MONITORING OF WATER TABLE FLUCTUATIONS IN KANO RIVER IRRIGATION SCHEME, NIGERIA

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ABSTRACT

The effect of seepage from canals and a non-functional drainage system has caused the water table to rise near the surface in many areas. The water table at shallow depths leads to the depletion of oxygen in the root zone and increases the risk of soluble salts and sodium near the soil surface. To address this issue in the Kano River Irrigation Scheme (KRIS), water table depth was monitored for two years using a Laser Distance Meter (40 m) from 85 wells drilled in the Scheme. Descriptive statistics and tests were carried out on the data collected. The study revealed that water table fluctuations were influenced by the rainfall observed during the rainy season and even though the water level raised to about 1 m to the ground surface, no part of the scheme had observed a water table to the surface. The shallowest water table depth of 0.7 was recorded in September 2020 and 2021. The t-test has shown that the water table depth for the rainy seasons of the two years is not significantly different. However, there is a high potential for salt accumulation as the capillary groundwater approaches the surface due to the likelihood of salt influx within the root zone.

Keywords: Groundwater · Irrigation · Salinity · Seepage · Water Table

1. Introduction

A shallow water table less than 2 m from the surface can cause salt accumulation in the root zone of crops [1]. In addition, water table at shallow depths also leads to the depletion of oxygen in the root zone and increases the risk of soluble salts and sodium accumulation close to the soil surface [2]. In many areas, the effect of seepage from canals and the non-functional drainage system has caused the water table to rise near to the surface [3].

Reference [4], investigated the effect of water table depth and soil salinity and reported a high correlation between soil salinity and groundwater table depth. Crop growth and yield primarily depend on the favorable environment in the root zone, rooting depth, the sensitivity of the crop to water, etc. Water table

management has been proven to increase crop production and drainage water quality in humid regions [5]. The severity of salinity is primarily determined by the depth of the water table, groundwater salinity and soil texture. A good understanding of water table contribution to crop water use may help in the management of water [6]. Reference [6], also studied the effects of water table depth on water use, growth and yield of soya bean in a lysimeter experiment. The findings revealed that 0.70 and 0.90 m of constant water table depth can result in higher yield, greater Water Use Efficiency and better root distribution than the irrigated treatments.
In Kano River Irrigation Scheme (KRIS), the issue of salinity and sodicity has been lingering for quite some time without adequate information about the sources of these problems and farmers were struggling in their ways and capacity to address the salt menace. Therefore, this research studied water table fluctuations in Kano River Irrigation Scheme (KRIS) for two years with a view to apply the findings in management of soil salinity and sodicity under irrigated condition in the study area.

2.0 Materials and Methods

2.1 Study Area

The Kano River Irrigation Scheme (KRIS) is located between latitudes 11°32`N to 11°51`N and longitudes 8°20`E to 8°40`E in North-Western Nigeria. The Scheme has a total area of about 62,000 ha which is divided into two phases. Twenty- two thousand hectares (22,000 ha) were to be developed under Phase I while the remaining forty thousand hectares (40,000 ha) were to be developed under Phase two (Figure 1). The two phases are both located in Garun-Mallam, Kura, and Bunkure Local Government Areas [7]. Vegetation in the area is Sudan savanna consisting of a variety of trees, shrubs, and grassland. The soils are mostly moderately deep to deep and well-drained with sandy loam texture at the surface and sandy clay loam textured subsoil [9]. There are two major seasons, these are the dry and rainy season.

The dry season starts in October and ends in June. Between Novembers and January, temperatures may drop to as low as 15 ° C and may rise to more than 40 °C from March to May. Average annual rainfall ranges from 635 to 889 mm, about 60% of which falls in July and August and varies considerably from year to year[10].

