time for each was noted
- The average time taken to fill the 15-litre bucket by pumping was found
- The average yield of the borehole was then determined : (15litre/average time)

Irrigation Water Requirement (IWR)

Food and Agriculture Organisation (FAO) Modified Penman-Monteith method was used to determine ET_c and hence IWR. The relation is given as

$$ET_c = K_c \times ET_O \quad [2]$$

$$IWR = K_c - P_e \quad [3]$$

Where; ET_C = Crop evapotranspiration
K_C = Crop coefficient
ET_o = Reference evapotranspiration
Pe = Effective precipitation

Population Growth to the Year 2050
If the current population were to continue to the year 2050 would some districts in the region face shortages of water to meet their needs? To answer this question, population forecasts for West Mamprugu, East Mamprugu, Muag-duri, Nakpanduri-Bunkpurgu, Yunyoo and Cheriponi districts of the North-East Region for the year 2050 were obtained for each of the six districts as follow:

$$P_n = P_o e^{nt} \quad [4]$$

Where; P_n = Projected population
P_o = Present population
n = Period of projection
t = Population growth rate

Methodology
In making projections under this scenario, three (3) assumptions were made:

- Changes other than population are not significant determinants of vulnerability to water resources
- Water use pattern remains unchanged from the 2020 level on a per capita basis and
- The water supply remains unchanged from the 2020 level.

The level of water use in 2050 was estimated under these assumptions.

Future Domestic Groundwater Use
The domestic groundwater use for the year 2050 was estimated by assuming that the per capita use in the year 2050 would be at the same level as it was in 2020. Thus the only factor that affects the level of groundwater use for domestic purposes is population growth. The following assumptions were made:

- There is no significant increase or decrease in the availability of groundwater within the areas.
- No significant institutional policy has been implemented that would promote groundwater conservation during the 2020-2050 period.

Per Capita Water Consumption
Data was collected on the quantity of water consumed daily (Qv) by households in terms of drinking, cooking, bathing, washing and other domestic purposes (performance of ablution, cleaning) in West Mamprugu, East Mamprugu, Muag-duri, Nakpanduri-Bunkpurgu, Yunyoo and Cheriponi districts of North-East Region for the wet and dry seasons. Women and children who are the main people who fetch water were interviewed. The quantity of water consumed by households was calculated based on their recall of water quantity consumed daily. The average quantity consumed (Qv) by households in each community was computed and the per capita water consumption (C) was also determined for each of the six (6) districts as follows;

$$C = \frac{Qv}{n} \text{ l/p/day} \quad \text{(Alice et al., 2022)} \quad [5]$$

Where; n = Average household size

RESULTS AND DISCUSSION
Groundwater Potential for Domestic and Irrigation Purposes
The surplus groundwater available in most of the groundwater facilities in the dry season shows water availability and potential of these groundwater supply systems for small-scale irrigation of vegetables. The potential of these water facilities would depend on several factors including the following:

- Adequacy of the systems
- People's willingness to use the facilities for this purpose and

- Availability of market for the produce.

The adequacy of the systems further depends on the yield, type of crop to be grown, soil characteristics, and climatic and water management factors. With regard to the people's willingness to use the facilities for small-scale vegetable irrigation, 58% in West Mamprugu District indicated their readiness to use provided the yield of the groundwater facilities in the entire district can support the course, 30% of the respondents at Loagri and Kukua communities indicated that they have artesian well which they are sure can help them to carry out irrigation activities effectively and 12% of the respondents expressed concern about the inadequacy of the systems due to poor yield of these water facilities.

In East Maprugu District 78% indicated their readiness to use the facilities for irrigation provided they can get assistance from NGOs, this is because the few who are already using the irrigation dam for farming during the dry season are not getting support and 22% also expressed concern about the inadequacy of the systems due to poor yield.

