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Short Communication

Assessment of Groundwater Recharge in Semi-Arid Region of Northern Nigeria

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Abstract. The average annual groundwater recharge value of three sites, representing the major geological basins of Northern Nigeria, ranged from 169 mm for Maiduguri to 837 mm in Kano area and the recharge coefficient for the zone ranged from 0.26 to 0.56. The month of August accounted for about 53% of the average annual estimate. About 69 mm (70%) of average annual potential natural groundwater recharge was lost, as a result.

Keywords: drought, groundwater recharge, semi-arid zones, Nigeria

The semi-arid zone of Northern Nigeria has great potential for large-scale economic development due to warm temperatures and bountiful resources including farmlands, minerals and thermal energy (Adelana *et al.*, 2003; Schoneich and Askira, 1987). The entire region (Fig. 1) is primarily oriented towards extensive agriculture and animal husbandry and is rainfall dependent. However, the infrequent and short duration of rainfall, less than 60 days, in most places has made water availability, one of the primary restrictive factors to economic development of livestock, agriculture and land resources. (Mustafa and Babatola, 1989; Thambyahpillay, 1987).

There is insufficient information available on groundwater recharge of the arid and semi arid regions of Nigeria (Olasehinde *et al.*, 2001).

The present investigation estimates the amount of groundwater recharge and the generated data can be useful in future planning and management of the resources and thus reducing some of the worst impacts of drought in vulnerable areas. The soil moisture deficit (SMD) model in view of its reliability and cost effectiveness (Ndubuisi, 2007, 2005; Odijie and Anyaeche, 1991; Rushton and Ward, 1979), was used to estimate the incidence of groundwater recharge. The method uses daily time steps to compute recharge (RECH) from rainfall after satisfying the soil moisture deficit (SMD), evapotranspiration (PE) and surface runoff (RO) demands. The estimate is for rainfall only, not taking into account any seepage along stream channels, irrigated agricultural fields, lakes and ponds etc.

In the model, recharge $\Delta S = P1 - PE - RO$, (1)

where:

P1= precipitation (mm)

PE = potential evapo-transpiration (mm),
RO = runoff (mm).

Negative value of ΔS represents an increase in soil moisture deficit and positive value indicates potential recharge.

Basically the possibility of recharge depends on the SMD, which can assume four states, i.e. A: SMD = 0; B: $0 \leq$ SMD $\leq$ RC; C: RC $\leq$ SMD < D; Da: SMD > D, where RC = root constant and D = maximum soil moisture deficit.

Odigie and Anyaeche (1991) have given details on the model and method for estimating its parameters. A computer programme presented by Ndubuisi (2005) was adopted and applied. Drought effect was estimated by comparison between the data for the years 2001 to 2003 and for 1974 to 1983. Validation was attempted by comparison with previous estimates in literature.

The study area covers three major geological basins namely, the Iullemmeden (Olasehinde *et al.*, 2001; Oteze 1991, 1989 and 1975); weathered basement rocks (Jones and Benson, 1991) or the Hadejia-Jamare and the Chad basin (Ndubuisi, 2001; Bumba *et al.*,1985), using data for selected stations representing each of the three major catchments basins: Sokoto, Kano and Maiduguri (Fig. 1). (Odige and Anyaeche, 1991; Odigie and Olu, 1985).

The average annual recharge is 764.9 mm for Sokoto, 837.2 mm for Kano and 169.1 mm for Maiduguri. The annual estimate is about 31.8% of the average annual rainfall for Sokoto area, 55.5% for Kano area, and 26.3% for Maiduguri and environs (Fig. 2a-c). Therefore, the ratio of recharge to rainfall, or recharge coefficient ranges from 26% to 56% for the study area. The higher coefficient for Kano may be attributed to relatively higher precipitation and lower actual evapotraspi-ration during the period of study.

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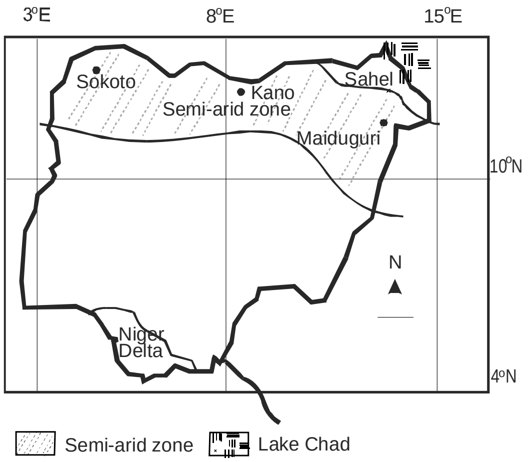

Fig. 1. Map of Nigeria indicating the study area.

