Water transfer in the system reservoir-ebb tide in the semi-arid region in Northeastern Brazil: evidences of preferential flow

A.C.D. Antonino[1], R. Angulo-Jaramillo[2], C. Hammeker[3], P. Audry[4], A.M. Netto[1], S.M.G.L. Montenegro[5]

[1]Departamento de Energia Nuclear, Universidade Federal de Pernambuco, Recife, Brazil.
[2]Laboratoire d'étude des Transferts en Hydrologie et Environnement, LTHE, UMR 5564 CNRS, INPG, IRD, UJF, Grenoble, France.
[3]Institut de Recherche pour le Développement, Dakar, Sénégal.
[4]Institut de Recherche pour le Développement, Recife, Brazil.
[5]Departamento de Engenharia Civil, Universidade Federal de Pernambuco, Recife, Brazil.

In the semi-arid Brazilian Northeast, river valleys, lowlands and the adjacent flat or slightly undulated areas, have the best potential for agricultural production, due to the best water availability. Water collected in the catchment areas; whether through intermittent rivers or underground flows, converge towards these areas, where traditionally small dams are built in order to retain water, creating small reservoirs. In Northeast Brazil, there are more than 70,000 small reservoirs.

After the rainy season, the small reservoirs become empty because of evaporation, possibly by infiltration and because of multiple domestic uses of water. While the water level in the reservoir decreases, saturated soil areas uncover on them borders, where ebb tide agriculture is performed. Ebb tide agriculture consists of cropping the margins of the reservoir, on slight slopes, while the water level progressively drops.

The problem of water resources is of major concern in the Northeast of Brazil, especially as it is related to agricultural water management in dry land, ebb tide and irrigated cultivation. However, in this area of Brazil, only few studies have been performed on these systems, and little is known on their water balance, and on the characterisation of unsaturated soil hydraulic parameters, and consequently few models describing this local specific condition are available. Many of the existing small reservoir- ebb tide cultivation systems are old and the seasonal behaviour of the system may induce several changes in the soil profile. In clay soils, for example, the wetting and drainage cycles may produce cracks, which form preferential water flow paths and alter the water flow conditions, contributing to more rapid infiltration. In this context, it is essential to be able to quantify preferential flow phenomena, which contribute to rapid water and solute infiltration into soils.

The quantification of this process is of major importance for conservation of water resources quality. This paper is focused on the analysis of preferential flow in a ebb tide cultivated area in the semi-arid region of Northeast Brazil, which has been monitored, in terms of water balance componentes and water dynamics, for a period of time. In the monitoring programme, the water dynamics in two different scales have been pursued: the system reservoir-ebb tide, and the plots individually.

The study has been performed in the ebb tide zone of the basin of Flocos dam, municipality of Tuparetama, PE (7°36'S and 37°18'O). Close to the dam, a meteorological station has been installed, equipped with automatic sensors for recording pluviometry, temperature, relative humidity, wind velocity and direction, as well as a class "A" tank and a "Ville de Paris" rain gauge. The plots have been instrumented with one neutron probe access tube and tensiometers at different soil depths. In the interface reservoir- ebb tide soil saturation extracts have been collected with depth using porous suction cups. Evolution of water level in the reservoir and of piezometric level in the ebb tide zone have been recorded. A transect of six piezometers

has been monitored for this purpose. The soils are classified as Fluvents. The soil bulk density increases with depth in the soil profile, and two distinct layers are identified along the profile: a superficial clay textured layer overlying a sandy layer. Unsaturated soil characteristics have been determined, from experimental field and laboratory data. Hydraulic conductivity near saturation has been determined with disk permeameter. The saturated hydraulic conductivity of the sandy layer is 100 times greater than of the superficial clay textured layer. During the monitoring programme, the presence of a network of cracks that remain open even under water was observed in the deepest part of the Flocos dam.

A simplified model has been proposed representing the system small reservoir-ebb tide by a set of different interacting water storage reservoirs. The first one is the small reservoir, which represents the main water storage, accumulated during the rainy season. The second reservoir is the ebb tide zone. This reservoir represents the total amount of water in the soil available for the crop. The link between the two reservoirs, the saturated zone, represents a buffer reservoir for water transfer. The water transfer in the system is described by a set of two balance equations and one flow equation defined in an analogous Darcy equation, with two unknowns: the water level in the small reservoir and a reference level of the water table underneath the ebb tide area, both time dependant. Solution of the set of equations depends on the effective saturated hydraulic conductivity of the medium and on atmospheric conditions, governing the evaporation and the water storage variation.

The recorded water and piezometic levels in the reservoir and in the ebb tide zone clearly shows that the saturated zone is supplied by the lake during the monitored period. The soil saturation extracts data reveals that the salinity decreases with depth in the interface reservoir-ebb tide, showing that no leaching from the surface occurs. The observation of the soil salinity behaviour in the interface during the dry period is an evidence of the preferential flow phenomena through the more permeable deep soil layer.

Simulations allowed the evaluation of the preferential flow contribution throughout the network of cracks in the deepest part of the dam. This contribution has been determined from the difference between the simulated flux considering an effective saturated hydraulic conductivity, calculated from field determined values in different layers, and the flux obtained by the identification of the effective saturated hydraulic conductivity reproducing the measurements of water level in the reservoir and piezometric levels in the ebb tide zone.

This study allowed a better understanding of the water transfer process in the system reservoir-ebb tide. The proposed simplified model was able to evaluate the preferential water flow contribution from the reservoir to the ebb tide throughout the network of cracks located in the deepest part of the dam.