Irrigation Water Quality in the Southeastern Dry Zone of Sri Lanka: The Kirindi Oya Scheme

Y. Matsuno, W. K. B. Elkaduwa, and Y. Shinogi[1]

ABSTRACT

The objectives of this study were to a) characterize the water quality of different sources in the Kirindi Oya Irrigation and Settlement Project (KOISP) area and b) assess the potential uses of shallow groundwater and drainage return flow for irrigation, with the aim of increasing the irrigation intensity.

The major quality parameter of irrigation water, Electrical Conductivity (EC) level, was monitored in currently used irrigation water, drainage water, and shallow groundwater for a 1-year period. The results showed that, throughout the period, the lowest average in EC was in irrigation water followed by drainage and shallow groundwater. Spatial and temporal variations were also observed in drainage and shallow groundwater, probably due to irrigation issue, landform, and drainage conditions.

There is potential to increase irrigation intensity with the conjunctive use of drainage, groundwater, and reservoir water. However, the existing climatic, soil, and hydrological conditions are favorable for salinization and waterlogging, especially in the downstream flat alluvial plain. Therefore, irrigation management should include the practice to avoid any secondary salinization of previously productive cultivated soil as a result of discharge of lower-quality water and inappropriate drainage management.

INTRODUCTION

As a result of increasing sectorial competition and overall demand for freshwater due to growing population and industries, efforts have been exerted to sustain agricultural production with less water input. In Sri Lanka, a large portion of water is used by the agriculture sector, which accounts for about 96 percent of usable freshwater (IIDE 1992). However, because of seasonal, annual, and regional variations of rainfall, water availability varies in time and space, especially in the dry zone of the country, which has often faced water shortage for irrigation and even for domestic needs. For this reason, there has been a growing interest to utilize alternative water sources for irrigation. Water quality has been an increasingly important issue because such water is often recycled so that it may pass through pollution sources and be used for human activities, etc., and thus contain more pollutants.

Salinity problems have been reported in a number of irrigated areas in the dry zone of Sri Lanka. The occurrence of salinity under different topographical and hydrological conditions

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is of a relatively small scale when compared with that in other countries. Even though less attention is paid at regional and higher levels, farmers have often faced a significant reduction in their crop production owing to salinity problems.

The Kirindi Oya Irrigation and Settlement Project (KOISP), located in the southeastern dry zone of Sri Lanka (figure 1), is known to have a salinity problem (IIMI 1995; Roonage, Amarasinghe, and Yapa 1995). Following the construction of the Lunugamwehera Reservoir commissioned under the KOISP in the1980s, irrigation water in the reservoirs located in the downstream was affected by the salt-enriched drainage from the newly developed area (IIMI 1995).

This area presently achieves irrigation intensities of 110 percent in 5,500 hectares of the newly developed area and 180 percent in 4,100 hectares of the already existing old area, the Ellegala Irrigation System (EIS). There is potential to bring additional fields under irrigation. To achieve this, improving performance at reservoir and field level, and supplementing supply of irrigation water are considered. In supplementing the irrigation supply, drainage water and groundwater can be used as alternative sources in the absence of diversion of water from any other basin. Such an approach would require a prerequisite knowledge of irrigation suitability of water from available alternative sources.

This study attempts to characterize the water quality of different sources for irrigation use in the Kirindi Oya scheme and to assess the potential to improve land productivity for using drainage and groundwater as supplementary water to increase the irrigation intensity.

