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Water Scarcity - the Driving Force of Underdevelopment in Rural Areas of Developing Countries

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***Abstract*— Water scarcity results to socio-economic problems and health complications. Attempts at solving water scarcity problems, such as groundwater extraction and stream damming, are not easily attainable in some locations due to geological formations and hydrologic features. The aim of this study is to investigate health and socioeconomic effects, causes and remedy of water scarcity in rural communities with difficult geological terrains. Water demand, water usage, population, and consequences of water scarcity were investigated through structured questionnaires. Data on water related diseases, topography, geology, rainfall and runoff were obtained and analysed. Malaria remained the highest occurring water related diseases in the study area and these were prevalent during wet seasons. The viable option to curb water scarcity in such environment is runoff harvesting and treatments.**

***Keywords*— Water Scarcity, Water related diseases, Geological formation, Water Quality, Water Quantity,**

I. INTRODUCTION

The importance of wholesome and adequate water for plant irrigation, conducive environment, heat removal, sanitation, hygiene, dirt removal and human consumption cannot be overemphasized. Water remains the most important natural resource necessary for life sustenance (Liu et al., 2016) . Lack of adequate and quality water can be threatening to humans, animals and plants existences (Jia et al., 2020). Man, animals and plants cannot thrive without water; since water makes up about 60 to 70% of plants and animals bodies. Inadequate water supply is the inability of supplied water to meet the demand of populace (Pande & Telang, 2014). Lack of adequate water to meet population demand are associated with water related diseases (DeNicola et al., 2015). Majority of water related diseases can be curtailed when people have access to adequate water supply (Omole et al., 2015). Water scarcity among other challenges such as poverty, energy shortage, food insecurity (hunger and malnutrition) and climate change facing developing countries; seems to be one of the most important. It cuts across all other challenges (UN DESA, 2015; Booker & Trees, 2020). Water scarcity is taking its toes on the world at large (UN- Water, 2018; Jia et al., 2020). This is resulting from exploding world population, increasing industrial and agricultural activities. These may lead to the next world war if adequate measures are not taken (Pande & Telang, 2014). These situations tend towards water insecurity; which is the incapacity of people to have access to acceptable water quality in adequate quantity needed for living, socio economic development, sanitation and ecosystem preservation in a peaceful and politically stable climate (UN Water, 2016).

Abundant water resources in the past are becoming scarce and this scarcity in turn affects other sectors such as health, food production and natural ecosystem (Seckler et al., 1999). In 2016, about 384 million people, faced drought around the world (Mekonnen & Hoekstra, 2016). Drought which has large impacts especially on agricultural production had led to annual financial losses in regions like the USA, China and other places around the world (CRED, 2016). More than half of the of the world population experience water scarcity for more than 30 days within 365 days (Mekonnen & Hoekstra, 2016). According to Lukenga (2015), 3.6 million people die annually from water related diseases. Forty-three percent (43 %) of water related death results from diarrhoea (Mekonnen & Hoekstra, 2016). Ninety-eight percent (98 %) of these water related deaths occur in the developing countries where about 884 million people lack access to safe water supplies (Lukenga, 2015).

Population of 2.8 billion and 4 billion people in 48 and 54 countries of the world would face water stress by 2025 and 2050 respectively (Lukenga, 2015; Jia et al., 2020).

Major fractions of the populace in many rural communities of Africa, spend about one quarter of their productive hours sourcing for water from long distances and would not mind the quality of any available water (Omole and Ndambuki, 2014; Omole et al., 2015). Many rural communities in Africa experience water stresses during dry seasons; as community dwellers walk long distances in search for water; thus spending lots of time and money on water (Molden, 2020). This is contrary to the World Health Organization (WHO) standard which recommends a maximum distance of 500 m from the water source to the point of use (WHO, 2003). Some also awaits the recharge of dry shallow wells before they could have access to inadequate water of questionable quality.