In Muag-duri District, however, 65% of the respondents indicated their readiness to use groundwater systems for dry season farming if the yield of groundwater systems can support the activities and also provided they can get support from the government and 10% expressed concern about the inadequacy of the systems due to poor yield and 25% do not just have interest in irrigation especially communities like Prima and Sakpaba where the White Volter river passes. This river flows throughout the year with no irrigation farming near it. One of the community members said to the researcher that they do not believe that there is economic gain in irrigation farming and also do not have seeds and the necessary equipment to help them carry out irrigation farming. That is why they depend solely on rainfed agriculture.
55% in Nakpanduri-Bunkpurugu, 75% in Yunyoo and 83% in Cheriponi expressed their readiness provided the groundwater facilities can help them in that course because they depend on only groundwater facilities for their domestic use during the dry season since most of the small water systems like ponds, streams and small dug-outs dry up in the dry season, but if they see that the groundwater facilities can support both their domestic and irrigation water use they would be happy and would embrace the idea.

However, an interview with some farmers at Kulgu-Duli and Prima communities in East Mamprugu and Muag-duri Districts who are using the dam and white volta lake respectively for irrigation revealed that there was a good market for all kinds of vegetables, especially amarantus, corchorus (*ayoyo*), tomatoes and pepper but no farmer in the six districts in the entire region use groundwater for irrigation which could be due to their ignorance of the potential of the groundwater facilities for small scale dry season irrigation farming.

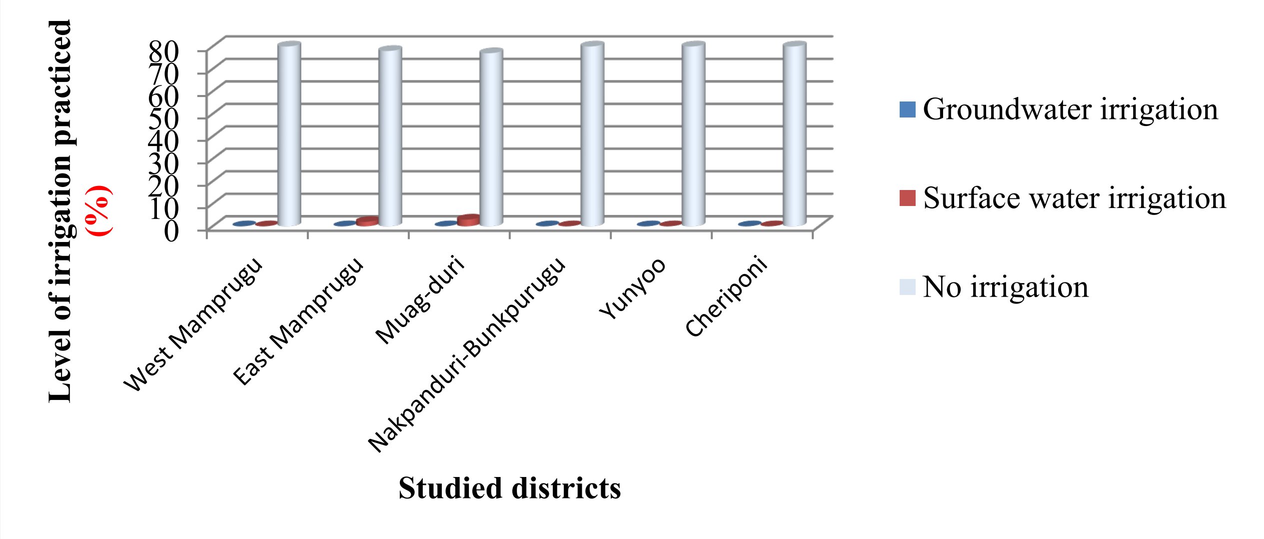

Figure 2: Level of irrigation practiced in the six districts of North-East Region of Ghana

The study has also revealed the level of irrigation practised in the six districts of the region. The study revealed that groundwater irrigation is not practised in any of the six districts of the North-East Region except in Muag-duri District where 3 (3.75%) use the white volta river for irrigation and 2 (2.5%) in East Mamprugu use the irrigation dam for dry season farming. This means that the people are not aware of the potential of the groundwater facilities for dry season irrigation.

