RECLAMATION AND DEVELOPMENT OF RICE CULTIVATION ON COASTAL LOW-LYING LANDS OF SOUTHERN AND WESTERN SRI LANKA

Indrajith BALASURIYA*

ABSTRACT

The data and experience from Sri Lanka's South-West Coastal Reclamation, Drainage and Flood Protection Schemes, over a period of 15 years, have revealed five basic requirements for rice-oriented reclamation projects; namely, in wet weather: (1) Controlled flooding, (2) Drainage improvement; and in dry weather: (1) Protection from coastal and inland salinity, (2) Prevention of transitory acid sulfate conditions, (3) Irrigation. An additional requirement is appropriate and acceptable agronomic technology.

There is recent evidence of rice cultivation on actual and/or old acid sulfate soils. The strong soil acidification and temporary inland salinity during droughty weather make irrigation a vital component for coastal rice projects. With appropriate reclamation and use of available agronomic technology the curent low rice yields of less than 1,590 kg/ha could be increased in the range of 2,655 kg/ha to 3,720 kg/ha and the land double-cropped. The unit of development should be individual projects of about 2,250 ha using the "Polder System" of reclamation, within an overall strategy of integrated multiple resource development. With arable land becoming increasingly scarce, development of rice production on coastal low-lying lands would release better drained rice lands for other food and agro-industrial crops.

Introduction

On the basis of climate, soils and vegetation, Sri Lanka could be broadly divided into three major agro-climatic zones, namely (a) Dry Zone (b) Intermediate Zone (c) Wet Zone, with an average annual rainfall of 1,270 mm to 1,904 mm (50 in to 75 in) 1,905 mm to 2,540 mm (75 in to 100 in) and over 2,540 mm (100 in), respectively. The total rice area is about 720,000 ha, of which approximately 75% is in the Dry and Intermediate Zones and 25% in the Wet zone. The geographical location of the island, between 6°N and 10°N of the equator, ensures a favorable air temperature (av.max.32°C, av.min.23°C) and adequate solar radiation for rice cultivation throughout the year in the Low Country region, namely up to 300 meters (1,000 ft) above Mean Sea Level (MSL), where 97% of the rice lands and 75% to 80% of the population are located.

The coastal low-lying lands receive two monsoons yearly, thereby providing water for two rice cropping seasons, namely (1) *Yala* (South-West Monsoon Season) from March to August (b) *Maha* (North East Monsoon Season) from September to February. However, the capricious seasonal monsoon rains, often violent, together with erratic tropical convectional and depressional rains constitute a poorly distributed and unpredictable water supply for rice cultivation. Flash flooding and poor drainage frequently alternate with droughty periods. Consequently, yields are low (less than 1,590 kg/ha) and risks high.

Nevertheless, rainfed rice double cropping is practiced whenever weather conditions are favorable, except where regularly unfavorable hydrological conditions result in a single long-aged rice crop.

The increasingly heavy cost of expanding the rice area in the Dry Zone, together with the need to relieve unemployment and under-employment and provide income support to the densely populated Wet Zone rural sector, has now generated a greater awareness of the need to

* Rice Agronomist and Head, Low-Lying Lands Rice Research, Department of Agriculture, Matara, Sri Lanka.

more fully utilize the human, environmental and infrastructural resources of the Wet Zone for increasing rice production. Moreover, development and productivity improvement of rice on these lands could release considerable extents of well-drained lands in the Dry and Intermediate Rainfall Zones for alternate high value food and agro-industrial crops.

This paper examines the major problems and discusses the technology required for developing rice cultivation in the coastal low-lying lands of the Wet Zone.

Definition of the term "coastal low-lying lands"

The term "low-lying lands" when used in Sri Lanka to describe the terrain in the southern and western coastal areas includes a wide range of hydrologic conditions, landscape positions, land elevations and soils. PANABOKKE (1977) suggested that the relatively better drained lands (mineral Entisols) on river levees be excluded from the term "low-lying, poorly drained lands". However, within the coastal flood plains, in contrast to inland flood plain areas, the natural river levees are virtually non-existent or less than 30 cm (1 ft) high, hence, practically subject to the same unfavorable hydrologic conditions as the surrounding low-lying lands.

Furthermore, the coastal low-lying lands have many common features, such as flooding, poor drainage, similar geomorphology and oligotropic or mesotropic mineral and organic soils with strong marine influence.