The qualities of surface water (which is the most common water source in rural communities) and shallow wells are more often than not impaired; during the wet season due to excessive runoff from rainfall events. The wet seasons may therefore be suspected to record more cases of water related diseases in hospitals. Water scarcity in rural communities had been combated in the past through the use of stream water, reservoir constructions and digging of shallow wells; but the problems are yet to be fully resolved; since streams are mostly polluted, stored water in reservoirs develops odour after a long time and dug wells might be close to septic tanks (Adesogan, 2014). Adequate, wholesome and sufficient water supply should be the goal, if water insecurity must be combated. However, in countries where the conventional water supply is moribund and in locations where ground water is not accessible due to geological formations and streams unavailable; the only source to be effectively harnessed is rainwater harvesting from roof catchments. However, in locations where rainwater harvesting is impeded due to non-existing, minimal and failing roof catchments, an alternative framework of water supply must be researched.

The aim of this study (which is preliminary to the design and development of runoff harvesting for water supply in rural communities) is to investigate the health and socioeconomic effects, causes and remedy of water scarcity in rural communities with difficult terrains. This was achieved by adopting a study area and by determining the season which records the highest cases of water related diseases. The study also entailed information on the socioeconomic impacts of water scarcity on human existences. The causes of water scarcity resulting basically from geological formations in some rural communities were established. These further assisted the suggestion of measures which can be taken to combat the problem of water related diseases especially in some rural communities of South Western Nigeria experiencing water scarcity.

II. METHODS

This study was done through surveys which included one on one interviews, notation of hydrologic features, demographic survey and data collection on occurrence of water borne diseases from nearby hospitals. Data on water related diseases were collected from the primary health care centres across the study area. Rainfall data were also obtained from the metrological data stations. Water demand and water usage investigations were done through the use of questionnaires and personal interviews granted by inhabitants during site visitations. The residential houses in the community of study as at the year 2017 are 100 units. There are five (5) religious institutions and (3) basic educational institutions; two of which are privately owned. Eighty-two (82) houses were sampled during the survey and representatives from each household responded to the questions used for the analysis. The analysis was conducted with precision of +/- 4 % and at confidence level of 95 %. The data obtained from the questionnaire and reported cases of water related diseases were statistically analysed and inferences drawn.

Demographic and population data were obtained from the National Population Commission at the Federal and Local Government Secretariats. The annual population growth was projected from equation 1:

$$P_n = P_0 \, exp \, (rt) \quad (1)$$

P_n = Projected population, P_0 = Initial Population, r = Growth rate (3.2% presently adopted by NPCC), t = time intervals or number of years to be projected.

The topographic mapping of the study area was done using Google earth images, Geographic Positioning System (GPS) and the Shuttle Radar Topographic Mission (STRM). The elevation data of the area were employed to produce the contour map and ARCGIS 10.1 software was used for delineation and mapping of the area (physiographic survey). This was necessary to determine the slope, highest and lowest elevation in the study area. The geologic map of the basin was also obtained and studied. It was important to investigate the geological formation of the catchment area as this determines the infiltration capacity, percolating potential and groundwater storage capacity, behaviour of percolated rainfall as well as the characteristic movement of sub surface flow.

III. RESULTS AND DISCUSSIONS

Demography, Water Demand and Socioeconomic Effects of Water Scarcity

The study area had total population of 595 people, according to the final results from the National Population Commission (NPC) during 1991 census. The population was projected to 1,367 in 2017 (taking the population growth rate as 3.2%). The water demand and usage investigation conducted shows that 68 % of the sampled population sourced water from distances beyond 500 m from their places of residence, 88.71 % have access to less than 25 litres of water per day, 66 % do their laundries more than 2 days' interval and about 74 % are denied access to hygienic sanitary systems. The estimated average water usage in this community is 20 lpcd. This is below the WHO minimum standard of 25 lpcd. The common water usages in the rural communities are dish, washing, cooking, bathing, drinking, bike washing and irrigation. Tables 1 through 5 respectively show the analysis of variance of the data on the distance of water source to places of residence, water use per person per day, common water usage, type of sanitary system and laundry frequency of respondents.

