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Effect of crop water intake on water table depth: A case study of Chanchaga irrigation scheme

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ABSTRACT
A study to determine crop water intake, on water table depth at the Chanchaga irrigation scheme was carried out by identifying and monitoring water table depth fluctuations. Three piezometric pipes were installed within the study area at varying distances apart to monitor the three wells (A, B and C). Infiltration rate tests were also carried out to determine the rate at which water infiltrates into the various types of soil in the study area. The water level was determined twice within a month during the months of January to May to determine their level of fluctuations. Soil physical properties such as moisture content, bulk density, porosity, available soil moisture holding capacity and the infiltration rate of the soil were investigated within the study area. The groundwater fluctuation at the project site shows that the water level in wells B and C were within the active root zone depth of shallow rooted and moderate rooted crops. The water level in the three wells indicates that areas surrounding wells should be drained only during August and September. This is to reduce the water logging effect at that period or, high water requiring crops like rice and sugarcane should be grown around well A. Around wells B and C, irrigation is needed slightly for October and entirely for the rest of the dry season.

Keywords: Fluctuation, infiltration rate, moisture content, soil, water, well

INTRODUCTION
Water is next to air in importance, for both human and plant existence (Egharevba, 2002). Plants require a constant supply of water to maintain growth (Nazirbay *et al.*, 2005). It has been estimated that during October to March in Nigeria rain ceases to fall and to sustain continuous crop production to meet the food need of the country or society; there is the need to practice dry season farming (Egharevba, 2002). Thus, there is a need to meet the water requirement of crops. Irrigation is an old practice, as early as civilisation. The importance of water in agriculture has been realised over time. Technical and scientific water management is essential for the control of water within the soil and irrigation time (Ojha, 2003).

In many areas of the world, the amount and timing of rainfall are not adequate to meet the moisture requirement of crops thus irrigation is essential to raise crop necessary to meet the need of food and fibre. Irrigation should be seen as a husbandry aid, the need for irrigation, depends on the available water at the root zone and the effect of water stress on the plant's stage of growth. Crop responds at a particular stage of growth when the use of irrigation during periods of rainfall deficiency is likely to show economic benefits, and water stress (Goldhamer *et al.* 2006).

Water which is a carrier of nutrient in its soluble form is needed in the required volume for the successful growth of crops. To increase productivity, the study of the possible relationship between surface drainage and groundwater becomes essential, since the distribution of water within the soil profile and the proportion of water remaining in the root zone for plant utilisation appear to be of a critical limitation than the total amount of rainfall. Therefore, in such an environment, an understanding of the use of water is fundamental to formulate a management strategy, to monitor the water level fluctuation and to make more efficient use of the limited seasonal rainfall (Michael, 2000).

When drainage water moves downward, and out of the soil, it encounters a zone in which the pores are saturated with water. Often, this saturated zone lies above a layer of impermeable rock or clay. The upper surface of this zone of saturation is called the water table and the water in the saturated zone is called groundwater. Water table ranges between 1 and 10m below the soil surface. The unsaturated zone above the water table is the vadose zone. The vadose zone includes unsaturated materials underlying the soil profile and so considered deeper than the soil itself. In some cases, the saturated zone may be high to cover, the lower soil horizons, with the vadose zone confined to the upper soil horizon (Brady, 1999).

On the other hand, if groundwater is too close or near to the surface, the lands ability to produce most crops becomes almost impossible. Therefore, a water table within the lower portion of the root zone may supply a substantial amount of water thereby reducing the cost of irrigation (Deng *et al*., 2006; Morison *et al*., 2008; Letey *et al*., 2011). Groundwater is taken through pumping for domestic and irrigational uses. Water saturated soil make upland plant and forest species difficult to develop if not impossible. Prolonged saturation also makes it difficult to carry out farm operation as a tractor and other equipment used for planting, tillage and harvest operation (Kang *et al.* 2002).

This study aims to determine the water table depth and moisture content of the Chanchaga Irrigation Scheme during the dry season and to investigate the rate of water fluctuations within the irrigation scheme.

METHODOLOGY

The irrigation scheme is located within Chanchaga Local Government Area of Niger State, Nigeria. The project is situated between latitude $9^{o}34^{''}$ - $9^{o}37^{''}$ N and longitude $6^{o}36^{''}$ - $6^{o}39^{''}$ E (Chukwu and Musa, 2008). The scheme gets its irrigation water at the Chanchaga River, and the crops grown on the farm include spinach, Okra, pepper, Alfalfa, pumpkins and Sugarcane. During the dry season, irrigation becomes a necessary means of supplying water to the various sections of the farm.