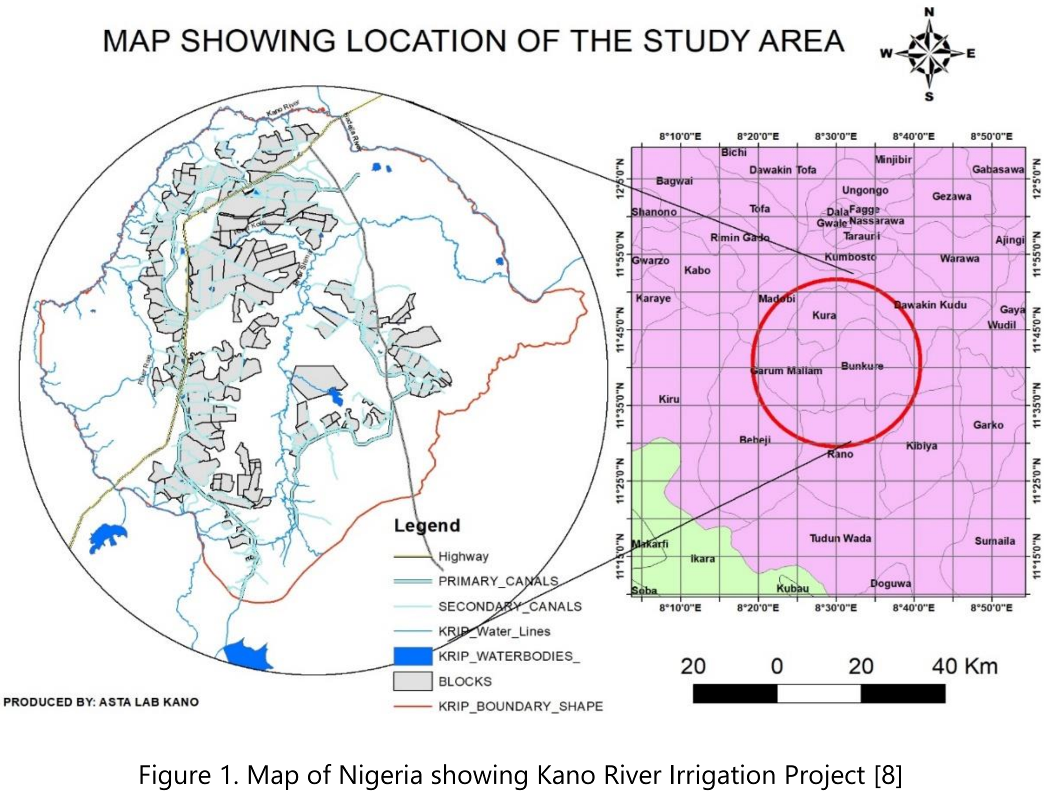

Figure 1. Map of Nigeria showing Kano River Irrigation Project [8]

2. Drilling and Installation of Observation Wells

In order to investigate the sources of salinity and sodicity in the KRIS, eighty-five (85) wells were installed and used for monitoring of groundwater fluctuation for twenty-four months with a view to applying the findings in the management of water for irrigation at different water table depths. Piezometric wells were drilled for monitoring of water table fluctuation and assessment of ground water quality to detect its influence on the lingering salinity problem. A local wash boring system which involved the use of cheap, easily portable hand drilling equipment was used. The wells were drilled with a casing through which a hollow drill rod with a sharp cutting bit at the lower end is driven through the soil. Water was forced under pressure through the drill rod which was raised and dropped, and also rotated. Cutting was done by forcing water under pressure through the rods operated inside the hole.

The cuttings were forced up to the ground and holes were advanced by chopping and twisting action. Each well was driven to a depth of 6.0 m. Stand pipes (4 inches in diameter) stabilized with cement at the base were installed and covers were placed on the stand pipes to prevent rain water from entering the well. Each stand pipe was 2 m above the ground level. The wells were labelled for identification and the coordinates as well as the sectors were also recorded for easy sampling and identification.

