# Crop and Forage Production Using Saline Waters

*Editors*
Mohammad Kafi
Muhammad Ajmal Khan

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# Salinity Development in the Dry Zone of Sri Lanka: A Review

M.M.M. Najim* and K.P.K. Jayakody
*Department of Agricultural Engineering,*
*Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka*
**E-mail: bmarambe@pdn.ac.lk, nazimhn@yahoo.com*

## ABSTRACT

Soil salinity development is identified as one of the problem in the Mahaweli development scheme and the dry parts of the agricultural areas in the country. The cause of salinity development in Sri Lanka is identified as the elevation of the groundwater tables and evaporation especially in the dry regions. In Nochiyagama block of the Mahaweli system H showed that 30 per cent of the lands are affected by salinity. In the areas where the salinity has developed more than 5 dS $m^{-1}$ has shown reduced paddy yields. It was calculated that about 757 kg $ha^{-1}$ of paddy yield is reduced when salinity is elevated to 5 dS $m^{-1}$. The salinity development has deteriorated the drinking water quality too. Few irrigation tanks in the Mahaweli system showed elevated levels of salinity, *i.e.* Alli Tank and Vakanneri Tank. Parakkrama Samudraya, Kanthali and Minneriya tanks also show occasional salinity levels. In the areas, the presence of salt deposits on the surface and also the decline in rice yields are reported by farmers. Certain localities have shown higher salinity levels in empirical studies too. Poor drainage, undulating topography, reuse of irrigation water, mono cropping for a longer period etc. are the major factors contributing to the salinity development in the area. Introduction of policies, research on salinity and related issues, maintenance of irrigation infrastructures with proper and adequate drainage, improving water productivity, crop rotation and good agronomic practices etc. are the management practices needed to curb the salinity development. Salt affected lands could be used for alternative crop productions such as forage production in order to improve livestock raring.

## Introduction

Sri Lanka is a tropical country and agriculture is the main economic activity. Dry zone of Sri Lanka is the main agricultural area in the country where salinity has been associated with irrigated agriculture since its early days. Irrigation often aggravate the effects of salinity, which occurs due to many reasons such as natural weathering of saline parent material from sea water deposits or other sources etc.. Salinity has also been associated with the rise of groundwater tables resulting from excess irrigation and poor drainage in large-scale, perennial irrigation systems; resulting shallow water tables bring salts to the upper layers of the soil profile. Salinity can also be induced by the use of pumped groundwater. In the dry zone of the country, water drained from one agricultural area is used in some other areas. The drainage water is high with some salt concentrations, which could lead to salinity development. The evaporation of water due to dry weather also concentrates salts on the soil surface. In these cases, the physical process underlying salinization is the absence of a downward soil water flux of sufficient degree to leach the salts from the root zone. Salinity can also result from sea water intrusion into coastal areas where the water tables have been lowered by the mining of groundwater.

In the recent years, some farmers have been abandoning their rice fields in the dry zone irrigation schemes due to the incidences of salinity. Many organizations and individuals have carried out few research works on salinity and associated problems in the dry zone. Mahaweli system H that includes Kalaweva Basin was the first project under the Mahaweli development program. Under the System H, approximately 38533 ha of lands are being cultivated by about 31000 farm families. Paddy, chili, vegetables, onion and legumes are the major crops that are being cultivated in the area. During the main rainy season Maha, paddy is the main crop due to the ample availability of water. During the off-season Yala the paddy is only cultivated in the areas where sufficient water supply is secured. In the other areas, the major crops are chili, vegetables, onion and other field crops. In general, Mahaweli system H contributes 25 per cent of paddy production, 30 per cent of chili and 20 per cent of big onion production of the country. Salinity development in these lands will have tremendous effect on the agricultural productivity from this area. In this paper the Irrigation-induced salinization in irrigation systems in dry zone and salinity problems in the Mahaweli system H of Sri Lanka will be discussed.

## Mahaweli System H

Land degradation due to salinity and water logging is primarily associated with coastal areas and irrigated lands in the dry zone of Sri Lanka, which covers half a million hectares (TAMS/USAID, 1980). The dry zone of Sri Lanka is the most important area as far as irrigation is concerned. In Sri Lanka, the dry zone occupies nearly two thirds of the land where people depend mainly on arable farming for food and income. The Mahaweli system H (Figure 26.1) is one of the major agricultural areas in the dry zone, which receives transbasin diversion water.