Table 1: Groundwater Supply Availability in the Districts

Districts	Communities	Number of Functional Boreholes and wells	Total available yield of groundwater facilities (l/s)	Total available yield of groundwater facilities (m^3/h)	Total available yield of groundwater facilities (m^3/day)
West Mamprugu	Loagri	3	1.48623	5.35	37.45
	Kukua	13	8.731254	31.43	220.01
	Banawa	5	2.911344	10.48	73.36
	Gagbeni	1	0.5556	2	14.00
East Mamprugu	Kulgu-duri	15	11.067552	39.84	278.88
	Sakugo	2	1.58346	5.7	39.90
	Zaratinga	2	1.33344	4.8	33.60
	Namasim	4	1.47234	5.3	37.10
Muag-duri	Prima	8	3.614178	13.01	91.07
	Sakpaba	7	3.280818	11.81	82.67
	Kuba	8	0.780618	2.81	19.67
	Loagri	2	4.394796	15.82	110.74
Nakpanduri-Bunkpurgu	Bombila	3	2.12517	7.65	53.55
	Kpemale	3	2.433528	8.76	61.32
	Dukluatuk	2	0.816732	2.94	20.58
	Naabtinga	2	0.5556	2	14.00
Yunyoo	Sitik	5	0.947298	3.41	23.87
	Jimbali	1	2.23629	8.05	56.35
	Danduri	5	0.386142	1.39	9.73

Cheriponi	Yunyoo	2	2.714106	9.77	68.39
	Adari	2	0.955632	3.44	24.08
	Banjani	2	0.433368	1.56	10.92
	Garinkuka	2	0.836178	3.01	21.07
	Mansawusi	2	0.872292	3.14	21.98

According to Gyau-Boakye and Dapaah-Siakwan (2000) for hand pumps and BHs meant to supply rural communities in Ghana, a successful yield is considered to be at least 13 l/min (0.78 m^3/h) or more. This minimum yield per BH is designed to meet the demand of communities with a population ranging between 200-2000 providing per capita water consumption of 25L.

All things being equal and supposing an average pumping period of seven hours per day (7h/day) as inferred from household respondents, Table 2 presents an estimated available groundwater supply from the current functioning facilities in the various communities.

Table 2: Water demand and available groundwater in the study communities in the dry season

Districts	Communities	Current Population (2020)	Average per capita water demand (litres)	Total domestic water demand per day (m^3)	Total available yield of groundwater facilities per day (m^3)	Surplus water available for any activity per day (m^3)	Total surplus water available over a dry period of six months (m^3)
West Mamprugu	Loagri	1603	29.56	47.39	37.45	Nil	Nil
	Kukua	2195	29.11	63.70	220.01	156.31	28135.80
	Banawa	158	28.89	4.57	73.36	68.79	12382.20
	Gagbeni	327	28.89	9.45	14.00	4.55	819.00
East Mamprugu	Kulgu-duri	3240.25	28.44	92.15	278.88	186.73	33610.91
	Sakugo	6927	28.11	194.71	39.90	Nil	Nil
	Zaratinga	1864	27.89	51.99	33.60	Nil	Nil
	Namasim	2198	27.67	60.82	37.10	Nil	Nil
Muag-duri	Prima	129	26.25	3.39	91.07	87.68	15782.40
	Sakpaba	156	26.00	4.10	82.67	78.57	14142.6
	Kuba	102	26.50	2.70	19.67	16.97	3054.60
	Loagri	698	25.75	19.97	110.74	90.77	16338.60
Nakpanduri-	Bombila	382	24.38	9.31	53.55	44.24	7963.20
	Kpemale	1705	25.25	43.10	61.32	18.22	

Bunkpurgu	Dukluatuk Naabtinga	643 264	24.88 22.22	16.00 5.87	20.58 14.00	4.58 8.13	3279.60 824.40 1463.40
Yunyoo	Sitik Jimbali Danduri Yunyoo	524 2500 510 1346	20.57 21.71 21.29 21.00	10.78 54.28 10.86 28.27	23.87 56.35 9.73 68.39	13.09 2.07 Nil 40.12	2356.20 372.60 Nil 7221.60
Cheriponi	Adari Banjani Garinkuka Mansawusi	209 106 1154 268	21.14 20.57 19.86 20.00	4.42 2.20 22.92 5.36	24.08 10.92 21.07 21.98	19.66 8.72 Nil 16.62	3538.80 1569.60 Nil 2991.60

Table 2, implies that for Loagri in West Mamprugu District, the total surplus water available might increase if the three broken boreholes are repaired. For Sakugu, Zaratinga Namasim communities in the East Mamprugu District, Danduri in the Yunyoo District and Garinkuka community in the Cheriponi District even though no surplus water available over the dry period of six months, water supply would have been adequate for domestic purposes or prevail in excess if the broken boreholes are properly repaired to ensure that the capacity of the facilities can sustain water in conjunction with other hand-dug well facilities for the communities throughout the year. It was revealed to the researcher that most of the dug-outs or surface water sources in the selected communities of the six districts dry up in the dry season except one at the Kulgu-duri community in the East Mamprugu District. This, however, revealed to the researcher that, there is a high dependency on groundwater in the entire region in the dry season due to limited surface water sources in the region. This also shows that most of the communities in the region have groundwater yields which are sufficient for domestic and other economic activities.

