WATER MANAGEMENT FOR SUSTAINABLE AGRICULTURAL DEVELOPMENT OF NORTH SINAI, EGYPT

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ABSTRACT

Optimum management of the currently available limited water resources in Egypt is important for making water savings for land expansion necessary for increased food security. One of the ways for more efficient use of this water is to recycle the agricultural drainage water through either direct use or after blending it with freshwater. The study reported here is based on an assessment of the water resources and cropping patterns in the North Sinai Development Project (NSDP) area. It reassessed the availability of drainage water from the Nile Delta and freshwater resources required to meet the demand of the quantity and the quality of the of irrigation water for the entire project area. The study re-examines the crop rotations originally planned by the project planners, and, considering the recent cropping interests of local farmers and expected changes in availability and quality of the drainage water, it suggests new cropping patterns and, accordingly, the readjusted water demand for the whole NSDP area. The crop intensity in the recommended cropping pattern will be 178% as compared to 167% in the original plan. The study also examines the current policy of allocation of the newly reclaimed land to various stakeholders (big investors, small investors, and small farmers) and it concludes that as the small-holder farmers tend to manage best the newly reclaimed lands allocated to them, their share in the allocation should increase. Irrigation with Nile water and drainage water mixtures in a 2:1 proportion, instead of 1:1 as originally planned, would be desirable to support sustainable agriculture in the area.

INTRODUCTION AND BACKGROUND

In an attempt to improve the productivity and sustainability of water use and increase water supply to bring 0.26 million ha additional land under cultivation, Egypt initiated the North Sinai Development Project (NSDP) in 1997. The irrigation canal of NSDP has been designed with the objective to discharge 4.45 billion m^3 of water, which is a 1:1 blend of agricultural drainage water with freshwater from River Nile.

The objective of the Project was to improve income distribution, to generate employment through the settlement of small holders, and to create new communities within the project

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area. To increase the amount of available irrigation water for the increased land, the Project focused on the reuse of agricultural drainage water by mixing it with fresh water from the river Nile. The salinity of drainage water is a function of the salinity of the applied water, soil salinity, and the salinity of the shallow groundwater (Ayers and Westcot, 1985, Pescod, 1992). Appropriate water management can reduce the volume of drainage water and make water available for other beneficial uses. Land management needs special consideration where competition for water is intense and where disposal of drainage water threatens ecologically sensitive areas.

In the next few years the amount of drainage water from the Nile Delta is predicted to be reduced due to the adoption of better water management practices. In this scenario, the use of drainage and fresh water in a 1:1 proportion will not be a pragmatic approach due to an increase in the salinity level of the drainage water.

In the early years of the NSDP, a small portion of the area had been reclaimed and handed over to the farmers settling there with a prescribed crop rotation plan. But after some time, when more migrant farmers got established there, they, based on economic considerations and traditional habits, started adopting new crops and rotations that were not prescribed by the Project in the original plan. Therefore, there is an urgent need to re-evaluate the planned cropping patterns considering the interest and values of local farmers and the changing situation regarding the volume and quality of drainage water for the scheme. The information would be of value to the NSDP planners because the Project was originally designed to meet the water requirements of the target area based on the planned cropping patterns. Therefore, it is necessary to reassess the available water resources and their use and develop appropriate recommendations to meet the objectives of NSDP. The study reported here was designed with two main objectives: a) to reassess the drainage water from Nile Delta and available fresh water resources and the proportion of their mixing to meet the quality irrigation water demand of the NSDP target area, and b) to re-assess the crop rotation plan considering the interest of local farmers.