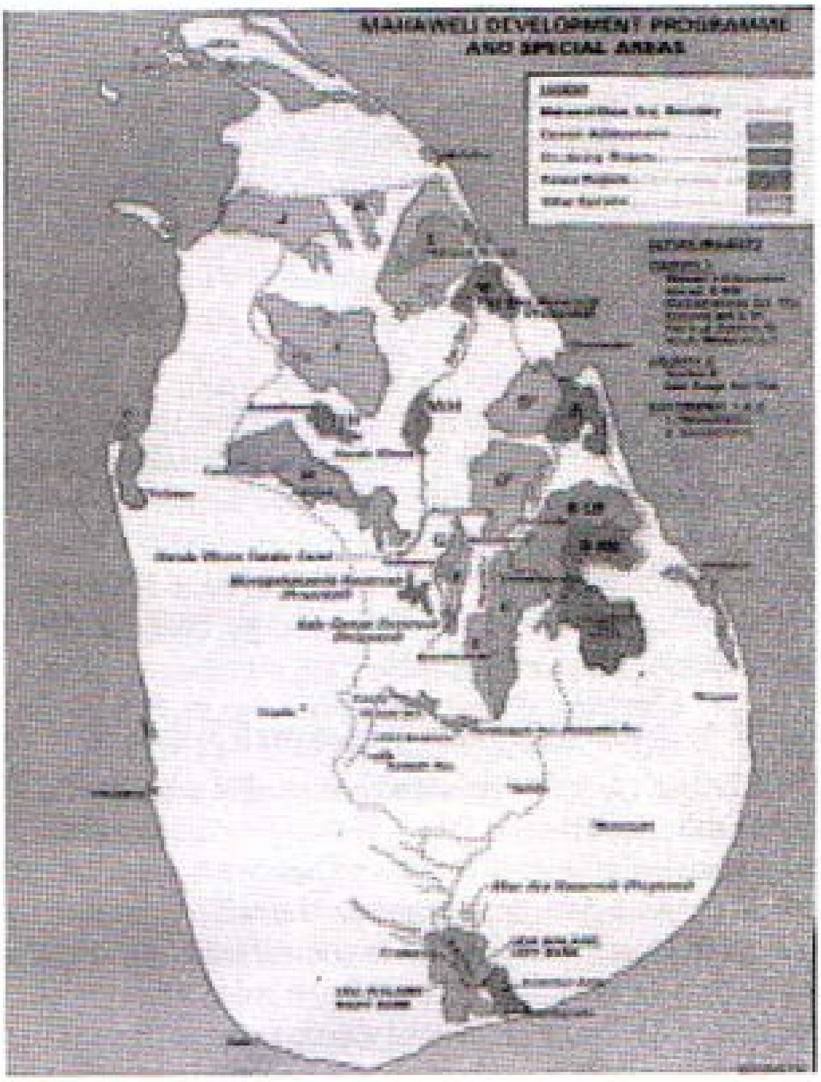


**Figure 26.1: Mahaweli Development Schemes**

## Topography and Soil

The landscape of the Mahaweli system H is undulating with slopes ranging from 1 to 4 percent (De Silva, 1987). The approximate slope along the transect from top to bottom are 3-10 per cent on tales slope, around 2 per cent in the convex portion and less than 1 per cent in the concave part. Rock landscape and erosion remains are found only in the concave part. The landscape has been transformed into bounded paddies. The side slope of the lower order valleys lead to the development of two main land types. The upper part of the side slope of the land is wet only during the wet weather and leaving rest of the year dry (De Silva, 1987). The lower part, on the other hand, is wet for a longer period about six month or more. The poor drainage in these wet areas has accumulated salts leading to salinity development.

## Geochemistry of Landscape

The two main land types that are found on the side slope of the lower order valleys of the inland dry zone have specific geochemical characteristic. The land located on the upper convex slope loses water, finer soil particles and soluble elements to the lower concave slope. Consequently soil in the convex part of the side slope becomes dry and well drained, coarse textured and relatively depleted of soluble elements. The soil in the concave part of the slope on the other hand becomes wet with a retarded drainage, finer textured and enriched with soluble elements (De Silva, 1987). This portion of the landscape is much prone to salinity development. Many ancient minor irrigation schemes, which are still operational, have experienced salinity patches within the command areas.

