MODIFIED DRAINAGE SYSTEM FOR RICE GROWING AREAS : A TOOL FOR WATER SAVING

Eng. Hussein El Atfy[1]

SUMMARY

In Egypt, rice is cultivated annually in about 420,000 ha in the Nile Delta. It is included in summer cropping pattern, which also includes cotton and maize as main summer crops in a two or three year's crop rotation. Meanwhile the agricultural area is about 3 million ha located mainly in the Nile Delta and the Valley, with cropping intensity of 200%.

In order to achieve maximum possible crop production, the Egyptian Government is implementing different development programs. One of these programs deals with land drainage to control water logging and soil salinity in all the old agricultural regions of Egypt. At present, about 2,000,000 ha are already provided with tile drainage in the Nile Delta. Another 700,000 ha will be provided with tile drainage in next 10 years.

The tile drainage system implemented in Egypt is a composite of the gridiron type consisting of laterals and main collector drain. The area served by one collector drain varies between 20 to 100 ha depending on the topography, field size and layout of main irrigation and drainage systems. There is usually more than one crop served by one collector drain at the same time. Meanwhile, the crops change their locations from one year to the other according to the crop rotation. The drainage criteria are based on the most important crop grown in the area i.e. cotton. The design rate for collector drainpipe capacity is 3 mm/day for rice growing areas. This rate was increased to 4 mm/day to enable adequate drainage condition for the dry-foot crops.

In spite of this increase in the design rate, water management problems occur in areas where rice is cultivated along with "dry-foot crops'. Some of the rice growing areas is already provided with conventional drainage systems. As rice is the only crop with standing water on the subsurface drainage systems, consequently, high irrigation losses occurred in the drained rice fields. To save water losses, farmers are inclined to block the Collector drainpipes at the nearest manhole with

---

[1] **Under Secretary of State for Minister's Office Affairs, Ministry of Water Resources and Irrigation, Egypt**

whatever is available, i.e. mud and straw, within the rice fields to reduce the losses. This unauthorized interference often causes serious damaging effects on the drainage system and the other crops in the upstream of the blocked section. The blocking objects (man-made plugs) often slip into the pipes causing serious maintenance problems. Meanwhile, blocking the pipes causes excessive pressure in the drain pipes. It may cause in this way water logging and salinization problems in the upstream fields.

In order to avoid unnecessary excessive drainage from the rice fields, to ensure safe performance of the drainage system, and to translate these farmers' practices into technically sound and environmentally safe subsurface drainage system, it was necessary to modify the layout and the design of the conventional drainage system. So, the concept of the modified layout has been introduced in the rice growing areas.

The main features of this concept are to restrict the outflow from the areas cultivated with rice, which result in saving irrigation water and to enable normal drainage conditions for the remaining areas (cultivated with "dry-foot" crops). It is based on the crop consolidation system, where crops are grown in units with fixed boundaries, which has been practiced in Egypt since 1960.

The modified layout consists of a main collector drain with several sub-collector branches. The design criteria within a sub-collector area (e.g. depth and spacing of the lateral drains) remained unchanged as they are still based on the growing conditions of the most important "dry-foot" crop (cotton). Each sub-collector coincides with one crop consolidation unit and is equipped, at the junction with the main collector, with a closing device to regulate the sub-collector outflow. If rice is cultivated in the drainage area of a sub-collector, the outflow of drainage water is restricted by closing this device. If any other crop is grown, the sub-collector is left open, enabling normal drainage conditions. As a consequence, the design rate for collector drainpipe could be reduced to 2-3 mm/day, the design rate for non-rice areas.

The new concept was tested on a pilot scale at several locations represented a major rice areas in the Nile Delta from the point of view of saving irrigation water, avoiding unnecessary excessive drainage, soil salinity and water logging, evaluating cost and improving soil environment.

A monitoring program to study the water management practices, validity and reliability of this system was carried out, in experimental fields for six successive years 1984-1990. Then a large scale monitoring program in farmers fields was *implemented for additional 3 years (1995-1998) to verify the previous findings and test the applicability of the (controlled) modified drainage system.*

This paper presents the results of the above programs and the different water management practices and highlighted the constraints and measures to be considered in order to implement the modified drainage system on a large scale.

The results could be summarized as follows :

The introduction of the modified layout of the subsurface drainage system in rice-growing areas in the Nile Delta resulted in :

- *Savings in irrigation water up to 30%. This irrigation water would otherwise be lost through the subsurface drainage system: the difference in drainage rates from rice fields between the conventional and modified drainage system amounts of 1 to 3 mm/day over a growing season of approximately 100 days;*
- *Protection of the drainage system from justifiable, although unauthorized and improper, interference by farmers to stop irrigation water losses from rice fields through the subsurface drainage system, and thus reduce the maintenance requirements.*
- *Protection of crops other than rice from the damaging effects of improperly blocked conventional collector drains;*
- *These benefits were obtained without any negative effects on either soil salinity or crop yields and with no increase in costs compared with the conventional system.*

In order to implement the modified system on large scale, the following measures should be considered:

- *Raising awareness of public and professionals is essential to explain about the controlled or modified drainage system.*
- *Enhancing the vital role of farmers participation through WUA's or CUA's in the operation and maintenance of Irrigation and Drainage Systems.*
- *Improving extension and introducing a system of incentives and/or penalties is required to motivate farmers to follow rice consolidation units.*
- *Strengthening the coordination and collaboration between all involved authorities (EPADP, DRI, MALR, IIP, IAS ... etc.), is of great importance.*

INTRODUCTION

In Egypt, rice is cultivated annually in about 420,000 ha in the Nile Delta. It is included in summer cropping pattern, which also includes cotton and maize as main summer crops in a two or three years crop rotation. Meanwhile the agricultural area is about 3 million ha located mainly in the Nile Delta and the Valley, with cropping intensity of 200% (Fig. 1).

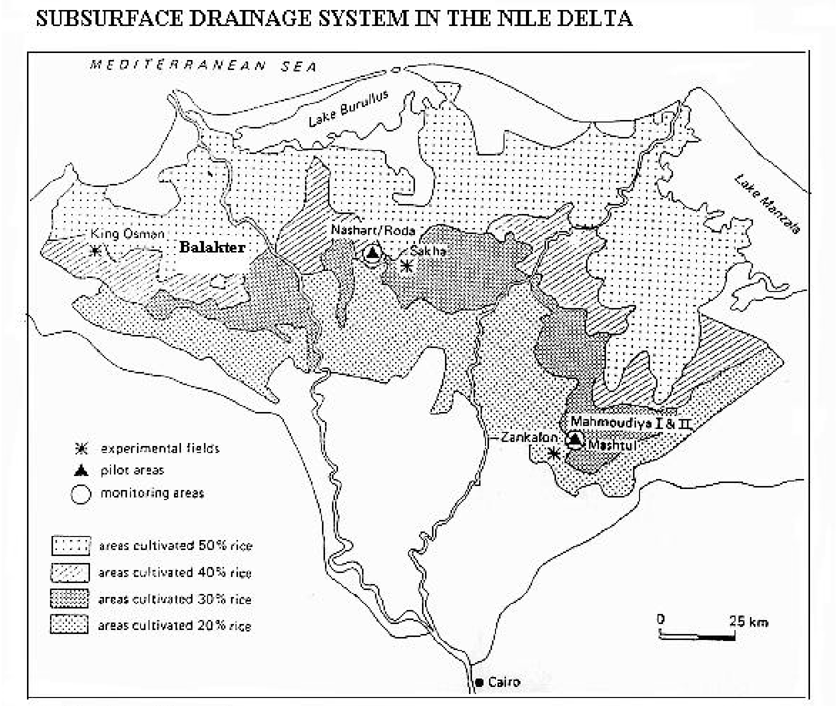


Figure 1. Location of the study areas

In order to achieve maximum possible crop production, the Egyptian Government is implementing different development programs. One of these programs deals with land drainage to control water logging and soil salinity in all the old agricultural regions of Egypt. At present, about 2000 000 ha are already provided with tile drainage in the Nile Delta. Another 700 000 ha will be provided with tile drainage in next 10 years.

The tile drainage system implemented in Egypt is a composite of the gridiron type consisting of laterals and main collector drains. The area served by one collector drain varies between 20 to 100 ha depending on the topography, field size and layout of main irrigation and drainage systems. (Fig. 2). There is usually more than one crop served by one collector drain at the same time. Meanwhile, the crops change their locations from one year to the other according to the crop rotation. The drainage criteria are based on the most important crop grown in the area (cotton). The design rate for collector drainpipe is 3 mm/day for rice growing areas. This rate was increased to 4 mm/day to enable adequate drainage condition for the dry-foot crops (Amer et al. 1990).

In spite of this increase in the drainage rate, water management problems occur in areas where rice is cultivated along with “dry-foot crops”, (Abdel Dayem and Ritzema, 1987). Some of the rice growing areas already have the conventional