The experimental plot was levelled by removing grasses and debris at the soil surfaces without altering the soil structure. A set of infiltrometer rings with a diameter of 600 mm and a height of 300 mm were placed on a separate portion of the farmland to determine the infiltration rates. The rings were gently hammered into the soil until a 25cm height is reached; care was taken to ensure eccentricity of the smaller ring in the bigger ring. Water was poured into the two rings to a height of 20cm and a stopwatch used to monitor elapsed time. Readings were taken at 0, 2, 5, 10, 15, 25, 35, 50, 70, 90, 110, 150, and 180 minutes and stopped when the steady state was achieved.

Soil samples were collected using a soil core at varying depths of between 2 to 20 cm at ten different locations and placed in airtight aluminium containers and conveyed to the laboratory. The various containers were clearly labelled to distinguish the sample. To determine moisture content, firstly, the can was weighed when empty and again weighed when filled with the wet soil sample. The considered cans containing the soil samples were placed in an electric oven at 105°C for 24 hours after which they reweighed to determine the various weights of the can and soil.

Pipes were installed in three sections of the soils using a hand-driven auger of length 1.5m. The pipes were radially perforated at 2cm apart across the depth of the pipe to allow sufficient and effective inflow of groundwater into the pipe to assume its original form and level. At the neck of the pipe on the ground surface, the clearance between the well and the pipe was sealed up using the concrete mix to disallow the vertical flow of water into the well by runoff or precipitation. A straight long wooden stick was used to taking the water depth measurement, by lowering the stick into the pipe, to the bottom of the pipe. After a few minutes, the stick was removed and the water level in each of the wells measured, by measuring the water gauge of the stick, with a standard meter rule.

RESULTS

Various crops are known to have various rooting depths. The various crops planted within the irrigation scheme with their corresponding root depth were observed (Table 1). It was observed that most of the crops planted during the dry season are usually between the rooting depth of 60 and 100 cm. Though it was found that some of the most commonly planted crops within the irrigation scheme were rice, onion, carrot, maize, tomato and sugar cane.

Table 1: Root depth of crops in the study area

Shallow-rooted crops (60cm)	Moderately rooted crops (80cm)	Deep-rooted (100cm)	Very deep rooted (120cm)
Rice	Wheat	Maize	Sugarcane
Potato	Groundnut	Sorghum	Citrus
Onion	Carrot	Tomato	

Figure 1 presents the depth of water within the threes considered during the study. Rainfall pattern within the same period of months for the same year which also shows a correlation between the water table depth and rainfall (Figure 2).