## Irrigation Pattern

Irrigation water delivery in the area is a rotation system. Under this system water is delivered to each farmer in sufficient quantity for a fixed period of time under a prearranged schedule. In this system, the farmer does not have sufficient irrigation water when he wants. For other field crops, farmers use supplementary water from shallow agro wells. High application efficiencies have not been achieved in the system. Effective rainfall can be utilized fully and standing water is not maintained continuously in order to prevent deep percolation losses. Utilization of rainfall is beneficial for flushing the accumulated salts.

## Salinity Status of Soil and Water in Mahaweli System H

Accelerated Mahaweli development scheme supplied water into the existing major and micro irrigation systems. These systems had reached a stable equilibrium over many centuries. Introduction of trans-boundary diversions into such systems have brought many changes to the water and salt balance in the area. Establishment of major irrigation schemes destroying forest cover in well drained land and supplying additional water to the whole landscape over a longer period of time has interrupted the established equilibrium for both salt and water in the region (Handawala, 1983). It was also shown that the field salinity observed in the opened lands in the Mahaweli system H can be attributed to the emergence of underground salt reserves. There was a gradual increase in the sodium absorption ratio (SAR) of irrigation water from 1978 to 1986 which indicates that there is a gradual build up of salts in soil solution in the Mahaweli system H (Pathmanathan, 1999). Handawala (1983) showed that after the Mahaweli system development, the drainage capacity of the natural stream and canals were badly declined, and that there were cases when farmers blocked drainage canals to obtain more water for irrigation. Such drainage blockages maintained and circulated released salts within the location for a longer period than necessary without being flushed out, thus causing salinity hazards.

In Nochiyagama block of the Mahaweli system H showed that 30 per cent of the lands are affected by salinity. In the areas where the salinity has developed more than 5 $dSm^{-1}$ has shown reduced paddy yields. It was calculated that about 757 kg ha-1 of paddy yield is reduced when salinity is elevated to 5 $dSm^{-1}$. The salinity development has deteriorated the drinking water quality too. As a solution, proper drainage is proposed in this area (Pathmanathan, 1999).

Few irrigation tanks in the Mahaweli system showed elevated levels of salinity, *i.e.* Alli Tank and Vakanneri Tank. Parakkrama Samudraya, Kanthali and Minneriya tanks also show occasional salinity levels. In the areas, farmers report the presence of salt deposits on the surface and also the decline in rice yields. Certain localities have shown higher salinity levels in empirical studies too (Wijesekera, 1981).

Sikurajapathy *et al.* (1983) estimated that about 4.96 per cent of the paddy fields were affected by salinity in the Mahaweli system H. Researchers indicated that more lands are likely to become salt-affected if improved drainage facilities are not provided. Dhruwasangary (1983) assessed the effects of drainage on salinity level and the cost involved in the Mahaweli H area and showed that subsurface drainage will improve crop yield significantly. Gangodawila (1988) in his study indicated gradual emergence of salinity problems in the Mahaweli system H.

Cascades in Mahawilachiya, Nuwaragampalatha central, Medawachchiya and Kahatagasdigiliya in the Anuradapura district showed salinity developments. Many paddy fields are seriously affected by salinity and the cultivation is totally stopped. These lands are neglected and the only vegetation that can be seen is salt tolerant native grasses and creepers. These areas can be used economically for forage production where the farming community can integrate it with animal husbandry.

Preliminary soil surveys in the Mahaweli system H prior to Mahaweli diversion showed that 80 per cent of the soils in the area contained manganese that is less soluble. The manganese content increased down the slope. Iron and aluminum, which are the least soluble of the elements, are hardly mobilized and generally settled in the well-drained soil (De Silva, 1987). According to preliminary soil surveys in the Mahaweli H area prior to its diversion there were low or medium salinity of soil and water in the region. Only certain locations have shown high salinity levels (Wijesekera, 1981).

The salinity levels of the irrigation water in the Mahaweli system H are always low or medium. Electrical conductivity (EC) of the irrigation water tends to increase from wet weather to dry. A survey of water quality of minor tanks in the area shows that the EC level increases in between the months March to November, which is the drier period in the area (De Silva, 1987). This phenomenon is similar in the major tank systems. Another observation is that the EC of tank water increases down the longitudinal slope of the valley, which is given in Table 26.1. This is a very clear indication that the drainage and return flows from the head end to the tail end concentrates along the gradient.