Therefore the term "coastal low-lying lands" should apply to those lands up to an elevation of 1.5 m (5 ft) above MSL, in the southern and western coastal sectors of the island, subject to flooding and poor drainage during some part of the cultivation season. The landscape positions occupied by these lands are mainly the low-lying flood plains of rivers and streams, backswamps, filled-up lagoons and depressions, tidal marshes and swamps.

Location, physiography and major landscape features

Along the southern and western coast of the island, the sea abuts on the narrow coastal barrier ridge consisting of Regosols and recent beach deposits underlain by limestone and old coral reefs. Between this coastal ridge and the foothills of the central mountains is a belt of low lands, the latter rising by a series of platforms, rises and terraces from below mean sea level to about 35m (120 ft) above MSL. The coastal low-lying lands, being below 1.5 m above MSL, occupy the lowest elevational position. They stretch along the South-West coast from the southern boundary of Matara district, in the South to North of Negombo, a distance of about 200 km (140 miles), and extend 4.5 km to 10 km (3 ml to 7 ml) to the interior, an area of about 1,350 sq km (521 sq ml). The region cuts across the coastal areas of Colombo, Kalutara, Galle and Matara districts, the most highly populated areas of the country, and the major part is located in the Wet Zone while the southern and northern extremeties extend into the Intermediate Rainfall Zone.

Physiographically the coastal lowlands consist of a series of discontinuous ridges and valleys underlain by Pre-Cambrian rocks of the Highland Series (Khondalites) and the Cambrian rocks of the Vijayan Series (Charnokites) which form the South-Western Group of rocks. Phosphate status of these rocks is consistently low (COORAY, 1967). The mineral composition of the rocks with characteristic garnet-sillimanite-graphite schists, suggests that the lowland soils of the region would be rich in iron, aluminium and sulfide minerals compared with calcium, magnesium and potassium. Overlying the ancient rocks are recent deposits of clay, sands, lagoonal deposits and lateritic material. A well-developed landscape feature is laterite, which is found capping the rocks on coastal headlands and the residual highlands (Plinthudults) bordering the low-lying valleys.

The geomorphology of the South-West coastal area has resulted in a multitude of readily distinguishable and discontinuous poorly drained low-lying valleys and filled-up lagoons, of varying shape and size with complex and specific hydrological characteristics. These valleys with post-Pleistocene aggradation soils are extensively used, wherever and whenever possible, for lowland rice cultivation, resulting in a high concentration of rice tracts within the coastal low-lying lands (Fig. 1). In fact, in the coastal districts of Colombo, Kalutara, Galle and Matara approximately 25% to 50% of the rice fields are found within this area.

