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Full Length Research Paper

Trend in ground water fluctuation in Gidan Kwano Inland Valley of Niger State Nigeria

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Trend in ground water table fluctuation was investigated on an experimental field of 18070.2 m^2 between June and March of a following year. Five Piezometers were used to monitor the depth of water table at different locations. Findings indicated a depth of water table fluctuation between 0.4 cm above the soil surface and 200 cm below surface. Further analysis carried out on possible relationship between depth of water table and time indicated a non linear polynomial of second order degree ($Y = a + b_1X + b_2X^2$) with 0.84 as the average regression coefficient (R^2). Trend in depth of water table (from ground surface) decreases with increasing rainfall from July to September but increases from September to March as rainfall decreases from September to November. Nevertheless, the sharp decline in rainfall between September and October do not translate to increase in depth of water table, this could be due to over saturation of soil in September that recharged the valley in October. The relationship between rainfall and depth of water table from the ground surface is statistically significant with regression coefficient of 73%.

Key words: Farming, groundwater, trend, fluctuation, inland valley.

INTRODUCTION

Good food and friendly environment promote socio-economic status and natural status of individuals, communities, states, nations and even the world in totality. Albeit this, the problem of food scarcity and environmental degradation (a result seemingly preserve on end, hence the struggle for food and water is as old as the creation. It started when man lost the privilege of environmentally friendly Garden of Eden. These problems have generated global concern in recent times, no wonder the words of Caryn (2002), “Lets stop talking about poverty and food security issues and actually get out there with practical ways of eliminating them through good management of land and water resources”.

The dynamics of hydrological phenomena are known to create water problems. In any environment water is either inadequate in supply or too much in circulation. Water distribution in an environment is therefore a stirring factor in water resources management. Good management of water resources could bring massive gains in agricultural yield and improve food security of resources of the poor farmers, the communities and the nations. According to Cos and Artkins (1979), the fraction of the earth water present in the soil and sub soil is exceedingly small, it corresponds to a depth of about 44 cm, and is replaced once in every 280 days. By contrast, the amount of water in the atmosphere at any one time corresponds to a depth of about 3 cm only; the water budget serves only as a point of departure for examining conditions that prevail in more specific situations. According to Dewhust et al. (1998), porosity and permeability are largely

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responsible for availability, amount and movement of ground water. Movements of course, eventually return ground water to surface reservoir of lake, stream and ocean. The combined effect of evaporation and transpiration picks up water from soil surface to become precipitation which infiltrates the ground and moves through pore spaces of soil and rocks http://www.ctic.purdue.edu/Groundsourfe.html. This made it imperative to evaluate rainfall statistics, ground water table, stream channel discharge and soil physical characteristics of agro ecological system such as the inland valleys.

Inland valley is the upper reaches of river system in which alluvial sedimentations are completely or almost absent (WARDA, 2004). They are valley bottoms submerged for period of years. They form hydromorphic fringes of its upland slopes and crest extending over areas that contribute runoff and seepage to valley bottoms. Inland valleys constitute important agricultural and hydrological assets and can make a major contribution to food security and poverty alleviation.

Our focus as an objective of this research is to understand the factors that control various components of the ground water fluctuations.

MATERIALS AND METHODS

Study area

The Gidan Kwano Inland Valley is located between latitude 9°15ˡ to 9°45ˡ N and Longitude 6°15ˡ to 6°45ˡ E (Figure 1). It forms the low land area of Garatu hill and also extended to Yadna hill. The valley covers an area of 13,930 km^2 and only 10% of this area is under cultivation. The problem in this valley has been variation in hydrology that creates seasonal scarcity of water as most of the river dries up during dry season and reappears again at commencement of rain. At peak of rain, there is problems of flooding of farm produce that culminate in the problems. Common crops such as yam, rice, millet, melon, sorghum, cassava are grown at peasant level while animals like cattle, donkeys, goats, and chickens etc are domesticated. Though the crops and livestock production are at peasant level but the valley produces enough food and dairies that feed urban centers of Minna, Kaduna, and Abuja.

