ARCN International Journal of Sustainable Development
ISSN: 2384-5341. Volume 13, Issue 1, (June, 2021) pages 77 - 88
journals@arcnjournals.org
www.arcnjournals.org

Spatio -Temporal Analysis of Irrigation Water Availability in the Jere Bowl, Borno State Nigeria

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Abstract: *Human welfare and socio-economic development generally depend on the availability and use of water. Around the world, human activities and natural forces are reducing the available water resources which are very significant in irrigation farming. The study aimed to analyze the Spatio-Temporal availability of irrigation water in the Jere Bowl, Borno State, Nigeria. Three (3) wards were purposively selected for the study and a total of 296 questionnaires were administered to the household heads (respondents) in the selected wards, where 65 questionnaires were purposively administered in Khaddamari, 101 in Gongulong and 130 in Dusuman ward respectively. The study revealed that Borehole (ground water) is the major source of irrigation water and is available throughout the dry season, but varies from one location to another and from time to time, whereas, the surface irrigation water (river/stream) is available from the months of December to February only. The study indicated that ground water is available at 6 to 9 meters depth at lower elevation of the bowl during the months of March and April while from May to June it the water level ranges from 9 to 12 meter depth. The study also noted that part of the Bowl with high elevation reaches up to 15 – 30 meter depth before getting water level during dry season. It is concluded that, borehole (ground water) is the major source of irrigation water and is adequately available for irrigation purpose with the use of suction pump when surface water is deficient in the study area. The stream/river water (surface water) is not reliable for irrigation in the months of March, April, May and June, because of its scarcity. Finally, it is recommended that, the pumps used by the farmers should be made available at affordable price through the2 Agricultural development program (ADP), improved varieties that are drought-tolerant should be provided to irrigation farmers, Research and extension services should be made available, access to farm credit facilities should be made easy, Provision of storage facilities/reservoirs for the storage of water and Good governance is also recommended.*

Key words: *Spatio-temporal, Irrigation, water, Bowl.*

Introduction

The most important natural resource which sustains life and enhances development especially in rural communities is water resources. Socio-economic development processes in rural communities are closely related to water resources as a result of diverse range of interactions between water resources and human activities. According Awulachew, *et al* (2005), Irrigation is one of the means by which agricultural productivity can be improved to meet the growing food demand. International agencies like the Food and Agricultural Organization (FAO) and the World Bank, as well as national governments of low and middle income countries point at irrigation as an important tool to overcome

food security. International food policy research institute (2001), revealed that access to irrigation water is the key to reduce the impacts of climate variability and change on food security and regional economies. Irrigation farming is one of the most important rural development investments that can have both direct and indirect impacts on poverty and food security in semi-arid tropical countries (IFPRI, 2001).

Arid and semi-arid regions are characterised by low precipitation and high evapotranspiration (ET). These regions are thereby especially vulnerable to decreased water availability due to land-water use and climatic changes. It is mainly the arid and semi-arid regions of the world that are reliant on irrigated agriculture for agriculture expansion and for efficient food production (Shiklomanov, 2000). Irrigation water withdrawals and associated ET increases have caused decreased river discharge in many arid and semi-arid regions (Falkenmark and Lannerstad, 2005). Some examples of large rivers that have been observed to dry up during parts of the year are the Yellow river, the Colorado river, and the Ganges river (Postel, 2000). However, in contrast to these exorheic river basins which discharge into the ocean, river flow reductions in endorheic river basins which discharge into terminal inland water, such as Lake Chad and the Aral Sea, may also lead to shrinking lakes with associated severe environmental consequences (Glantz, 1999). The pressure on water resources in semi-arid and arid regions necessitates sustainable strategies to meet the requirements of water availability and water quality. In some countries and regions, water is already being transferred out of irrigation and into urban industrial uses, putting additional stress on the performance of the irrigation sector (Rosegrant and Ringler, 2000).