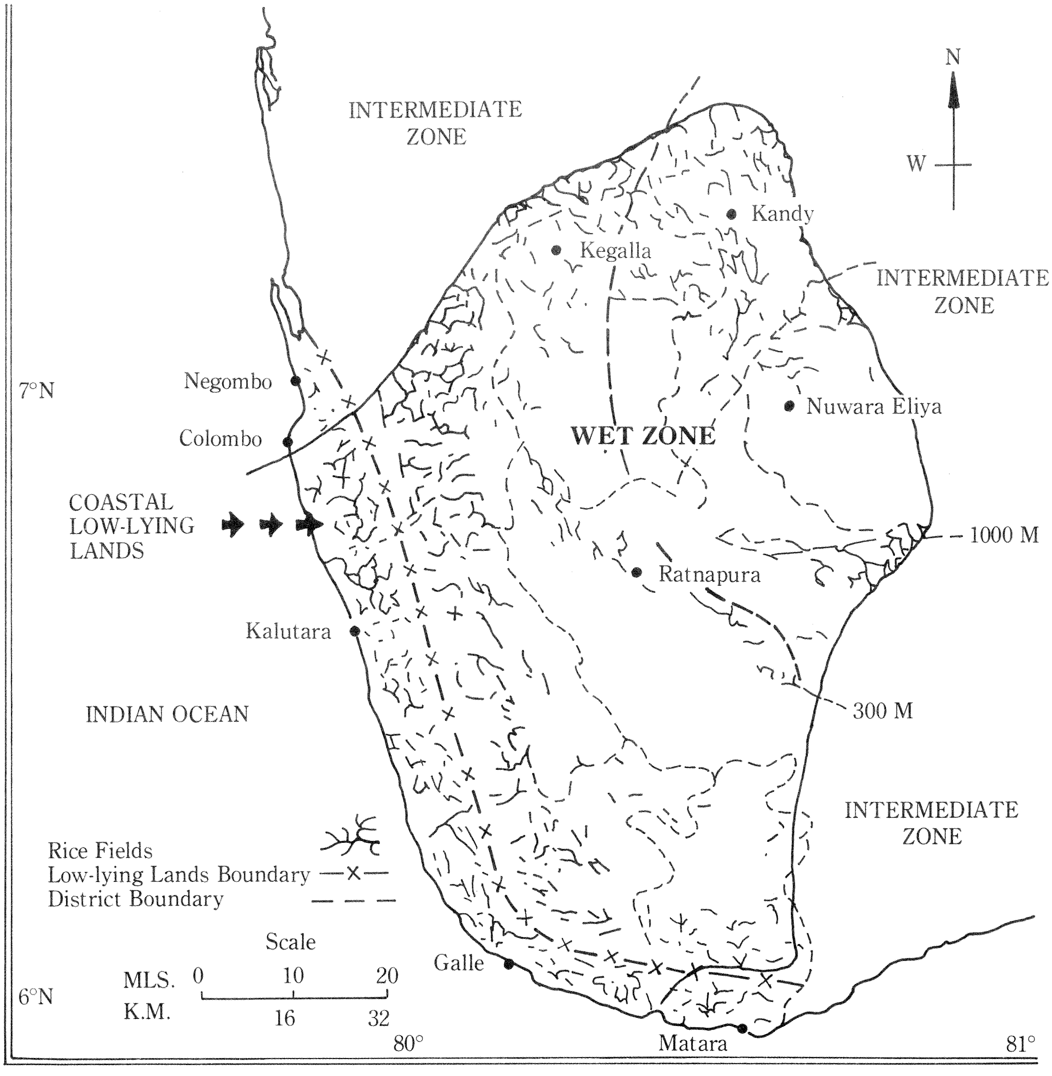

Fig. 1 Location of the Wet Zone coastal low-lying lands and distribution of rice fields.
Source: Adapted from BALASURIYA (1982).

Estimated extents of South-West coastal low-lying lands

Between the elevation 0.3 m (1 ft) above MSL and 1.5 m (5 ft) above MSL there are approximately 30,200 ha of low-lying, poorly drained, flood-prone Half Bog (Entisols and Inceptisols, including Sulfic Sub-Orders) and Bog soils (Histosols, mainly Hemists), together with 3,000 ha to 3,400 ha of mineral alluvial soils of variable drainage and texture (Entisols, with Sulfic Sub-Orders) and a total of 33,200 ha to 36,000 ha where presently rice is regularly or occasionally cultivated.

Below 0.3 m (1 ft) above MSL, mainly between 0.3 m (1 ft) above MSL and mean sea level, there are approximately 8,900 ha to 11,000 ha where, despite acute hydrologic and coastal salinity-related problems, a single, long-aged rice crop is cultivated in favorable years, hence, a total extent of about 42,000 ha of high risk and low productivity lands.

In addition, of about 28,900 ha of unutilized swamps, tidal marshes and grassland, approximately 50% could, with appropriate technology, be reclaimed and developed for rice cultivation.

Therefore, an overall total extent of about 56,450 ha to 61,450 ha are available for developing rice cultivation.

Land categorization for developing rice cultivation

The magnitude of the hydrologic and soil problems increases with decreasing elevations. Hence, the relatively least problematic lands are those above 0.6 m (2 ft) MSL, followed by lands between 0.6 m (2 ft) above MSL and mean sea level, while the most problematic ones are those below mean sea level. However, the recent experience from the Nilwala Ganga Flood Protection Scheme indicates that with appropriate engineering and hydrological measures lands between 0.3 m (1 ft) above MSL and 0.6 m (2 ft) above MSL, where previously a single long-aged rice crop was occasionally cultivated, could be double-cropped, hence, categorized with lands above 0.6 m (2 ft) above MSL. Therefore, in general, for developing rice cultivation the lands could be categorized into (a) Class I - above 0.3 m (1 ft) MSL, (b) Class II - between 0.3 m (1 ft) above MSL and mean sea level, (c) Class III - below mean sea level.

OUDSHOORN and DEGLOPPER (1969), DIMANTHA (1977), PANABOKKE (1977) and SILVA (1977) have reported on some aspects of reclamation, soils, flood and land systems and engineering in the South-West sector coastal low-lying lands. BALASURIYA (1982) studied the available rice agronomic data from the South-West Sector drainage and reclamation schemes, from 1971 to 1979, and discussed the potential and development strategies relevant to Land Class I.