2.3 Monitoring of Water Table Depth

The water table depth below the ground in a piezometer was monitored for two years with Laser Distance Meter (40 m), an infrared meter that gives direct readings. The observations were made from 85 wells. The depth of water table below the top of the stand pipe extending above the ground level was measured as H and the water table depth below the ground level (h) is obtained by using equation 2.1 (Figure 2)

$$h = H - x \qquad (2.1)$$

Where:
h = depth of water table below the ground surface
x = height of the stand pipe above the ground
H = height of the piezometric pipe above the round

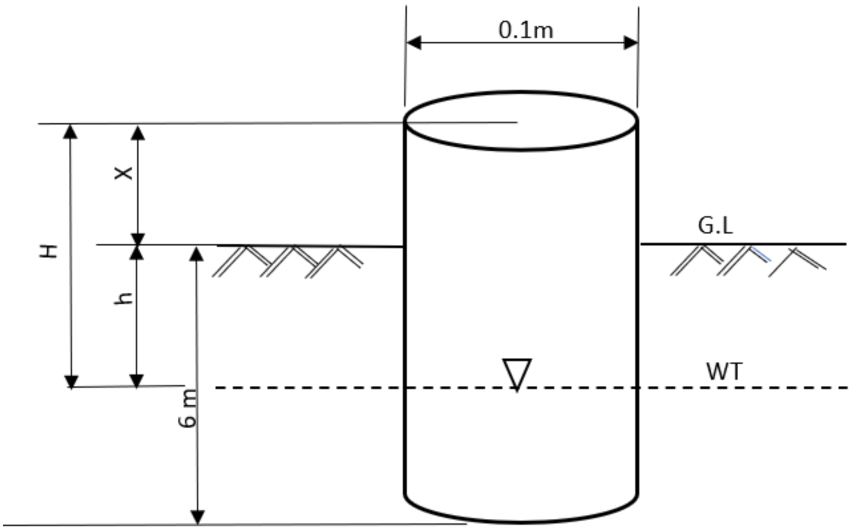

Figure 2. Measurement of Water Table Depth

2.4 Statistical Analysis

Descriptive statistics were carried out on the data collected. A 2- sample t- test was also carried out to test if there is a significant difference between the mean depth of water in the dry season of the year 2020 and the corresponding season of the year 2021.

3.0 Results and Discussion

3.1 Ground Water Fluctuation

The mean values of the water table in the west and eastern command are presented in Figures 3 and 4, respectively. The depth of the water table increased from November 2019 to May 2020, then began to decline, reaching its lowest mean value of 1.0 m for the year in September. The shallowest water table depth of 0.75 m was observed in September 2021 in the western command, which is lower than the value of 1.0 m recorded in 2020. At this depth, the water table is capable of meeting the water requirement of wheat [11]. When an optimal water table depth is maintained for crops, it can be considered as an accessible water source to support crop water management. However, most of the irrigation scheduling assumes that the water table is too deep and that only surface irrigation water is required to meet plant water requirements [6]. With good water management, ground water can be utilized to save cost and the need for frequent irrigation.