WATER RESOURCES OF THE DELTA AND SINAI

Of the 55.5 billion m^3 water reaching Egypt via Nile River, most is used for irrigation purposes along the Nile Valley and the Delta generating approximately 14.0 billion m^3 of drainage water flowing out to the Mediterranean Sea. Rapidly increasing food demand in the face of limited water resources available is threatening development in Egypt. Therefore, full exploitation of the limited water resources is very important, especially through the improvement of irrigation system. Recognizing this fact early, the Egyptian Ministry of Water Resources and Irrigation (MWRI) initiated mitigation measures and a number of development projects were started to increase irrigation efficiency and agricultural productivity, as well as to improve drainage and groundwater management. For example, the objective of designing and implementing subsurface drains on 2.7 million hectares and open drains on 3.1 million hectares, has led organizational development for the past 30 years. By 2005, more than 75% of the horizontal pipe drains in the “planned” areas, and more than 95 % of the open drain areas, had been completed

(Carlos Garcés-Restrepo, 2005). The so-called "official" reuse of drainage water has increased from 2.6 billion m^3 in 1988/89 to 5.0 billion m^3 in 1998/99. In addition to the "official" reuse of drainage water, there is a significant amount (between 2.8 and 4.0 billion m^3) of "unofficial" drainage water being used by individual farmers throughout the region. There is no control on the amount of this unofficial reuse by farmers (Carlos Garcés-Restrepo, 2005). The NSDP canal is planned to discharge 4.45 billion m^3 water, of which 2.340 billion m^3 will be agricultural drainage water from the El-Serw (about 0.435 billion m^3), Bahr Hadous (about 1.905 billion m^3) and Farskour drains (to supply the rest of the amount of drainage water needed). The required amount of fresh water to meet the 1:1 ratio (fresh water: drainage water) is supplied from the Nile river. The information on total water resources of Egypt and the amount of discharge water from each drain is given in Table 1. The mean precipitation in Sinai is 200 mm, which is considered to be very high in Egypt. Most of the rain water goes to the sea and some causes occasional disasters. Thus, precipitation in Sinai is not considered to be a water source.

Table 1. Water resources supply in Egypt and Sinai Development Project

Egypt Water Resources	Supply (BCM)	Sector	Demand (BCM)	Sinai Water Resources	Supply (BCM)
Nile River	55.50	Agriculture	61.00	Damietta branch	2.11
Renewable GW*	5.50				
Non-Renewable GW	0.50	Municipalities	4.60	El Serw drain	0.435
Drainage Water Reuse:					
-Nile Delta	4.90	Industry	7.50	Bahr Hadous drain	1.905
-Nile Valley	4.95				
-Unofficial	2.80	Navigation	---	Faraskour drain	Drainage water deficit
Wastewater Reuse	1.00				
Effective Rainfall	1.00	Hydropower	---		
Desalinization	0.03				
Losses	3.00	Fisheries	---		
Total	73.18		73.10		4.45

*GW is ground water

Abou Rayana et al. (2001) reported that the groundwater with salinity level ranging from very high (TDS=20,000 mg l^{-1}) to low (TDS=300~700 mg l^{-1}). The groundwater with low salinity level is used for domestic and agriculture purposes. In the northern coastal areas, about 1,260 wells have been used to draw about 108,500m^3 d^{-1}water, of which 58,000m^3 d^{-1} is used to irrigate 4,134 ha of agricultural land and about 50,000 m^3 d^{-1} is for municipal use (Table 2).

Table 2. Discharge and total area irrigated from groundwater on the north coast of Sinai

Area	Number of wells	Daily discharge ($m^3 d^{-1}$)	Total irrigated areas (ha)
El-Arish	195	51,500	2,142
Sheikh Zuwayid	147		244
Rafah	256	43,000	1,395
Bir El-Abd	662	14,000	353
Total	1,260	108,500	4,134

CROPPING PATTERNS FOR NSDP

For NSDP, three cropping pattern scenarios were examined: the planned cropping pattern as set out in the original project design, the actual cropping pattern being followed currently by farmers in the area, and a cropping pattern recommended for wise use of water taking into consideration the economic and cultural needs of the farmers and current availability of water resources. The project plan suggested different crop rotations for the three different soil types, namely clay, sandy and coastal soils, common in the area. On the farm level, farmers are required to divide their land in to three sections each having one of the phases of a specific three year crop rotation planned based on the soil type and irrigation system. For example, crop rotation with rice on clay soil helps to leach down the salts and consequently, controls soil salinity hazards. Similarly, the project planners suggest surface irrigation system for clay soil. Under sandy and coastal soils; sprinkler irrigation has been suggested for agricultural crops while drip irrigation was suggested for fruits.