Principal rice production constraints

1 Flooding

The nature of the monsoon rains, characterized by short periods of high intensity rains, causes sudden flooding of varying duration, flood height and frequency. Small elevational differences within the gently sloping or concave rice tracts result in significant differences in hydrology, which in turn, determine the nature of flooding and the physico-chemical conditions of the soil. Flooding usually occurs at the beginning of each season, May to June for *Yala* and October to November for *Maha*, when the rice crop is usually 2 to 7 weeks old. The crop is often subject to more than one flooding each season. Each flooding ranges in duration from a few hours to 7 to 10 days and the flood height rarely exceeds 1.5 m (5 ft) above field level. In general, rice crops are partially or totally damaged by flood 3 out of 5 years on lands above 0.6 m (2 ft) MSL, 4 out of 5 years between 0.6 m to 0.3 m (2 ft to 1 ft) above MSL and 5 out of 5 years below 0.3 m (1 ft) above MSL.

2 Poor drainage and water-logging

During rainy weather the removal of flood waters from low elevation lands is impeded owing to the rapid rise of groundwater to the soil surface, and even above, which prevents vertical drainage. For instance, in an area in the Nilwala Ganga Scheme, between mean sea level and 0.3 m (1 ft) above MSL, the water in a piezometer (1 m deep) rose from 7.5 cm to 10 cm above the soil water surface during heavy rains, thereby indicating a high hydraulic pressure from the ground aquifer. Furthermore, the weak seaward gradient drastically reduces horizontal or surface drainage. Consequently, during rainy weather the land gets quickly water-logged, with standing water of a few contimeters riding from 30 cm to 60 cm (1 ft to 2 ft) for periods ranging from a few days to even 2 to 3 months. Water-logging could also occur owing to blocked drainage pathways or restricted valley outlets. This condition is most serious on lands below 0.3 m (1 ft) above MSL. Water-logging interferes with cultural operations and aggravates soil reduction. Retarded root growth, and blackening of rice roots due to hydrogen sulfide, together with frequently associated "bronzing" or iron toxicity, are common features on severely water-logged soils. Moreover, in water-logged acid peaty soils toxicities from reduction products could occur too, namely hydrogen ion carbon dioxide, volatile organic acids, methane. In fact, it is frequently observed that poor tillering, yellowing and early senescence of lower leaves are associated with water-logged soils. Hence, drainage improvement, but with adequate care to prevent over-drainage and soil drying, is important for increasing rice production.

3 Coastal salinity

Along the South-West coast the tidal range is small with a maximum of 45 cm (spring tide) to 25 cm (neap tide). Nevertheless, in droughty weather the reduced river discharges and tidal movements at sea outfalls cause saline water intrusions into rice fields along coastal weterways and drainage pathways up to an elevation of 0.6 m (2 ft) above MSL. The high hydraulic conductivity of organic soils further aggravates this problem and fields at a considerable distance from waterways are affected, together with contamination of groundwater. Moreover, erratic rainfall at the beginning of cropping seasons frequently results in 1 to 5 weeks old rice seedlings being subject to high salinity levels, namely 2.5 mmho/cm to 4.5 mmho/cm at the stage when they are most susceptible. The actual salinity level depends on the distance from the sea outfall, land elevation and drought duration. During a severe drought in the coastal flood plain of the Nilwala Ganga the coastal salinity level of rice tract waterways was in the range of 2.5 mmh/cm to 4.5 mmho/cm, while that in the main river was 7.8 mmho/cm one kilometer from the sea outfall and 0.125 mmho/cm 5½ km upstream. DIMANTHA (1977) reported a conductivity value of 8.0 mmho/cm 29 km up the Bentota river. Hence, there are considerable differences in the magnitude of this problem both within and between rivers. This needs to be considered when designing coastal reclamation and drainage schemes aimed at rice production.

4 Inland salinity

Recent studies in areas where coastal salinity was eliminated, namely the Nilwala Ganga Scheme, showed that in submerged rice fields the salinity level was low, being less than 0.200 mmho/cm. However, during drought periods in non-submerged soils, particularly unripe organic soils, deep cracks appeared together with whitish salt deposits on the surface. Moreover, with the falling water table the conductivity of free water, in piezometers, sharply increased and peak values of 6.0 mmho/cm to 7.0 mmho/cm were obtained when the water table depth was over 45 cm below the soil surface. Conversely, in pyritic soils the strong acidity (pH below 3.5) of the shallow free water decreased with increasing depth of the water table and the pH rose to 6.5 to 7.0. The increased salinity and reduced acidity of groundwater with increasing depth may be explained by the presence of marine calcareous material in the deeper soil body, usually 75 cm to 1.25 m below the soil surface. Rains and consequent up-welling of groundwater through the calcareous material result in soil submergence and a rapid decline in salinity to a safe range of around 0.200 mmho/cm to 0.500 mmho/cm (Fig. 2).