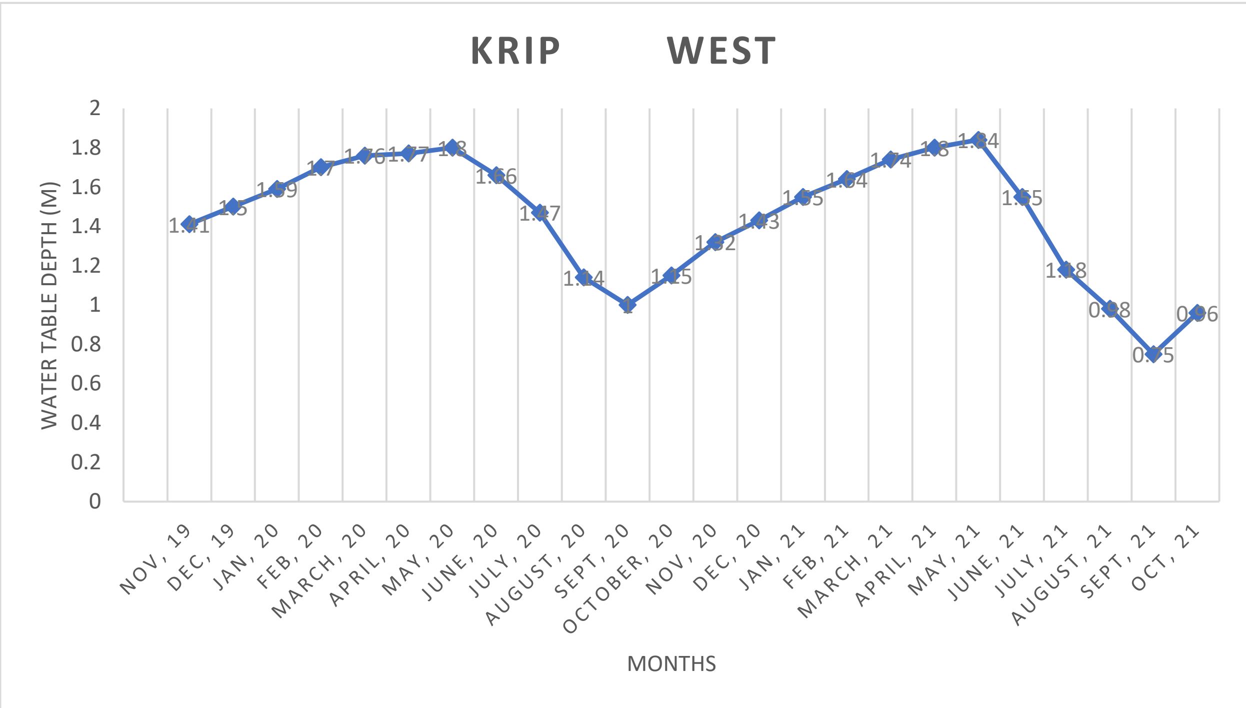

Figure 3. Water Table Fluctuation in Western Command

Water users and technical officers can take advantage of shallow water table depth in sectors like Makwaro Gabas in western command to save cost and maximize profit. However, in some cases, the determination of precise irrigation requirement are necessary to optimize crop production and keep the groundwater table below the root zone to avoid salinization [12]. The water table rises from November and reached a peak value of 1.8 m in May 2020 (Figure 5). The high water table recorded in some areas might probably be due to seepage caused by the breakage of most canals in the sectors as well as rainfall contribution to the ground water recharge in the area. Referenced [13], studied groundwater fluctuation and its implication along Niger -Benue confluence. The finding revealed that the soil is critically waterlogged between February and September with rainfall depth significantly affecting the fluctuation.