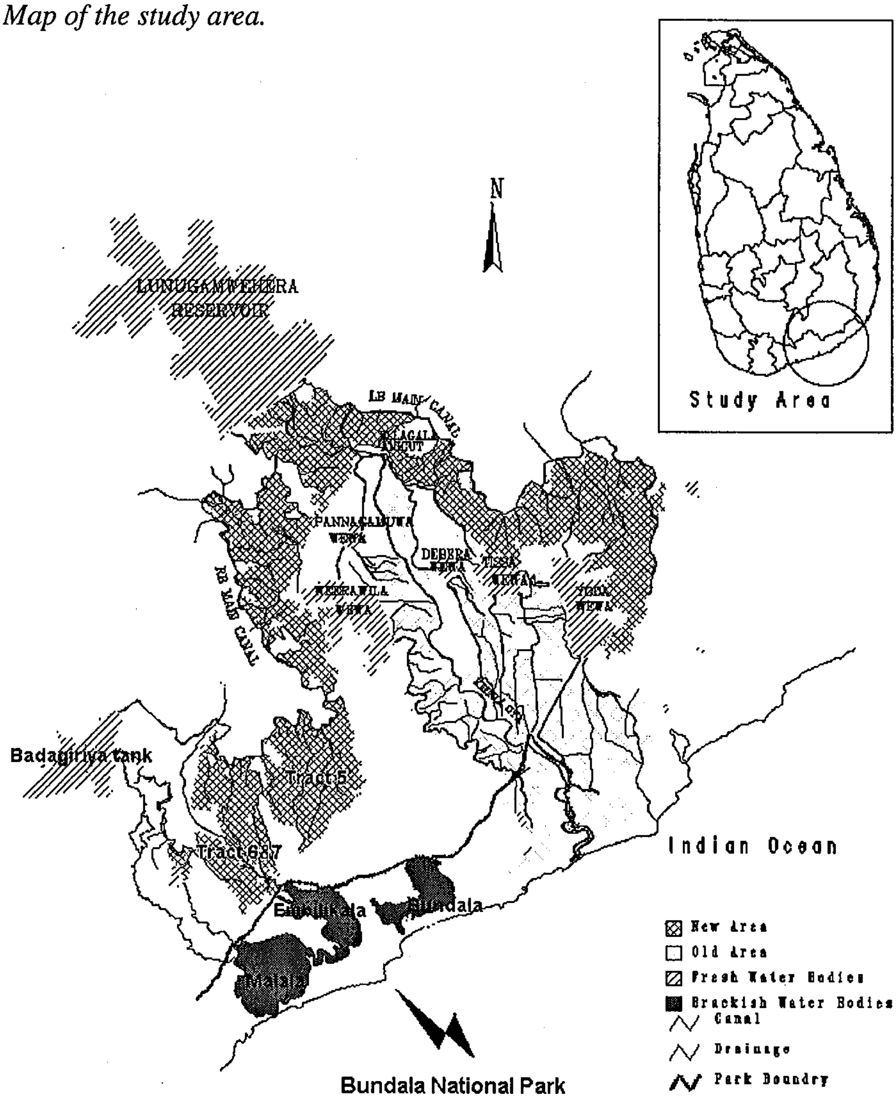
BACKGROUND

The Kirindi Oya Irrigation Scheme covers the Kirindi Oya River Basin on both banks between the Lunugamvehera Dam in the north and the coastal lagoons in the south. The project area lies within the agroecological region, which is a part of the dry-zone low country, and represents a semiarid tropical environment. At 75 percent probability level, the 100-year mean annual rainfall of the project area is 970 mm and, of this amount, 67 percent occurs in the *maha* (wet) season from October to February and 29 percent in the *yala* (dry) season from March to August. Temperature is nearly constant and remains in the range of 26 °C–28 °C. The 20-year mean annual evaporation of Class A open pan is 2,000 mm and evaporation exceeds precipitation in all months except in November and December. As the annual potential evaporation is about twice the rainfall and strong dry westerly winds during the June–September period bring in cyclic atmospheric salts, there is potential for significant accretion of salts in this region.

The major reservoir, Lunugamvehera, with a capacity of 198 million cubic meters (MCM) was commissioned in 1986. The reservoirs in the EIS (Pannagamuwa, Weerawila, Debara Wewa, Tissa Wewa, and Yoda Wewa) receive water from the Lunugamvehera Reservoir through the main Left Bank (LB) canal. In addition, considerable drainage water is received from the newly irrigated areas and a limited inflow of catchment runoff from rainfall. Part of the drainage water of the LB reaches the Debara Wewa, Tissa Wewa, and Yoda Wewa through the command of the new area. Drainage discharge from the Tissa Wewa irrigation command area also reaches the Yoda Wewa. Part of the drainage water from the Right Bank (RB) reaches the Pannagamuwa and Weerawila tanks. Drainage water from the RB is also discharged into the Embilikala Lagoon located in the Bundala National Park.