The valley is characterized by favourable climate, deeply drained up landscape element with sandy slopes and shallow impermeable layers and clay valley bottom, it is of great economic importance for both agriculture and settlement. It is in recognition of this that the permanent site of the Federal University of Technology, Minna was located within the valley. In like manner, resource-poor farmers and Nomadic Fulanis of Northern Nigeria generally concentrate their settlement in the available inland valley after migration.

Field experiments and collection of data

Extract from existing geographical map of Niger State (Minna Topo-Sheet 40) was collected from the Survey Department of the Federal Ministry of Works and Housing, Minna (FMWH, 1986)). The topographical map was used to identify and locate water catchments within the valley. An experimental field measuring 120 m × 170 m × 124 m × 150 m and bonded by natural stream channel which flows in the east west direction was mapped out and surveyed for investigation of fluctuation in ground water table and infiltration characteristics (Figure 2).

Measurement of depth of groundwater table

In the investigation of the level of ground water table, five sample wells of varying depths were drilled within the experimental field at varying locations and depths and piezometers installed in each of then. Well (W_1) was located at the centroid and four others located at different distances and locations from W_1 for convenience of fair distribution. W_1 was chosen as the centroid because of the high depth before obstruction as it will enhance longer period for water depth monitoring. Table 1 gives vivid description of depth of wells and their varying distances from each other. A 50-mm diameter soil auger was used to drill out well manually on rotary motion and PVC pipes 50 mm diameter (piezometers) were installed with 10 mm clearance from the pipe for backfilling. The variation in the depth of wells was experienced due to underlying rock formation which do not assume uniform depth.

The PVC pipes were first perforated spirally using Φ 5 mm drill at 10 cm spacing in order to prevent envelope material from entering into the well and also sizable and spaced enough to allow discharge of water into the well laterally. The perforated pipes were screened with fine net materials (filter) to prevent soil particles from water discharging into the well laterally. The pipes were lowered into the wells with the perforated end below the ground surface and allowed to protrude 30 cm above the ground surface to prevent inflow of runoff water. Gravel envelope materials of average diameter equal to 10 mm were used to backfill a depth of 1.2 m from well bottom. The remaining depth was filled with clay materials to prevent inflow of surface water and to enhance stability. Each piezometer has its open end covered with polyethene materials to prevent evaporation of water from the well and feeding by rain water (Figure 3).

Measurements of depth of water table were carried out for nine months using steal tape dusted with chalk particle. The tape is gently lowered into the well until it touched the bottom of the well. It is then drawn out gently. The height of water table (h) from the bottom of the well was obtained by deducting depth of water table (d) in the well from the total depth (D) of the well as shown in Equation 1. Depth of water from the surface is obtained by deducting the height h from the total depth of well D. This is expressed mathematically as:

$$h = D - d \tag{1}$$

Where,
h = height of water table from the bottom in well (cm).
D = total depth of well (cm).
d = depth of water table in well from the ground surface (cm).

The expression relating the depth of ground water table with time for the various piezometric points were established. The regression coefficient of best fit, R^2 for all the well locations were similarly evaluated.

9° N 6° E 9° N 7° E

Figure 1. Topographical map of Minna showing the study area.