**Table 26.1: Salinity Variation in Tanks in Dry and Wet Seasons**

| *Name of the Tank* | *Electrical Conductivity $dSm^{-1}$ (Dry Season)* | *Electrical Conductivity $dSm^{-1}$ (Wet Season)* |
|---|---|---|
| Kalawewa | 0.40 | 0.20 |
| Kalankuttiya | 0.45 | 0.25 |
| Katiyawa | 0.45 | 0.35 |
| Rajangana | 0.70 | 0.35 |

*Source*: Salinity Status of Inland Dry Zone of Sri Lanka, De Silva, 1987.

Nochchiyagama block in Mahaweli system H is located at the end of the right bank channel of the main irrigation tank Kalawewa. This area has a very high vulnerability to salinity compared to other blocks in the system H. Table 26.2 gives the salinity test results in Nochiyagama Block of Mahaweli system H.

**Table 26.2: Salinity Test Results in Nochchiyagama Block**

| *Salinity Range ($dSm^{-1}$)* | *Salinity Category* | *Total Number of Farmers* | *Farmers (%)* |
|---|---|---|---|
| 0-2 | Low | 33 | 30 |
| 2-5 | Medium | 43 | 40 |
| 5-8 | High | 26 | 23 |
| >8 | Severe | 8 | 7 |

*Source*: Economic and environment assessment in land degradation caused by soil salinity in Nochchiyagama Block of the Mahaweli system H, Pathmanathan, 1999.

The salinity levels in Table 26.2 shows that 30 per cent of the farmers are operating under salinity free conditions (2 $dSm^{-1}$) and about 40 per cent are operating under medium level of salinity. The severity of salinity varies from plot to plot and also within the plot. The pH values of soil in the block were in the range of 7-9 that indicates that there is no alkalinity and sodic problem. The high pH values were recorded in the more water logged areas. The pH values of the major irrigation schemes, which are located in the dry zone, were found to be around 8 (Amarasiri, 1975). It has been reported that the surface water logging in Nochchiyagama could have been caused by gradual increase in water table since the inception of Mahaweli project. This may be the reason for high salinity in Nochchiyagama block.

In the Mahaweli system H, salinity is common in the following sites (De Silva, 1987).

1. Point at which the slope changes from convex to concave or vise versa, where seepage flow tends to emerge out.
2. Poorly drained sites with inadequate supply of water to maintain a layer of saline water.
3. Old tank beds and other depressions with insufficient drainage.
4. Heaps and elevations located within the capillary rise reachable stagnant water pools.
5. Fields wetted by capillary rise from canal seepage.
6. None irrigated fields that are receiving seepage or capillary rise from adjacent irrigated fields.

## Crop Yield and Salinity

Salinity build up directly influences the crop yields that could be found out by Cobb-Douglas form of production function. According to Pathmanathan (1999), salinity values up to the threshold level, paddy production will not be affected. Beyond the threshold limit salinity level shows negative effect on yield. About 61 per cent of the variation in paddy yield is determined by many factors including salinity (Pathmanathan, 1999). The expected negative production elasticity of soil salinity was the important determinant of yield, which dominated over fertilizer, capital and labor inputs and also soil salinity coefficient was very much significant both magnitude wise and statistical wise at 1 per cent (Pathmanathan, 1999). This indicates that a 1 per cent increment in soil electrical conductivity reduces the yield by 0.8 per cent in Nochchiyagama block in Mahaweli system H.

According to Thiruchelvam and Pathmarajah (2003) in salinity-affected areas, the soil salinity is the principal factor that determines rice production. In moderately saline areas, the yield loss ranged from 10 per cent -15 per cent ; in high and severe soil salinity areas, yield was reduced by about one third. Therefore, it is important to identify such areas in the irrigation projects and reclaim the soil from permanent damage.

Salinity has reduced rice productivity by 33 per cent in 7 per cent of the areas away and about 1 per cent in the areas close to the main reservoir in the Mahaweli system H. About 55 per cent of the productivity loss in medium and high salinity areas was due to soil salinity, indicating the need for technological and management interventions to prevent the soil salinity damages. Drainage improvements are economically feasible in medium and high salinity affected areas and is highly uneconomical in severe soil salinity areas (Thiruchelvam and Pathmarajah, 1999).

