DOUBLE CROPPING OF RICE IN SRI LANKA

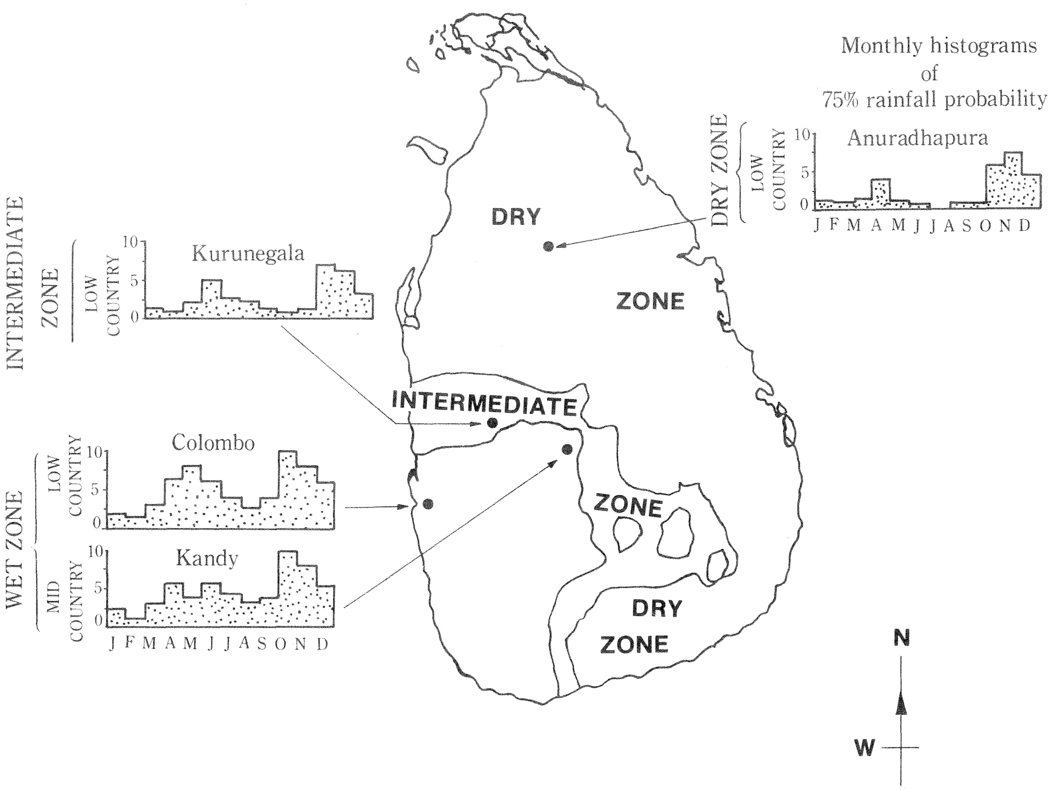
Indrajith BALASURIYA*

ABSTRACT

At the present time, inadequate and unstable water supplies and pest and disease control are the major constraints for rice double cropping in Sri Lanka. The development of low cost, low risk and convenient technology, together with low environment damage, for small rice farmers requires greater attention. Technology which requires considerable financial commitment by small farmers requires in addition an economic evaluation too. Therefore, at this juncture a multiprofessional approach is appropriate for further development of rice double cropping in Sri Lanka involving plant breeders, agronomists, engineers, ecologists and even economists.

Introduction

The geographical location of Sri Lanka, between latitudes 6°N and 10°N of the equator,



Map 1 The main agro-climatic zones and rainfall distribution in representative rice-growing areas.

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

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 and Mid-Country areas, up to an elevation of 1,000 m above Mean Sea Level (MSL). However, in Up Country areas (above 1,000 m MSL), which constitute approximately 4% of the total rice area, low air and water temperatures from November to January restrict rice cropping to a part of the year. Hence, 96% of the country's 720,000 ha of rice land could be double-cropped provided there is adequate water.

Annual rainfall distribution over most parts of the island follows a well-defined bi-modal pattern. Consequently, there is a well-expressed seasonality with two rice-growing seasons, namely, the South-West Monsoon season or *Yala* season from March to August and the major North-East Monsoon season or *Maha* season, from September to February.