The interdependence between water availability and development is exemplified by the link between water and poverty. When water is inadequate in either quantity or quality, it can be a limiting factor in poverty alleviation and economic recovery, resulting in poor health and low productivity, food insecurity and constrained economic development. Rural communities in many developing nations have to obtain their drinking water from untreated sources, often situated far away from their residence. For instance, in many Nigeria rural communities, water supply infrastructures are still at development stage or are completely absent (Rossiter, Owusu, Awuah, MacDonald, and Schafer, 2010). Furthermore, the availability of water varies greatly, while some people pay dearly for domestic water, others have an easy access to adequate clean water and sanitation due to their location and social status in the society (Hunter, Pond, Jagals, and Cameron, 2009a). The current study is about irrigation water availability which could be influenced by climate change and ecological problems; the economic values of crops grown with irrigation and also the impacts of irrigation agriculture on food security, sustainable development and the contributions to the household economy in the study area.

Review of related literature

The primary sources of water include: rainwater, surface water (stored in lakes, streams, and ponds), and groundwater. The distribution of water, however, is quite varied; many locations have plenty of it while others have very little. Water exists on earth in three forms solid (ice), liquid or gas (water vapour). Oceans, rivers, clouds, and rain, all of which contain water, are in a frequent state of change (surface water evaporates, cloud water precipitates, rainfall infiltrates the ground, etc.). However, the total amount of the earth's water does not change. Owing to glaciers, rivers and groundwater flow. Water is essential to life. Without it, the biosphere that exists on the surface of the earth would not be

possible. The earth is called as the 'water' planet, water's molecular arrangement of water is very simple, two hydrogen atoms to each oxygen atom. One special characteristic of water is its ability to change state very easily under earth conditions. It can be found readily on the planet in all of its three forms, solid, liquid, and gas.

The hydrologic cycle is a conceptual model that describes the storage and movement of water between the biosphere, atmosphere, lithosphere, and the hydrosphere. It is a complex and dynamic system that is strongly interconnected with the energy and biogeochemical cycles (Hagemann, 2011). It describes the continuous movement and retention of water through and in the Earth's spheres, driven by solar energy and gravitation (Brooks et al., 2012).

In general, atmospheric water vapor precipitates on the Earth's surface, eventually flows as runoff to the ocean or inland water sinks while being transferred through the soil, the ground and/or surface water bodies, and finally evaporates again. Thereby, water fluxes and storage conditions are strongly interconnected and influenced by various climatic and physio-geographic factors. For instance, dependent on temperature, precipitation most commonly occurs as rain or snow, but also includes drizzle, sleet, hail, and in a broader sense fog, dew and frost. Besides temperature, also wind, topography, vegetation and physical obstructions determine the deposition and accumulation of snow and ice. Whether snowmelt and liquid precipitation infiltrate depends on various factors such as the moisture status of the soil, its maximum water-holding capacity, the network and size of pores within the soil matrix, the condition of the soil surface including the vegetation cover, as well as rainfall and snow melt rate (Blume *et al.,* 2010). Additionally, human activities influence the hydrological cycle among others by building reservoirs, withdrawal from water storages, or land-use activities that modify vegetation and water bodies, which in turn influences for instance evapotranspiration and the distribution of snow (Brooks *et al.,* 2012). While its allocation in storage or circulation varies in time, the mass of water remains constant on the global scale. Thus, the components of the hydrological cycle can be estimated for a distinct area by the water balance. Accordingly, input by precipitation P equals the output represented by evapotranspiration ET (comprising transpiration, evaporation from interception, bare soil and open water surfaces) and stream flow Q (including surface runoff, interflow and base flow) and the change of storages ΔTWS such as ice, snow, soil moisture, ground water and surface water bodies (Schmidt *et al.,* 2008).