Soil Infiltration Rate

Infiltration is the downward entry of water into the soil from the surface. The velocity at which water enters the soil is the infiltration rate. Water from rainfall or irrigation must first enter the soil for it to be of value. Infiltration is an indicator of the soil's ability to allow water movement into and through the soil profile. Soil temporarily stores water, making it available for root uptake, plant growth and habitat for soil organisms.

The infiltration rate can be restricted by poor management. Under these conditions, the water does not readily enter the soil and it moves downslope as runoff or ponds on the surface, where it evaporates. Thus, less water is stored in the soil for plant growth, and plant production decreases, resulting in less organic matter in the soil and weakened soil structure that can further decrease the infiltration rate. Basic steady-state infiltration rates for different soil types are summarized in Table 3

Table 3: Basic Steady State Infiltration Rates for Different Soil Types

Soil type	Steady infiltration rate (mm/h)
Sand	>30
Sandy loam	20-30
Loam	10-20
Clay loam	5-10
Clay	1-5

Since most areas of land are used for agricultural production, a small loss in the infiltration capacity of agricultural soils may produce serious impacts on flood intensity. For instance, water infiltration rates less than 15 mm/h were found to be related to increased flood intensity (Sparovek et al., 2002). Therefore, sustaining enhanced water infiltration ability into the soil of agricultural areas is considered important because it provides water needed for vegetation growth and enhances groundwater storage.

The infiltration rate decreases with increased time of wetting. Therefore, the amount of water applied to each irrigation will affect the fraction of the water that enters the soil and the fraction that will runoff. Soil basic infiltration rates at three points each in six of the studied communities with operational facilities are shown in Table 4

Table 4: Soil Infiltration Rates in the Study Areas

Districts	Communities	Soil type	Basic Infiltration Rate (mm/h)			Average Basic Infiltration Rate
			First Point	Second Point	Third Point	
West Mamprugu	Kukua	Sandy loam	26	25	24	25.00 ±1.00
	Banawa	Sandy loam	26	25	25	25.33 ±1.00
	Gagbeni	Sandy loam	24	23	23	23.33 ±1.00
East Mamprugu	Kulgu-duri	Sandy loam	27	29	28	28.00 ±1.00
Muag-duri	Prima	Sandy loam	25	25	26	25.33 ±1.00
	Sakpaba	Sandy loam	24	25	25	24.67 ±1.00
	Kuba	Sandy loam	23	27	30	26.67±1.00
	Loagri	Sandy loam	20	22	24	33.00±1.00
Nakpanduri-Bunkpurgu	Bombila	Sandy loam	27	29	26	27.33±1.00
	Kpemale	Sandy loam	30	25	23	26.00±1.00
	Dukluatuk	Sandy loam	25	21	28	24.67±1.00
	Naabtinga	Sandy loam	23	27	25	25.00±1.00
Yunyoo	Yunyoo	Sandy loam	22	26	21	23.00±1.00
	Sitik	Sandy loam	20	23	25	22.67±1.00
	Jimbali	Sandy loam	24	26	29	26.33±1.00
Cheriponi	Adari	Sandy loam	25	27	21	24.33±1.00
	Mansawusi	Sandy loam	26	20	23	23.00±1.00
	Banjani	Sandy loam	21	23	25	23.00±1.00

The soil type is sandy loam which is characterized by a high infiltration rate as indicated in the table above. Drip irrigation is suitable for most soils. On sandy soils higher emitter discharge rates will be needed to ensure adequate lateral wetting of the soil.