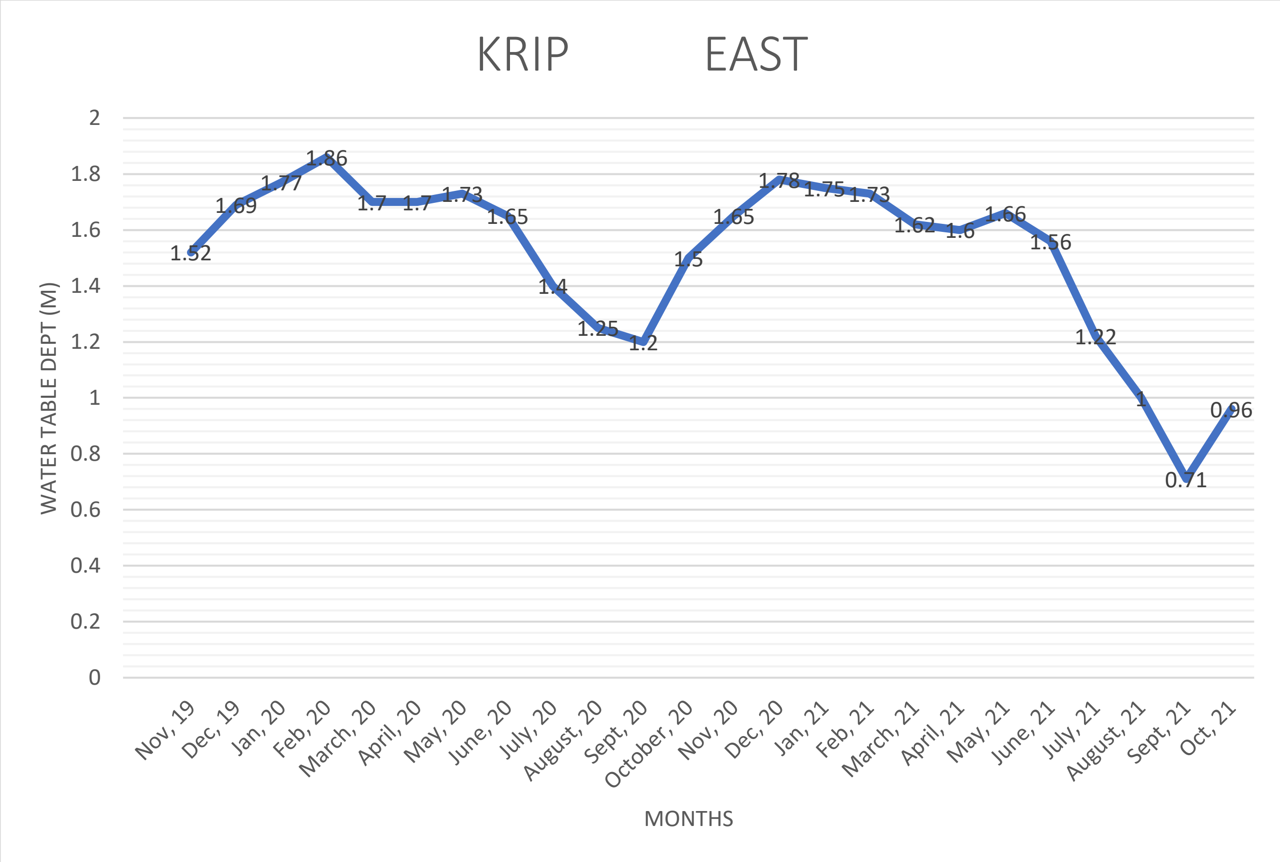

Figure 4. Water Table Fluctuation in Eastern Command

The trend in the eastern command is not the same, there was a decrease in the depth of the water table between February to May and there was a slight increase in May possibly due to the contribution of irrigation water. As lands are continuously irrigated, salinity levels in the soil and water table increases. Over some time in the absence of drainage systems, the depth of the water table decreases and saline shallow water table is developed near the surface [11]. The lowest depth of 0.71 m was recorded in 2021 and the deepest value of 1.86 m was recorded in February (Figure 5). This is within the period of the dry season when most irrigated crops are at the vegetative stages. Generally, the water table in the KRIS is capable of making a significant contribution to soil salinity and sodicity in August and September due to a shallow depth of less than 2 m [3]. Reference [14], reported a positive and strong correlation (*r*2 = 0.84) between the concentration of salt on the soil surface and water table levels of 0.70 m or less.