Before the start of NSDP, this kind of crop rotation plan was prepared for the newly rehabilitated farmers (Fig. 1). Part of the project area (Tina plain and South of East Qantara) in North Sinai has been now developed and the farmers there have been advised to adopt the above mentioned crop rotation plan. Most of the crops which were being cultivated by the local farmers before the start of project were not included in the planned crop rotations.

Before the start of the irrigation canal construction for development of North Sinai in 1997, wheat, barley, tomatoes, and cantaloupe were the main winter crops and the main summer crops were tomatoes, cucumber, cantaloupe, and watermelon. But all these crops were not included in the planned crop rotation for that area. With the passage of time, farmers started including these crops in the rotation, not sticking to the plan. Therefore, re-assessment of the planned cropping pattern considering the interest of the local famers was needed. This was also important for the project planners because NSDP was designed to meet the water requirements of the target area based on the planned crop rotations rather than those actually being practiced by the farmers. A socio-economic study was recently conducted by Drainage Research Institute (DRI) and Water Management Research Institute (WMRI) of Egypt to assist the development of future agricultural plans for farmers in El-Tina Plain (DRI and WMRI, 2006). The result indicated that 67% of the selected farmers preferred agricultural crops such as cotton, rice, wheat and alfalfa, 21 % of the selected farmers preferred fruits, 8 % of the selected farmers preferred vegetables and only 4 % wanted to plant trees.

Based on the above survey done in 2006, the cropping pattern of local farmers before 1997, and the current interest of newly rehabilitated farmers in the area, a new recommended crop rotation pattern has been postulated and presented in juxtaposition with the originally planned crop rotations (Fig. 1). It can be noticed that the planned rotations have different combinations of crops than the crops cultivated by the farmers before 1997 as well as their current preference as indicated by the survey. For example, wheat and barley, which accounted for 92% of the total area under winter crops in Sinai area during 1997, have not been included under any soils type in the planned cropping pattern. Under recommended crop rotation plan, we suggest not only inclusion of wheat and barley, but also Egyptian cotton because of its high economic returns. To maintain soil fertility, crops such as clover (alfalfa) have also been included. Moreover, the land use has been increased to 178 % under the recommended cropping pattern as compared to 167 % under the rotations planned by the Project.

In the planned crop rotation, under clay soils, short clovers, onion, vegetables and sugar beet for winter and soybean, rice and sorghum for summer season were included. However, in the recommended cropping pattern, we have included wheat and barley for winter and cotton for summer season (Fig. 1). The introduced crops will meet the demand of local consumption, maintain the soil fertility, meet onsite farmer needs and take into consideration the current food security crisis in the country. Based on the recommended cropping pattern, Tina plain is recommended to have 66.7, 16.7 and 16.6 % of the irrigated area under cereals, fodder and vegetables, respectively.

On the sandy soils, planner suggested fruits, long-duration clovers, vegetables and potato. But we have included wheat, barley and short-duration clover for winter and potato and maize for summer season in the recommended crop rotation (Fig. 1). Based on these modifications, the pattern on sandy soil is recommended to have 43.3 % area under cereal crops, 20 % under fodder crops, 26.7 % under vegetable irrigated by sprinkler system, and 10 % under fruit trees to be irrigated by drip system.

