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The Nile delta's water and salt balances and implications for management

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ABSTRACT

The Nile Delta and its 2.27 million ha of irrigated land makes up two thirds of Egypt's agricultural land. It is also the terminal part of a river basin that spans and feeds 11 countries. Increases in dam and irrigation development in upstream parts of the basin is poised to conflict with agricultural expansion and population growth in Egypt. Understanding where and how waters comes into and leaves the delta is therefore a crucial question for the future of the country. This paper revisits the surface and groundwater balances of the delta, emphasizes the additional relevance of drainage water reuse and of the salt balance, and evidences a relative stability of the outflow to the sea over the past 30 years. Various reasons for such a phenomenon and the scope for saving water are explored and discussed. The confusion between plot-level and delta-level efficiency and the relatively limited gains possible are emphasized. Beyond the overall water balance and quantitative issues, water management in the delta remains a complex task of spatially distributing the resource over a complex ramified network. Finally, limitations in the analysis related to data availability and accuracy are emphasized.

1. Introduction

The Nile Delta is the terminal part of a 3.17 million km^2 wide river basin that spans 11 countries before joining the Mediterranean Sea in Egypt. Nile waters are diverted to irrigate 5.36 million hectares (Mha) of land basin-wide, of which 3.4 Mha are to be found in Egypt (FAO 2011) and around 2.27 Mha in the Nile Delta proper (MALR 2011). In Egypt 55% of the population are dependent on the agricultural sector for their livelihood, a sector that accounts for about 15% of a Gross Domestic Product (GDP) of US$232 billion, and close to one-third of total employment (FAO, 2000).

A dense network of waterways dissects the Nile Delta, including 40,000 km of canals that branch off the Nile River and convey water to over 2 million farmers across several nested geographical scales and institutional levels (van Achthoven et al., 2004). Intermingled with these conveyance canals are 18,000 km of drains, where water is partially both reused by farmers and pumped back to higher-level delivery canals, and eventually conveyed to coastal lakes and the sea. As agriculture is the main user of water in Egypt, accounting for 85% of national demand, the question of irrigation-water-use efficiency over a range of scales (i.e. from on-farm to basin) is key to satisfying growing non-agricultural needs and possibly to expanding agriculture to provide livelihood opportunities for Egypt's rural population.

Indeed increasing the efficiency, productivity and equity of water use and management at all levels while conserving the resource base are the most salient objectives of both the National Water Resources Plan 2017 (MWRI, 2005) and the Government of Egypt's Strategy for Sustainable Agricultural Development 2030 (ARDC, 2009). Any discussion of the potential for increasing efficiency and how to achieve this is eventually linked to the question of the overall water availability. In other words, this starts with understanding how much water enters the Nile Delta, how it is then distributed, how much is drained to the sea, and whether and how this amount can be reduced to free up water for other consumptive uses. Such knowledge is critically in demand at a time when Egypt's water supply is threatened by dam and irrigation development in the upper part of the Nile basin while its own needs increase.

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This paper offers a general discussion of the Delta water balance, within the constraints associated with the limited availability and accuracy of data. We review sequentially the various terms of the water balance, then discuss the importance of associated salt balances, while the relative stability of the outflow to the sea observed over the past 30 years leads us to discuss how this is compatible with known changes in supply and demand. The conclusion emphasizes possible reasons for a stable outflow, the limitations associated with the large uncertainty in most terms of the water balance, and the limited means and scope for improving overall efficiency of water use in the Delta.

2. Inflow to the delta

2.1. Rainfall

Rainfall varies from 250 mm on the north-western coast to 50 mm in Cairo. Its contribution to the Delta water balance is taken by IRG (1998) to be 0.8 billion cubic meters (Bm^3). We rely here on an average rounded-up value of 1 Bm^3.

2.2. Nile river

The quantity of water that reaches the Delta depends on how much has been released from the High Aswan Dam (HAD) and how much has been consumed for human and agricultural purposes along the Nile Valley. This second term varies with cropping patterns but is relatively stable since all return flows end up back in the river (with the exception of those in the Fayoum, which end up in a sink – the Qaraoun Lake). Releases from HAD depend on the run-off received by the dam, but its high capacity has in general allowed managers to even out variations, and average releases are estimated to be around 57 Bm^3/y (El-Atfy et al., 2009; Gohar and Ward 2010; El Kassar 1991; CAPMAS 2007). This is slightly more than the official quota of 55.5 Bm^3, partly because Sudan is not taking its full share and partly due to favorable hydrological conditions in the late 2000s. Data on the total inflow to the delta for the period 2008–2012 indicate values between 38.3 and 47.4 Bm^3, representing a substantial variation of over 9 Bm^3 between 2008 and 2010 (DRI, 2013). We rely here on an average inflow of 42 Bm^3.