RESULTS AND DISCUSSION

Trend in ground water table

The trend of the ground water table fluctuation for the study period is as given in Figure 4. Critical examinations of fluctuation in depth of ground water table monitored show a decrease from July to September and assume constant level to October and increase to March. This may be due to the recharge of the perched water table by

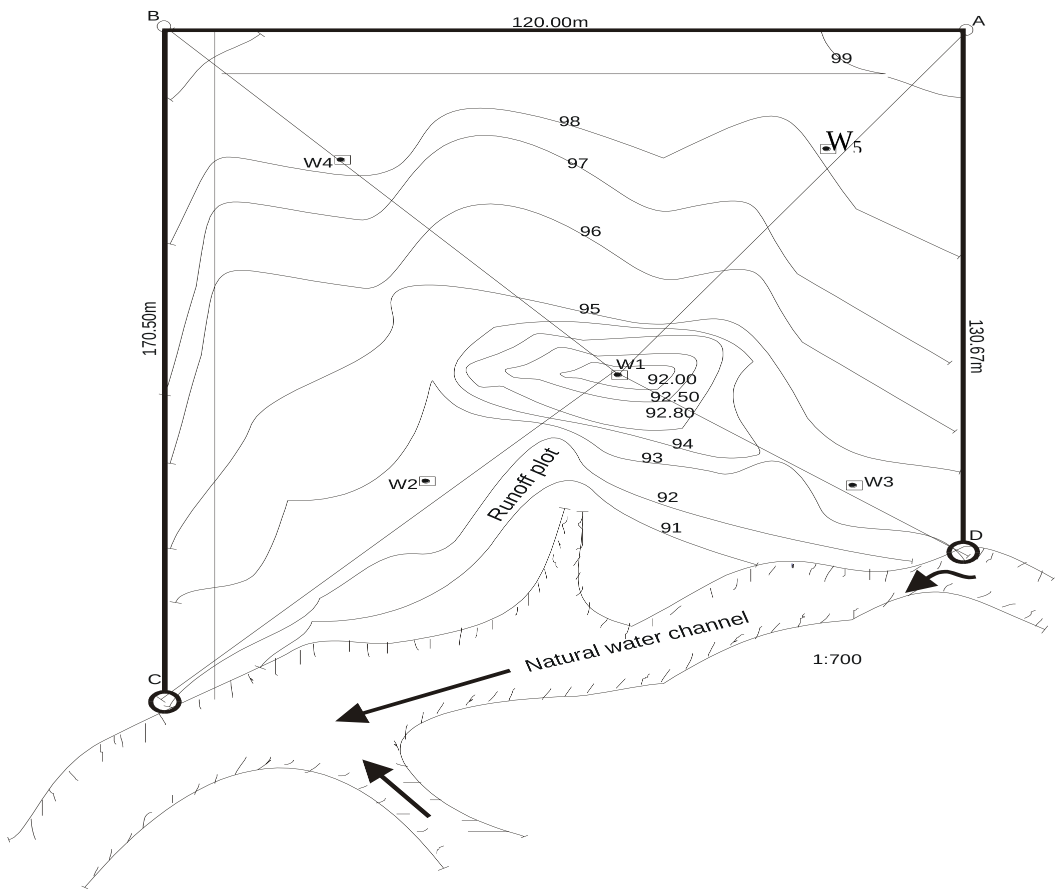

Figure 2. Experimental field showing the location of well.

Table 1. Piezometers locations and their depths.

Well	Distance from centroid (cm)	Depth (cm)
W1	0.0	212.0
W2	553.0	196.0
W3	740.0	154.0
W4	560.0	180.0
W5	760.0	169.0

Figure 3. Installed Peizometer.

deep percolation resulting from rainfall events. However, as rainfall depth increases, the water table rises steadily and decreases steadily too after the recharge period elapsed. The trend in all the piezometric points appears similar except for well No 3 which showed little deviation from the general trend as its lowest value occurred in October and with nearly the same depth in August and September. The only plausible reason could be because of the proximity of W3 to the stream channel which serves as source of drainage.