The landforms of the KOISP are characterized by a flat alluvial plain and an undulating mantled plain. The EIS is exclusively within the flat plain of the Kirindi Oya and is sloped at 0–3 percent gradient. Although natural levees, particularly Kirindi Oya River banks (extensively used as homesteads), occupy a slightly elevated position than the rest of the flat plain, there is only a slight difference in elevation between the extensive paddy fields and the interspersed coconut lands of the EIS. The slightly higher aspects of the micro-relief consist of

Figure 1. Map of the study area.



imperfectly drained brown alluvial soils while the lower aspects consist of poorly drained grey alluvial soils. On the other hand, the new area of KOISP is located exclusively in the mantled plain, which is characterized as moderately sloped at 2–8 percent gradient.

The major reservoirs of the EIS are located in the transitional landscape between the undulating residual plain and the flat alluvial plain. The soil in about 75 percent of the undulating residual mantled plain is Reddish Brown Earth (Chromic Luvisols Lvx) while the soil in the rest of the area is Solodized Solonets (Gley Solonetz Sng), which is a sodic soil with an exchangeable sodium content of more than 15 percent of the exchange complex.

Compared with the flat alluvial plain of the EIS, the new area has better drainage conditions facilitated by the undulating terrain, well-drained to moderately well-drained soils, higher drainage density, and satisfactory gradients of drainage canals. The Kirindi Oya River cuts through the center of the flat alluvial plain, with a distinct incised drainage path providing the main drainage, and with variations in the drainage within the flat alluvial plain.

The Weerawila irrigation command area (i.e., old RB area) is situated in a slightly uplifted and dissected alluvial plain, which grades into the main Kirindi Oya in a convex-concave transverse profile with a slope of 1.5–2.5 percent. In the flat alluvial plain, the highest drainage density is evident in this type of landscape and, together with the gradient of drainage ways to the Kirindi Oya incised main drain, it provides a steady outflow from the irrigation command area. In contrast, the Tissa Wewa and Yoda Wewa irrigation command areas (old LB area) are located in the flat alluvial plain with an average slope of 0.5 percent and a relatively less drainage density and, therefore, have a comparatively sluggish natural drainage. The natural drainage in the Tissa Wewa and Yoda Wewa irrigation command areas is governed by the gradient to the bed level of the incised Kirindi Oya, which is about 5 m below the land surface in lower reaches of Kirindi Oya. However, the irrigated lands of the Yoda Wewa are a distance away from the Kirindi Oya and drainage is mainly through a drainage canal with an outlet located just above the sea level, which is impeded by the formation of a sand dune ridge. As a result, drainage conditions in the Yoda Wewa irrigation command area are inferior to those of Tissa Wewa.

MATERIALS AND METHOD

Irrigation water quality was monitored in the reservoirs of Lunugamwehera and the EIS for 1 year, from January to December 1997. Monthly water samples were taken from all the major reservoirs of the KOISP and analyzed for the content of Ca, Mg, and Na. Electrical Conductivity (EC) and pH were also measured using portable field equipment. The water quality was analyzed by the procedure recommended by the National Water Supply and Drainage Board (NWSDB) of Sri Lanka. After the analysis, the Sodium Absorption Ratio (SAR) was calculated.

Additionally, the EC of surface water and shallow groundwater of main drainage canals including three locations at the Kirindi Oya River, and selected shallow wells was measured during the same period but more frequently in all the major reservoirs of the KOISP. EC levels were monitored at weekly intervals during the first 5 months followed by 2-week intervals for the rest of the period. Wells are not equally distributed in the project area, though every effort was made to select them at random. In 30 of the 83 wells selected from the project area, EC levels at different depths of water (i.e., at 25 cm, 50 cm, and 75 cm from the surface water level, and at the bottom of the well) and also the salinity of a water sample drawn from the well were measured. In all of these wells, there was no significant variation in salinity at different depths or in the water sample drawn at a given time. The magnitude of variation observed was only to the second decimal point of salinity measured in deciSiemens per meter (dS/m) in a few of the wells. Therefore, in each well, EC was consistently monitored only at one depth, about 30 cm below the water surface.