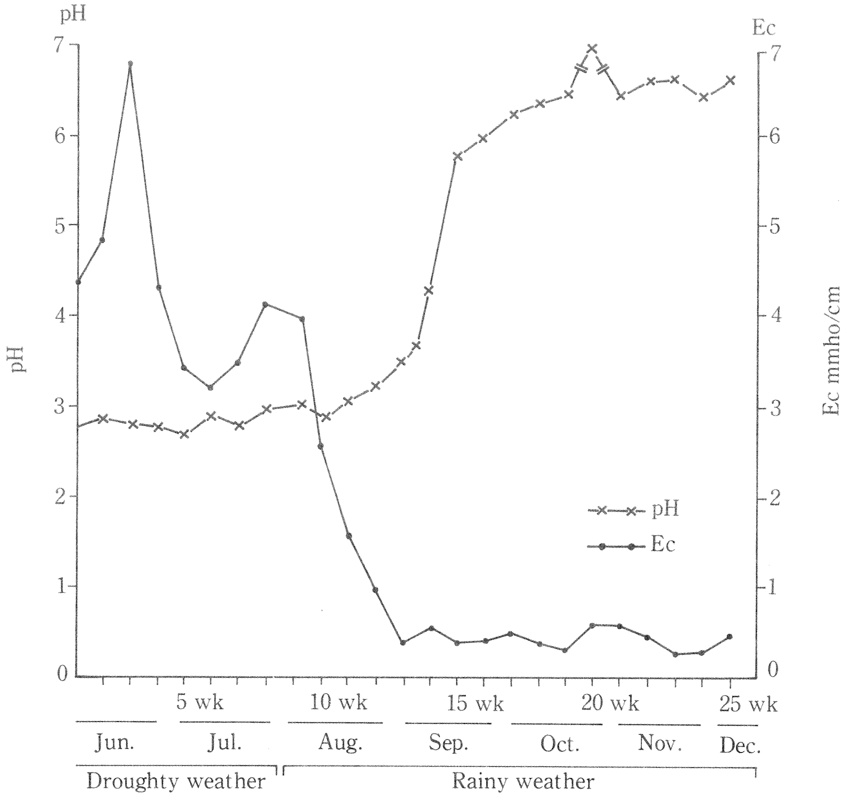

Fig. 2 Acidity and salinity conditions at Kiralakelle Reclamation Scheme (*Yala* 1983).

5 Acid sulfate soils

Recent studies in the Nilwala Ganga Scheme showed that during droughty weather, in some areas strong soil acidification occurred, with pHs in the range of 4.2 to 2.8 together with the appearance of orange yellowish Jarosite-like material on the soil surface. Moreover, in dry weather, with decreasing surface water and corresponding sharp increase in acidity, there was a slow but steady increase in salinity too. However, before threshold toxic salinity values were reached, namely 2.5 mmho/cm for seedlings and 4.0 mmho/cm for older crops, the pH dropped sharply below 3.5 bringing about lethal acid sulfate conditions. Hence, these data suggest that actual and/or old acid sulfate soils could be used for rice cultivation. On such soils, that are usually found below 0.6 m (2 ft) above MSL, owing to erratic rainfall, the rice crop, particularly the young crop (up to 5 weeks), is subject to the devastating effects of acid sulfate conditions, namely aluminium and iron toxicities, together with low phosphate availability. Hence, the death of rice in coastal areas during droughty weather, often attributed by farmers to "Kivula" (Sinhala), is in fact frequently due to a combination of injurious factors associated with soil acidification, salinity and water stress.

On coastal pyritic soils, despite the low elevation, the water level could drop to 1 m below the soil surface. Nevertheless, with rains the water level rises rapidly to re-submerge the fields and the high conductivity values fall sharply, usually within 1 to 2 weeks, to low levels around 0.110 mmho/cm to 0.500 mmho/cm and the pH rises too. However, the rise in pH from below 3.5 to a peak of around 7.5 and a stable range of pH 5.5 to 6.5 was slow and took 2 to 6 weeks, depending on the location. Since this phenomenon occurs during drought periods and clears up with the rains it could be termed "transitory acid sulfate conditions".