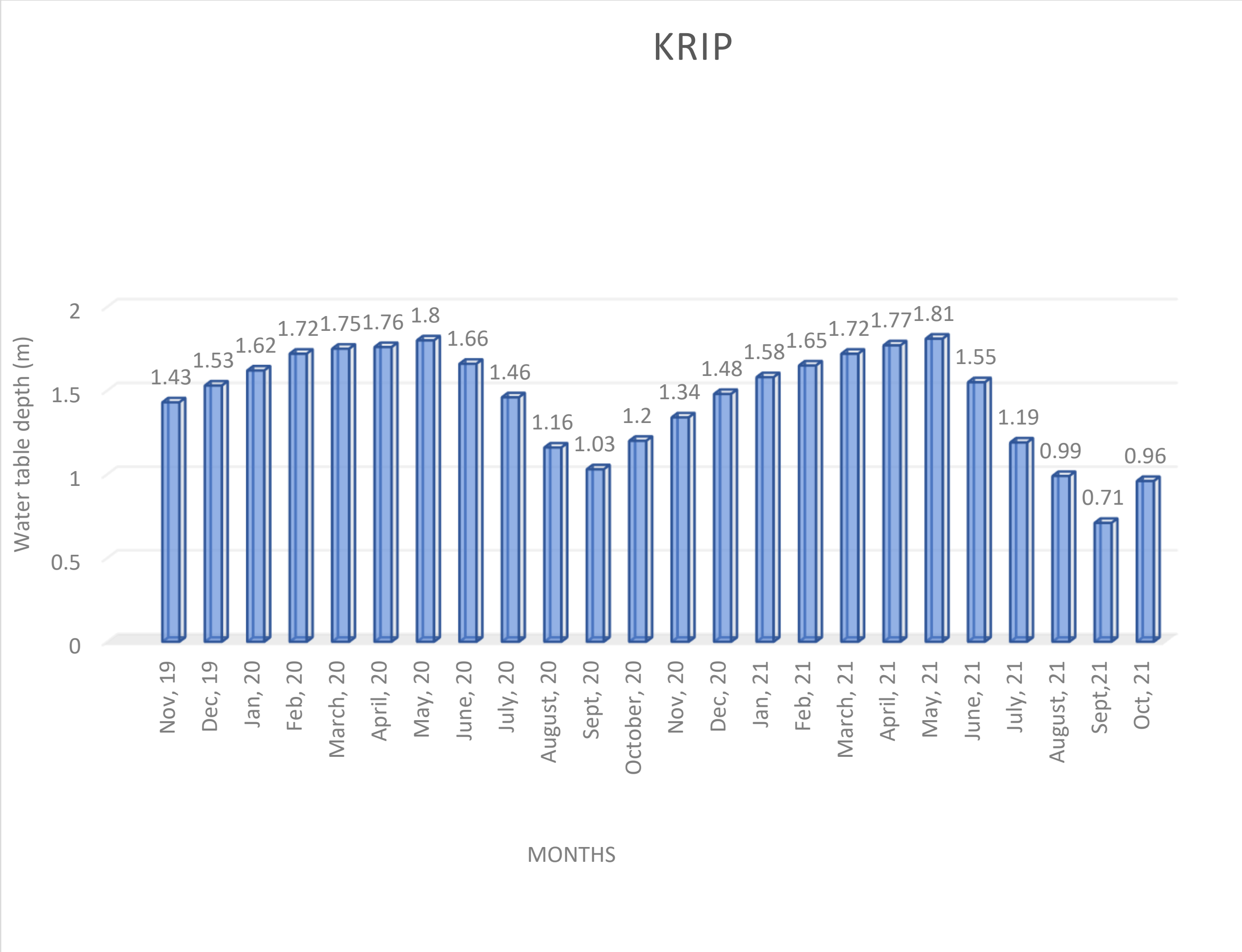

Figure 5. Water Table Fluctuation in KRIP

In the entire KRIP, the mean monthly water table depth is less than 2.0 m below the surface (Figure 5) and this implies high potential for salt accumulation on the surface as the capillary groundwater approaches the soil surface [1]. Reference [3] reported that at a water table depth less than 2 m below the soil surface, most crops can obtain a substantial portion of their water requirement from the groundwater and consequently irrigation rates can be reduced below evapotranspiration rates. Reference [15], compared soil salinity and water table depth at the beginning of the growing season in the Yinchuan Plain of China and discovered that areas with water table depth between 0.9 m and 3.0 are mostly affected by salinity. Based on these findings, all areas of KRIS are likely to be affected by salinity. However, [3] stated that, in a shallow water table depth less than 3 m, some crops can absorb water from the soil and the amount of water applied through irrigation can be reduced without causing the yield reduction.

In September 2021, the mean depth of the water table is 0.71 m which increased to 0.96 m in October of the same year (Figure 5). Reference [6] studied the effect of water table depth on water use, growth and yield of soya beans in a lysimeter experiment and the results indicated that 0.70 and 0.90 m of constant water table depth can result in higher yield, greater Water Use Efficiency and better root distribution compared to shallow water table depths. This implies that soya beans can provide a good yield when planted between September and October in the KRIS based on the trend of the water table. Reference [17], stated that low water table and low salinity are necessary for maximum yield and quality of grain. This implies that crops grown in some areas of the western command with deep water tables will give higher yields of better quality compared to those grown in areas of shallow water tables.

