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Factors controlling the evolution of groundwater dynamics and chemistry in the Senegal River Delta

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ABSTRACT

Study region: Senegal River Delta.
Study focus: The Senegal River Delta is a strategic region for the development of irrigated agriculture. Despite a Sahelian climatic context, the management of the river with dams ensures water availability throughout the year. With the intensification of agriculture, degradation of cultivated soils is observed, mostly linked to the existence of a shallow salty aquifer. In this context, regional surveys were performed to characterize groundwater–surface water interactions and to identify the impact of artificial river management and agricultural intensification on the evolution of groundwater dynamics and chemistry.
New hydrological insights for the region: Results show that groundwater far away from rivers and outside irrigated plots has evolved from marine water to brines under the influence of evapotranspiration. Near rivers, salinity of groundwater is lower than seawater and groundwater mineralization seems to evolve in the direction of softening through cationic exchanges related to permanent contact with fresh water. Despite large volumes of water used for rice cultivation, groundwater does not show any real softening trend in the cultivated parcels. Results show that the mechanisms that contribute to repel salt water from the sediments correspond to a lateral flush near permanent surface water streams and not to vertical drainage and dilution with rainfall or irrigation water. It is however difficult to estimate the time required to come back to more favorable conditions of groundwater salinity.

1. Introduction

The Senegal River Delta (SRD) has a great potential of agricultural land, estimated at 150,000 ha and a large availability of water through the Senegal River. It is for this purpose an agro-economic zone of major importance for the development of irrigated agriculture and food self-sufficiency in Senegal. However, the practice of irrigated agriculture in the SRD is now seriously threatened by salinization leading to the abandonment of many developed areas (Barbiéro and Laperrousaz, 1999).

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Most studies on this salinization question have pointed the presence of a shallow (maximum 2 m depth) salty aquifer resulting from alternating episodes of marine transgressions and regressions that have driven the evolution of the SRD during the Quaternary (Audibert, 1970; Trénous and Michel, 1971; Michel, 1973; Loyer, 1989; Ceuppens et al., 1997; Barbiéro et al., 2004). In addition, in a recent past, sea waters continued to frequently invade the floodplains of the river during low surface water levels (Cogels, 1994; Gac et al., 1986). To face these invasions, the countries bordering the river, associated within the OMVS interstate organization (Senegal River Basin Development Authority), built the anti-salt Diama dam in 1986 (26 km upstream of St. Louis). A second dam was erected in 1988 at Manantali in the Malian territory to store the surplus rainwater on the upper basin. It took more or less 10 years to reach equilibrium of river water levels at 1.5 m above sea level upgradient from the Diama dam (Gning, 2015). From that time, the combined management of both dams has helped maintaining sufficient water for irrigation of agricultural areas throughout the year and the emergence and diversification of agricultural production systems. Many programs have been developed in the SRD with the primary objective of achieving food self-sufficiency, resulting in an intensification of agricultural activities, an increase in planted areas and in volumes of water used for irrigation.

However, this improvement in water availability and increased irrigation have certainly had hydrological and hydrochemical consequences, particularly on the shallow aquifer. In this context, the objective of the research is to establish a conceptual model describing the origin and evolution of groundwater chemistry in the SRD, and the impact, at regional scale, of the artificial river management and agricultural intensification on this evolution, as a support for future solutions of water management for sustainable agriculture in this region.

2. Description of the study area

The SRD is located northwest of Senegal, 260 km from the capital Dakar. On the Senegalese side, it covers an area of 3500 km^2, extending over a length of 250 km from Richard Toll to St Louis (Fig. 1). This area is dominated by vast flatlands limited to the north by the Senegal River, to the west by the Atlantic Ocean, to the east by the Guiers Lake, to south-west by dunes and southeast by the Ferlo Valley (not shown in Fig. 1).

In this North Sahelian zone, annual rainfall does not go beyond 400 mm/year and potential evapotranspiration reaches 2500 mm/year (Diaw, 1996; Malou, 2004; Diaw, 2008). The hydrographic network is very dense and includes the main branch of the river Senegal which has many distributaries. The river also feeds, through the Taoué channel, the Guiers Lake which is a depression of 300 km^2 (Fall, 2006). The various distributaries of the river and the lake allow irrigation of many agricultural areas (light green patterns in Fig. 1) by a complex system of watercourses and open channels. Rice, which is the main crop in the delta, is irrigated by submersion, maintaining a significant layer of water on the soil surface for several

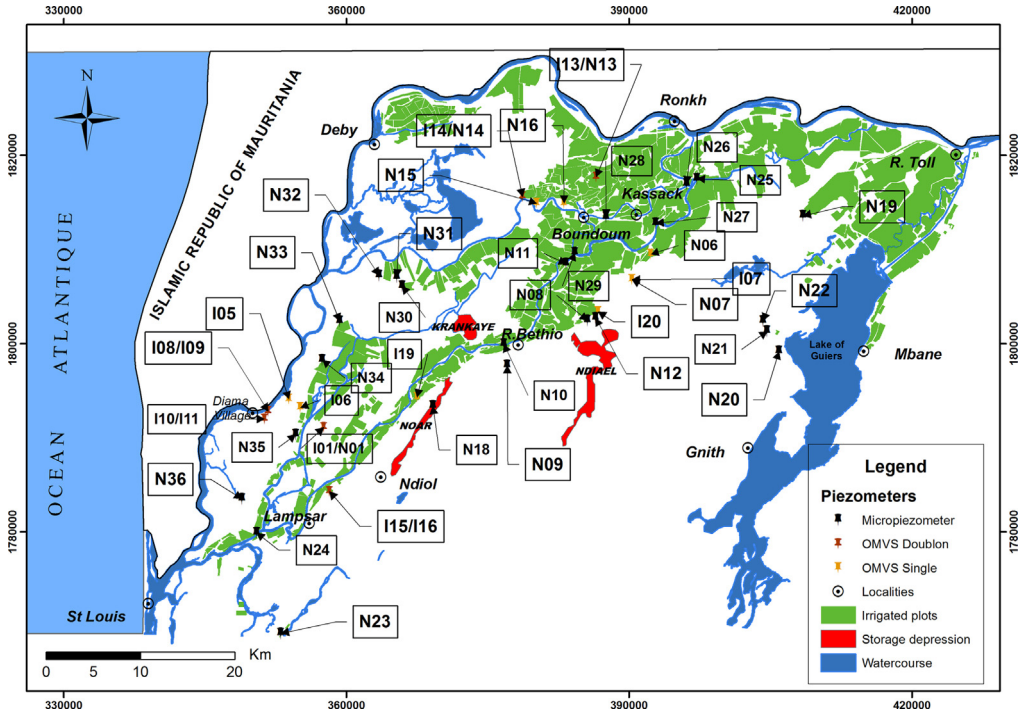

Fig. 1. Location map and main features of the Senegal River Delta. (For interpretation of the references to color in the text, the reader is referred to the web version of this article.)