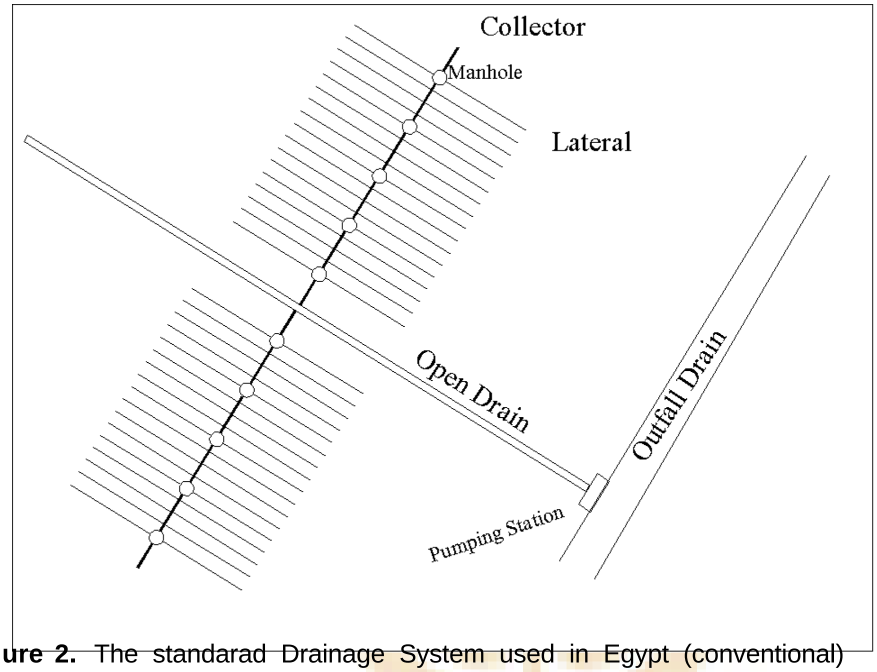


Figure 2. The standarad Drainage System used in Egypt (conventional)

drainage systems. As rice is the only crop with water standing on the subsurface drainage systems, consequently, high irrigation losses occurred in the drained rice fields. To save irrigation losses farmers are inclined to block the collector drainpipes at the nearest manhole with whatever is available, i.e. mud and straw, within the rice fields to reduce the losses. This unauthorized interference often causes serious damaging effects on the drainage system and the other crops in the upstream of the blocked section. The blocking objects (man-made plugs) often slip into the pipes causing serious maintenance problems. Meanwhile, blocking the pipes causes excessive pressure in the drain pipes. It may cause water logging and salinization problems in the upstream fields.

In order to avoid unnecessary excessive drainage from the rice fields, to ensure safe performance of the drainage system, and to translate these farmers' practices into technically sound and environmentally safe subsurface drainage system, it was necessary to modify the layout and the design of the conventional drainage system. So, the concept of the modified layout has been introduced in the rice growing areas.

The main features of this concept are to restrict the outflow from the areas cultivated with rice, which result in saving irrigation water and to enable normal drainage conditions for the remaining areas (cultivated with "dry-foot" crops). It is based on the crop consolidation system, where crops are grown in fixed boundaries, which has been practiced in Egypt since 1960.

The modified layout consists of a main collector drain with several sub-collector branches. The design criteria within a sub-collector area (e.g. depth and spacing of the lateral drains) remained unchanged as they are still based on the growing conditions of the most important "dry-foot" crop (cotton). Each sub-collector coincides with one crop consolidation unit and is equipped, at the junction with the main collector, with a closing device to regulate the sub-collector outflow. If rice is cultivated in the drainage area of a sub-collector, the outflow of drainage water is restricted by closing this device. If any other crop is grown, the sub-collector is left open, enabling normal drainage conditions. As a consequence, the design rate for collector drainpipe could be reduced to 2-3 mm/day, the design rate for non-rice areas. (Fig. 3).

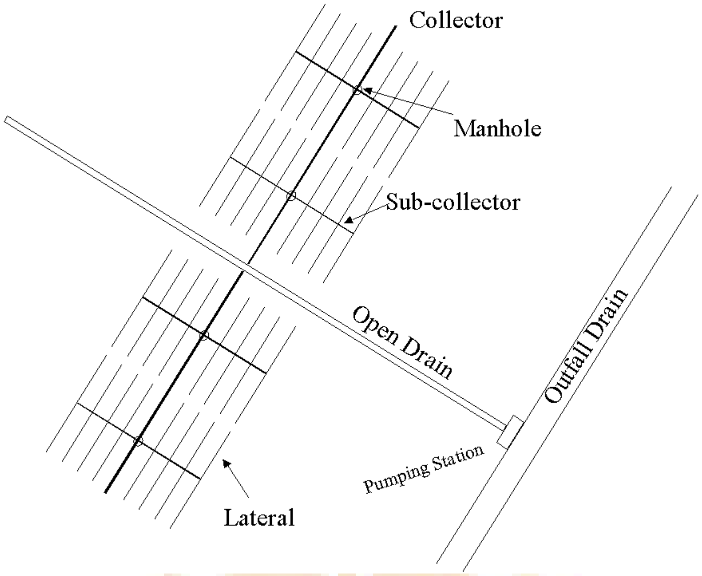


Figure 3. Modified layout of Drainage Systems in Areas With Rice in the crop rotation

The new concept was tested on a pilot scale at several locations represented a major rice areas in the Nile Delta from the point of View of saving irrigation water, avoiding unnecessary excessive drainage, soil salinity and water logging, evaluating cost improving soil environment.

A monitoring program to study the water management practices, validity and reliability of this system was carried out, in experimental fields for six successive years 1984-1990. Then, a large scale monitoring areas in farmers fields 1995-1997, was implemented to verify the previous findings and test the applicability of the (controlled) modified drainage system (Fig. 1).

The aim of this paper is to present the results of the monitoring programs and different water management practices and highlighted the constraints and measures to be considered in order to implementing the modified system on large scale.

MONITORING PROGRAM

The principles of the modified layout were tested on a pilot scale at several locations each representing a major rice-growing area in the Nile Delta. The objectives of the monitoring program were to obtain a better insight into (El Atfy et al., 1990):

- The reliability of the crop consolidation maps;
- The effects of the water management practices on crop production and soil salinity;
- The effects of the water management practices on the performance of the subsurface drainage system;
- The operation and performance of the closing devices in the modified drainage system.