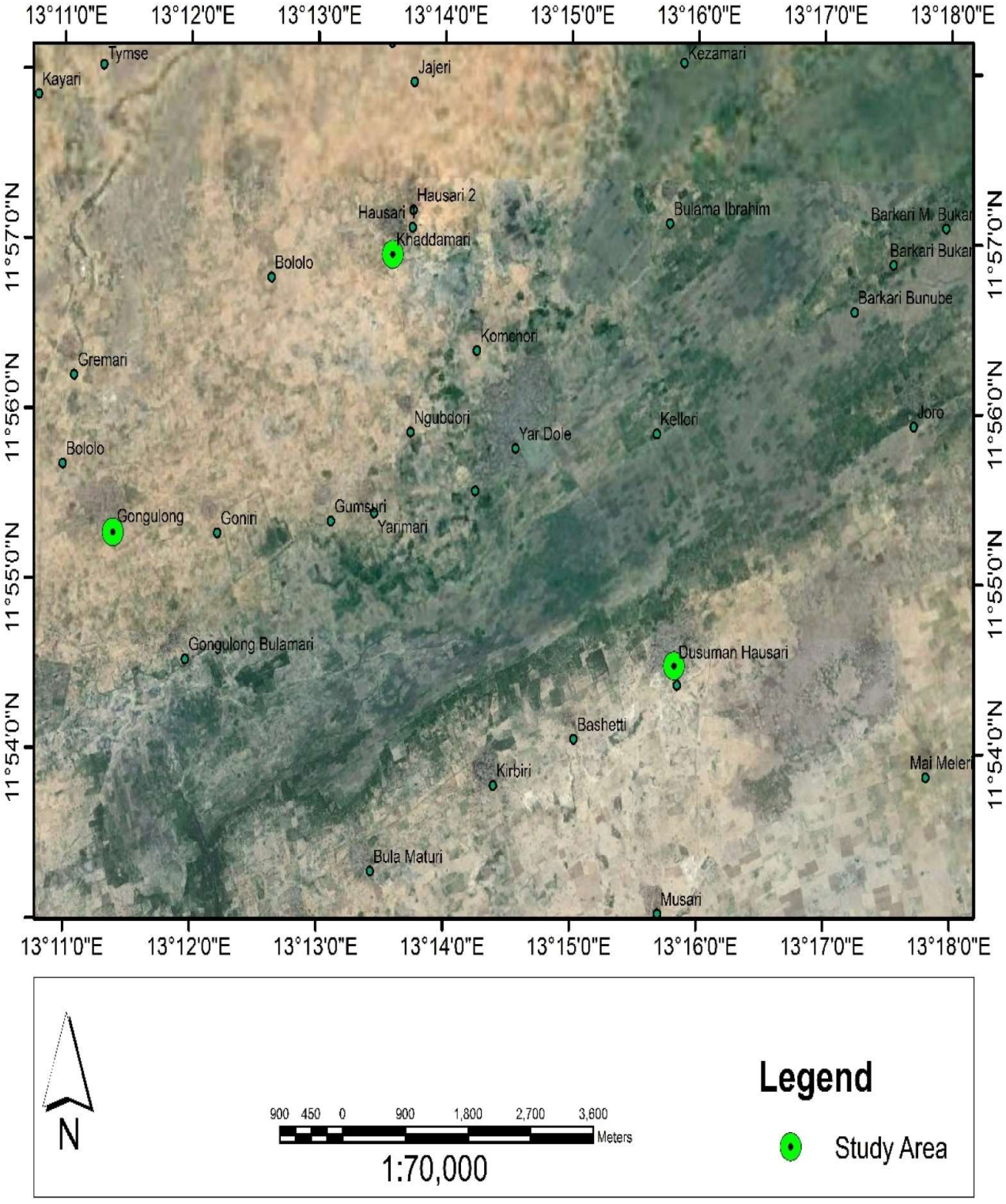
Basically, all sources of fresh water originate from rainfall, which is slightly acidic due to dissolution of carbon dioxide in the atmosphere. In the form of surface run-off, it will gather considerable amount of organic and mineral matters, soil particles, micro organisms, etc. when surface run-off infiltrates into subsoil it forms ground water. Perennial springs are the fountainheads of surface water bodies such as streams, rivers, and lakes. Thus, water supply for rural community can be organized with the use of rainwater, groundwater, springs, and surface water. The major sources of water supply for the rural populace were hand-dug wells, natural springs and streams, together with rainfall harvest, majority of which are highly unreliable during the dry seasons. (Makoni, *et al.,* 2004). Similarly, according to MacDonald *et al*.,(2005), the main sources of water for households are piped supply from treated water sources, untreated piped water from groundwater sources, shallow boreholes, wells and pond, springs, lakes, rivers, and streams. According to Ushurhe (2005), numerous rural communities in Nigeria are served by one or more rivers, streams, ponds or lakes as their major source of water supply.