## Drainage and Impact on Yield

According to Table 26.2, about 30 per cent of interviewed farmers are affected by high soil salinity but only few farmers on this group uses considerable amount of labour to improve the drainage facilities through the techniques of cleaning and deepening the drainage channels. Table 26.3 shows that nine farmers used less than five labourers for drainage improvement while majority of affected farmers (18) used 5-10 labourers for drainage improvement. Even though this number of labourers for drainage action is insufficient, it gave 5 per cent yield increase than those who used less than five labourers. But the seven farmers who used more than 10 labourers for drainage improvement received about 12.5 per cent yield increase than those who used less than 5 labourers. Thus cleaning and deepening of drainage channels helped to get an advanced yield increase of about 5-12.5 per cent (Pathmanathan, 1999). This reveals that more labourer investment for drainage improvement may receive more advantages to the farmer at the present level of technology available in the area. A few number of farmers are using the paddy straw as organic matters to improve the drainage, but the amount applied is much below the required rate which is essential to show any significant effect on salinity (Pathmanathan, 1999).

## Salinity Management Techniques for the Dry Zone

Maintenance of irrigation infrastructures could play a vital role in salinity management. This leads to reduce seepage and unexpected rise of the water table. Conservation of water in the catchments and rain in irrigated areas also help to reduce the salinity development.

Table 26.3: Relationship Between Labourer Employment in Drainage Improvement and Paddy Yield

| No Labor Used for drainage | Number of Farms Affected by Salinity | Average Yield (kg $ha^{-1}$) |
|---|---|---|
| <5 | 9 (8 per cent) | 3520 |
| 5-10 | 18 (16 per cent) | 3082 |
| >10 | 7 (6 per cent) | 3931 |

*Source*: Economic and environmental assessment of land degradation- caused by soil salinity in Nochiyagama block Mahaweli H, Pathmanathan, 1999.

Proper drainage is a good management to control salinity development. Construction and maintenance of new and existing drainage facilities to remove the excess water quickly from the fields will be very important. Reuse of drainage water should only be done with great care and precaution.

Good agronomic practices such as introduction of different crops with crop rotations, use of less-water demanding crops, use of more drought and salt tolerant ones, irrigate according to crop water requirement preventing excess water in the field, reduce irrigated area by using high tech irrigation methods such as drips and sprinklers, on-farm watercourse improvement and precision land leveling and application of soil amendments to improve root zone environment. Utilization of the salt affected lands for forage production will also be a good solution where the forage production could enhance livestock raring.

Policies should be introduced for water and land management with special reference to salinity development. Farmers also should be involved in water resource management and maintenance. Introduction of management information systems on land and irrigation management would ensure high-quality salinity management in dry zone in the future. Research on salinity and water quality in terms of salinity development is not much reported from Sri Lanka. Therefore, promotion of research activities on salinity, drainage and water productivity should be introduced and funded by the policy makers in the agricultural sector in the country.

At present, there are few areas of uncertainty that are identified in salinity development in the dry zone of Sri Lanka. The two main concerns are the present inability to quantitatively predict the effects of salinity using different quality irrigation waters on crop yields, and the infiltration rate and hydraulic conductivity of the irrigated soils. Future research studies should be involved with studies of the effect of using saline water throughout the longer period of time. Therefore physical and chemical changes occur in root zone with saline water, leaching requirement with different type of commercially valuable crops under different types of salinity level and different types of soil, and crop yield responses under different conditions of salinity should be carefully studied. In the future these findings may facilitate to increase the land productivity with lesser quantity of water supplied as economic value for good quality water increases day by day.

## Conclusion

Land degradation due to salinity and water logging is primarily associated with coastal areas and irrigated lands in the dry zone of Sri Lanka. Mahaweli system H is one of the prime areas in the country, which produces considerable amounts of paddy and other field crops. Salinity development in this area shows an increasing trend. Poor drainage, undulating topography, reuse of irrigation water, mono cropping for a longer period etc. are the major factors contributing to the salinity development in the area. Introduction of policies, research on salinity and related issues, maintenance of irrigation infrastructures with proper and adequate drainage, improving water productivity, crop rotation and good agronomic practices etc. are the management practices needed to curb the salinity development. Salt affected lands could be used for alternative crop productions such a forage production in order to improve livestock raring.

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