The investigations were conducted at three levels, namely: (1) fully controlled experiments at three experimental field stations; (2) in-depth studies in farmers fields; and (3) large-scale monitoring programs in the pilot schemes. At each location, the soil and hydrological characteristics as well as the farmers' practices were assumed to be identical for the adjacent modified and conventional areas, the only difference being the restricted outflow of the sub-collectors of the units in the modified system cultivated with rice. The controlled experiments were conducted in Zankalon (East Delta), Sakha (Addle Delta) and King Osman (West Delta). The studies in the farmers' fields were conducted in three pilot areas: Mashtul (110 ha), which is part of the first pilot scheme, Mahmoudiya, an area of around 1600 ha in the Eastern in Nile Delta, in Nashart/Roda, which is located in the Middle Delta, and in Balakter (50 ha), which is a part of the Balakter scheme (4000 ha).

The monitoring program includes part of Balakter area, which was provided with improved irrigation system. The irrigation canals (meskas) were lined, and continuous flow with single left point was implemented, and Farmers Water User Association (WUA's), and Collector User Associations (CUA's) were formed (Fig. 1).

RESULTS AND DISCUSSIONS

Cropping Pattern and Intensities

The crop consolidation is the backbone of the modified system. The actual cropping patterns in two project schemes were compared with the crop consolidation maps on which the design of the subsurface drainage system is based. In Mashtul pilot area, which is part of the first pilot scheme (Mahmoudiya), the actual cropping pattern was surveyed during the study period. The area cropped in accordance with the crop consolidation map was found to range between 96 and 100% (DRI, 1985). For the total Mahmoudiya area, the actual cropping pattern in the summer of 1985 was compared with the crop consolidation map.

Discrepancies occurred in 9% of the total area, although only 3% caused operational problems, namely when rice was cultivated with either maize or cotton in the same sub-collector. The remaining 6% was a mixture of cotton and maize, both in need of unrestricted drainage outflow. Discrepancies were mainly observed in small areas surrounding villages. It should be emphasized that a change of crop within a complete crop unit does not violate the operation of the modified drainage system.

On the basis of these findings, the sub-collectors in the second pilot scheme (Nashart) were designed in cooperation with the Agricultural Department in Kafir El Sheikh (DRI, 1986b). Slight modifications of the crop consolidation units reduced the number of sub-collectors needed. The results of the monitoring program of 1988 (DRI, 1989b) showed that also in a negligible percentage (3%) of the area was cultivated with rice along with either cotton or maize.

It can be concluded that the crop consolidation maps are a sound and reliable basis for the design of the modified layout. The required information is easily obtainable at the agricultural departments at district level.

The liberalization of cropping pattern and no imposing of crop rotation which is recently introduced - represent the main constraint for implementing the modified drainage system. However, in Balakter area, where farmers groups were formed, it was observed that the farmers are showed their deep interest in performing controlled drainage modified system principles, and the idea of rice consolidation areas.

Raising awareness, enhancing extension about controlled drainage, and create motivation or incentives, and/or penalties towards implementation the modified system are of great importance.

Irrigation Water Applications

Water management practices in rice fields differ greatly between the modified and the conventional systems. Rice fields under modified drainage conditions require less irrigation water to maintain the same height of ponding water because of the restricted outflow of the subsurface drainage water. During the summer seasons, fully controlled water management experiments were conducted in modified and conventional units in three experimental fields, in addition to farmers fields, where traditional and improved irrigation system are established. All units were cultivated with rice under optimum water management conditions. If the average height of the standing water dropped below 5 cm, irrigation water was supplied to a level of 9 cm. The irrigation water supply, as well as the daily drop in standing water, was measured in both systems. The differences in water use are due to the different hydrological conditions (DRI, 1986a, 1986b, 1997). Nevertheless, in all three areas, the fields with a modified layout required around 40% less irrigation water than the conventional units (Fig.4).

Farmers could not manage to maintain optimum water conditions because of irrigation water shortages; this occasionally resulted in no standing water at all, especially in fields with a conventional layout. As the daily drop was averaged over the whole cropping season, it seems that the drop is much lower in the farmers’ fields compared to the experimental fields. If the data had been corrected for the number of dry days, the differences would have been less. In the farmers’ fields, however, the daily drop in the modified units was again less than the daily drop in the conventional units, the difference being between 22 and 35%.