Analysis of variance shows statistically significant difference between the three groups of distances of water source (< 500 m, > 500 m and 500 m) to residences since $F > 3.15$ and $P < 0.05$ (Table 1). The differences between the three groups of daily water use (lpcd) (>15 L, >20 L and >25L) are also significant since $F > 2.53$ (Table 2). The difference in water usage patterns are statistically significant ($F > 1.903$) (Table 3). The difference in the number of people engaging in different laundry frequency options (Daily, 2 days, 5 days, and weekly intervals) are significant ($F > 2.73$) (Table 4). Finally, the difference in the number of people employing different options of sanitation practices (Water system, Pit latrine, opened defecation, buried defecation) are significant since the F greater than 2.77 (Tables 5).

Some of the socio economic effects which reportedly evolved from water scarcity according to the respondents include far distance of water sources from residences, lateness of children to schools, inherent dangers when community members move out during the early hours (before day break) in search of water, lack of adequate water quantity and quality and high risk of being exposed to water related diseases (which reduces strength and productive hours). Other effects include water rationalization, possibility of skipping bathe (which encourages skin infections), spacing of laundry and dish washing and inadequate sanitation (resulting from open defecation practices) among others. These are in line with Seckler et al., (1999) and FGN, (2000) who both reported that some effects of water scarcity in communities may include low enrolment in schools, high crime rate against women due to open defecation, uncontrolled population growth from unplanned pregnancies, water related diseases leading to high infant mortality, low productivity and absenteeism from school and work. These indicate obvious connections exist between water supply, sanitation and other economic sectors such as agriculture, health, education, productivity and environment. Water supply is thus the centrality of efficiency of other sectors (FGN, 2000).

Table 1:
Analysis of Variance for Distance of Water Source to Residence

Source of Variation	SS	DF	MS	F	F CRIT
Distance of Water Source	19.93	2	9.97	65535	3.15
Error	0	59	0		
Total	19.935	61			

Table 2:
Analysis of Variance for Quantity of Water Use (lpd)

Source of Variation	**SS**	**Df**	**MS**	**F**	**F crit**
Daily Water Usage	0	4	0	65535	2.53
Error	0	57	0		
Total	0	61			

Table 3:
Analysis of Variance for Water Usage Pattern in Houses

Source of Variation	**SS**	**Df**	**MS**	**F**	**F crit**
Water Usage Pattern	4636.52	9	515.17	65535	1.90
Within Groups	0	406	0		
Total	4636.529	415			

Table 4:
Analysis of Variance for Laundry Frequency in the Households

Source of Variation	**SS**	**Df**	**MS**	**F**	**F crit**
Laundry Frequency	121.02	4	30.25	65535	2.54
Within Groups	0	56	0		
Total	121.0164	60			

Table 5:
Analysis of Variance for Type of Sanitary System in Houses

Source of Variation	SS	Df	MS	F	F crit
Sanitary System Practiced	39.74	3	13.25	65535	2.76
Error	0	58	0		
Total	**39.74194**	**61**			

A. *Water Scarcity And Accompanying Health Consequences*

The present unsustainable water source in the study area is located at Longitude 3.837^0 E and Latitude 7.252^0 N. The water volume in the pond usually has noticeable reduction, during long and intense dry periods. This exposes the inhabitants to water rationalization and water related disease vulnerability (DeNicola et al., 2015). Water related diseases used as indicators for this study are malaria and diarrhoea.

The malaria cases reported throughout the study area for the year 2013 had the highest occurrence in September. This is 12.1 % of the reported cases for that year (Fig. 1). Years 2014, 2015, 2016, and 2017 experienced the highest malaria cases in June, August, April and July respectively. The percentages are respectively 11.6 %, 10.8 %, 12.8 % and 10.3 %. The highest percentages of reported diarrhoea cases in the study area for the years 2013, 2014, 2015, 2016 and 2017 occurred in July, November, October, November and September respectively (Fig. 2). The highest percentages diagnosed with diarrhoea for the years are 16.8 %, 13.2 %, 12.4 %, 13.3 % and 10.4 % respectively. These findings gave credence to the fact that water related diseases are prevalent during peak rainy periods. That is, the annual periods between March and November. High occurrences of water related diseases during wet seasons can be attributed to accumulated contaminations from unhygienic practices during dry and water scarce seasons (Seckler et al., 1999). Malaria had high number of occurrences during this season. These are coherent with the findings of (Omole et al., 2015) where the cases of water related diseases reported in Ado/ Odo Ota local government area of Ogun State was investigated. From the study, the highest occurring water related disease remains malaria.