Irrigation Water Requirements

The estimated total crop water requirement (CWR, ETc) and irrigation water requirement (IWR) of tomato crops grown in the field for 180 days in the study areas during the period of Oct-Mar/April were 1015.03mm and 923.68 mm respectively in West and East Mamprugu Districts, 1015.03mm and 818.06mm in Muag-duri District, 1015.03mm and 775.42 in Nakpaduri-Bunkpurgu and Yunyoo Districts, and 1015.03mm and 707.34 mm in Cheriponi District. Gross irrigation water requirement (GIWR) was therefore 1319.54 mm, 1168.66mm, 1107.74mm, and 1010.49 mm for West and East Mamprugu, Muag-duri, Nakpanduri-Bunkpurgu and Yunyoo and Cheriponi Districts respectively taking into consideration the irrigation efficiency of 70% for watering cans likely to be used. The difference in the estimated values of this research in the six districts may be due to climatic data used in the estimation. According to Agodzo (1998), the CWR and IWR of tomato in Tamale are 668 and 604 respectively during the period of Nov-Feb/Mar. For Limantol (2009), the CWR and IWR of tomatoes in Saboba are 1012.61 mm and 847.35 mm respectively during the period of Oct-Mar/April. Keraita and Drechsel (2007) also observed for vegetables grown in the field for 90-120 days, the crop water requirements ranged between 300 mm and 700 mm depending on the climatic conditions and the season of the crop at the location. The difference between the estimated values in this research and those of literature (Agodzo, 1998) (Limantol, 2009) may be due to irrigation frequency, number of days, and irrigation efficiency as well as the number of years of climatic data used in the estimation. A daily irrigation frequency was used in this research. In the savannah areas where ETc is very high, daily application is the appropriate frequency for vegetables if they are to look fresh and give good yield. However, daily frequency means higher CWR and IWR hence the above values. Given water scarcity in some of the areas, it would be prudent if the farmers use the drip irrigation method with higher efficiency to reduce water wastage and hence low IWR. This will be best done by pumping water into overhead tanks especially where yields are very low. It will also reduce the labour intensiveness and drudgery of the traditional method of using watering cans.

Irrigation Potential of the Available Water

Considering the GIWR of tomato being 1231.67 mm (≈1.23 m), 1260.24mm (≈1.26 m) 124319mm (≈1.24 m), 1217.39mm (≈1.22 m), 1233.16mm (≈1.23 m) and 1214.26mm (≈1.21 m) in West Mamprugu, East Mamprugu, Muag-duri, Nakpanduri-Bunkpurgu, Yunyoo and Cheriponi Districts respectively, it implies that to irrigate a hectare of tomato, the total amount of water required in each of the districts can be calculated as:

a) For West Mamprugu District;

Total GIWR = GIWR × Total area to be irrigated.

Total tomato GIWR = 1.23 m ×10000 m^2 = 12300 m^3 /ha.

b) For East Mamprugu District;

Total GIWR = GIWR × Total area to be irrigated.

Total tomato GIWR = 1.26 m ×10000 m^2 = 12600 m^3 /ha.

c) For Muag-duri District;

Total GIWR = GIWR × Total area to be irrigated.

Total tomato GIWR = 1.24 m ×10000 m^2 = 12400 m^3 /ha.

d) For Nakpanduri-Bunkpurgu District;

Total GIWR = GIWR × Total area to be irrigated.

Total tomato GIWR = 1.22 m ×10000 m^2 = 12200 m^3 /ha.

e) For Yunyoo District;
Total GIWR = GIWR × Total area to be irrigated.
Total tomato GIWR = 1.23 m ×10000 m^2 = 12300 m^3 /ha.

f) For Cheriponi District;
Total GIWR = GIWR × Total area to be irrigated.
Total tomato GIWR = 1.21 m ×10000 m^2 = 12100 m^3 /ha.
This pre-supposes that for the facilities in West Mamprugu District, the current functioning facilities at Kukua are capable of meeting domestic water demand and irrigate about 2.29 ha of tomatoes, those at Banawa can irrigate about 0.10 ha of the same crop whilst at Gagbeni, irrigating about 0.07 ha is also possible. However, in East Mamprugu District the only community that has the facilities capable of meeting domestic water demand and can irrigate about 2.67 ha of tomatoes is the Kuldu-duri community.