Crop rotation planned for loamy soils included fruits, short clover, vegetable and sorghum. In the recommended crop rotation we have included wheat, barley and maize in addition to the planned crops (Fig. 1). Consequently, the cropping pattern on loamy soils is recommended to have 43.3% area under cereals crops, 26.7% under fodder crops and 20% under vegetables to be irrigated by sprinklers and 10% under fruit trees to be irrigated by drip system.

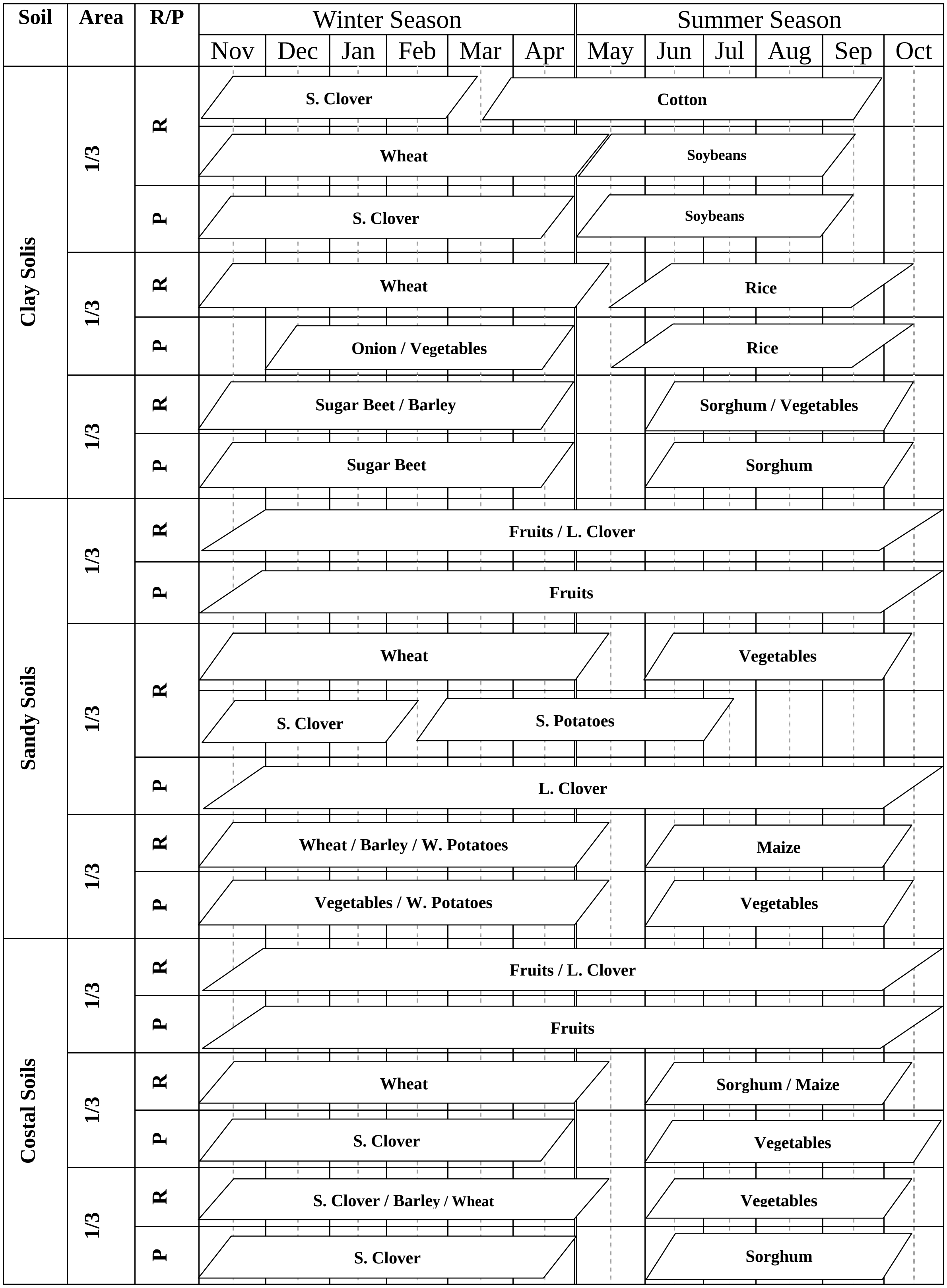

Figure 1. Planned (P) and recommended (R) crop rotation patterns for the North Sinai Development Project