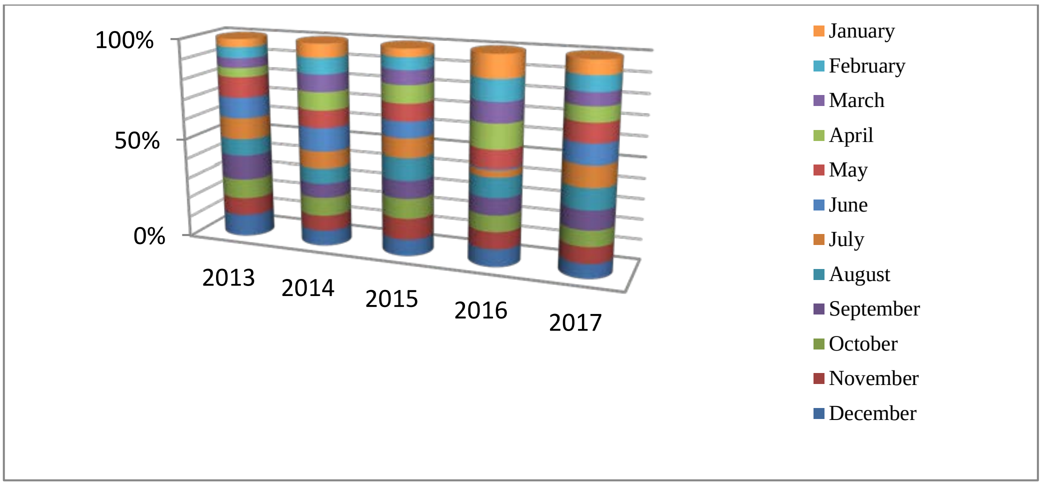


Fig. 1: Comparison of Monthly and Annual Reported Malaria Cases

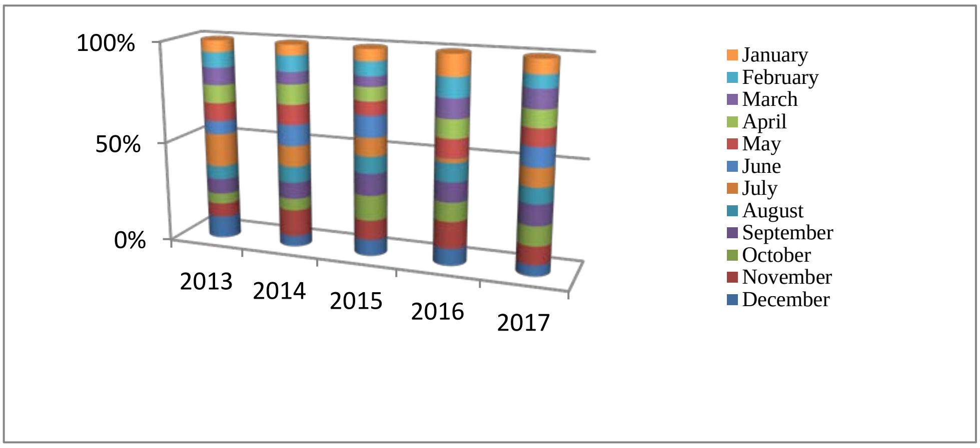


Fig. 2: Comparison of Monthly and Annual Reported Diarrhoea and Stooling Cases

The differences in the malaria and diarrhoea cases reported annually are statistically significant, that is; P is less than 0.05 (Table 6 and 7). The differences in the cases of malaria and diarrhoea reported monthly are insignificant that is, P > 0.05 (Table 6 and 7). The post hoc test using LSD shows the difference between the malaria and diarrhoea cases reported in 2013 and the remaining years are significant. There are also significant differences between the malaria cases reported in 2014 and those of 2015 and 2017. The differences between the number of diarrhoea cases reported in 2014 and 2015 are significantly different from those reported in 2017. The differences between the monthly occurrences of malaria are insignificant. The diarrhoea cases reported every January are significantly different from those reported in September. In the same vein, the diarrhoea cases reported in March and June are significantly different from those reported in November.

