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ESTIMATION OF GROUND WATER RECHARGE AT NCAM, ILORIN FOR IMPROVED IRRIGATION MANAGEMENT.

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ABSTRACT

The recharge rate is a very important parameter required in the successful development of ground water resources, as often, it is this rate that can be safely abstracted as safe yield from wells and boreholes. Groundwater recharge was estimated for 2 wells located in areas representing the different land uses at NCAM using the water table fluctuation method. The yield from sites A and B were 0.02 – 0.2 m^3/hr and 0.008 – 0.03 m^3/hr respectively while the peak scheme water demand required for producing dry season vegetables for 0.5ha was obtained as 0.002 m^3/s. Achieving better understanding of the mechanisms that control groundwater recharge is crucial towards improving groundwater management.

KEYWORDS: groundwater recharge, over-extraction, yield, water demand

INTRODUCTION

Water is indispensable to all life on earth. Fresh water is constantly formed newly through a phenomenon known as hydrological cycle. Groundwater, on the other hand, is a replenishable resource widely distributed under the ground. It is free from pollution and can be developed with small capital cost in the least possible time (Raghunath, 1991). It allows the practice of intensive irrigation with possibilities of double or triple cropping, including commercial crops. In addition, supplemental irrigation during periods of deficient surface supply can be practiced thus making all year round farming possible. Rainfall is the principal source for replenishment of moisture in the soil water system and recharge of ground water.

Groundwater recharge or deep drainage or deep percolation is a hydrologic process where water moves downwards from surface water to groundwater. It is also the process whereby water below the land surface is replenished by either direct infiltration of rainfall or by leakage from surface water bodies like streams and lakes. The amount of moisture that will eventually reach the water table depends on the rate and duration of rainfall, the subsequent conditions at the upper boundary, the antecedent soil moisture conditions, the water table depth and the soil type. A good aquifer is capable of transmitting water through its pores at a rate sufficient for economic extraction by wells.

The recharge rate varies both spatially and temporally. Factors influencing groundwater recharge include characteristics of the recharge beds, such as topography, land use and vegetation cover, existing soil moisture and the ability of the recharge beds and aquifer materials to capture and transmit water (Bureau of Rural Science, 2007). Agricultural land uses as categorized by US, EPA (2008) include: Cropland; Irrigated cropland; Range and pasture; Orchards; Permanent hay land; Specialty crop production; and Nursery crop production. Zhang and Schilling (2006) observed that grass cover lowered the water table, reduced soil moisture through ET losses, and thus reduced groundwater recharge. The key factors controlling groundwater recharge are highlighted as: climatic, the amount and intensity of rainfall and evaporation; soil and aquifer hydraulic properties; type and amount of vegetation cover and types of land use; topography, in particular the slope of the land surface; the nature and geometry of aquifers in the catchment; residual (or antecedent) soil moisture stored in the soil profile from previous rainfall events.

The recharge rate is a very important parameter required in the successful development of ground water resources, as often, it is this rate that can be safely abstracted as safe yield from wells and boreholes. Quantification of the rate of natural ground water recharge is a pre-requisite for efficient ground water resource management. It is particularly important in regions with large demands for ground water supplies, where such resources are the keys to economic development. Few studies deal explicitly with groundwater recharge in temperate and humid zones, because recharge is normally included in regional groundwater investigations as one component of the water balance. According to Jacobus and Simmers (2002), emphasis is accorded to (semi-)arid regions because the need for information is greatest in those areas – groundwater is often the only water source, is vulnerable to contamination, and is prone to depletion.

Importance of noting the recharge rate include knowing the number of wells needed for water supply per day as well as the spacing of such wells so that the drawdown of one does not affect the other (Ewemoje and Oluwalogbon, 2006). Interest in quantifying recharge rate has increased because of concerns that land use changes may reduce recharge and that ground water resources in some areas may not be sustainable during drought periods (Risser *et al*., 2005). A robust estimate of the amount of water entering a groundwater system and the rate at which the water is transmitted through the aquifer are essential if over extraction is to be avoided. The consequences of over-extraction can include lower water tables and decreased access to groundwater supplies, decreasing environmental flows to groundwater dependent ecosystems, movement of poor quality (saline) water into the aquifer, the possibility of land subsidence and a decline in the contribution of groundwater to the base flow of river systems. Even if the total amount of groundwater being pumped from an aquifer is less than the recharge, there may be localized impacts if local groundwater pumping exceeds the rate at which water can be transmitted through the aquifer.

There has been a significant increase in the extraction of groundwater resources for consumptive uses during the 1980s, 1990s and into the 21st century. This has led to increased awareness of the importance of managing such resources to ensure their long term sustainability. An important aspect of managing groundwater lies in understanding how the resource is being replenished or recharged. Understanding critical groundwater management issues, including rising water tables, acceptable levels of development or groundwater contribution to environmental flows are ultimately based on estimates of groundwater recharge rates. An important emerging issue is the potential for climate change to alter dramatically the existing recharge regimes. In particular, understanding how the magnitude and regularity of large rainfall events may change is a priority for managing the future health of our groundwater systems. The outcome of this research would assist the planners and decision makers to come up with control measures for ongoing land use practices and groundwater development activities ensuring its long-term sustainability in groundwater systems.