Study Area and Methodology

Jere Local Government Area is one of the twenty-seven Local Government Areas of Borno State. The Local Government Area was carved out of Maiduguri Metropolitan Council (M.M.C) in 1996 (BOSG, 2007). It lies within latitudes 11º 40" and 12º 05" N; longitudes 12º 20" and 13º 50" E, it occupies a total landmass of 160 square kilometer (MLS, 2008). Within the state, it shares boundaries with Mafa Local Government Area to the east, Maiduguri Metropolitan Council to the north and Konduga Local Government Area to the south. The Jere Bowl covers an area of about 22,000ha; out of which a gross area of 15, 850ha was identified as suitable for irrigated agriculture from the results of an agricultural soil survey (Shettima, 1998).

The study area is basically a sedimentary series of rocks and the topography is generally low land plain which is a flat land having a gentle slope towards the Lake Chad. It has it's main river as the river Ngada which discharges it's water into the Lake Chad. According to Nyanganji (2002), the main hydrological features of the environment are the conspicuous absence of the perennial streams and the over- dependence of the perennial ponds and ground water sources by man and animals; which are supplemented by the seasonal stream flow. Most of the streams originated from the southern highlands and flows either into the Lake Chad or, like the Ngadda, forms inland deltas on the Chad Basin plain. The Ngadda Channel also breached the Bama Beach Ridge at Maiduguri to drain into the Jere Bowl (Nyanganji, 1994).

The climate of the area is characterized by long dry and hot seasons, with minimum temperature ranging from 15-20°C, while the maximum temperature ranges from 37-45°C. The annual rainfall is characterized by high variability and intensity which ranges from 500 to 700mm per annum (NMA, 2008). The vegetation of Jere Local Government is that of savanna type (sudan savanna). It is characterized by short grasses, shrubs, and widely scattered trees mainly neem and acacia trees which are mostly drought resistant.



Source: *Adopted and Modified from Satellite Image 2016.*

Figure 3.3 Satellite Image Study Areas

The study area is located in Jere Local Government Area. Three (3) wards out of the twelve (12) Wards were purposively selected for the study based on their high level of irrigation activity and proximity to the Jere Bowl. These Wards are; Khaddamari, Gongulong and Dusuman Wards. Research questionnaire was used as an instrument for primary data collection. These questionnaires was administered to the 296 household heads of the three (3) selected wards out of this number, 65 respondents were selected in Khaddamari, 101 in Gongulong and 130 in Dusuman wards respectively.Data collected from the study were presented using the frequency distribution tables, pictures, plates, diagrams and charts. For the presentation of data, percentages, tables, bar charts, and simple diagrams were used.

Results and Discussions

The results from the study revealed that borehole is the major source of irrigation water in the study area with 85.9% of the respondents relying on this source which is consistent with the findings of Y. Bukar, (2016) "in recent times, access to water is gradually becoming a problem due to its declining availability as a result of natural factors and the formal irrigation projects in the Jere Bowl. The increase in irrigation activities based on small petrol pumps is also extremely common and widespread. These small pumps lift water from shallow aquifers in river channels to supply water to the largely commercial production of vegetables". The study also revealed that, those whose source of irrigation water is river/stream constituted 9.1%, while well constituted 4% of the respondents' sources of irrigation water.