Currently, Ministry of Agriculture and Land Reclamation is monitoring the cropping patterns. The government officially controls the area under rice and cotton cultivation. Rice growers need to obtain a cultivation permit from the Ministry of Water Resources and Irrigation (MWRI). These observations by the government will help to evaluate the recommended crop rotation in the area after a few years of application. It is worth mentioning that the cropping pattern will have to be reviewed every few years considering the interest (reaction/response) of the local famers and the change in the availability of water resources.

NSDP LAND ALLOCATION

As soon as the area is reclaimed, it is distributed among the big investors, small investors, and small farmers. Fifty percent of the land is allocated to big investors, 35% to small farmers and graduates and 15% to small investors. Table 3 presents the land allocation, reclamation and revegetation of land in the NSDP area until March 2007. Data show that the area used for cultivation by different stakeholders of Tina plain varied markedly from what was planned: small farmers (56.1%) > big investors (31.3%) > small investors (12.3%). In case of South Qantara, the distribution was: small farmers (54.5%) > big investors (26.2%) > small investors (19.3%). In general, 29.8 and 75.8 % of Tina plain and South of East Qantara areas were cultivated, respectively. It is clear from the data that the small farmers paid the most attention on the newly reclaimed soils and did maximum cultivation. Therefore, we recommend the reallocation of reclaimed lands to increase the percentage of land for the small farm holders.

Table 3. Allocation of privatized, delivered, cultivated, and prepared area (ha) in Sahel El Tina plain and south-east of Qantara to big and small investors and small holders under the NSDP up to March, 2007

Region	Category	Privatized areas	Delivered areas	Cultivated areas	Processed areas for Agric.	Prepared areas for planting	Categories allocated (%)
El Tina Plain	BI	7,560	7,560	1,327	1,665	4,575	50
	SI	2,110	2,110	525	532	1,053	15
	SH	4,536	4,536	2,381	1,187	968	35
	RF	42	42	13	-	2,9.4	-
Sahel El Tina		14,247	14,247	4,246	3,376	6,625	-
S of E. Qantara	BI	4,775	4,631	2,915	21	1,695	50
	SI	5,229	3,718	2,142	25.2	1,551	15
	SH	9,116	6,311	6,048	37.8	225	35
S of E Qantara		19,120	14,660	11,105	84	3,471	-
Total		33,367	28,907	15,351	3,460	10,096	-

BI = Big investors, SI = small Investors, SH = small Holders and RF = Research Farm

IRRIGATION WATER SALINITY

As the fresh water resources are limited, therefore, the area under NSDP was supposed to be irrigated with a mixture of drainage and fresh water in a ratio of 1:1. The required amount of drainage water is pumped into the fresh water (El-Salaam canal) from the Nile River. The suitability of reuse of drainage water for irrigation is determined by the amount and kind of salts, generally using with FAO guidelines (FAO, 1985).