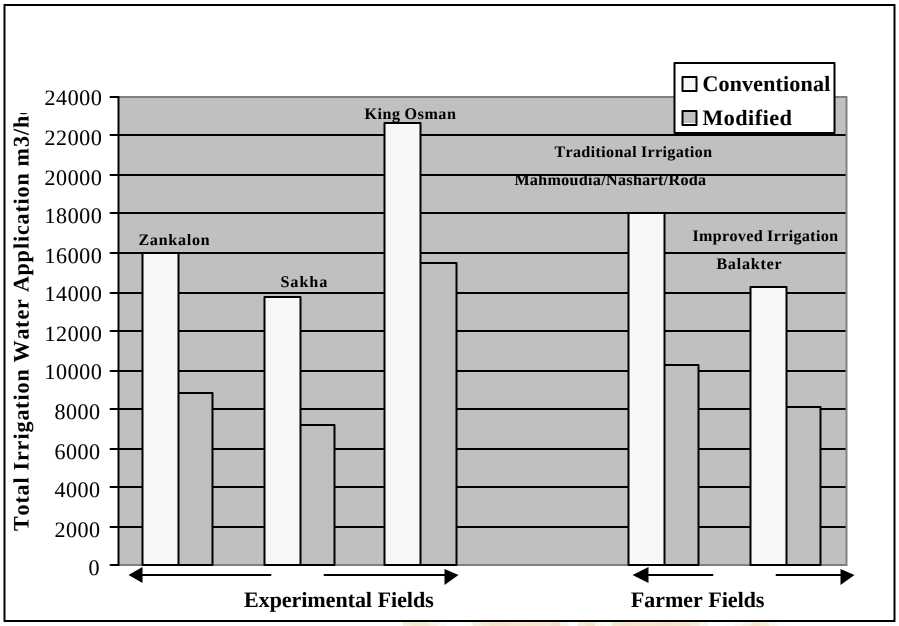


Figure 4. Total Irrigation Water Application to rice fields

Fig. 4 shows the water applied during rice season for the modified and the conventional systems in experimental fields, traditional irrigation fields, and improved irrigation fields. The average amount of irrigation water used for rice modified system area is 8000 m3 /ha, 10000 m3 /ha, and 8 000 m3/ha, respectively. This compared with average irrigation water used for rice conventional area 14 900 m^3/ha, 18 000 m^3/ha, and 14 000 m^3/ha in experimental, traditional and improved irrigation areas, respectively.

It can be concluded that the average saving in irrigation water supply to the rice plots in the modified system is around 30-40%. As a consequence, farmers in the modified system need irrigation water application less frequently, which also implies savings in operational activities.

Collector Discharges and Salinities

Discharges were measured at the outlet of the collector drains with a bucket and stopwatch and simultaneously the salinity of the drainage water with a portable conductivity meter. Each year the measurements started in June and continued until October, covering the total summer season. Each collector was measured at least once a week (DRI, 1989b).

The data from the different areas are in good agreement with each other: differences in water management practices clearly result in lower discharge rates in tile modified systems. The analysis of the individual collector drains (DRI, 1985, 1987b, 1989a), showed that in the modified systems the 90% cumulative discharge rate was independent of the rice intensity in the drainage area. This is in contrast to the conventional units, where the average 90% cumulative discharge rate increased from approximately

2.0 mm/day for collector with more than 60% rice. The discharges from collectors with less than 20% rice were in the same order of magnitude as the discharges from the modified collectors, although in the latter, the rice intensity was much higher. It is clear that the introduction of the modified system reduced the discharge through the collector drains. As a consequence, the design rate for collector drain (3 mm/day) can be reduced even further, as the discharge rate at 90% cumulative frequency did not exceed 2.3 mm/day.

Performance of Closing Devices

The function of a closing device is to restrict the outflow of a sub-collector serving an area cultivated with rice. Four types of closing devices were tested namely the steel flap gate, the steel sliding gate, the aluminium disc plug, and the wooden plug (DRI, 1985). The steel flap gate emerged as the most promising device and was tested on a large scale. A total of 31 flap gates were installed in the Mahmoudiya pilot area during the spring of 1985 and their performance was monitored during the following summer season (DRI 1986b). The performance was evaluated by the difference in water level between the upstream and downstream manholes and by regular visual inspection. The performance of 73% of the gates was rated as good, bad performance being mainly due to difficult installation conditions (submerged outlets of the collector pipes).

In the spring of 1988, the same prototypes were installed in the other project area (Nashart). The best performance observed was again by the steel flap gates and, to a lesser degree, by the wooden plugs (DRI, 1989b). Although some leakage occurred, the outflow from sub-collector areas cultivated with rice was considerably reduced. Neither the sliding gates (too much leakage) nor the aluminium disc plugs (pushed out by the water pressure) performed satisfactorily. From an operational point of view, the steel flap gates are preferred above the wooden plug, because they are permanently installed, whereas the wooden plugs have to be removed after each rice season. To guarantee a satisfactory performance, it is important to install the gates during construction of the sub-collector drains, or at least under dry conditions. Operation of the gates does not require special skills and can be done by either the farmers or the maintenance team.

Soil Salinity

Soil samples were collected two times during each summer season. The first sampling was done just before the start of the rice season, and the second sampling during harvest. The soil samples were collected from three layers, i.e., the surface layer (0-25 cm), the subsoil surface (25-50 cm), and at drain depth (125-150 cm). The salinity of the saturation extract was measured at the soil laboratory of DRI. To compare the data, the average salinity level over the top 0.50 m of the soil was calculated (DRI, 1989b).