Expression relating depth of ground water table as a

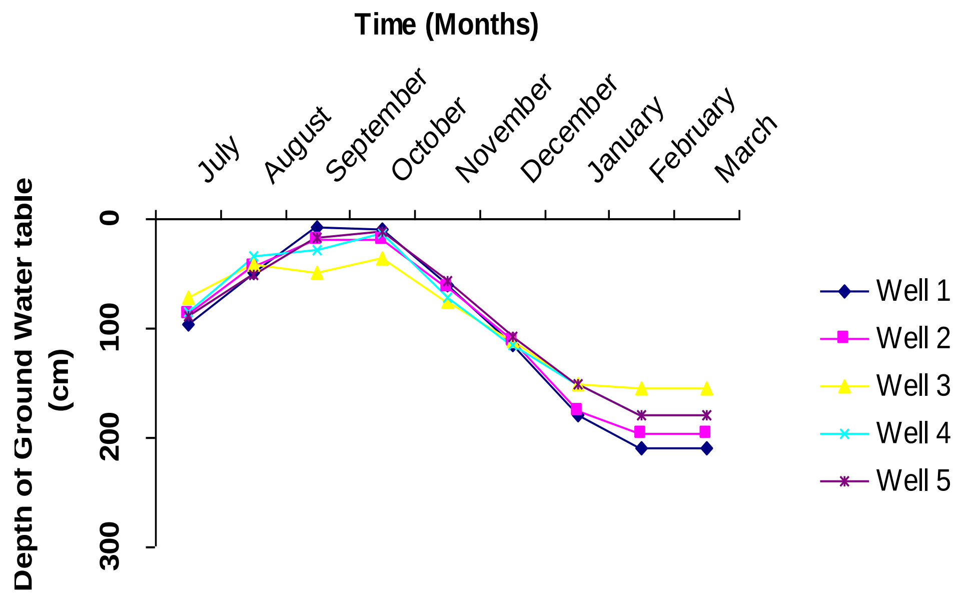

Figure 4. Ground water table fluctuation during the study period.

function of time for each well location was determined using quadratic function for curve estimation. This choice was informed based on the visual appreciation of the depth of ground water table versus time plot which is curvilinear, (a second order quadratic function). Although a hyperbolic third order function was also tried but because of its irrationality in approximation in terms of best fit curve and general results (Richard and Willard, 1986) it could not fit to this situation. Sequel to the above reasoning, the quadratic function under this curve estimation principle is purely a regression equation as given by Equation 2

$$Y = a + b_1 X + b_2 X^2 \quad (2)$$

Where;

Y = Depth of ground water table in cm.
a = Constant of regression.
b_1, b_2 = are parameters of the equation of fit.
X = time in days.

a and b are evaluated from the plot of depth of water table from the ground surface versus time (months) as shown in Figure 5.

The value of the regression coefficient R^2 from the plot of mean depth of water table with time as polynomial function ranges from 0.73 to 0.84 with the mean percentage of 84% (Table 2). From Figure 5, the high value of regression coefficient of 84% shows that fluctuation in ground water table is stochastic (time dependent) as conditioned by rainfall pattern of the study area(Table 3).

Monthly rainfall and depth of water table

The monthly rainfall amount, duration and mean depth of water table is presented in Table 3. The relationship between mean monthly rainfall amount and the mean monthly depth of water table from the ground surface is plotted in Figure 6. While the depth of water table from the ground surface decreases to September and hence increases to mid November and below, rainfall is on the opposite with decrease from July to October and increases hence forth. However, at end of October an equal relationship was established between the two factors.

The correlation between rainfall and depth of water table was statistically carried out and 72% correlation was established. This is in conformity with the dependency of depth on rainfall although 28% of the rainfall do not translate to depth of water table as the might have been lost as runoff and evapotranspiration.