6 Water supply and rainfed rice cultivation

PANABOKKE (1980) included the entire South-West coastal low-lying lands in the Wet Zone, agro-ecological region WL4. However, the southern and northern extremities of this region receive a long term average annual rainfall of 1,955 mm to 2,032 mm, hence are in the Intermediate Rainfall Zone, while the central areas receive over 2,540 mm and are in the Wet Zone. This difference has important implications for agriculture, particularly for rainfed rice. A study of the long term rainfall data from the southern coastal area, namely Matara, revealed that only during two months each season, namely May, June (*Yala*) and October, November (*Maha*) or at most three months, does the rainfall satisfy a water requirement of 200 mm/month, the rest receiving between 48 mm to 168 mm/month. Moreover, although a 4 month rice crop, including land preparation, requires 1,240 mm water/crop (YOSHIDA, 1981), the average rainfall received each season is only 981 mm and 1,024 mm (Table 1).

In the low-lying lands, although in most years, many areas received around 1,270 mm

Table 1 Sri Lanka: monthly, seasonal and annual rainfall means in selected areas within the coastal low-lying lands - millimeters (1931 - 1960)

	Locations					
	Negombo	Colombo	Kalutara	Galle	Matara[1]	Mean
a) *Yala season*						
March	124	117	147	117	107	122
April	205	230	310	251	183	236
May	275	394	401	302	261	327
June	173	221	249	221	196	212
July	101	140	170	170	132	143
August	74	103	152	178	145	130
Seasonal (total)	952	1205	1429	1239	1024	1170
b) *Maha season*						
September	132	193	201	180	183	178
October	304	348	391	356	246	329
November	326	333	343	323	257	316
December	124	144	208	185	168	166
January	74	101	114	114	79	96
February	51	67	102	117	48	77
Seasonal (toatl)	1011	1186	1359	1275	981	1102
Annual average	1963	2391	2788	2514	2005	2332

Source: Sri Lanka, Department of Meteorology.
1 From: 1917 - 1955.

rainfall/season, nevertheless, in general, rainfed rice cultivation carries a high risk owing to frequent drought periods and the danger of developing transitory acid sulfate conditions and salinity.

7 Solar radiation

The solar radiation data from a high rainfall location, namely, Bombuwela (Kalutara district) and a lower rainfall location further South, namely, Labuduwa (Galle district), both within the coastal low-lying lands, are shown in Fig. 3. Although, the average annual rainfall at Bombuwela is 2,788 mm and Labuduwa is 2,514 mm, nevertheless, during the reproductive and ripening period of rice the solar radiation at both locations in *Yala* (June, July, August) and *Maha* (December, January) is over 324 cal/cm²/day and sufficient for yields of over 5 t/ha (YOSHIDA, 1981). Therefore, the present low rice yields of less than 1,590 kg/ha are not due to low solar radiation.