The average monthly estimate for August is about 52.6% of the average annual value for the region. A comparison of rainfall and groundwater indicates that among the three stations and for the three consecutive years, 2001-2003, the month of August consistently had the highest monthly groundwater recharge and that the incidences of recharge occur within the wet months, June to October only. The relatively lower daily SMD, APE and higher P1 during this month can explain this.

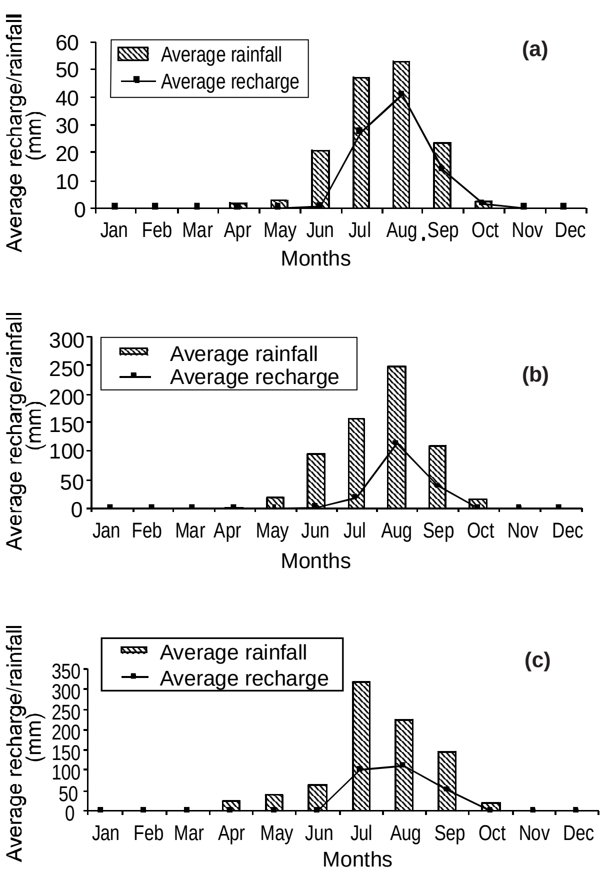

Fig. 2. Variation of average rainfall and recharge (2001-2003) for(a) Kano (b) Maiduguri (c) Sokoto.

The recharge value of 264.8 mm for Sokoto for 2001-2003 does not differ significantly from 255.0 mm obtained for 1960-1965 for the same area (Table 1). However, the annual average for 2001-2003 in Maiduguri is 169.1 mm (or 69%) higher than 100. 29 mm for 1974-1983, which included the drought period. Therefore, there was about 69% loss of potential groundwater recharge during the drought period. This may be responsible for the low water levels and drying of hand-dug wells reported by Mustafa and Babatola (1989).

Table 1. Comparison of the recharge results

Month	Sokoto		Kano	Maiduguri	
	1960-1965	2001-2003	2001-2003	1974-1983	2001-2003
January	0.0	0.0	0.0	0.0	0.0
February	0.0	0.0	0.0	0.0	0.0
March	0.0	0.0	0.0	0.0	0.0
April	0.0	0.0	0.0	0.0	0.0
May	0.0	0.0	0.0	0.0	0.0
June	4.0	0.0	4.7	0.0	2.0
July	39.8	101.2	273.4	22.18	17.2
August	137.6	111.5	407.7	49.58	113.1
September	69.6	52.1	137.1	28.53	36.8
October	3.9	0.0	14.3	0.0	0.0
November	0.0	0.0	0.0	0.0	0.0
December	0.0	0.0	0.0	0.0	0.0
T_A	254.9	264.8	837.2	100.29	169.1

T_A = annual average recharge (mm)

The range of annual recharge of about 169 mm-255 mm (Maiduguri -Sokoto) compares favourably with the values of 100.9 mm -365 mm reported by Odigie and Anyaeche (1991) and Odigie and Olu (1985). This indicates that the predicted natural recharge and the drought effect are consistent and reliable for the semi-arid environment of Nigeria.

An assessment of groundwater recharge in the semi-arid region of Nigeria shows that the annual recharge ranges from 169.1 mm in Maiduguri to 837.2 mm in Kano area and that recharge coefficients range from 26% to 56%. The results further indicated that the month of August accounts for about 53% of the average annual recharge and 19.4% of the average annual rainfall. The effect of drought on groundwater recharge from rainfall was found to contribute an annual loss of 69 mm potential groundwater recharge in the area. (Thanks are due to the management of Ambrose Alli University, Ekpoma, Nigeria for the financial support).

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