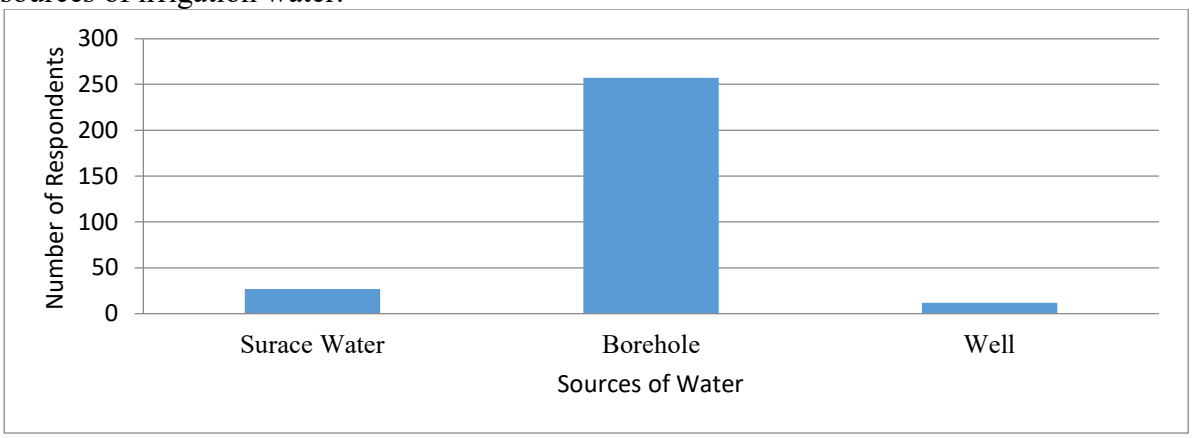


Figure 1 Sources of irrigation Water

Plate 1 Surface water (Stream/Rive) during water surplus period in November – January

Table: 1. Availability of irrigation water from the various sources the study area.

Availability of irrigation Water	No of Respondents	Percentage (%)
Adequately available	269	91
Not adequately available	27	9
Total	**296**	**100**

Study on the availability of irrigation water revealed that, 91% of the respondents feel irrigation water is adequately available in Jere Bowl. Only a few respondents (9%) said there was inadequate water for irrigation, which is as a result of using stream, and wells as major sources of irrigation water which normally shrink over time during the dry season. The gardeners use water pumps to supply water from the shallow aquifers along river channels to irrigate their crops. Contact with irrigation famers revealed that streams in the study area used to shrink with time which is caused by several factors such as irrigation activities, evaporation, infiltration, animal consumption and domestic use.
Irrigation farming in the study area is usually started in the month of January and ended in May-June of the same year. Both surface and underground water in the Jere Bowl varies within the farming season from one month to another and also from one location to another which is basically due to the influence of factors such as rainfall, temperature or solar intensity, gradient, soil, and relief.