The objectives of this study are to determine the rate of groundwater recharge and the adequacy of water supply from groundwater source for proper irrigation management at the National Centre for Agricultural Mechanization (NCAM).

MATERIALS AND METHODS.

Experimental Site:

The study was conducted at two sites located within the National Centre for Agricultural Mechanization (NCAM), Ilorin. Ilorin is situated on Longitude 4º 35′ East and Latitude 8º 29′ North with an altitude of 370 m above sea level. The Sites were selected to represent the different agricultural uses to which the Centre's land was subjected to namely: Irrigated cropland, orchard / nursery production and farmland. These sites were subsequently named as sites A and B respectively.

Experimental Procedure.

Groundwater recharge was estimated using the water table fluctuation method. Recharge is equated to the volume of water stored in the incremental volume of aquifer defined by the water table rise. Existing water in the wells were pumped out and initial level recorded. Subsequent daily readings were taken at 24hr interval. Measured water table rise is correlated to rainfall event under the assumption that any rise in groundwater level is due to percolating water reaching the water table.

Volume of water entering the well is obtained from the expression:

$$dV = A\,dh \qquad (1)$$

where: A = cross-sectional area of the well; dh = change in water head.
Volume could also be expressed as:

$$dV = Q\,dt \qquad (2)$$

where: Q = rate of discharge in the well

$$Q \propto h\,; \qquad Q = Kh$$

$$dV = K\,h\,dt \qquad (3)$$

Equating (1) and (3) gives

$$K\,h\,dt = A\,dh \qquad (4)$$

The minus sign indicates that h decreases as time increases.
Integrating equation (4) between the limits t = 0 and t = T when h = h_1 and h_2 respectively gives:

$$\frac{K}{A}\int_0^T dt = -\int_{h_1}^{h_2}\frac{dh}{h} \quad \text{or} \quad \frac{K}{A}\int_0^T dt = \int_{h_2}^{h_1}\frac{dh}{h}$$

from which

$$\frac{K}{A}T = [log_e h]_{h_2}^{h_1}\,; \frac{K}{A} = \frac{1}{T}\,log_e\frac{h_1}{h_2}\,; \;\frac{K}{A} = \frac{2.303}{T}\,log_{10}\frac{h_1}{h_2} \qquad (5)$$

$\frac{K}{A}$ is known as the specific yield of an open well in $m^3/hr/m^2$ of the area through which water percolates under 1m depression head. This value can be deduced from the values of h_1, h_2 and T obtained from the recuperation test.

The discharge from the well is thus calculated as:

$$Q = \frac{2.303}{T}\left(log_{10}\frac{h_1}{h_2}\right)A\,H \qquad (6)$$

where Q = yield from well in m^3/hr.

Other parameters that influence recharge were estimated thus:
- i) Porosity was determined as the ratio of volume of pores spaces in soil sample to volume of core.
- ii) Infiltration rate was estimated using a double ring infiltrometer.
- iii) Soil moisture content was obtained gravimetrically (oven method). Soil moisture at saturation was obtained by soaking the samples in water for 24 hours before oven drying.
- iv) Water holding capacity was determined as the difference between the weight of saturated soil and the weight of oven dried soil.
- v) Field capacity was obtained by saturating the sample then draining by gravity for 3 days after which the sample is weighed.
- vi) Permanent wilting point was assumed to be half of the amount of field capacity (FAO, 1988).
- vii) Hydraulic conductivity was be determined by collecting an undisturbed sample in a core. An inverted conical flask filled with water delivered water to the soil core through a delivery tube. The soil core was placed in a funnel over a calibrated beaker and filled with water to a known height. The conical flask was refilled to maintain the water head. Water collected in the beaker was recorded every 5 minutes until equilibrium was attained.
- viii) Saturated hydraulic conductivity was obtained in similar manner except that the sample was saturated for 24 hours.
- ix) The crop coefficient of crops established in the study area (Adeogun and Ahaneku, 2000) was utilized.

RESULTS AND DISCUSSION.

The physical and chemical properties of soils as well as the soil textural classification of the study sites are presented in Table 1. The rates of infiltration for both sites are presented in Figures 1 and 2 respectively.

The specific yield determination commenced in the month of May when rainfall for the year under study had been established. Table 2 shows the yield obtained from rainfall events for the months of May to October. Yield values were higher for all the months at Site A. This could be attributed to the soil texture (sandy loam) which is more porous and permeable than the loamy soil of Site B. Specific yield $(\frac{K}{A})$, is a function of the type of soil being higher in sandy soils than in clay soils.

The well at Site A was cleaned before commencing recuperation tests while Site B was left in its original state. This action could also be responsible for the significant difference in yield values.

Table 1: Physical and Chemical Properties of Soils of Study Area.

