Water salinity of alluvial aquifer in semi-arid context: origin, dynamics and anthropogenic impacts.

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Context

The Brazilian Northeast (750 000 km², 51 million inhabitants) is a semi-arid region (P ≤ 700 mm.yr^{-1}, ETP > 2000 mm.yr^{-1}) where the high annual rainfall deficit is accentuated by a short rainy season (3 months) and strong rainfall irregularity. Spatial and temporal heterogeneity of precipitations combined with shallow soils, crystalline basement and high evaporation, lead to intermittent river flow with a mean duration of less than 3 months **(Cadier, 1996)**.

In the semi-arid Brazilian Northeast, the development of alluvial aquifers exploitation during the last 10 years has increased water availability in dry season for irrigation and domestic supply to rural communities; however, water availability for all the categories of uses and users is an open question. In the Forquilha watershed (221 km²; 5°17' S, 39°30' W), the 23 km long and 250 m wide alluvial aquifer (2,3 hm3) is used for irrigation and domestic water supply (Fig. 1). Alluvial aquifer dynamics is seasonal, with recharge during rainy season and water table decreases during the dry season, accentuated by pumping **(Burte et al, 2005)**. During the dry season, groundwater salinity increases from 0,2 up to 1,5 g/L imposing pumping restrictions.

Methods

Water table and electric conductivity (EC) monitoring, environmental isotope and chemical analyses have been conducted from 09/2000 to 06/2007 in order to investigate the variations of observed EC in time and space and propose a model of aquifer functioning. A mass-balance conceptual model, based on hydrological model **(Burte et al, 2005)** has been set up and used, with a 20 years time series, in combination with geochemistry to investigate the origin of salinity of alluvial groundwater and to evaluate long-term contribution from basement fractured-rock to the alluvial aquifer. The hypotheses on the functioning have been tested with 3D physical-based finite-element hydrological and transport modeling (Feflow®) on a section (1,5 km length) of the alluvial aquifer where exploitation is intense.

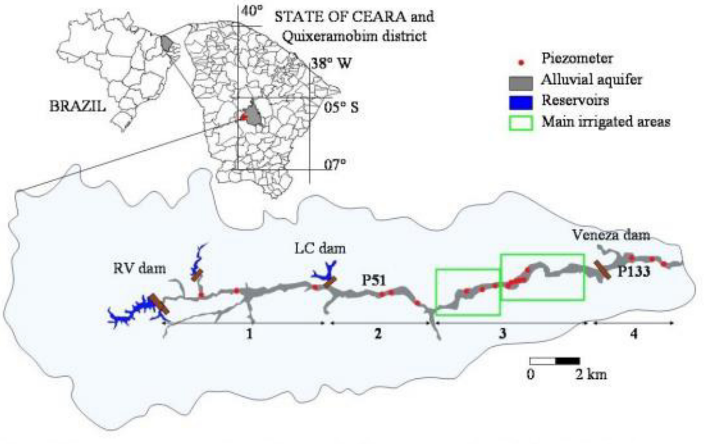

Fig. 1: Main water ressources in Forquilha watershed (reservoirs and aquifers), with the 4 main hydrological parts of alluvial aquifer; monitoring piezometers and main irrigated areas.

Results and discussion

• Temporal variograms **(Skoien et al., 2003)** of piezometric levels show generally (10 of 20 piezometers) a 12 month regular structure indicating strong influence of seasonal hydrological processes. Release events and a new dam built in 2002 can explain perturbations in some piezometers. Finally, for the piezometers located far away from recharge areas, the variograms don't show the same regularity. Only few temporal variograms of EC show a regular structure (Fig. 2).

• Geochemistry of the alluvial aquifer in flood and drought periods is different (Cl, Na, EC) (Table 1).

• EC within-year variations can be explained 1) by the main recharge mechanism of the aquifer being flood infiltration in the river-bed, 2) by the local groundwater renewal rate, related to hydraulic conductivity heterogeneity of the layers and 3) by the mass flux originating from the basement aquifer.

• Intense pumping of alluvial ground water for irrigated crops leads to higher recharge with low salinity water during flood events and, that way, to short-term decreases in EC. However, irrigation water evaporation in soils leads to salt accumulation in the unsaturated zone that can, subsequently, be leached towards the saturated zone when extreme flood event occur, like, for example, the one observed in 02/2004.

• Simulations for the 1970-1988 time series show that, for a salt contribution from the basement of 45.10³kg/month (calibrated value with the 2000-2006 observed period (Fig. 3)), salt mass in the alluvial aquifer is around 1100 T and EC around 750 µS/cm (Fig. 4). The different components in the mass balance have been calculated (Fig. 5). This value is lower than observed (920 µS/cm) and suggests that basement input could be higher. The simulations also show that pumping does not lead to long term increasing salinity. Nevertheless, there are restrictions on the use of alluvial groundwater for irrigation because of positive residual alkalinity (RSC) of water **(Marlet & Job, 2006)**.