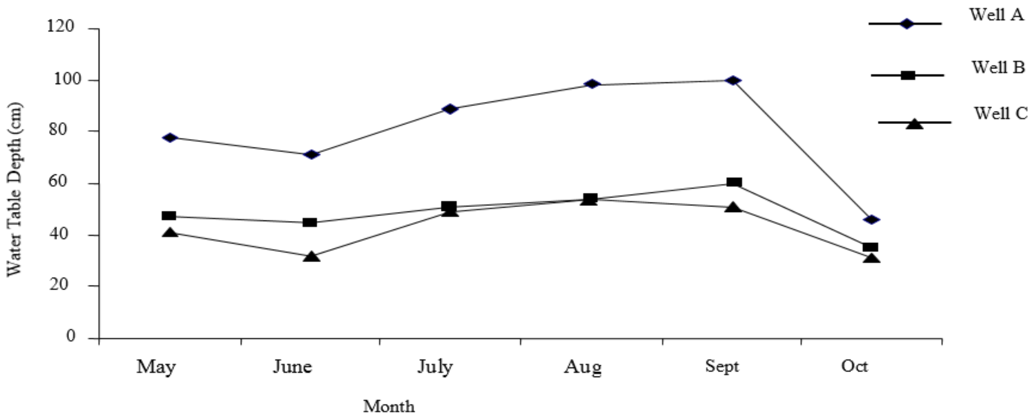

Fig. 1: Water table depth in study area

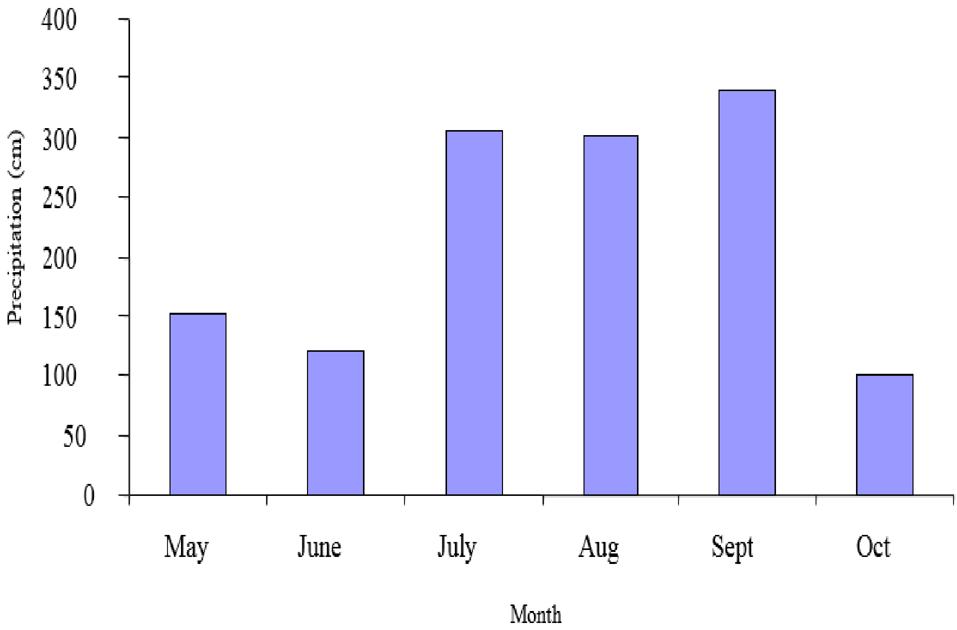

Fig. 2: Monthly precipitation rate in study area

The rate of infiltration of water into the soils of the study area shows a gradual decline in the intake rate with increase in time. Figure 3 presents the graph of infiltration rate against time while Table 2 presents the results of some of the parameters considered during the study and Table 3 below shows the trend of water fluctuation between May and October of the same year. Readings were taken twice within each month. It was observed that well A had the highest average value of fluctuation of 80.25 cm while wells B and C had amounts of 48.58 and 42.75 cm respectively.