Generally, results had shown that groundwater indicates a pattern of the trend of the fluctuations that happened every year. Fluctuations of the water table were influenced by the rainfall received during the rainy season.

3.2 Descriptive Statistics of Water Table

The data of water table depths were subjected to a descriptive statistics analysis. Based on the analysis, the minimum water table depth of 0.6 m was recorded in the rainy season of 2021. While the maximum observed value of 3.16 m occurred during the dry season of 2020, (Table 3.1). This phenomenon was also observed during the dry season of 2021, when the maximum value was 2.6 m, compared to 0.6 m during the rainy season of the same year (Table 3.1).

Table 1. Descriptive Statistics of the Depth of Water Table in the Sectors

Period	N	N*	Mean	SE Mean	St Dev	Min	Q1	Median	Q3	Max	Skewness
Dry Season 2020	85	0	1.6576	0.0456	0.42	0.91	1.39	1.53	1.86	3.16	1.05
Rainy season 2020	85	0	1.2007	0.0378	0.3485	0.45	0.98	1.2	1.35	2.47	1.09
Dry season 2021	85	0	1.6257	0.0345	0.3182	1.1	1.395	1.55	1.76	2.61	1.17
Rainy Season 2021	85	0	1.0886	0.024	0.2214	0.6	0.955	1.06	1.205	1.613	0.19

The data are relatively normally distributed with dry seasons (2020 and 2021) slightly skewed to the right and rainy seasons (2020 and 2021) skewed to the left.

3.3 t- Test on the Water Table Data

A 2- sample t- test was carried out to test if there is a significant difference between the mean depth of water in the dry season of the year 2020 and the corresponding season of the year 2021. The test hypothesis used is as follows:

H_0: $\mu_1 - \mu_2 = 0$
H_1: $\mu_1 - \mu_2 \neq 0$

Where:
μ_1: mean of Water Table Dry Season 2020 μ_2: mean of Water Table Dry Season 2021
Difference: $\mu_1 - \mu_2$ Equal variances are assumed for the analysis.

Table 2. Estimation of Difference Dry Season

Differences	Pooled ST Dev	95% CI for Differences	T-Value	DF	P-Value
0.032	0.3726	-0.0809, 1448	0.56	168	0.577

In Table 2, the null hypothesis states that the difference in the mean water table depth between two years is 0. Because the p-value is 0.577, which is greater than the significance level of 0.05, the decision is to accept the null hypothesis and conclude that the water table depth of the two seasons is statistically not different. A similar test was conducted on the data for the rainy seasons of the year 2020 and 2021 (Table 3.3).

The result revealed that the difference in the mean water table depth between two years is statistically not significant as the p-value is 0.013, which is also less than the significance level of 0.05, the decision is to reject the null hypothesis and conclude that the depth of water table for the rainy seasons (2020 and 2021) are different.

If μ_1: mean of Water Table Wet Season 2020

μ_2: mean of Water Table Wet Season 2021

Then:

H_0: $\mu_1 - \mu_2 = 0$

H_1: $\mu_1 - \mu_2 \neq 0$

Table 3. t –Test for Rainy Season

T-Value	DF	P-Value
2.5	168	0.013

4.0 CONCLUSION

The study revealed that, the mean monthly water table depth over the entire KRIP is less than 2.0 m below the surface and this implies high potential for salt accumulation as the capillary ground water approaches the surface. The water table in 2021 was found to be shallower during the rainy season compared to 2020 due to the deterioration of the conveyance system which led to an increase in seepage. The trend in the eastern command is not the same compared to the western command, there was a decrease in the depth of the water table between February to May and slight increase in May possibly due to the contribution of irrigation water. The shallowest water table was recorded in September 2020 and 2021. The t-test revealed that the water table depths for the rainy seasons (2020 and 2021) do not differ significantly. In general, the findings of this study revealed that the groundwater at KRIS indicates a pattern of the trend of the fluctuations that occur each year. Water table fluctuations were influenced by the rainfall received during the rainy season.

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