For Muag-duri District the current functioning facilities are capable of irrigating 1.27 ha of tomatoes in Prima, 1.14 ha of tomatoes in Sakpaba, 0.25 ha of tomatoes in Kuba and 1.32 ha of tomatoes in Loagri.

For Nakpanduri-Bunkpurgu District the current functioning facilities are capable of irrigating 0.65 ha of tomatoes in Bombila, 0.27 ha of tomatoes in Kpemale, 0.07 ha of tomatoes in Dukluatuk and 0.12 ha of tomatoes in Naabtinga.

For Yunyoo District the current functioning facilities at Yunyoo community are capable of irrigating 0.59 ha of tomatoes and those at Sitik and Jimbali can irrigate 0.19 ha and 0.03 ha of tomatoes respectively.

For Cheriponi District the current functioning facilities at Adari, Mansawusi and Banjani communities are capable of irrigating 0.29 ha, 0.25 ha and 0.13 ha respectively tomatoes The potential may be higher in all the six districts if crops with lower CWR like okro, *ayoyo*, or other leafy vegetables are grown as well as upon repairs of the broken-down water facilities in the various communities.

According to Gyau-Boakye and Dapaah-Siakwan (2000), although the BH yields in the Voltaian System are relatively low compared with the Basement Complex and the Coastal Provinces which have yields ranging from 2.7-12.7 and 3.9-15.6 m^3/h respectively, the Voltaian System is less densely populated compared with those two other hydrogeologic units of Ghana. This simply implies that groundwater extraction in the Votaian System may be less.

Impact of Population Growth on Future Domestic Water Demand from Groundwater

Future Domestic Water Demand

Population Growth

Future population forecast is used to assess the level of future domestic water requirements and the vulnerability of various districts to water stress. Table 5.6 depicts future population growth of the six districts from 2020 to 2050 using equation 3.

Table 5: Projected Population Growth to the Year 2050

Districts	Communities	2020	2030	2040	2050
West Mamprugu	Loagri	1603	2230	3102	4315
	Kukua	2195	3053	4247	5908
	Banawa	158	220	306	426
	Gagbeni	327	455	633	881
East Mamprugu	Moag-duri	3240	4507	6269	8720

	Sakugo	6927	9635	13402	18642
	Zaratinga	1864	2593	3607	5017
	Namasim	2198	3057	4252	5915
Muag-duri	Prima	129	179	249	346
	Sakpaba	156	217	302	420
	Kuba	102	142	198	275
	Loagri	698	971	1351	1879
Nakpanduri-Bunkpurgu	Bombila	382	531	739	1028
	Kpemale	1705	2372	3299	4589
	Dukluatuk	643	894	1244	1730
	Naabtinga	264	367	510	709
Yunyoo	Sitik	524	729	1014	1410
	Jimbali	2500	3477	4837	6728
	Danduri	510	709	986	1372
	Yunyoo	1346	1872	2604	3622
Cheriponi	Adari	209	291	405	563
	Banjani	106	147	204	284
	Garinkuka	1154	1605	2233	3106
	Mansawusi	268	373	519	722

Ghana's population increased by 27.1% from 24,223,431 in 2010 to 30,792,608 in 2020 made up of 15,610,149 females and 15,182,459 males. Overall, females make up 50.7% of the population and males 49.3% given a national sex ratio of 97 males for every 100 females. The annual intercensal growth rate in 2010 was 2.1%. Population density has increased from 102 in 2010 to 129 in 2020. Not all districts have shown the same rate of growth. The data presented in Table 5.6 indicates that the highest relative increase in population that is likely to occur during this period (2020-2050) is in the East Mamprugu District which is closely followed by West Mamprugu and Yunyoo Districts with Muag-duri District having the lowest. All six districts have shown population growth in excess where it is observed that the population may double during this period from 2020 to 2050.

Vulnerability of Districts to Water Stress

The vulnerability of a district to water stress is presented using the combined water availability-demand measure. Various districts are shown by per capita availability and demand.