Information on rainfall, reservoir inflow and outflow, tank water levels, irrigation water issues, etc., was obtained from the records maintained at the Irrigation Department KOISP Office and from personal communications with officials attached to this office. Drainage ways in and out of different irrigation command areas of the KOISP were identified using the available maps and field observations. The information gathered through field observations and discussions with local people was used as a guide to identify the possible cause-effect relationship.

RESULTS AND DISCUSSION

Irrigation Water

Table 1 shows the statistics of irrigation water quality parameters measured in the KOISP. According to the irrigation water quality guidelines by Ayers and Westcot (1985), the measured range of EC and SAR falls within the slightly to moderate effect on the infiltration problem.

Table 1. Irrigation water quality in KIOSP.

Parameter	Average	Standard deviation	Maximum	Minimum
Temperature (water) (°C)	28.97	1.71	33.00	25.20
pH	7.22	0.60	8.25	6.07
EC (dS/m)	0.44	0.13	0.79	0.20
SAR	0.21	0.30	1.02	0.02

EC is considered the main criterion for determining the quality of water for crop irrigation and is probably one of the most widely monitored indicators of water quality. It is also a good estimate for other quality parameters such as salinity, total dissolved solid (TDS), nutrient level, dissolved oxygen, and inorganic ions (Wang and Yin 1997). Figure 2 shows the comparison of average EC in different sources over the study period. EC in the reservoir

Figure 2. Comparison of average EC values in different sources. Vertical bars indicate the standard deviation.

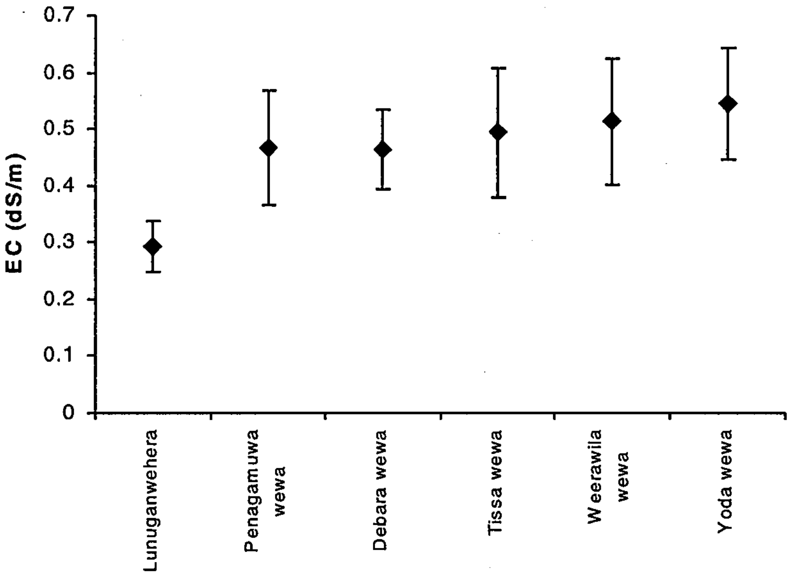
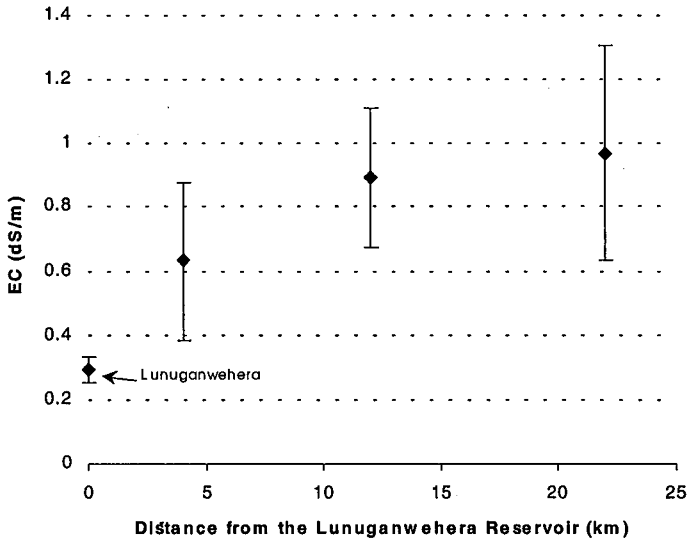