The presented data on Table 8 shows annual increases in population. This was observed to influence the annual increase in reported diseases cases. Comparison of the annually projected populations and respective reported cases revealed appreciable percentages of the total population experiences water related diseases annually. For example, 6.31 % and 0.34 % of the populations respectively reported malaria and diarrhoea during the year 2013. The percentages had respectively doubled to 12.79 % and 0.78 % during the year 2017 (Table 8). This is in line with the predictions of Lukenga (2015) which emphasized that population growth favours water stresses. Water stresses in turn results to high index cases of water related diseases such as diarrhoea (WHO, 2015). Diarrhoea remains the leading water related disease causing human mortality (Lukenga 2015). Flood, depressions storages, intrusion of untreated runoff into unprotected water sources and generally poor water management are some of the leading causes of water related diseases during wet period (Seckler *et al*, 1999). The consumptions of these polluted water without treatment are common; especially in rural areas facing water stresses.

Having established that water related disease are prevalent during the wet seasons, linear (equation 2) and non-linear models (equation 3) relating the number of people affected annually (N in people/year), annual rainfall intensity (R) (mm/year) and annual population (P) (people) were developed to predict the likely cases of water related diseases which may be reported in the coming years; provided the present trends of water scarcity and sanitation remain unabated and unattended to by stake holders. The developed linear and non-linear models are respectively:

$$N = 0.67 - 19.19R - 127418 \quad (2)$$

$$N = (0.18lnP - 0.02lnR - 2.08) \text{ x } 10^6 \quad (3)$$

The predictions made from equations 2 and 3 (Table 9) compares favourably with the actual values. This is evidenced from the correlation coefficients relating the actual and predicted values which are close to unity (Table 10). The values predicted from the linear equations correlated with the value 0.975 while the values predicted from the non-linear equation correlated with 0.978. The values predicted from both the linear and non-linear equations correlated with 0.998. The predictions from the linear and the non-linear equations respectively have RMSE values 1933 and 2332 people/year (Table 10). These values are very close; this thus imply any of the equations could be employed for the predictions of annual cases of water related diseases which will be reported provided the trend of water problems and scarcity remain unabated.

Table 6:
ANOVA of Malaria Occurrences in the Study Area

Source of Variation	SS	Df	MS	F	P-value	F crit
Months	2630295.9	11	239117.81	0.55	0.85	2.01
Years	21735957	4	5433989.3	12.60	6.51E-07	2.58
Error	18982496	44	431420.35			
Total	43348749	59				

Table 7:
ANOVA of Diarrhoea and Stooling in the Study Area

Source of Variation		SS	Df	MS	F	P-value	F crit
Months		16673.53	11	1515.78	0.80	0.64	2.01
Years		85190.5	4	21297.63	11.30	2.15E-06	2.58
Error		82924.3	44	1884.64			
Total		184788.33	59				

Table 8:
Comparison of Estimated Water Related Diseases and Population

Years	**2013**	**2014**	**2015**	**2014**	**2017**
Estimated Population	254,255	262, 821	271, 367	280, 192	289, 302
Malaria Reported (%)	6.31	9.33	11.80	10.99	12.79
Diarrhoea Reported (%	0.34	0.62	0.59	0.65	0.78

Table 9:
Prediction of Water Related Diseases from Population and Annual Rainfall Depth

	2013	2014	2015	2016	2017	2018
Actual	16915	26166	33709	32642	39273	
Linear	18387	23375	31444	30892	40007	50057
Non Linear	17219	22580	30284	31081	39001	47822

Table 10:
Correlation Coefficients and RMSE Values of Water Related Diseases Predictions

	Actual	Linear	Non Linear	RMSE
Actual	1			
Linear	0.975	1		1933
Non Linear	0.978	0.998	1	2332

Causes of Water Scarcity (Geologic Survey)