In spite of the reduced irrigation applications and the corresponding lower drainage rates, sufficient leaching took place in the modified units to keep the soil salinity levels well below the critical value for rice. This critical value is defined as the average level of the soil salinity above which reduction in yield will occur. For the prevailing soil and hydrological conditions in the Nile Delta and the rice varieties used in Egypt, the critical value is around 3.5 dS/m (Abdel-Dayem and Ritzema, 1990). Regardless of the type of subsurface drainage system (modified or conventional), the level of the standing water in the rice fields results in a downward flux of the water in the soil, which is sufficient to maintain favorable soil salinity levels. Furthermore, in the modified system, the closing devices are opened at the end of the rice season to drain off the excess water. In the recently constructed projects, the decrease in soil salinity levels was the same for the conventional and modified units, although the total amounts of salts removed by the subsurface drainage system were much higher in the conventional units. (Fig. 5-a, 5-b). This can be attributed to the higher irrigation water requirements in the conventional units and the fact that the salinity of this irrigation water is relatively high due to the occasional reuse of drainage water in periods with water shortages.

Crop Yield

The yield of any crop is a function of a combination of factors (e.g, agricultural inputs and practices, soil and hydrological conditions etc.), which makes it difficult to quantify the influence of each parameter separately. Nevertheless, it is assumed that in each selected area, these factors are the same for the modified and conventional units, the only difference being the type of subsurface drainage (modified or conventional). So it is possible to compare the yield figures obtained in the fields with a modified system and those from the fields with a conventional system. Samples of the rice and maize crops were taken from the same locations used for the soil samples. Data on the yield of cotton were obtained from the Agricultural Cooperatives.

The yield of the individual fields was characterized by high variability, which is not surprising because of the many factors that influence crop production. For both the conventional and the modified units of each area, the average yield were calculated (DRI, 1989b, 1997). Although there is some variation between the seasons and between the areas, no significant differences could be established between the modified and the conventional units (Fig. 6).

COST COMPARISON BETWEEN MODIFIED AND CONVENTIONAL SYSTEM

For the two large pilot projects (Mahmoudiya 1 and Nashart), both, conventional and modified design were made. On the basis of unit prices, the differences in construction costs between the two systems were calculated (DRI, 1985, 1986b). The total length of pipes in the modified system is greater because of the introduction of sub-collectors which, together with the installation of closing devices, leads to extra costs. On the other hand, the lower design rate implies a reduction in the size of the collector pipes as compared to the current design norms and thus leads to cost savings. Savings in maintenance costs and the benefits of a more reliable system have not been considered in the analysis.