Figure 3. Average and standard deviation of EC in the reservoirs of KOISP.



including the Lunugamwehera is clearly lower than that of drainage (including the Kirindi Oya River) and shallow groundwater. A lower standard deviation of reservoir EC is an indication of a relatively stable EC relating to seasons and locations. The lowest level of salinity was found in the Lunugamvehera Reservoir throughout the study period (figure 3). Compared to EC levels reported in the 1990–1993 period (Roonage, Amarasinghe, and Yapa 1995), no appreciable change in the EC level of Lunugamvehera Reservoir has taken place during 1997 and water remains good for irrigation use for most parts of the year. The drainage discharge should be responsible for higher EC levels in the EIS reservoirs, and the difference in EC among the EIS tanks could be related to the proportion of drainage water received by them compared with water from other sources such as the Lunugamvehera Reservoir and catchment rainfall-runoff.

DRAINAGE WATER

When compared with the EC in the reservoirs, a higher level of EC was observed in drainage water (figure 2). The high variation in EC measurements could be caused by both spatial and temporal variations. Figure 4 shows an increasing of EC in the Kirindi Oya River as the distance from the Lunugamwehera increases. The EC of the reservoirs also shows similar trends as it increases at the downstream locations (figure 3). The salt content of drainage water also changed greatly during the season and probably relates to the irrigation water issue to the command area. Figure 5 shows a trend of higher EC in the RB main drainage when less irrigation water was issued to the RB main canal. The highest EC was monitored in the RB drainage among all drainage locations. A similar relationship was also observed between Yoda Wewa irrigation issue and the EC of the Yoda Wewa main drainage. It is supposed that drainage flow depends on irrigation supply and rainfall. But rainfall during the period did not correspond to the fluctuation of the drainage EC, and therefore, irrigation water was a dominant factor in determining the EC fluctuation during the period.

Figure 4. Change in EC along the course of the Kirindi Oya River. Vertical bars indicate the standard deviation.

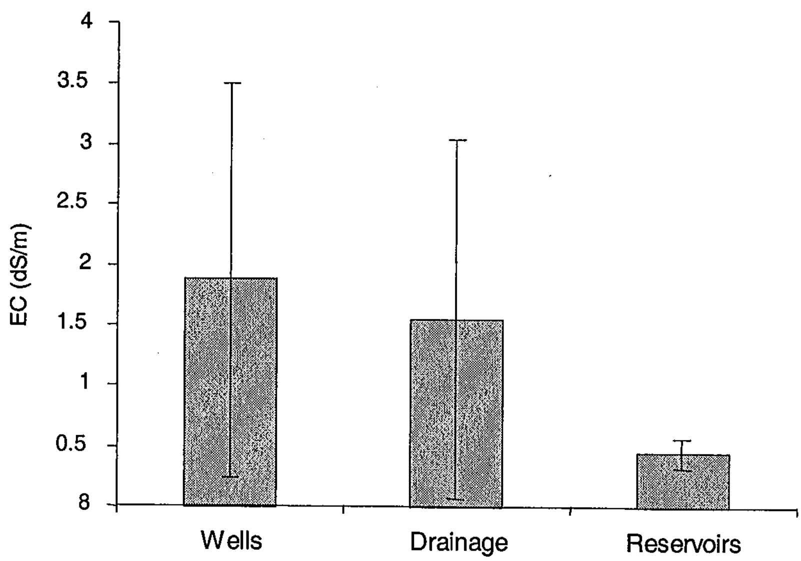
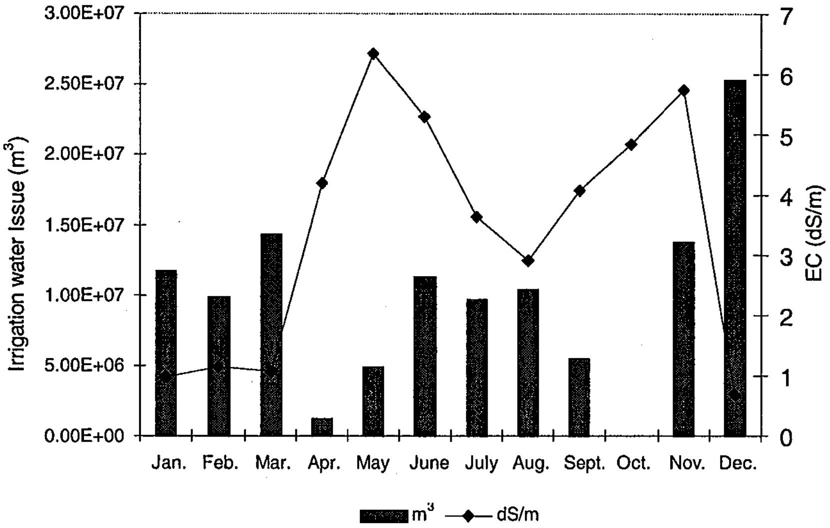