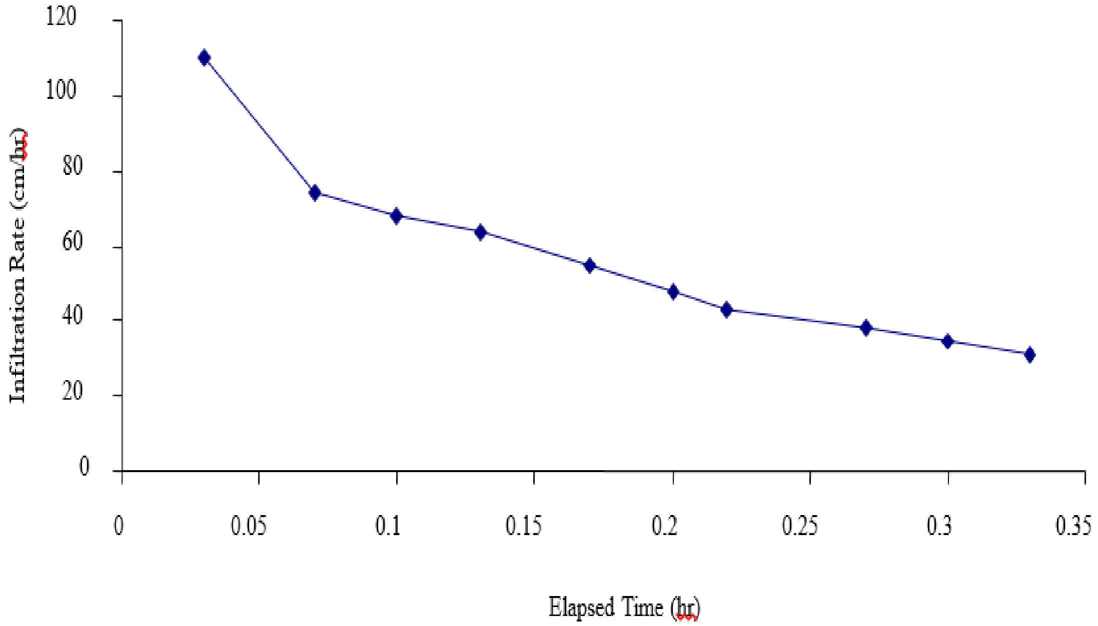

Fig. 3: Infiltration rate against time

Table 2: Physical properties at different depths

Depth (cm)	The weight of wet soil (g)	The weight of oven dry soil (g)	Moisture content in the dry base (%)	Moisture content in wet bases (%)	Wet bulk density (g/cm^3) ρ	Dry bulk density (g/cm^3) ρ	Available holding capacity	Available moisture carrying capacity in crop root zone
0-20	322.70	255.74	26.18	20.75	1.78	1.41	36.91	74.01
	304.55	270.82	12.45	11.08	1.68	1.50	18.68	
20-40	302.10	269.90	11.93	10.65	1.67	1.49	17.78	48.44
	290.35	262.94	10.42	9.44	1.60	1.45	15.55	
40-60	288.45	263.51	9.47	8.65	1.59	1.45	13.73	26.73
	286.26	262.69	8.97	8.23	1.58	1.45	13.00	
60-80	286.03	262.13	9.12	8.36	1.58	1.45	13.22	26.13
	285.18	261.88	8.90	8.47	1.57	1.45	12.91	

Table 3: Trend of Water Table Fluctuation

	May		June		July		August		September		October		
Days	12th	25th	8th	20th	10th	25th	12th	25th	12th	25th	8th	18th	Average
A	70	72	76	80	88	90	99	96	100	100	52	40	80.25
B	44	45	47	47	49	53	54	54	62	58	38	32	48.58
C	30	33	39	42	48	50	54	54	52	49	32	30	42.75

DISCUSSION

The three wells set up within the study area to monitor the water table showed that well A had the highest water table in September which was the highest peak of the rainy season. A sharp decline was observed after September which also tells a lot about the nature of soil within the area where the well was located. The soil analysis within the area showed that the area was mostly sandy loam and the most common crops planted here are carrot, onion, maize and tomato. Water table depths for the three wells considered within the study area between May and October of the year 2008 revealed that well A had the highest water table from May to October compared to wells B and C (Figure 1).

The rain pattern was observed that July and August had the same amount of rainfall which shows that they were second highest during the year while September had the highest precipitation for the year. It was observed that a flat rate of infiltration was reached faster than necessary and also shows that infiltration rate reduces with time. Though, an upsurge was seen in the 25th minute during the infiltration which indicates the possible presence of air in the soil. Figure 3 below shows the graph of infiltration rate against time.
The primary determinant of the rate of water of water intake is mainly dependent on the type of soil available within the area where the infiltration rate test is conducted and for adequate infiltration to occur the compactness of the soil must be considered. Thus, the soil should be loose, to enable the water to flow freely between the voids. Also, it helps crop roots to penetrate easily.

The result in Table 2, it was observed that the weight of the wet soil was higher at the upper part of the soil profile than at the lower part. The moisture content (for both dry and wet bases) were also found to be higher which could be the possible effect of the hardpan created overtime within the area or a possible hard rock underlayer located some distance from the top of the soil as the geological view of the area depicts this. The low nature of the moisture content recorded at the lower part of the soil profile could be as a result of the seasonal stream channel situated at the bottom of the study area. At both upper and lower part of the soil profile, the moisture content decreases with increases in depth until 60cm depth. The moisture content at that level starts to increase, which may be as a result of capillary rise. It is also observed, that wet bulk density, moisture content in wet base, available moisture holding capacity, and porosity decreases with increase in soil depth.
It is seen that well A fluctuate at a 6-8cm interval from May to July and 6cm from July to September, with a higher fluctuation in October due to the low amount of rainfall and slope. In July and September, the well was pounded with water, and this could be attributed to the depression around the well which usually stores precipitation water. Well B fluctuates between (1cm -12cm) depth. Well C fluctuated between depth (1cm – 16cm) depth. Both well B and C were at their peak during August and September due to the high precipitation at those periods.

CONCLUSION

This study has demonstrated the position of groundwater avaliability within the various wells during the dry and wet seasons of the study period as associated with the existing type of soil in the study area. Differences in soil water content in field situations can be very large which could be due to the topography and depth of groundwater during the two seasons. It is therefore concluded that irrigation activities can be carried out within the study area with short life span and non-water loving crops as the nature of soil does not retain water for a long time during the dry season.

RECOMMENDATION

Areas surrounding well A should be drained only in August and September to reduce the water logging effect. A drainage pumping or a surface drainage system should be employed to correct the area. Alternatively, crops which do well in waterlogged areas like sugar cane and rice can be grown around well A. At well B, the water level from July to September seems adequate for most food crops but should be supplied with water from May to

June to enable the land meet up with crop water requirements while full irrigation is required during the season of the remaining month of the year. Finally, around well C irrigation is slightly needed from May to October, while full-term irrigation is needed at the rest of the month to enable continuous crop farming. During the wet season, irrigation is slightly required around well C if water-loving crops are to be planted from May to October.

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