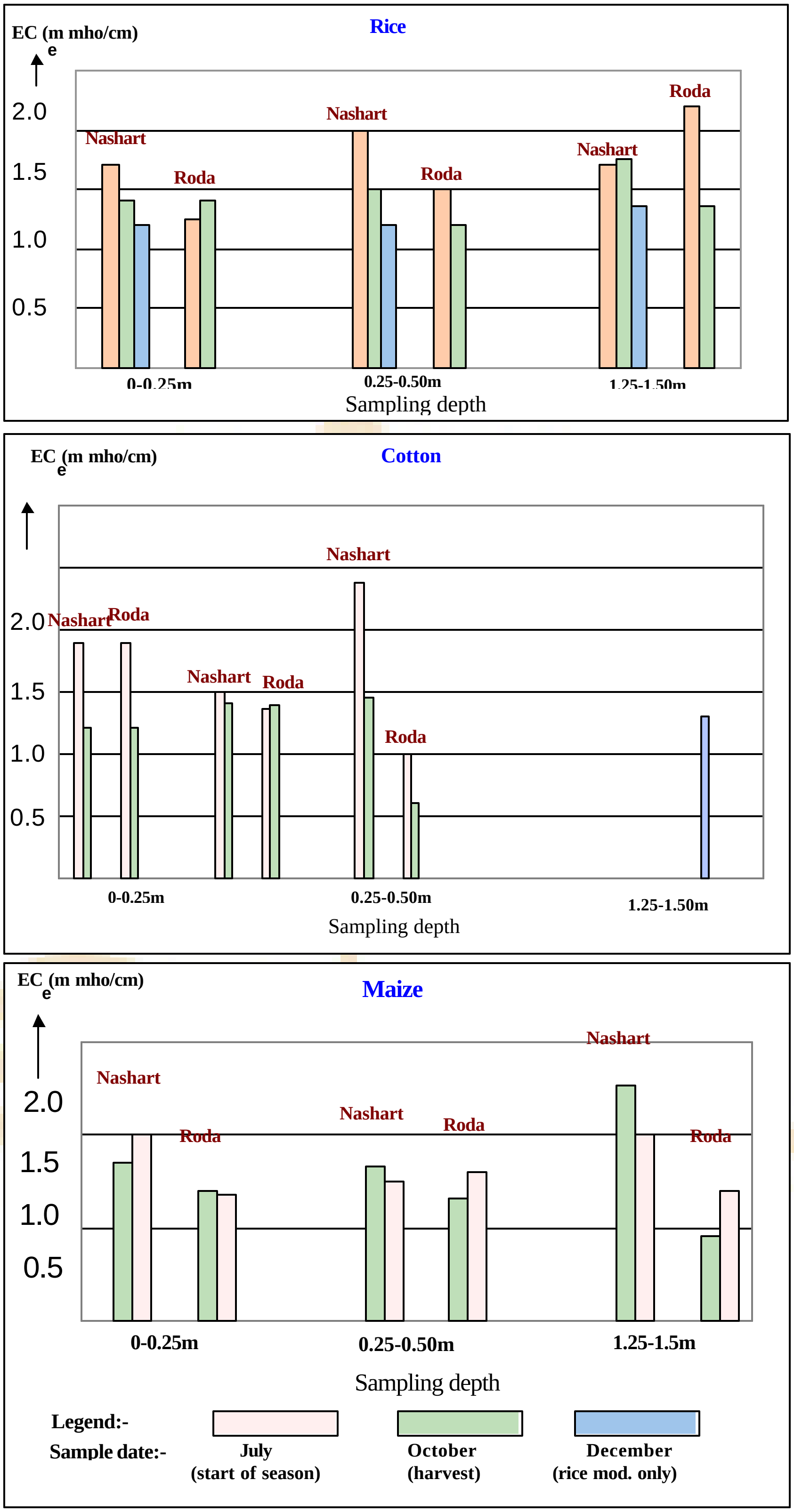


Figure (5-b). Soil salinity levels in farmers fields (Roda and Nashart)

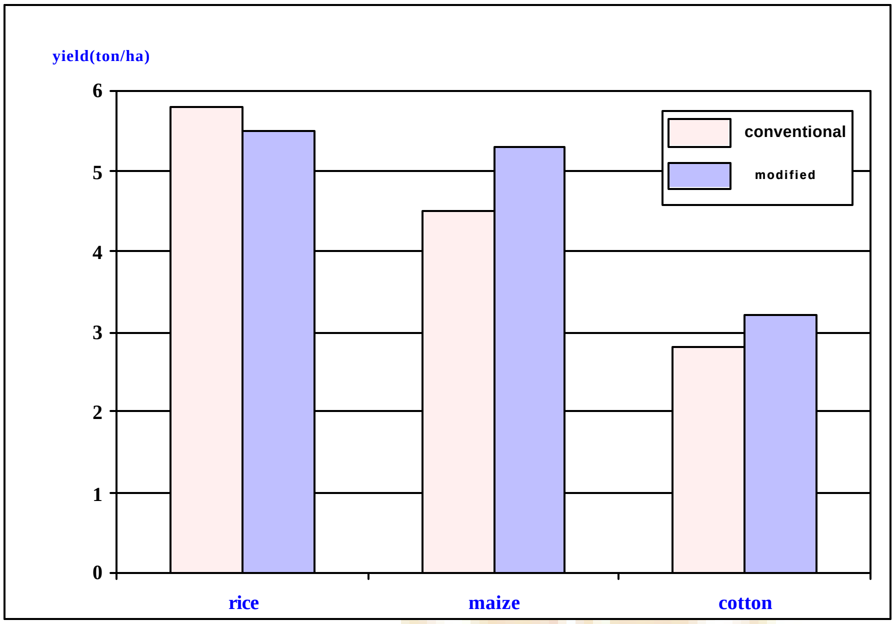
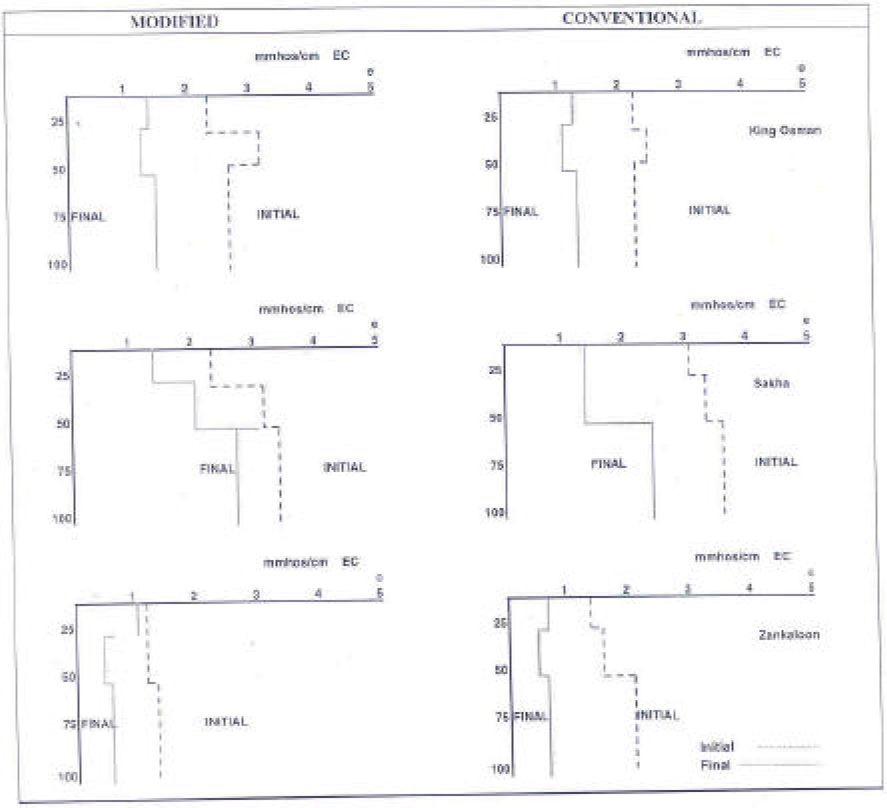