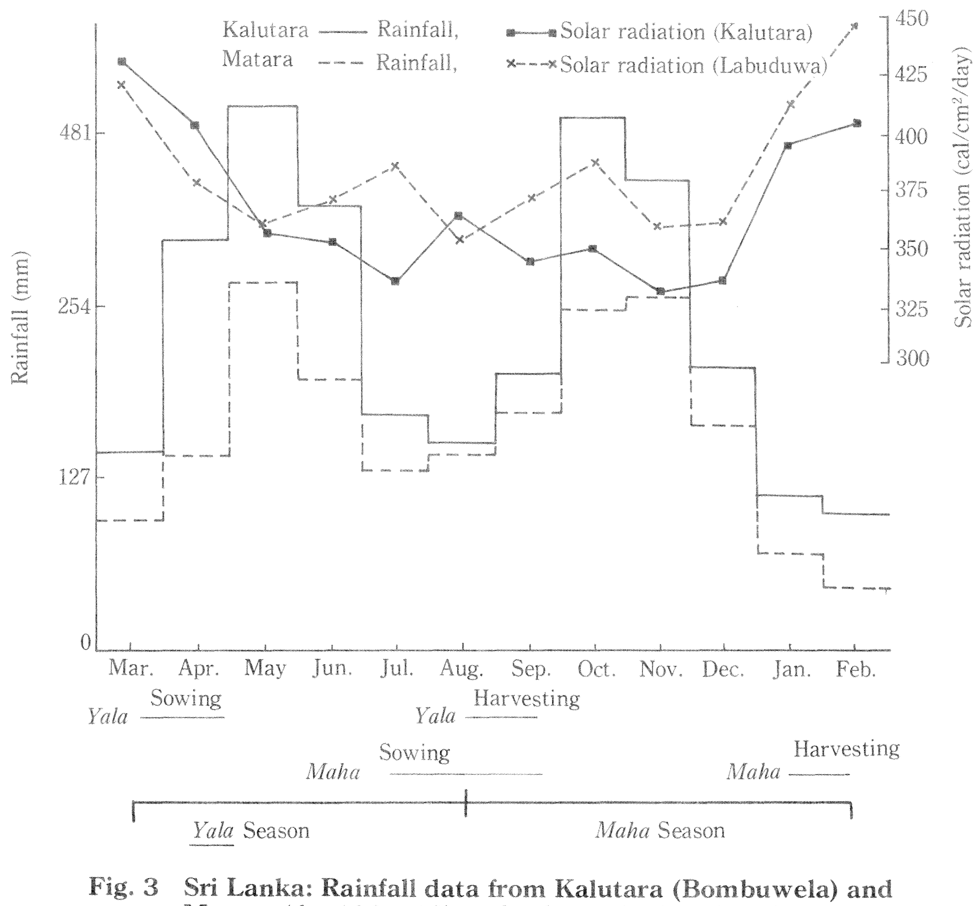

Fig. 3 Sri Lanka: Rainfall data from Kalutara (Bombuwela) and Matara (Av 1931-60) and solar radiation data from Bombuwela and Labuduwa (near Matara).

Outline of reclamation and development strategy

1 Flood control

With small rivers, improvements to flood plain internal drainage alone could be sufficient to ensure an acceptable level of flood protection. However, where heavy flood flows of large rivers are involved flood protection bunds of appropriate height and with an overtopping frequency of once in 10 years or more are required. However, complete exclusion of flood water is undesirable. In order to utilize flood flow silt, clay and nutrients in rice fields, which reduces dependence on expensive chemical fertilizer, and to allow the natural development of the flood plain, ideally, controlled flooding should be practiced. This could be achieved with flood control regulators on the bunds. These could also be used, together with river anicuts or diversions, for irrigation too.

2 Drainage

Improvements to the internal drainage system are necessary for rapid disposal of local rainfall, thereby reducing the duration and height of flooding and alleviating water-logging. However, over-draining should be avoided in order to prevent soil subsidence, transitory acid sulfate conditions and salinity. The construction of drainage control regulators across the main drainage channels would ensure both controlled drainage and, in dry weather, enable the heading-up of water to maintain a high water table.

3 Coastal salinity

The exclusion of tidal saline water during dry weather is essential, particularly during the first 6 weeks of the broadcast crop. Nevertheless, during dry spells, in the absence of fresh water irrigation, recourse to even tidal irrigation is necessary to prevent soil drying and the development of injurious soil conditions.

4 Control of soil acidification and inland salinity

The recent findings from the Nilwala Ganga Scheme indicate that the only practical remedy for preventing strong soil acidification, development of transitory acid sulfate conditions and inland salinity, is to ensure soil submergence and regular field flushing throughout the growth of the rice crop (BALASURIYA, 1984, 1985).

The application of lime to ameliorate the acidity is both expensive and impractical for small farmers, as the quantities required are large, vary from field to field and if a drought occurs, at the early stages of the crop, it would compound the salinity problem.

5 Irrigation

Entirely rainfed rice cultivation is a risky undertaking, owing to the highly unstable rainfall regime. Hence, irrigation is a priority requirement. Irrigation water could be obtained from nearby perennial rivers, springs, reservoirs and, in the last resort, even tidal irrigation. When using tidal irrigation, monitoring of the water quality is essential.

6 Crop management

On lands below 0.6 m (2 ft) above MSL, where pyritic soils are likely to be found, during inter-season dry weather the soils could dry out resulting in high salinity and acidification. Hence, ideally, prior to broadcasting the fields should be kept inundated for 3 to 4 weeks for leaching out the salinity and allowing the pH to rise. Dry seeding should be avoided. Although, presently broadcast seeding is the predominant method of crop establishment, nevertheless, transplanting with seedlings of 4 to 6 weeks merits consideration, as older sedlings are known to have higher tolerance to aluminium and iron toxicities, salinity and submergence. However, this would require irrigation.