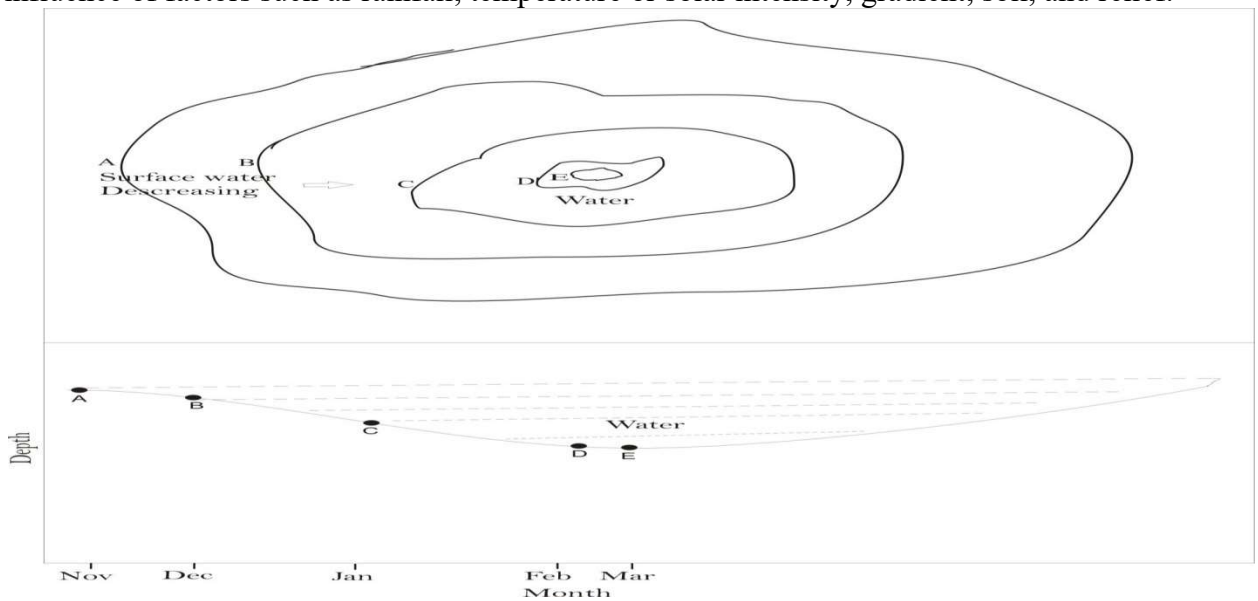


Figure 2.Surface water decreasing with time

Surface water is abundant in the Jere Bowl during the months of November, December and January because of the rainfall, but decline heavily in February and March as shown in figure 2. Findings from the research conducted on sources of irrigation water revealed that only 9.1% of the respondents depend on surface water as major source of irrigation water. Irrigation farmers whose major source water is either stream or river mostly have an alternative source of water during scarcity period but those who have no alternative source of irrigation water lost their crops completely. Figure 2 describes how surface water rapidly decreases from November to March in the Bowl. During the

month of March, the only source of irrigation water in the Bowl is the groundwater. Figure 3 shows the availability of groundwater at different times in a particular season. Investigation during the study revealed that irrigation water is available at 5m to 9m depth at lower elevation in the Bowl during the months of March and April while from May to June it drops to about 9 to 12 meter depth. The study also noted that part of the Bowl with higher elevation reach up to 20 – 35 meter depth before getting water.