Table 6: Vulnerability of Districts to Future Water Stress in the Dry Season

Districts	Communities	Average water demand (l/c/d)	Projected population to 2050	Projected average domestic water demand per day (m^3) to the year 2050	Total yield of groundwater facilities (m^3/h)	Total available groundwater per day (m^3)
West Mamprugu	Loagri	29.56	4315	127.55	5.35	37.45
	Kukua	29.11	5908	171.98	31.43	220.01
	Banawa	28.89	426	12.31	10.48	73.36
	Gagbeni	28.89	881	25.45	2.00	14.00

East	Moag-duri	28.44	8720	248.00	44.55	311.85
Mamprugu	Sakugo	28.11	18642	524.03	5.70	39.90
	Zaratinga	27.89	5017	139.92	4.80	33.60
	Namasim	27.67	5915	163.67	5.30	37.10
Muag-duri	Prima	26.25	346	9.08	13.01	91.07
	Sakpaba	26.00	420	10.92	11.81	82'67
	Kuba	26.50	275	7.29	2.81	19.67
	Loagri	25.75	1879	48.38	15.82	110.74
Nakpanduri-	Bombila	24.38	1028	25.06	7.65	53.55
Bunkpurgu	Kpemale	25.25	4589	115.87	4.86	34.02
	Dukluatuk	24.88	1730	43.04	2.94	20.58
	Naabtinga	22.22	709	15.75	2.92	20.44
Yunyoo	Yunyoo	20.57	1410	29.00	9.77	68.39
	Sitik	21.71	6728	146.06	3.41	23.87
	Jimbali	21.29	1372	29.21	8.05	56.35
	Danduri	21.00	3622	76.06	1.39	9.73
Cheriponi	Adari	21.14	563	11.90	3.44	24.08
	Banjani	20.57	284	5.84	1.56	10.92
	Garinkuka	19.86	3106	61.69	3.01	21.07
	Mansawusi	20.00	722	14.44	3.14	21.98

In West Mamprugu District, Kukua and Banawa communities which are relatively small water users will not become vulnerable to water stress in 2050 due to the large availability of water. However, three factors should be kept in mind:

I. The balance of supply and use of water is based on the district's average domestic demand.
II. Inter-year variations in water availability are not taken into account. It is conceivable that during low supply years, some districts may become vulnerable to water source supply and availability and
III. Seasonal variability in the availability of water and its use is also not considered.

From Table 6 it is obvious that districts endowed with groundwater sources having high yield, such as those at Kukua and Banawa communities in West Mamprugu District, may not face any serious vulnerability to water stress in 2050 due to the two existing artesian wells and more boreholes water facilities with high yield.

In communities, such as Namasi, Zaratinga, and Sakogu in the East Mamprugu District, water demand in 2050 may be higher than the water supply except for the Kulgu-duri community. However, one of the inhabitants explained to the researcher that because of the existence of a large irrigation dam in that community, the groundwater facilities do not dry up in the dry season and this may be due to surface-groundwater interaction. It is also revealed to the researcher that communities like Prima, Sakpaba, Kuba, Loagri, in Yagaba District, Bombila and Naabtinga in Nakpanduri-Bunkpurgu District and Yunyoo and Jimbali in Yunyoo District may not face water stress. Communities, such as Kpemale and Dukluatuk in Nakpanduri-Bukpurgu District, Sitik and Danduri in Yunyoo District, water demand in 2050 may be higher than the water supply. This situation has significant implications for their sustainable development in the future. Because the rate of water withdrawal would exceed the net recharge, mining of groundwater occurs, which may result, as suggested by Al-Ibrahim (1991) in a variety of problems including fast depletion of groundwater resources and deterioration of their quality. This would have serious socio-economic implications for the communities and the district as well. Unlike the Garinkuka community which may become vulnerable to water stress in 2050, communities like Adari Banjani and

Mansawusi in Cheripni District may not face water scarcity.

It is, however, shown in Table 6 that due to the existence of artesian wells and boreholes with high yield, most of the communities in the six districts may not be vulnerable to water stress in 2050.