BALASURIYA (1982) carried out studies on fertilizer application and varieties in coastal drainage and reclamation projects from 1971 to 1979 and reported the following, among others: On these oligotropic and mesotropic soils rice responded well to NPK fertilizer. Moreover, application of all three nutrients, as a basal dressing, namely 13 kg to 20 kg N, 40 kg P_2O_5, 40 kg k_2O/ha, resulted in higher seedling submergence tolerance than in unfertilized crops. Concentrated superphosphate (CSP) performed better than rock phosphate, with improved short- and medium-aged varieties, even on acidic soils. Seedling elongation was faster with CSP than with rock phosphate. The currently available old improved variety H_4 and new improved varieties, namely Bg and BW series, were capable of net grain yields[1] of 2,390 kg/ha to 3,186 kg/ha and 2,655 kg/ha to 3,720 kg/ha, respectively, at a rate of 46-58-58 kg/ha and 73-58-58 kg/ha N, P_2O_5, K_2O, respectively, amounting to a 50% to 100% and 66% to 133% increase with old improved and new improved varieties, respectively, over current yields.

The "Polder System" of reclamation

The differences in topography and hydrology within short distances result in a wide range of environmental diversity in a target area, which is best catered to using the "Polder System". In this system protection for floods and coastal salinity is achieved by constructing perimeter bunds with regulators which parcel the target area into a number of individual land units where hydrological conditions can be independently controlled. A distinct advantage of this system is that at the time of land preparation, sowing and harvesting, the water in a polder can be controlled independently of other polders. Thus, when localized rainstorms cause sudden inundation of some areas or when farmers delay to commence operations in a particular area, work could proceed in the unaffected areas independently of the affected areas. Furthermore, it has the advantage of minimal interference with the aquatic resource base, particularly inland fisheries.

Multiple resource development strategy

Owing to the small size of holdings, namely less than 0.4 ha, and with remote immediate prospects for consolidation into larger units, rice farming in the low-lying lands would continue, at least in the short term, to be a small farmer activity with minimal marketable surpluses. Hence, rice farming alone cannot meet the income requirement of farm families and alternate income support is needed. Moreover, a reserve of unutilized or underutilized family labor needs to be gainfully engaged too.

The coastal environment offers a rich resource base which includes: rice cultivation in the lowlands, perennial economic tree crops i.e. rubber, coconut, spice crops on highlands of low relief, fisheries, aquaculture, animal husbandry, horticulture and market gardening, fodder crops and commercial marsh sedges, i.e. *Eleocharis acutangula* Schult and *Cyperus haspen.* This diverse resource base provides an excellent opportunity for developing alternate income support. However, owing to the close linkages between the terrestrial and aquatic resource base, the use of pollution-producing chemicals and practices for rice cultivation, particularly pesticide application into paddy field water, should be strongly discouraged. The appropriate development model is an integrated development and management of the entire multiple resource base, with the focus on rice cultivation.

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[1]Note: Net yield/ha = Gross yield (experiment plot yield adjusted to a hectare) minus 15% for bunds and 10% for non-experimental conditions in farmers fields. i.e. gross yield - 25%.

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Discussion

Perez, A.T. (ADB): Thank you for your interesting presentation on the application of technology for the reclamation and development of new farmlands in Sri Lanka. Could you indicate the maximum potential area of rice lands involved in this reclamation project.

Answer: The extent of land within the low-lying land region is approximately 40,000 ha of which double cropping involves 20,000 ha with inconsistent results and 10,000 ha are single-cropped.

Soetjipto Partohardjono (Indonesia): In reclaiming the coastal swampy land you recommend the "Polder Design" to develop individual units of land for rice growing. What factors should be considered to define a unit of polder. From what source of fresh water will you irrigate the polders? During the dry season do you encounter salinity problems?

Answer: The size of the polder would depend on the landform, hydrological conditions and elevation. It should be of manageable size. The lands within a polder should be at the same elevation. There are several perennial rivers in the area. Water from these rivers could be used with careful monitoring of the salinity level. There is the problem of coastal salinity during dry weather, as I mentioned. However due to the low tidal range in the area it is not generally a serious problem above 0.6 m MSL. In fact, in the Nilwala Ganga Project during a severe drought the salinity level in field channels ranged from 2.5 mmho/cm to 4.5 mmho/cm. There are variations from area to area which require careful monitoring.

Dat Van Tran (FAO): What is the development cost of land reclamation?

Answer: I can not give you any precise information in this regard. The flood protection and reclamation schemes are not only designed to improve the rice-growing environment but also to protect property and roads from flood damage to improve accessibility. The cost would have to take into consideration these benefits too. For instance the Nilwala Ganga flood protection and reclamation project is a multipurpose project with numerous social benefits. I assume that the cost for Stage I would be approximately Rupee 445 million and for Stage II Rupee 950 million. The rice area involved covers approximately 6,500 hectares.