Figure 5. Monthly irrigation issues to the RB and EC values in the RB main drainage.



Besides the incised Kirindi Oya River, which serves as the main drainage, the EIS used to have a good drainage network leading out to several outfalls into the sea. However, they were disrupted during the 1969 flood and have not been restored to the previous conditions. The present maintenance of the drainage network is unsatisfactory and water stagnates in many drainage canals due to farmer interference to reuse these drainage flows, etc. This impeded drainage, particularly due to siltation in the final 2-km stretch of the narrow canal leading to the sea and the sand barrier that formed at the outfall to the sea. These conditions have resulted in stagnant water in the Yoda Wewa drainage canal most of the time without adequate flushing. A recent survey (unpublished) conducted by the Irrgation Department reported that the soils are affected in this area and soil saturation extracts of EC and SAR were as high as 32 dS/m and 31dS/m, respectively. In fact, waterlogging due to poor drainage has caused severe problems of salinity in the lower reaches of the Yoda Wewa irrigation command area, resulting in about 80 hectares of paddy land being totally abandoned for the past 10 years.

The present level of irrigation water has a potential to cause yield reduction under the least drainage facilities prevailing in the Yoda Wewa irrigation command area. Considering the present drainage conditions, the RB of EIS (i.e., Pannagamuwa and Weerawila irrigation command areas) could tolerate more saline irrigation water compared to those in the LB (i.e., Debara Wewa, Tissa Wewa, and Yoda Wewa irrigation command areas). Irrigated lands in the new area could tolerate higher salinity in irrigation water compared to that of the EIS because of a better drainage condition.