Figure 6. Overall average crop yield



Mahmoudiya 1 was the first area where the modified system was introduced on a large scale; it was constructed in 1982. Based on 1983 prices, the costs of the modified system were 12% higher than those of the conventional system. This difference can be attributed to:

- the relatively small size of the sub-collector units in the modified system;
- the design rate for the collector drains in the modified system was 3 mm/day, which is quite high compared with the design rate for non-rice areas (2 rnm/ day). The design rate for the conventional system was 4 mm/day.

Based on the experiences obtained in the Mahmoudiya area, the design of the Nashart area was slightly adjusted. In cooperation with the Agricultural Department in Kafir El Sheikh, minor modifications were made in the crop consolidation scheme to reduce the number of small sub-collectors. Also the design rate of the collector drains in the modified system was reduced to 2 mm/day. Based on the prices of 1985, the costs of the modified system at Nashart were approximately 6% lower than those of the conventional system.

CONCLUSION & RECOMMENDATIONS

To reduce irrigation water losses from rice area without restricting the subsurface drainage from “dry-foot” crops, a modified design for the subsurface drainage system is required. The modified system, which is based on the crop consolidation scheme, was tested at several locations in the Nile Delta. After the principles were studied in experimental fields, detailed investigations were carried out in farmers’ fields and followed-up by large-scale monitoring programs. The study covered a nine years period running from 1983 to 1999. The introduction of the modified layout of the subsurface drainage system in rice-growing areas in the Nile Delta resulted in:

- Savings in irrigation water up to 30%. This irrigation water would otherwise be lost through the subsurface drainage system: the difference in drainage rates from rice fields between the conventional and modified drainage system amounts of 1 to 3 mm/day over a growing season of approximately 100 days;

- Protection of the drainage system from justifiable, although unauthorized and improper, interference by farmers to stop irrigation water losses from rice fields through the subsurface drainage system, and thus reduce the maintenance requirements.

- Protection of crops other than rice from the damaging effects of improperly blocked conventional collector drains;

- These benefits were obtained without any negative effects on either soil salinity or crop yield and with no increase in costs compared with the conventional system.

In order to implement the modified system on large scale, the following measures should be considered:

- Raising awareness for public and professionals is essential to explain about the controlled or modified drainage system.
- Enhancing the vital role of farmers participation through WUA's or CUA's in the operation and maintenance of Irrigation and Drainage Systems.
- Improving extension and introducing a system of incentives and/or penalties is required to motivate farmers to follow rice consolidation units.
- Strengthening the coordination and collaboration is of great importance between all involved authorities (EPADP, DRI, ~1@, IIP, IAS ... etc.).

REFERENCES

Abdel-Dayem, M.S. and Ritzema, H.P., 1987. Covered systems in areas with rice in the crop rotation. Pap. No. 87-2588, Int. Winter Meeting of the ASAE, Chicago, USA, December 15-18, 1987, ASE. Joseph, USA.

Abdel Dayem, M.S. and Ritzema, H.P., 1990. Verification of drainage design criteria in Egypt. Symp. On Land Drainage for Salinity Control in Arid and Senii-Arid Regions. February 25 to March 2' ‘ 1990, Cairo, Egypt, Vol. 2, pp. 300

Abdel-Dayem, M. S., Ritzema, H.P., El-Atfy, HE., and Amer, M.H., 1990. Pilot areas and drainage technology. In: M.H. Amer and N.A. de Ridder (Editors), Land Drainage in Egypt. Drainage Research Institute, Cairo, pp. 103-161.

Amer, M.H., Abdel-Dayem, M.S., Osman, M.A. and Makhlouf, M.A., 1990. Recent developments of land drainage in Egypt. In: M.H. Amer and N.A. de Ridder (Editors), Land Drainage in Egypt. Drainage Research Institute, Cairo, pp. 67-93.

El Guindi, S. and Risseeuw, I.A., 1987. Research on Water Management of Rice Fields in the Nile Delta, Egypt. Publ. 41, International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.

El-Atfy, H.E., Abdel Alim, M.Q. and Ritzema, H.P., 1990. Experiences with a drainage system for rice areas in Egypt. Symp. On Land Drainage for Salinity Control in Arid and Senii-Arid Regions, February 25th to March 2 nl, 1990, Cairo, Egypt, Vol. 3, pp. 129-141.

DRI, Drainage Research Institute, Cairo, Egypt. Technical Reports of the Pilot Areas and Drainage Technology Project: (1984, 1985, 1986, 1987, 1989, 1990, 1997, 1998, 1999).