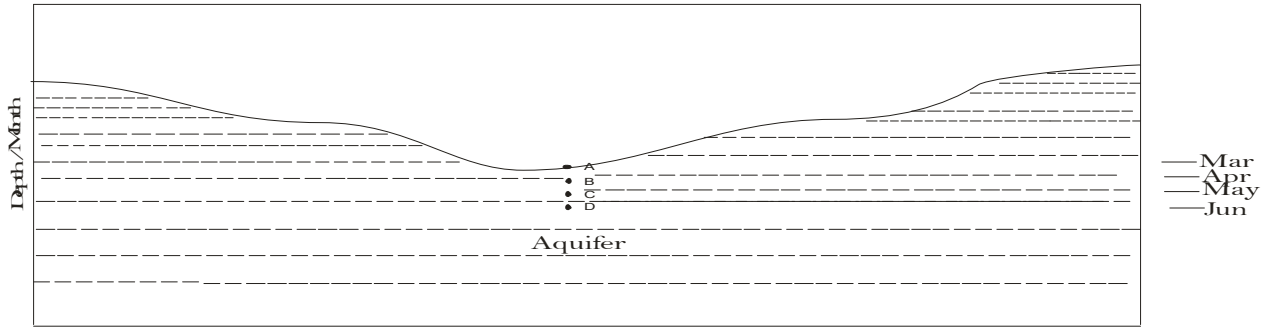


Figure 3 Variation of ground water volume with time

Table 2: Water Level (m) of selected boreholes in the Jere Bowl

S/ NO	Borehole Area (Ward)	Position		Level of water (Mar-Apr)	Level of water (May-Jun)	Level of water (Nov -Feb)
		Longitude	Latitude			
1	Khaddamari	11º57′27″N	13º14′02″E	20m	35m	13m
2	Khaddamari	11º56′13″N	13º15′19″E	20m	35m	12m
3	Dusuman	11º55′24″N	13º12′11″E	16m	30m	11m
4	Dusuman	11º54′58″N	13º13′71″E	16m	30m	11m
5	Gongulong	11º54′18″N	13º16′06″E	20m	30m	10m
6	Gongulong	11º55′36″N	13º17′91″E	20m	30m	10m
7	Center of the Bowl	11º55′21″N	13º14′71″E	9m	12m	Filled
8	Center of the Bowl	11º56′40″N	13º15′31″E	6m	9 m	Filled

It has been observed that the study area used to experience water surplus phase l (Figure 3) in the months of November, December, January, and February. It is in this phase that most crops under market gardening are planted and surface water is available for irrigation. Phase ll which is termed as water deficit period within which the harvesting period falls normally starts from the months of March to May. At this period the water table becomes very low and surface water is completely absent. The available water for irrigation at this phase is the underground water by using the petrol water pump. Majority of the irrigation farmers plant their crops at location D because some places are still damp and water can be reached at just 5 – 9m depth. The third period (phase lll) is the No irrigation period where irrigation activities are silent. This period starts in the month of May and ends in November of the same year. In this phase, most of the irrigation farmers are engaged in rainfed agriculture because of the rainfall which usually starts in the month of May.

The study revealed that, variation of seasonal irrigation water availability influences the type and variety of crops grown with irrigation in the study area. The irrigation schedule chart (Figure 3) shows that most crops under market gardening are planted and harvested within a period of 3 to 5 months. The cost of farming is also affected by the seasonal variation of irrigation water availability in the Bowl. Figure 3 shows the water deficit period (phase ll) which started from March to May and at this period some crops are still not harvested. At this period, surface water is not available but only the underground water which requires the use of petrol powered water pump. By using the water pump for irrigation, the cost of farming increases which consequently increases the cost of farm produce after harvest.