Figure 3 is the geologic map of the study area and its environs located at the outskirt of Oluyole Local Government Area in Oyo State. It lies within the Basement Complex of Nigeria between Latitude 7^{0}12'00''N – 7^{0}15'15''N and Longitude 3^{0}50'00''E – 3^{0}52'45''E. Some of the prominent settlements around are Abanla, Olorunda, CRIN, Idi-ayunre, Odo-Ona nla, Ajila, Onipe, Orile Odo and Arowojede. The communities are linked by secondary roads, primary roads, and road cuts. The major rock associations within the area are part of the basement complex of Nigeria. Basement complexes are often not good groundwater sources, due to their minimal thickness, poorly developed fractures and their weathering into less permeable clayey soil (Olorunfemi and Fasuyi, 1993; Arabi et al., 2010). Groundwater is usually found in deformed, fractured, weathered or faulted rocks and the quantity depends on the thickness and lateral decomposition of the rock (Nur and Kujir, 2006; Arabi *et al*, 2010). Several areas underlain by the basement complex are characterized by thin discontinuous mantle with minimal thickness and little water holding capacity (Arabi *et al.* (2010). This is basically the reason for insufficient groundwater accumulation in the study area of interest. The area is underlain majorly by migmatite gneiss and undifferentiated gneiss and schist. The minor rocks such as amphibolite, pegmatite and quartzite / quart schist occur as intrusions in the major rock types. The entire western part of the study area is underlain by migmatite gneiss while the eastern part is predominantly made up of undifferentiated gneiss/schist (Fig. 3). The migmatite gneiss stretches through from Abanla to Alata through Idi Ayunre and its environs.

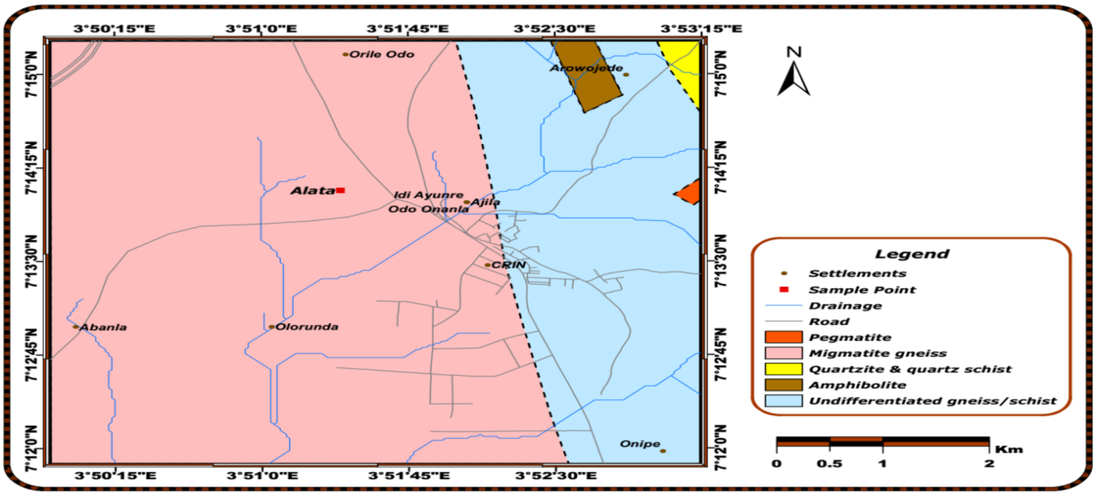


Fig. 3: Geologic Map of the Study Area and its Environ

B. Proposed Remedy to Water Scarcity

The total number of residential building in the study area is 100 units; the average area of each roof was estimated as 48.04m^2. Some of the roofs are dilapidated, while majority of the roofs have developed brown colours which resulted from rusts. The total volume of harvestable water from the roof catchments, if the entire roof areas are put into use is approximately estimated on annual time basis as shown on Table 11. The annual rainfall volumes (litres) for the available forty-two years' rainfall record were calculated taking coefficient of runoff from the roofs as 0.9 (to cater for losses such as evaporation). The pond which is the sole water source in the rural community of interest as at 2017 has an average recharge rate of about 1.725 m^3/day during the rainy season and 0.98 m^3/ day during the dry periods. The pond was dimensioned as 2 x 14 x 0.38 m^3, which is assumed to be constant throughout the year. This cannot effectively cater for the water needs of the community. A daily water demand of 55 lpcd (recommended for level I water supply) by the population of 1500 people sums up to an annual requirement of about 30.11 x 10^6 L. The quantity of water needed to balance this water requirement is 28.17 x 10^6 L when both water sources are used. At water demands of 15 l/p/d, 20 l/p/d and 25 l/p/d, for a population of 1500, the water deficits are 6.26 x 10^6L, 9.01 x 10^6L and 11.74 x 10^6L per annum respectively.