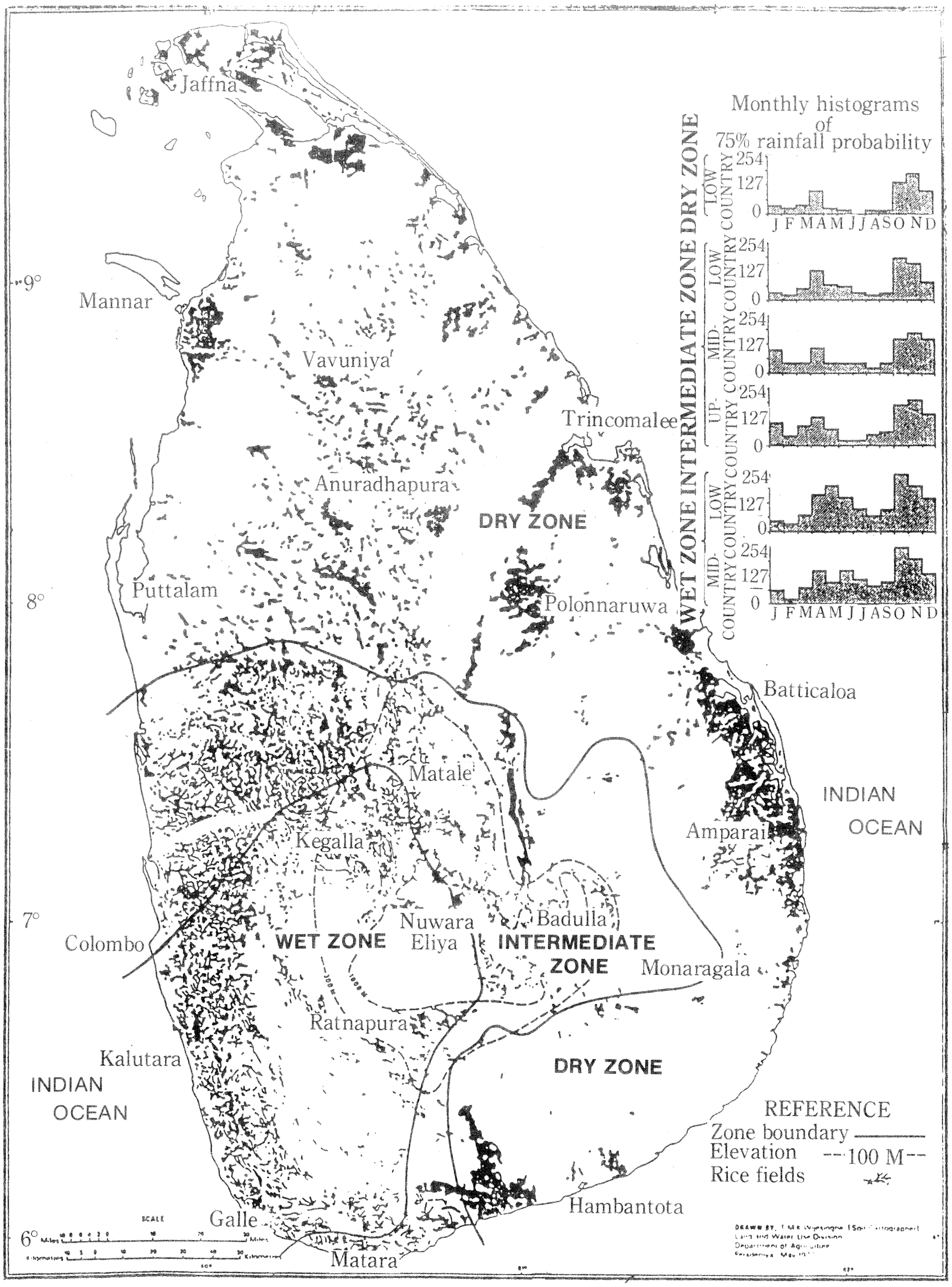
On the basis of climate, soils and vegetation, Sri Lanka could be broadly divided into three major agro-climatic zones, namely (a) Dry Zone (b) Intermediate Zone (c) Wet Zone, with an average annual rainfall of 2,270 mm to 1,904 mm (50 ins to 75 ins), 1,905 mm to 2,540 mm (75 ins to 100 ins) and over 2,540 mm (100 ins) respectively (Maps 1 and 2). The Dry and Intermediate Zones receive the major part of the annual rainfall during the *Maha* season when a rainfed rice crop could be raised with some irrigation. However, in the following drier *Yala* season a second rice crop could only be grown under fully irrigated conditions. On the other hand, the Wet Zone receives adequate rainfall, in most years, in both *Maha* and *Yala* seasons for rainfed, lowland rice double cropping. However, since nearly 72% of the country's rice lands are in the Dry and Intermediate Zones, with around 28% in the Wet Zone, the country's overall rice double cropping is heavily influenced by the cropping intensity in the Dry and Intermediate Zones, which in turn pivots on the availability of irrigation water for raising a second crop during the dry *Yala* season.