The planning of NSDP was started in 1986 and was partially completed in 1997. Their decision to use the proportion 1:1 of fresh water to drain water was based on the data available up to 1997, but during the last few years changes have been observed in the amount of drainage water generated in the Nile Delta. The reduction, especially during 1993 and 1994, might be attributed to the adoption of better irrigation water management practices in the area. However, with the reduction in drainage water there has been a commensurate increase in the concentration of total dissolved solids (TDS). Figure 2 shows the average TDS values of El-Serw, Faraskour, and Bahr Hadous drains in the period from 1988 to 1998 ranged from 992 to 2,896 mg l^{-1} with an average of 1,341 mg l^{-1}. The highest values in the period from 1989 to 1994 were recorded in the month of February because of the lower volume of drain water discharged during this month. To determine the relationship between amount of discharge in ($m^3 s^{-1}$)(Q) and TDS concentration (ppm) in drainage water, a simple polynomial relationship was identified from the monthly drains discharge and TDS data of El-Serw, Farskour, and Bahr Hadous drains from 1988 to 1998 as shown below:

$$TDS = 0.725\ Q^2 - 85.13Q + 3688 \qquad (1)$$

As the degree of fit was very good ($r^2 = 0.7114$), this relationship can be used to predict the future water quality of the drainage water available for the Project.

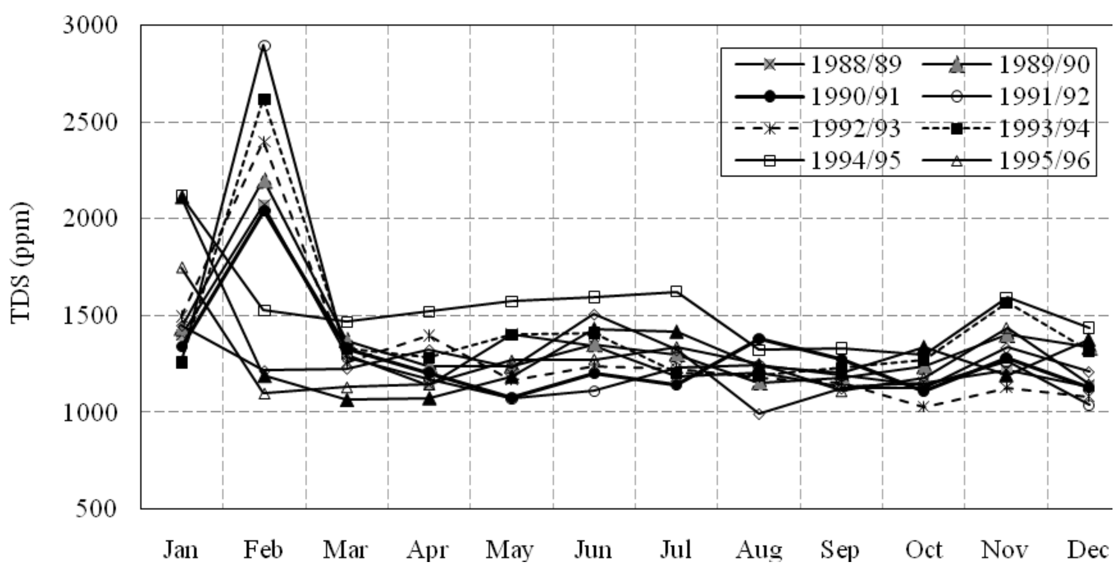

Figure 2. Monthly total dissolved solids (TDS) in NSDP drains during 1988-98.

Water samples were also taken by Hafez et al., (2008) along the main El-salaam and El-Sheikh Gaber canals (carrying blended water), to analyze the soluble cations, anions, EC, sodium adsorption ratio (SAR) and pH by using standard laboratory methods (Table 4). The SAR of water was computed to obtain an indicator of potential soil sodification using the following equation:

$$SAR = [Na^+]/\sqrt{([Ca^{2+}]+[Mg^{2+}])/2} \quad (2)$$

Table 4. Chemical properties of the irrigation and drainage water and soil of NSDP (Hafez et al., 2008)

Location	pH	EC (µmhos)	SAR	TDS (mg l^{-1})	Cation (meq l^{-1}) Na^+	K^+	Ca^{2+}	Mg^{2+}	Anion (meq l^{-1}) HCO_3^-	Cl^-	SO_4^{2-}
1	7.9	680	32.7	967	195	9	62	34	277	266	138
2	7.8	1400	32.7	967	195	9	62	34	277	266	138
3	7.9	1400	34.6	678	206	9	62	36	231	271	123
4	7.7	3200	69.0	2092	512	14	96	78	291	687	412
5	7.8	4000	74.0	2556	613	16	121	98	352	973	371
6	7.8	3800	75.6	2506	609	16	114	94	322	943	449
7	7.2	1500	75.3	2513	612	16	116	92	328	943	512

where, Na^+, Ca^{2+} and Mg^{2+} are expressed in meq l^{-1}.