3. Groundwater use and balance

3.1. Aquifer recharge

The quaternary aquifer of the delta is semi-confined, as its top is covered by a thin clay layer whose thickness varies from 5 m in the south to 20 m in the middle and 50 m in the north of the Delta, while disappearing in some places (Mabrouk et al., 2013). Depths to groundwater range between 1 and 2 m in the north, 3–4 m in the middle and 5 m in the south (ibid.).

Deep percolation from excess irrigation water and seepage from the river branches (notably the Rosetta Branch), canals and drains in the southern and middle parts of the Nile Delta recharge the aquifer, while there is some upward seepage in the northern part of the Delta (Kashef 1983; Sefelnasr and Sherif 2013). The Nubaria Canal (west) and Ismailia Canal (east) that run along the fringes of the Delta have substantial infiltrations, enhanced by lighter soils and widening operations that disrupt the clay deposited in these canals (African Water Facility 2007).

Downward leakage towards the aquifer due to water used for irrigation and canal infiltration has been estimated at between 0.25 and 0.80 mm/day in the central and southern parts of the Delta (DRI, 1989; Nofal et al., 2015). These values are associated with a total recharge rate (by infiltration) of 6.78 Bm^3/y (FAO 2013; Mabrouk et al., 2013; Mohamed and Hua, 2010), a value already used in the 1980s (e.g. Kashef 1983). However, this key term of the water balance is extremely difficult to measure or estimate and is not known with much accuracy.

Groundwater modeling studies generally neglect the contribution of rainfall (with an average between 25 and 200 mm/year) to recharge since it is very small compared to the recharge rate (Mabrouk et al., 2013). Additionally, there is no data available for the inflow from the valley part of the Nile aquifer. It is therefore not considered here. Groundwater in the Delta is not a separate or additional resource and is directly fed by surface water brought by the Nile River.

3.2. Aquifer discharge

Groundwater discharge from the Nile Delta aquifer takes place in different indirect and direct ways: through seepage to waterways (drains and, in some parts, canals), seepage to water bodies and evapotranspiration, inter-aquifer flow, outflow to the sea and direct groundwater abstraction through wells.

3.2.1. Outflow to lateral aquifers

Outflow of the Nile Delta aquifer occurs towards the Moghra aquifer along the fringe of the western Nile Delta, with a transfer estimated by RIGW/IWACO (1990) between 50 and 100 Mm^3/year. Because of the depletion of the Moghra aquifer it is likely that this value has dramatically increased. We have tentatively considered here a value of 100 Mm^3.

3.2.2. Outflow to waterways and evapotranspiration

In the northern fringe of the Delta, the aquifer is semi-confined and subject to upward seepage. Groundwater is discharged to the relatively incised drainage system but also to canals: during the 'off' turn of water distribution some seepage of very saline water can be observed and this has to be flushed away at the beginning of the next 'on' period before farmers can use the water. Some water also makes its way to the soil and the crop roots, contributing to plot evapotranspiration. In official water balances this contribution ('intrusion') to both waterways and ET is sometimes taken at 1 or 2 Bm^3 (Oosterban 1999; MWRI 2002) or disregarded altogether.

We may use the overall salt balance of the Delta to estimate the order of magnitude of this contribution. In rounded-up values the amount of salt released by the Aswan dam is roughly 11 million t (55 Bm3 × 0.2 g/l), while the amount released to the sea is around 36 million t (12 Bm^3 × 3 g/l). This means that approximately 25 million tons of salt are brought up from saline aquifers in the semi-confined part of the Delta and residual soil salinity in the western delta.

DRI's yearbook data show that the main salt-flushing point corresponds to the drains coming from western new lands and that around one third of the total [around 8 million tons] can be attributed to the new lands. We can estimate the corresponding volume of upward seepage with a rough calculation. The salinity in drains near the lakes and seashore is around 3–10 g/l and includes a mix of drainage water (at around 1 g/l) and upward seepage, taken tentatively here at 15 g/l on average.[1] In order to account for 17 million t of salt (25-8), this upward seepage (with an average salinity of 15 g/l) has to amount to 1.1 Bm^3–a significant value. We rely here on a rounded value of 1 Bm^3.

[1] Maps provided by Morsy (2009) or FAO (2013) show a large spatial variability of this value. Maps are often drawn based on the interpolation of very few points, when it comes to the northern part of the delta. This value is indicative of an average for the irrigated area undergoing upward groundwater seepage.