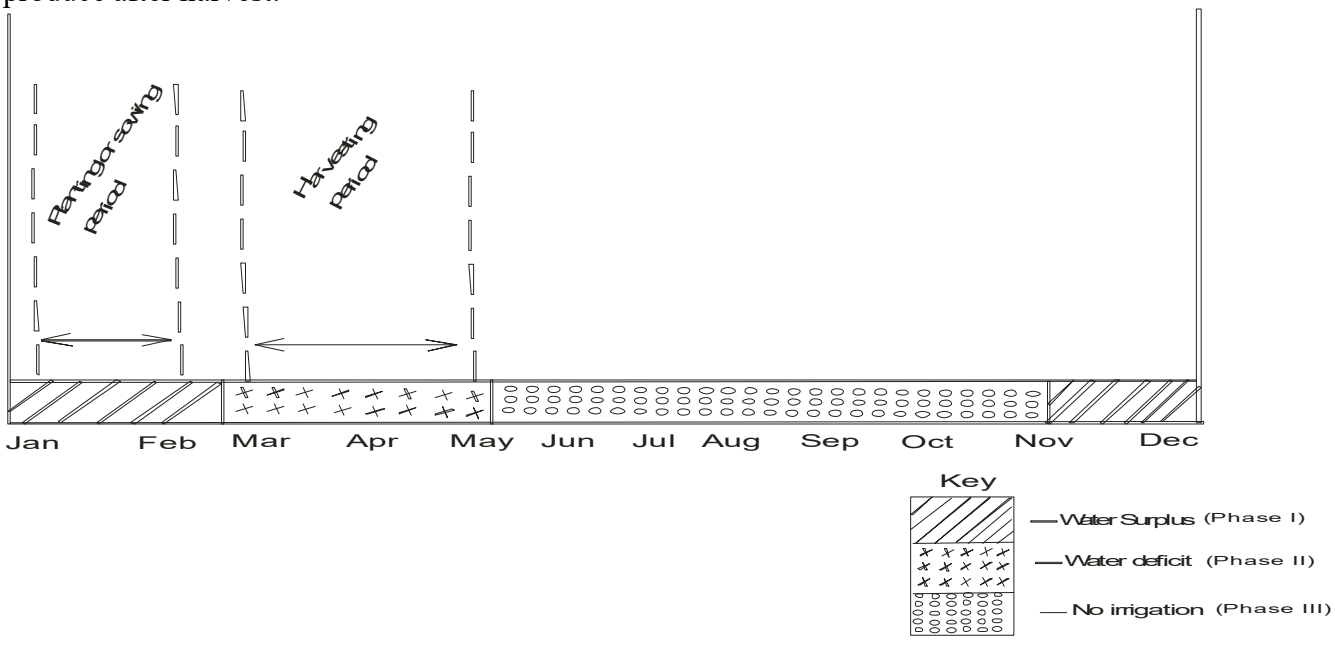


Figure: 3 Irrigation Schedule in the Jere Bowl

Seasonal variation of irrigation water greatly influence the crops grown under market gardening in the Jere Bowl in several way because it determine the irrigation schedule by setting the period of planting and harvesting in the area; it determine the type and variety of crops to be planted; it determines the location of planting within the season; it could also influence the cost of farming since irrigation

water varies from time to time and from one location to another within a particular season in the area and this consequently affect the price of farm produce(crops). Investigation also revealed that the variation of irrigation water in a given season control the irrigation schedule as described in Figure 3. It clearly shows the planting/sowing and harvesting periods of major crops grown with irrigation in the area. The planting periods of most crops started in the month of January through February while the harvest started in March and end in May for most crops. Hence, the schedule of irrigation is controlled by the availability of water in the Jere Bowl.

Conclusion

The research which aimed to analyze Spatio-Temporal availability of irrigation water in the Jere Bowl noted the use of both surface and groundwater for irrigation farming and concluded that, borehole (groundwater) is the major source of irrigation water and is usually available at 5m to 9m depth at lower elevation in the Jere Bowl between the months of March and April, while from May to June is ranging between 9 and 12 meter depth. But for other parts of the Bowl with higher elevation, the ground water level ranges between 20 and 35 meter depth. Irrigation water is adequately available for irrigation with the use of petrol water pumps (suction pump) specifically when surface water is deficient. The stream/river water (surface water) is not reliable for irrigation in the months of March, April, May and June, because of its scarcity. Seasonal irrigation water availability and variability influences major crops grown with irrigation in the following ways by determining the: irrigation schedule, type and variety of crops to be grown, appropriate location of planting within the season, cost of farming since irrigation water varies from time to time and from one location to another which consequently affect the price of farm produce (crops).

Recommendations

Although irrigation water is available throughout the season with the use of suction pumps from boreholes, but the pumps used by the farmers should be made available at affordable price through the Agricultural development program (ADP). The provisions of improved varieties that are drought-tolerant (drought resistant crops) to irrigation farmers is recommended to enable them grow their crops within favourable irrigation period in a season. Research and extension services should be made available to the irrigation farmers through Agricultural extension workers so that farmers will be enlighten on new agricultural innovations and technologies for dry land farming. Similarly, irrigation farmers should have access to farm credit facilities so as to enable them increase farm output from Agriculture and Rural Development Bank, the Central Bank of Nigeria and other programs such as FADAMA Projects of the World Bank and finally the provision of water storage facilities/reservoirs is recommended.

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