Rice cultivation - A historical sketch

Rice is said to have been introduced to India around 2500BC and to Sri Lanka about 1000BC (HUKE, 1976). However, information is lacking on rice cultivation technology in Sri Lanka prior to 500BC.

History records that around 500BC settlers from India, generally believed to be from North India and of Aryan stock, settled in the drier North-Central plain called the Rajarata and also in the southern plains called Ruhunu-rata, both areas within the Dry Zone of the island (Map 1) (MENDIS, 1938). These early settlers, together with successive later migrations from India, brought with them a knowledge of irrigated lowland rice cultivation and the art of "Tank" or reservoir construction. Moreover, in the Dry Zone the hydrology and soils of the valley bottoms, namely Tropaqualfs or Low Humic Gleys, had good chemical and physical properties which made them well-suited to irrigated rice cultivation.

The topography of the Dry Zone with its undulating landform and broad valleys, together with lands of high relief and rocky erosion remnants (Monadnocks), was well-suited to the construction of earth dams spanning highground for storing water. Into these storage reservoirs (Tanks) water was diverted from rivers and streams or dams were built across seasonal rivers to head up and store their water. Many of these tanks had massive dams such as the Kaudulla tank constructed in the 3rd Century AD with a dam length of 8 kilometers enclosing 1.28 meter cubes (104,000 ac.ft) of water. In addition, there were hundreds of small low head tanks constructed along streams at different intervals. Consequently, spanning a period of about 1,700 years, from 500BC to 1200AD, a highly developed and organized hydraulic civilization evolved in the Dry Zone, centered around irrigated lowland rice cultivation and supported by an elaborate system of interlinked tanks and a vast canal network (BROHIER, 1934). In this context it is interesting to recall a statement of the ancient King Parakrama Bahu I (1153-1186 AD) who ruled in the North-Central Dry Zone, "It is my chief duty to gather up an abundance of grain .... In the Kingdrom that belongs to me there are many paddylands that



Map 2 Distribution of rice fields in Sri Lanka.
Source: PANABOKKE 1977, with modification.

are watered chiefly by the rain clouds; but the fields that depend upon a perpetual supply of water from rivers and tanks (reservoirs) are very few in number ...... In a country such as this not even a drop of water that is obtained by rain should be allowed to flow into the sea without benefiting man." The ancients undoubtedly knew how scarce, critical and precious water was in the Dry Zone. On its storage and efficient management depended not only rice production but survival itself. This is true even today.

The ancient population, variously estimated between 2 to 3 million and 20 million but more likely around 6 million, was concentrated in the Dry Zone where the solar radiation, temperature and soils were favorable for rice production. Under these conditions a single rice crop in the wet *Maha* season, with adequate irrigation, could have been sufficient to feed the population. During the dry *Yala* season fallow, nutrients were replenished from natural release and the organic manure from cattle grazing. The fallow also reduced insect populations and disease build-up. In addition, during the *Maha* season unirrigated highlands were used in "Chena" or shifting cultivation for growing non-rice cereals, pulses, vegetables and oil crops for supplementing the diet. Thus, an ecological, resource and nutritionally balanced food crop agriculture prevailed. However, this system cannot satisfy the food security requirements of today's 16 million people.