Seven sites were selected for water sampling from intake of fresh water into El-Salaam canal namely; 1) at intake of El-Salaam canal (Nile river), 2) at 17.0 km from intake point (before blending at El-Serw drain), 3) at 18.0 km from intake point (after blending at El-Serw drain), 4) at 47.2 km from intake point (after blending at Hadous drain), 5) at 87.0 km from intake point (before Suez Canal Siphon), 6) at 0.50 km from intake point of El-Sheikh Gaber canal (after Suez Canal Siphon), and 7) at 25.0 km from intake point of El-Sheikh Gaber canal. The SAR was minimum (32.7) at fresh water intake point of El-Salaam canal (Nile river) and the SAR values increased to 75.3 at the last sampling point (25.0 km from intake point of El-Sheikh Gaber canal), which were higher than the accepted SAR value (14) for irrigation water (FAO, 1985). Similarly, the EC also increased from the intake point (680 µmhos) to the last sampling point (1500 µmhos).

The data clearly show that the TDS values are fluctuating near the upper limits in locations 4, 5, 6 and 7. Abu-Zeid (1988) and Kotb et al. (2000) defined the criteria for mixing drainage and fresh water on the basis of drain water TDS. They suggested different blending ratios for different TDS values of drain water. At a TDS of <700 mg l^{-1} the drainage water can be used directly, at 700-1500 mg l^{-1} TDS it should be blended with fresh water at 1:1 ratio, at 1500-3000 mg l^{-1} TDS blending should be at 1:2 or 1:3 ratio, and at >3000 mg l^{-1} TDS, the drainage water was not recommended for use. Based on this classification it is clear that the TDS values are nearing the upper limit, even exceeding the limit in some cases (1994). Therefore, it can be inferred that the use of blending ratio of 1:1 would not be a pragmatic approach for sustainable agricultural development under NSDP. In the scenario of water shortage in drains and increasing TDS level in blended water, there will a need to increase the fresh water input in El-

Salaam and El-Sheikh Gaber canals. It is suggested that the currently used blending ratio of 1:1 be replaced by a ratio of 1:2 ratio. Additional Nile water needed for this purpose could become available from the water saved through irrigation improvement projects (IIP and IIIMP) in the Nile Delta in Egypt and/or implementation of upstream water conservation projects for the entire Nile River basin that will also increase the availability of Nile water for all the other Nile River basin countries.

CONCLUSIONS

Attention must be given to measures that minimize short- and long-term effects of elevated salinity of irrigation water on soil productivity. Based on the salinity results, it is recommended to use it by mixing Nile water and drainage water at a 2:1 ratio. In case of serious fresh water shortage, irrigation with Nile water and drainage water at 1:1 ratio could be applied temporarily. The consumption of wheat in Egypt has increased by 4% from 2006 to 2008 and demand has been met by increasing imports by 7%. To augment domestic wheat production, there is a need to include wheat in the crop rotation now to be recommended to the farmers in the NSDP area. It is expected that such an introduction of wheat in the project area will result in a production of 391,000 tons of wheat each year. Also, the cropping pattern will have to be reviewed and readjusted every few years based on the socioeconomic, food security and water resource availability in the Project area. For the rapid and lasting development in NSDP area, it is recommended to revise the allocation policy for the reclaimed lands and increase the percentage allocation for the small farm holders over the level originally planned in the project.

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