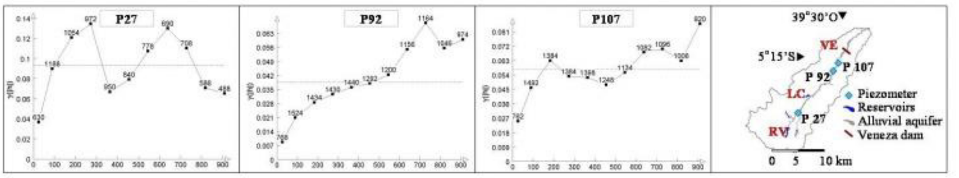

Fig. 2: Temporal variograms of alluvial groundwater salinity in piezometers P27, P86 and P106.

Table 1: Comparison of median values of composition of diferentes types of water (mmol.L^{-1}) e CE (mS.cm^{-1}) by Mann-Whitney teste, for P<0,05. Identical groups in a column are identified by the same letter.																
	n	Alc*		Cl		Ca		Mg		Na		RSC		CE	
Reservoirs	8	1,78	a	1,00	a	0,56	a	0,34	a	0,86	a	-0,00	a	0,29	a
River	13	4,36	bc	3,31	b	0,72	ab	1,58	b	4,32	b	-0,37	a	0,78	b
Alluvial aquifer (flood period)	49	4,69	b	2,96	b	0,82	ab	1,51	b	4,88	bc	0,28	a	0,86	b
Alluvial aquifer (drought period)	47	5,94	c	5,09	c	0,92	b	1,78	b	5,10	c	0,47	a	1,10	a
Basement aquifer	376	5,69	c	21,2	d	3,34	c	4,05	a	13,0	a	-9,34	b	-	

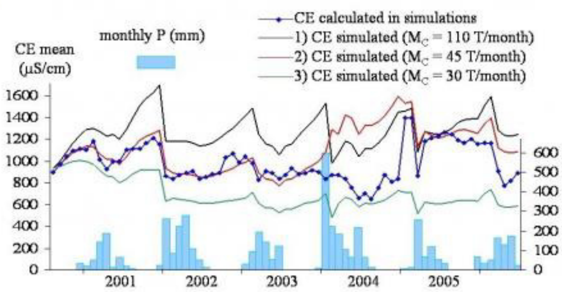

Fig.3: Alluvial aquifer water CE calculated for a basement contribution of 30, 45 and 110 tons/month.

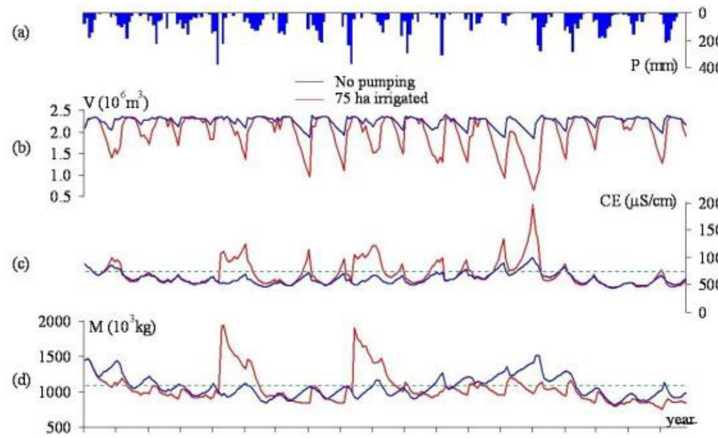

Fig. 4: Monthly rainfall in 1970-1988 period (a) and results from simulation of alluvial aquifer water volume (b), CE (c), salt mass (d) in the case of zero pumping (blue lines) or 75 ha irrigated (red lines).

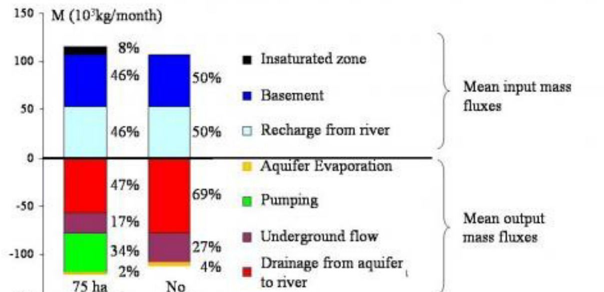

Fig. 5: Monthly rainfall in 1970-1988 period (a) and results from simulation of alluvial aquifer water volume (b), EC (c), salt mass (d) em case of no pumping (blue lines) or 75 ha irrigated (red lines).

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