Parameter	Site A	Site B
Sand (%)	69.52	53.52
Clay (%)	20.48	29.49
Silt (%)	10.00	17.05
Textural Class	Sandy Loam	Loamy
Organic Matter	4.93	5.71
Moisture Content (%)	11.72	12.97
pH water	6.0	5.2
Conductivity	0.00	0.00
Nitrogen (%) kjedal	0.150	0.052
Total Acidity	0.072	0.130
ECEC (mol/kg)	2.02	5.29
Na (mg/kg)	2.6	2.24
K (mg/kg)	0.05	0.28
Mg (mg/kg)	2.20	1.23
Ca (mg/kg)	6.21	1.42

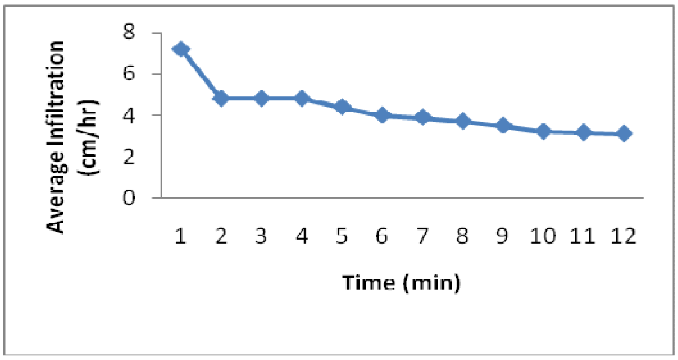

Figure 1: Graph of Infiltration versus Time elapsed for Site A.

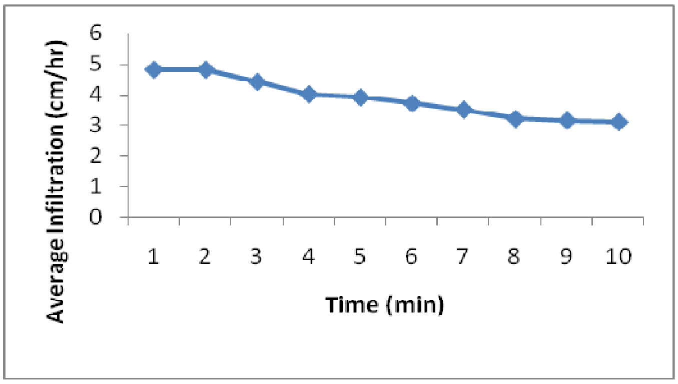

Figure 2: Graph of Infiltration versus Time elapsed for Site B.

Table 2: Rainfall and Yield data from wells at Sites A and B

Locations		Site A	Site B
Month	Rainfall Amount (mm)	Average Daily Yield (m^3/hr)	Average Daily Yield (m^3/hr)
May	65.9	0.019	0.008
June	199.9	0.040	0.010
July	207.9	0.134	0.033
Aug.	157.0	0.098	0.004
Sept.	170.3	0.198	0.020
Oct.	155.6	0.168	0.009

The results indicate similar trend between the rainfall and specific yield. Rainfall increased monthly with a decrease recorded in the month of August which was also displayed in yield values.

Crop water demand

The water demand needed to grow dry season vegetables on 0.5ha for duration of 120 days with water requirement of 450mm, and a peak water demand that could be twice the average value is obtained as:

Seasonal crop water requirement (m^3/ha) = crop water requirement (mm) x 10
450 x 10 = 4500 m^3/ha
Average crop water requirement = 4500/120 = 37.5 m^3/ha
Peak daily crop water requirement m^3/d/ha = average crop water requirement x 2
37.5 x 2 = 75 m^3/ha; 75 x 0.012 = 0.9 l/s/ha

The peak scheme water demand, expressed in l/s, is obtained as follows:
Irrigation efficiency (%) = field application efficiency (0.8) x distribution system (0.6)

$$\text{Peak water demand (l/s/ha)} = \frac{\text{Peak crop water requirement (l/s/ha)}}{\text{Irrigation efficiency (\%)}} = 0.9 / (0.6 \times 0.8) = 1.875 \text{ l/s/ha}$$

Peak scheme water demand (l/s) = Peak water demand (l/s/ha) x cropped area (ha) x 24 hours of operation (h).
For 0.5ha pumping for 10 hrs each day during the peak demand period:
Peak scheme water demand = (1.875 x 24 x 0.5) /10 = 2.25l/s = 0.002 m^3/s

The seasonal water demand of the scheme (m^3) is calculated as:

$$\text{Seasonal scheme water demand} = \frac{\text{crop water requirement } (m^3/\text{ha}) \times \text{cropped area (ha)}}{\text{Irrigation efficiency}}$$

Thus for a seasonal crop water requirement of 4500 m^3/ha
Seasonal Scheme water Demand = (4500 x 0.5) / (0.6 x 0.8) = 4687.5 m^3

CONCLUSION

The rate at which groundwater is recharged is important in determining the sustainable rate at which groundwater can be extracted. The peak scheme water demand required for producing dry season vegetables for an area of 0.5ha was obtained as 0.002 m^3/s, while the yield from sites A and B were 0.02 – 0.2 m^3/hr and 0.008 – 0.03 m^3/hr respectively.

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