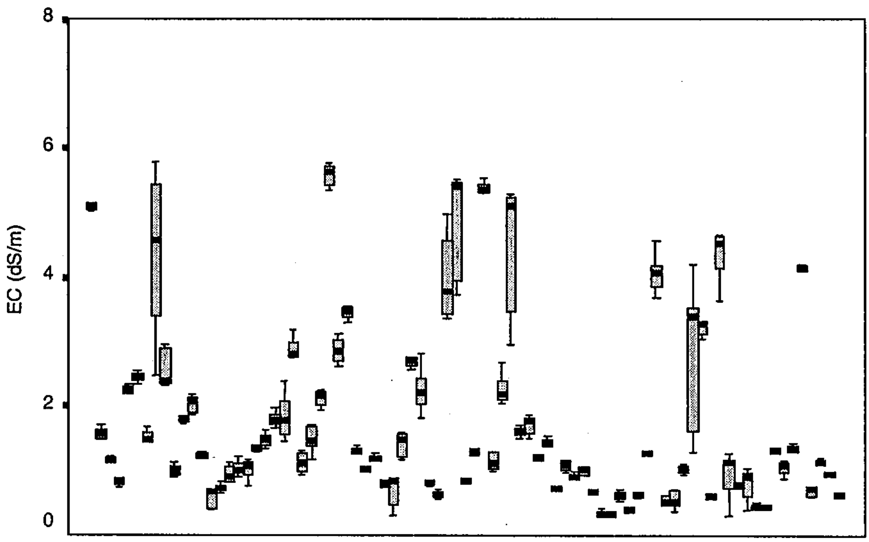
The shallow groundwater EC was the highest among the three sources with a high variation. Groundwater quality generally depends on soils and the amount and source of the groundwater. Major sources of the shallow groundwater are rainfall and irrigation water including seepage from the canals and reservoirs, both sources having much less salinity than that observed in groundwater. Therefore, a higher proportion of dissolved constituents found in groundwater could be the result of greater exposure to soluble material in geologic strata and environmental factors, such as accumulation of salts in the wells from shallow aquifers due to poor subsurface drainage conditions.

GROUNDWATER

Figure 6 shows the EC of monitored shallow wells plotted as a box-plot. The EC in the majority of wells observed did not vary during the period, while there were more variations between wells. This implies that the spatial variation of the groundwater EC was relatively higher than its temporal variation. It seems that wells having a relatively higher range of EC also have a high temporal variation. Further analysis is being carried out to relate these variations to the locations of wells.

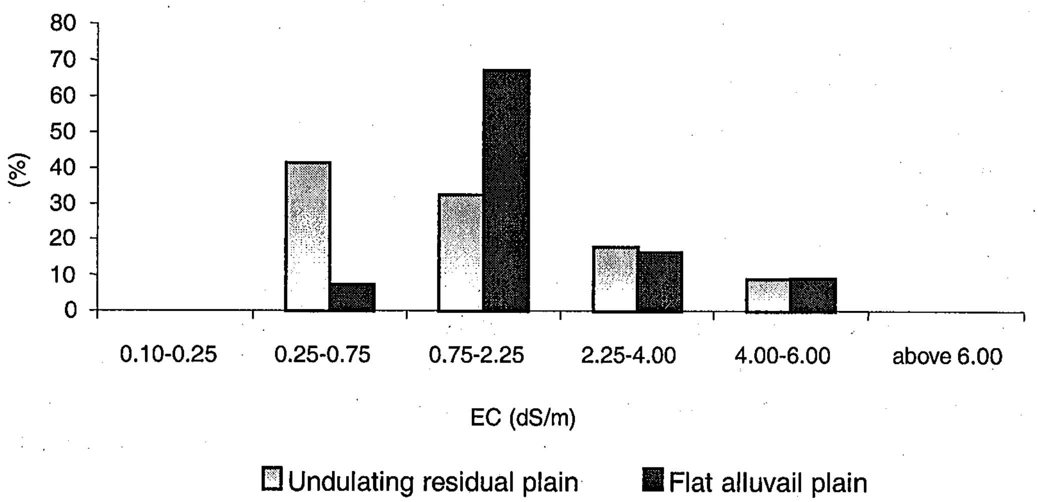
Using the average values of salinity observed in each well, the wells were ranked from the lowest to the highest EC levels and then divided into groups of different water-quality categories in accordance with the irrigation water salinity classification by the US Salinity Laboratory (Agricultural Compendium 1981). The result (figure 7) shows that wells with the class 2 quality (EC: 0.25–0.75 dS/m) shallow groundwater are mostly in the newly irrigated areas and their surroundings, which are located in the undulating residual mantled plain. The class 3 quality (EC: 0.75–2.25 dS/m) groundwater is common within the EIS in the flat alluvial plain of the Kirindi Oya basin. The class 3 shallow groundwater is also found in some parts of the undulating residual plain. The classes 4 (EC: 2.25–4.00 dS/m) and 5 (EC: 4.00–6.00 dS/m) quality groundwater is found both in the undulating residual and alluvial plains. However, the number of wells with the classes 4 and 5 quality is less compared to that of the classes 2

Figure 6. Box-plot of EC values in 83 shallow wells, indicating maximum, minimum, and median, and 25 percent and 75 percent percentiles.



and 3 quality. The number of wells with such poor quality categories of water is less in the mantled plain than in the flat alluvial plain. Therefore, it is reasonable to conclude that the spatial distribution of salinity levels of shallow groundwater is governed mainly by the drainage conditions determined by landscape hydrology and other drainage characteristics such as drainage density and gradient of drainage ways.