Conclusion

Agricultural productivity in Gidan Kwano Inland Valley requires an in-depth knowledge of the hydrological dynamics for better management of land and water

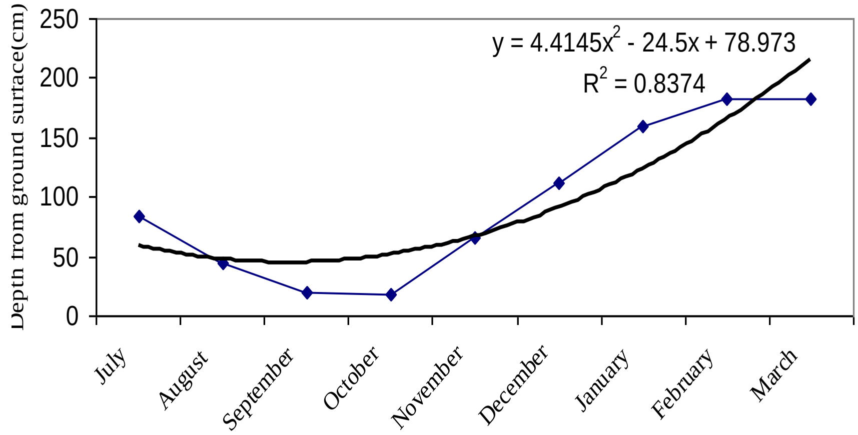

Figure 5. Plot of mean depth of water table with time as a polynomial function.

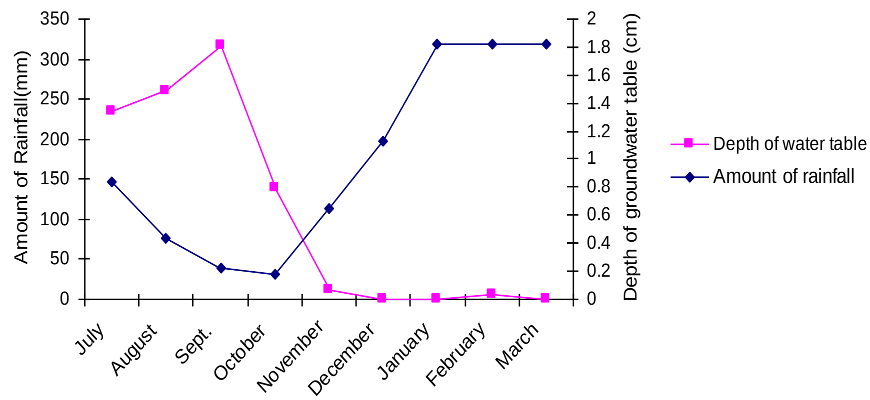

Figure 6. Plot of rainfall and depth of water table with time.

Table 2. Depth of Ground water table expressions and the corresponding R^2 values.

Well	Equation of best Fit	R^2
$W1$	$Y = 97.5 - 36.28X + 5.94X^2$	0.84
W_2	$Y = 84.62 - 28.54X + 5.02X^2$	0.85
W_3	$Y = 108.22 – 41.78X + 5.99X^2$	0.74
W_4	$Y = 75.77 – 22.94X + 4.23X^2$	0.83
W_5	$Y = 91.61 – 31.25X + 4.99X^2$	0.83
$W_{1\text{-}5\ Mean}$	$Y = 78.97 – 24.5X + 4.41X^2$	0.84

Table 3. Monthly rainfall amount, duration and mean depth of water table.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Amount (mm)	0.0	5.7	0.0	11.5	97.9	202.4	234.5	260.7	316.9	139.5	12.0	0.0
Duration (s)	-	27	-	132	422	2345	1201	2293	2988	1194	101	-
DWT (cm)	1.82	1.82	1.82	1.60	1.12	0.66	0.84	0.44	0.20	0.18	0.65	1.12

Source: Nigerian Metrological Agency, Minna.

resources. It could be established from this research that; the maximum rainfall depth is 345.9 mm in the month of September while the minimum is 1.2 mm in February.

Depth in ground water table from ground surface decreases from 1.82 m and below in January to 0.20 m in October, and increases again to 1.82 m and below in March on the average. The general trend obeys a second order polynomial.

These findings therefore, are farm indicators for cropping intensities, when to irrigate or drain excess water from the field and also useful in planning of land and water resources.

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