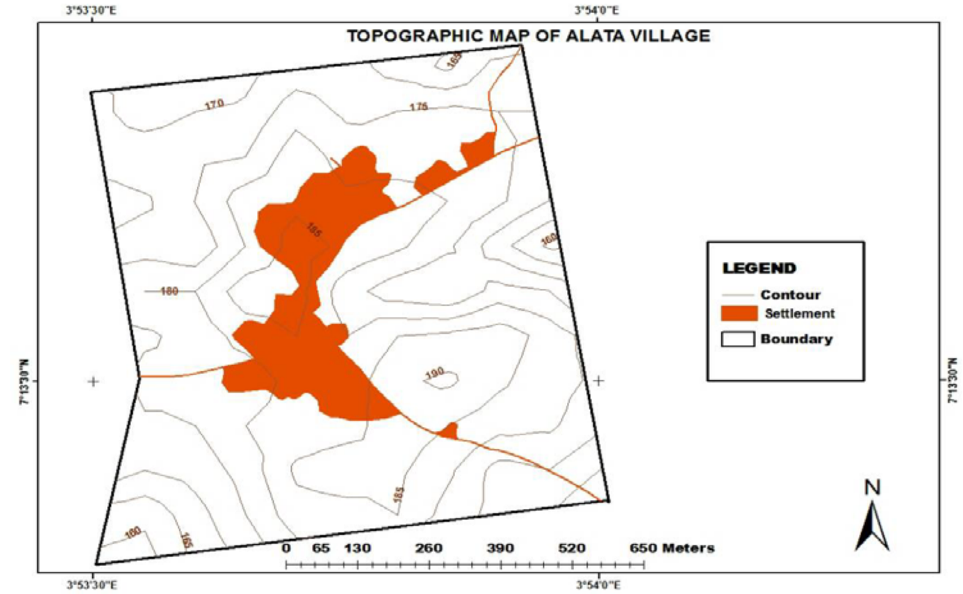
The total water volume which could be supplied from ponds and rainfall harvesting from roofs could not meet the water demand of the community. A maximum annual rainfall depth of 1663 mm was experienced in 1979, yet a deficit of 22.92 x 10^6 L is likely to be experienced in water demand even if maximum rainfall is experienced annually. The runoff for the year 1979 was estimated to be 1628 mm. If this is harvested from an approximate land area of 0.14km^2 (including bare soil, vegetated soil and roofs), the total water demand for the year could be met with surpluses. The lowest annual runoff depth estimated for the year 1983 is 347mm, yet a total surplus of 21.94 x 10^6 L was obtained. These results emphasized the unharnessed potentials of direct runoff harvesting for water supply. This is strongly recommended source of water supply for farm settlements and communities with few roofs for rainwater harvesting. Though water from direct runoff could be strongly polluted during rainfall events, however, a relatively economic solution to such problems was proposed in another research paper. More water volumes could be harvested from direct runoff, since large expanse of land is put to use, as compared to the harvesting done only from roof areas which have limited sizes.

Table 11
Comparison of Water Sufficiency from Pond, Rainfall Harvesting and Runoff Harvesting