CONCLUSION AND RECOMMENDATION

The potential groundwater for domestic and dry-season irrigation to improve food security and livelihoods in the North-East Region of Ghana has been investigated. A total of 125.11m^3/day, 399.67m^3/day, 30.16m^3/day, 74.28m^3/day, 104.19m^3/day and 34.9m^3/day domestic groundwater demand as against 344.82m^3, 389.48m^3/day, 304.15m^3/day, 149.45m^3/day, 158.34m^3/day and 70.05m^3/day of total available yield of groundwater facilities which gives Surplus water available for any activity per day of 229.65m^3, 186.73m^3, 273.99m^3, 75.17m^3, 55.28m^3 and 45m^3 in West Mamprugu, East Mamprugu, Muag-duri, Nakpanduri-Bunkpurgu, Yunyoo and Cheriponi districts respectively. This means that the total surplus water available over dry period of six months is 41337m^3, 33610.91m^3, 49318.2m^3, 13530.6m^3, 9950.4m^3 and 8100m^3 which can be used to irrigate an acre or more vegetables in West Mamprugu, East Mamprugu, Muag-duri, Nakpanduri-Bunkpurgu, Yunyoo and Cheriponi districts respectively.

There is a large potential to expand groundwater irrigation in the region depending on the availability of sufficient suitable lands. The current groundwater yields are far more than what is abstracted for all uses in most of the communities. If appropriate and affordable technologies for siting and drilling wells are made available and irrigators are supported with access to credit facilities, land, stable market and extension services, groundwater irrigation could be expanded to increase food production and create employment, contributing to improved food security and livelihoods in the region.

There is a demand for analyses of groundwater–surface water interactions for Muagduri community in West Mamprugu District. The need for the analyses is reflected in the high values of groundwater yield of most of the boreholes within the vicinity of the irrigation dam even during the driers period of the year.

REFERENCES

Alice, G., Janine, G., Miqueias, P. B., Elisa, H. and Andreza, K. (2022). Assessment of water consumption in households using statistical analysis and regression trees, Sustainable Cities and Society,Volume 87,104186,ISSN 2210-6707,https://doi.org/10.1016/j.scs.2022.104186.

Altchenko, Y.,Villholth, K.G. (2015). Mapping irrigation potential from renewable groundwater in Africa-a quantitative hydrological approach. *Hydrol Earth Syst Sci.* 2015;19(2):1055–1067. doi: 10.5194/hess-19-1055-2015.

Domenech, L. (2015). *Improving irrigation access to combat food insecurity and undernutrition*: a review. *Glob Food Secur.* 2015;6:24–33. doi: 10.1016/j.gfs.2015.09.001.

Falowo, O., Oluwasegunfunmi, V., Akindureni, Y., Olabisi, W. and

Aliu, A. (2019) *Groundwater Physicochemical Characteristics and Water Quality Index Determination from Selected Water Wells in Akure, Ondo State*, Nigeria. American Journal of Water Resources, 7, 76-88.

Gibrilla, A., Anornu, G. and Adomako, D. (2018). Trend analysis and ARIMA modelling of recent groundwater levels in the White Volta River basin of Ghana. Groundwater for Sustainable Development, 6, 150-163.

Koncagül, E. and Tran, M. (2022). UNESCO World Water Assessment Programme The United Nations World Water Development Report 2022: groundwater: making the invisible visible. https://unesdoc.unesco.org/ark:/48223/pf0000380733.

MacDonald, A.M., Richard, G. T. and Hele n, C. B. (2012). Groundwater in Africa is there sufficient water to support the intensification of agriculture from "Land Grabs"? British Geological Survey, West Mains Rd, Edinburgh, EH9 3LA, UK, amm@bgs.ac.uk 2Departmnt of Geography, University College London, Gower Street, London WC1E 6BT.

McGrath, M. (2012). Huge' water resource exists under Africa. Science reporter, BBC WorldService https://www.bbc.com/news/science-environment-17775211

Margat, J. van der Gun, J. (2013). *Groundwater around the world: a geographic synopsis*. London: Taylor & Francis Group; 2013.

Shrikant, K., Shridhar, K. and Prajkta, J. (2020) *Water Quality Analysis of Urun-Islampur City*, Maharashtra, India. Applied Water Science, 10, Article No. 95.https://doi.org/10.1007/s13201-020-1178-3

Tirkey, P., Bhattacharya, and Chakraborty, T. (2013) Water Quality Indices- Im- portant Tools for Water Quality Assessment: A Review. International Journal of Advances in Chemistry (IJAC), 1, 1-17.

UNESCO, (2012). *World's Groundwater Resources Are Suffering from Poor Governance*; UNESCO Publishing: Paris, France, 2012.

Yamane, Taro. (1973), Statistics: An Introductory Analysis. London: John Weather Hill, Inc.