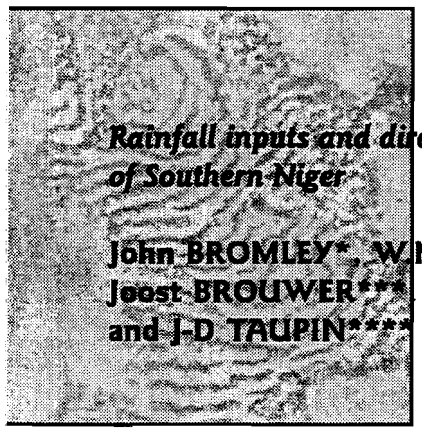

Rainfall inputs and direct recharge to the deep unsaturated zone of Southern Niger

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An estimate of direct groundwater recharge below a region of natural woodland (tiger bush) has been made in south west Niger using the solute profile technique. Data has been collected from a 77 m deep well dug within the study area covered by HAPEX-Sahel, an international large scale energy, water and carbon balance experiment carried out during the summer of 1992. So far as the authors are aware this is the deepest profile to have been obtained in the Sahel region and as such provides a uniquely long record of recharge in the historic past. 20

The principle of the chloride profile technique is as follows. Chloride is introduced into the soil both in rainfall and as dry deposition. Since chloride does not evaporate from the soil surface, and vegetation does not take up significant quantities, it becomes concentrated by evapotranspiration. Water in the soil can be broadly categorised into either upward or downward moving water, with the zero flux plane (ZFP), separating the two.The upward water flux is driven by evaporation of water from the soil surface and transpiration through plants taking up water via their roots. Where there is sufficient infiltration for water to move below the root zone and the maximum depth of the ZFP, the water will continue to move down as deep drainage until it eventually reaches the water table.

Under conditions of recharge the ZFP represents the point below which a net, steady state, moisture and solute transfer takes place toward the water table. The amount of chloride crossing the ZFP varies in relation to antecedent rainfall over one or more seasons, thus causing oscillations in the chloride profile. Under steady state conditions the

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average chloride concentration of pore water in this profile, $\overline{C_s}$, will be proportional to the concentration factor, $\overline{P}/(\overline{P}-\overline{E})$, (where: $\overline{P}$ = long term average precipitation and $\overline{E}$ = long term average evapotranspiration). This assumes no loss or gain of chloride to or from minerals, and that the water and chloride are transported at the same rate. Where the surface run-off component is negligible, and assuming there are no reactions with minerals the recharge is given by:

$$\overline{R_d} = \frac{(\overline{F_p}+\overline{F_d})}{\overline{C_s}} = \frac{(\overline{PC_p}+\overline{F_d})}{\overline{C_s}} \quad (1)$$

Where:

$\overline{R_d}$ is the space and time averaged direct recharge flux.

$\overline{F_p}$ and $\overline{F_d}$ are the average rainfall and net dry deposition fluxes (= input)

$\overline{C_p}$ is the averaged concentration of chloride in the rainfall

$\overline{C_s}$ is the averaged interstitial water concentration

It follows that direct recharge can be calculated if the following values are known; the volume averaged concentration of chloride in the rainfall ($\overline{C_p}$); the averaged interstitial water concentration ($\overline{C_s}$); the long term average rainfall ($\overline{P}$) and, the net dry deposition chloride flux ($\overline{F_d}$). If $\overline{F_d}$ = 0, then the fraction of rainfall contributing to direct recharge is given by the ratio $\overline{C_p}/\overline{C_s}$.

The solute profile well is positioned at latitude 13° 15'44" N and longitude 2° 3' 31" E, at an elevation of 262 m. It lies at the edge of a large area of tiger bush close to the village of N'douroua on the western side of the Say plateau. Locally, the ground slopes gently toward the south west at a gradient of 1 in 120. The site is underlain

by the Continental Terminal formation, a 49.4 m thick sequence of terrestrial sediments, which are Miocene to Pliocene in age. These sediments rest on a pre- Cambrian basement of mainly granitic gneiss. Only the upper unit of the Continental Terminal, the "Gr 8As argileux du moyen-Niger" is present in this area. The water table lies within the basement at a depth of 74.1m, which is 24.7m below the base of the Continental Terminal.

During well construction samples were taken from the unsaturated zone at the following intervals: every 25 cm from 0 - 10 m; every 50 cm from 10 - 62.5 m, then every metre to the bottom of the well. Pore water was extracted from each sample either by centrifugation or elutriation and analyzed for chloride; moisture contents of samples were obtained gravimetrically. This data has been used to produce depth profiles of pore water chloride concentration and moisture content throughout the unsaturated zone. From these profiles it has been possible to derive an estimate of historic direct recharge at the site. The chloride concentration of rainfall, which is required to make the estimate, was determined from the analysis of 123 rainfall samples collected from 5 EPSAT rain gauges in 1992. A mean recharge rate of 13 mm/yr is estimated for the upper 70 m of the profile, with a total residence time of 790 years. This is considered to be a representative estimate of the magnitude of direct recharge taking place below tiger bush areas.