Figure 7. Percentage of average EC values in wells categorized by the irrigation salinity class.



Although there are a few locations with temporal variations, the dependence of spatial distribution of shallow groundwater EC on the overall drainage condition is an indication that high EC results mainly from net inflow of groundwater and surface water in poorly drained parts of the landscape, micro depressions, and areas with drainage congestion in adjacent drainage ways. Therefore, relatively high saline groundwater areas are in low-lying poorly drained lands as a result of the mobilization of large quantities of salts by leaching of irrigation water, and the subsequent accumulation of the salt in localized areas with restricted drainage in the landscape where the water table is near the soil surface. This is further exacerbated by the accumulation of salt in the soil due to evaporation-driven processes. Restricted drainage is mainly due to the presence of shallow groundwater related to topographic position and poor permeability of soils due to high content of alluvial clay, which impede downward movement of water. As a result, wells show less salinity when leaching out of salt occurs through near-surface soil profile with rain (particularly in the maha season) and irrigation water, as revealed by the temporal variation in salinity.

Relatively better drainage conditions and better quality of groundwater in the new area compared with the EIS area provide a potential for use of groundwater in conjunction with presently used irrigation water from the Lunugamvehera Reservoir. Even now, shallow groundwater is used for irrigation of non-rice field crops during the yala season on a very limited scale in areas located outside the irrigation command of the LB. However, while attempting to increase the irrigation intensity in the new area, care must be taken not to disturb the present salt balance that maintains water at Ellegala tanks at the optimum EC range for crop production.

CONCLUSIONS

Considering the prevailing hydrological situation and salinity level, approaches should include the following combination of practices to increase irrigation intensity while preventing reduction of production.

1. Implementation of more efficient irrigation water management practices with presently used class 1 quality water available from the major Lunugamvehera Reservoir and class 2 quality water from all other reservoirs of the EIS.
2. Conjunctive use of shallow groundwater and drainage water together with presently used irrigation water (i.e., water in Lunugamvehera Reservoir and tanks of the Ellegala system) to achieve this higher irrigation intensity. This would also aid in lowering water table elevations. The introduction of other suitable field crops at least in the new area, particularly during the yala season, should be considered, as they would demand less water.
3. Improvements in the existing drainage conditions in both project and on-farm levels to achieve a good drainage network to intercept and quickly remove drainage water, particularly in the EIS, and to minimize salinization of soils and groundwater, the other alternative sources of water. Drainage water from the KOISP system is ultimately discharged into the sea and the downstream lagoons.

It is very important to preclude any secondary salinization of previously productive cultivated soil as a result of both discharge of low-quality water into good-quality water and inappropriate drainage management. The existing climatic, physiographical, and hydrological conditions are favorable for salinization and waterlogging, particularly in the flat alluvial plain, if quality of irrigation water and management become poor. The water table is almost at the surface during irrigation periods. Periodical measurements of water quality are important to ensure that salinity is being kept below the acceptable levels.

Similar salinity problems have been observed in other irrigation schemes in the dry zone of Sri Lanka. The problems are likely to occur when irrigation water supply is not sufficient to leach out the excessive salts and/or drainage facilities are not adequate or properly maintained. The former can be seen at tail-end farms and in the irrigation schemes that often face water-scarce situations. This was also reported in the KOISP (Roonage, Amarasinghe, and Yapa 1995), while the latter has been discussed in this study and others (Gangodawila 1994).

The situation can be improved if the government authorities as well as farmers take appropriate action to gain adequate knowledge in dealing with salinity.

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