Year	Rainfall Vol * 10^6 (L)	Vol of Pond * 10^6 (L)	Total Vol * 10^6 (L)	Water Demand * 10^6(L)	Water Deficit * 10^6 (L)	Runoff Vol * 10^6 (L)	Water Surplus * 10^6 (L)
1977	4.123	0.0053	4.129	30.11	25.98	133.69	103.58
1978	5.184	0.0053	5.189	30.11	24.92	174.54	144.43
1979	7.189	0.0053	7.195	30.11	22.92	244.23	214.11
1980	5.993	0.0053	5.998	30.11	24.11	200.27	170.16
1981	3.587	0.0053	3.593	30.11	26.52	119.2	89.092
1982	1.794	0.0053	1.799	30.11	28.31	58.625	28.512
1983	1.664	0.0053	1.669	30.11	28.44	52.056	21.943
1984	6.029	0.0053	6.035	30.11	24.08	203.79	173.67
1985	6.255	0.0053	6.26	30.11	23.85	211.82	181.71
1986	6.575	0.0053	6.58	30.11	23.53	220.94	190.83
1987	6.644	0.0053	6.65	30.11	23.46	225.57	195.46
1988	5.719	0.0053	5.725	30.11	24.39	193.52	163.41
1989	5.274	0.0053	5.28	30.11	24.83	178.24	148.13
1990	6.796	0.0053	6.802	30.11	23.31	229.93	199.81
1991	6.047	0.0053	6.053	30.11	24.06	201.55	171.44
1992	6.050	0.0053	6.056	30.11	24.06	203.58	173.47
1993	6.917	0.0053	6.922	30.11	23.19	233.69	203.57
1994	5.685	0.0053	5.69	30.11	24.42	182.76	152.64
1995	5.639	0.0053	5.644	30.11	24.47	190.41	160.3
1996	4.822	0.0053	4.828	30.11	25.28	162.45	132.34
1997	4.525	0.0053	4.53	30.11	25.58	151.1	120.99
1998	3.405	0.0053	3.411	30.11	26.7	109.41	79.295
1999	6.229	0.0053	6.235	30.11	23.88	209.26	179.14
2000	5.038	0.0053	5.044	30.11	25.07	169.98	139.87
2001	4.532	0.0053	4.537	30.11	25.58	150.59	120.48
2002	5.781	0.0053	5.786	30.11	24.33	195.45	165.34
2003	6.937	0.0053	6.942	30.11	23.17	234.48	204.37
2004	4.774	0.0053	4.779	30.11	25.33	160.26	130.15
2005	5.213	0.0053	5.218	30.11	24.89	174.48	144.37
2006	4.980	0.0053	4.986	30.11	25.13	169.94	139.83
2007	5.633	0.0053	5.638	30.11	24.47	187.44	157.33
2008	4.680	0.0053	4.686	30.11	25.43	156.6	126.49
2009	4.801	0.0053	4.806	30.11	25.31	159.34	129.22
2010	4.548	0.0053	4.554	30.11	25.56	154.26	124.15
2011	4.882	0.0053	4.887	30.11	25.23	164.05	133.93

2012	4.497	0.0053	4.502	30.11	25.61	150.49	120.37
2013	5.530	0.0053	5.536	30.11	24.58	186.88	156.77
2014	5.699	0.0053	5.705	30.11	24.41	188.46	158.35
2015	5.172	0.0053	5.177	30.11	24.94	173.98	143.87
2016	6.628	0.0053	6.633	30.11	23.48	225.33	195.22
2017	5.949	0.0053	5.955	30.11	24.16	200.39	170.27
2018	5.105	0.0053	5.111	30.11	25	173.24	143.13

Figure 4 shows the topographic details and features of the study area. The topographic map shows that the highest elevation in the mapped area is 190m above sea level. This is followed by 185m above sea level (which is the highest elevation in the area inhabited). The lowest point on the mapped area is 160 m above sea level. This will encourage runoff harvesting if water collection reservoirs are located along the lowest elevations. This prevalent slope is about 6 %. Figure 5 shows the study area has relatively high elevation compared to the surrounding communities.



This confirms the possibility of groundwater drainage to surrounding areas.

Fig. 4: Topographic Map of the Study Area

Fig. 5: Topographic Map of the Study Area with Respect to the Environs

IV. CONCLUSION

It was clearly established that communities with difficult terrains especially basement complex geological formations are bound to experience water scarcity due to low groundwater storage. The consequences of water scarcity range from health effects such as malaria and diarrhoea to socioeconomic effects such as loss of productive hours, high crime rate and use of unhygienic sanitary systems. Rainwater harvesting are not viable in such rural communities due to limited roofs. The proposed option to combat water scarcity in such rural communities with difficult terrain is runoff harvesting and remediation.

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