The ancient Dry Zone civilization collapsed in the 13th century AD and then began a population drift to the Western and South-Western parts of the island, that is, the Wet Zone. This new environment was not suited to the conventional irrigation systems of the Dry Zone and also had higher rainfall. Therefore, irrigated lowland rice gave way to more hazardous rainfed lowland rice cultivation. In this region, during periods of heavy rainfall, flooding and water-logging of rice fields were common. Moreover, the rice soils, being mainly hydromorphic associates or alluvial derivatives of Ultisols (Aquults), together with Inceptisols, Entisols and Histosols, were chemically and physically less favorable for rice cultivation than those of the Dry Zone. However, rice double cropping under rainfed conditions was possible, if required. Rice yields remained around 1,300 kg/ha up to the 1950s.

Recent rice production strategies

1 Development policy

World War I highlighted the vulnerability of over-dependence on food imports, particularly rice, to feed the population. This factor, together with high population pressure in the Wet Zone, set in motion in the 1930s a policy of establishing in the sparsely populated Dry Zone government-sponsored, food production-oriented, colonization or land settlement schemes. The main objectives of this policy were to relieve population pressure in the Wet Zone, increase food production, particularly rice, generate employment and regional development and establish a class of prosperous peasant farmers. A further reason was the nostalgia for the hydraulic civilization of the past and a desire to recreate it.

The outbreak of World War II and the disruption of the country's imported food supplies gave added impetus to the policy of Dry Zone colonization. Moreover, ever since Independence, in 1948, all governments set the goal of self-sufficiency in rice as a high national priority. Since these settlements were centered around a tank or reservoir, irrigated lowland rice became the main economic activity. It was also envisaged that rice double cropping would be practiced utilizing the reservoir water.

In pursuit of this policy of land settlement and increasing rice production, through rice double cropping in the Dry Zone, massive investments of public resources and foreign aid were made in this region, over a period of 3 to 4 decades, in irrigation, agriculture, social infrastructure and production incentives to rice farmers. On the other hand, alternative investment areas, such as the plantation sector, manufacturing industries and even rice production in the Wet Zone, received much less attention.

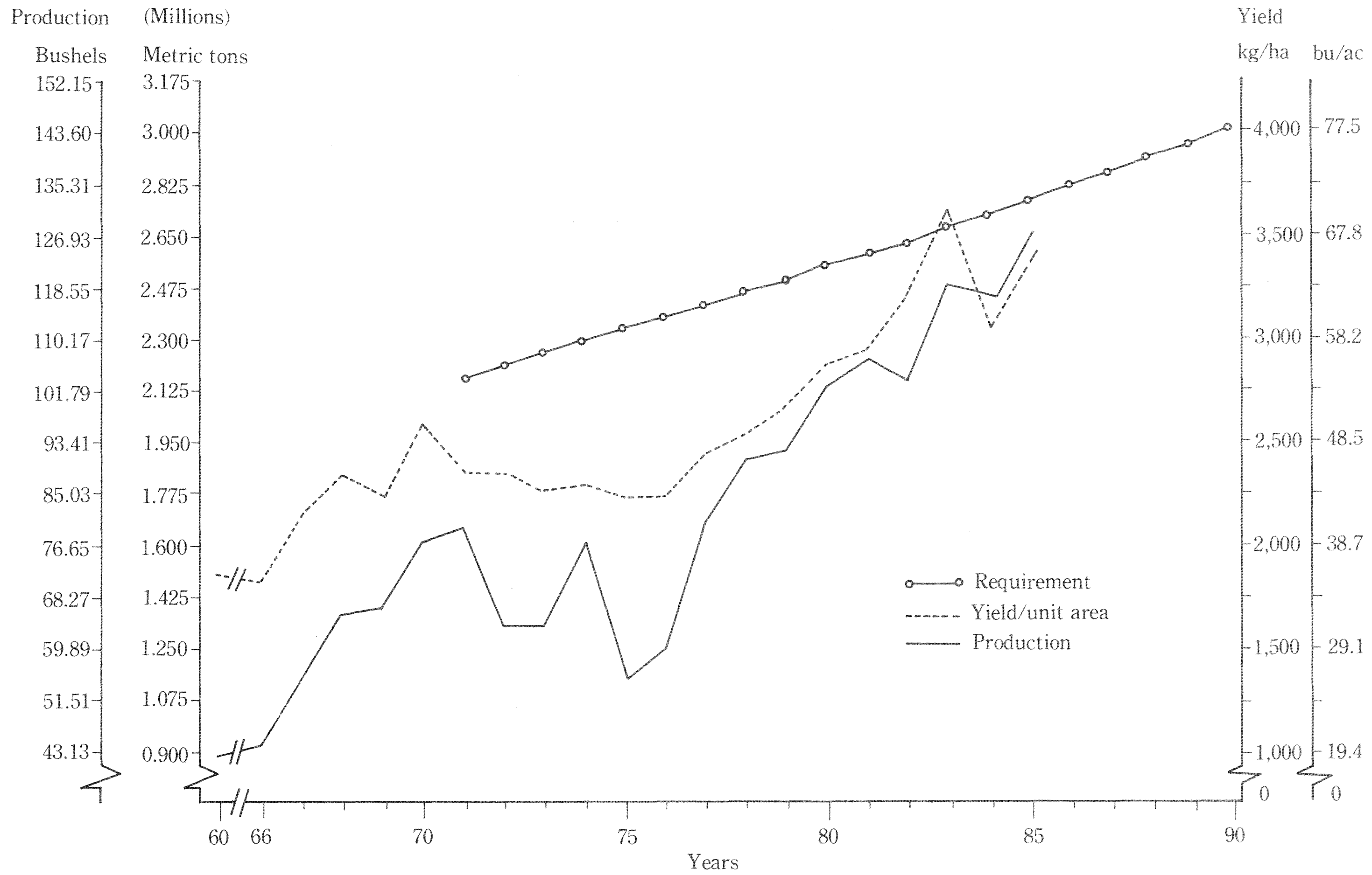


Fig. 1 Sri Lanka: Annual paddy production, estimated paddy requirement and yield.

2 Technological support

Rice research and extension programs were strengthened and oriented to the needs of the Dry Zone. In particular, a strong rice breeding program was initiated in the early 1950s for developing improved photoperiod-insensitive, rice blast (*P. oryzae*) resistant, 120–135 day (medium-aged) varieties which could be used for rice double cropping. Traditionally, photoperiod-sensitive long-aged varieties played a key role in rice production. In 1958 the well known medium-aged, photoperiod-insensitive variety H_4, with resistance to rice blast and a yield potential of 8,251 kg/ha (YAMADA, 1959), was developed and released. Also for minor irrigation schemes, with less than 80 ha of rice lands, and where irrigation water was uncertain, improved 3 and 3½ months photoperiod-insensitive varieties were developed, such as H_{10} and H_7. These old improved varieties (OIVS), which could be grown in the Wet Zone too, together with others and associated fertilizer and management practices increased rice production from 625,000 metric tons in the mid 1950s to 1.65 million metric tons in 1971. The release of even higher-yielding Bg series of varieties in the early 1970s with yield potentials between 7,735 kg/ha–10,300 kg/ha gave further impetus to the rice production program. The average annual productivity (i.e. yield per hectare) increased from less than 1,547 kg/ha in the mid-1950s to 3,610 kg/ha in 1984, an increase of over 100%, and production surged forward, particularly in the period 1978–1985, and rose to 2.66 million metric tons in 1985 (Fig. 1). The asweddumized extent (i.e. land available for cultivation) increased from 390,000 ha in the 1950s to 720,000 ha in 1985 (Fig. 2). This brought the country to virtual self-sufficiency in rice. However, a serious cause for concern is the low cropping intensity (i.e. double rice cropping), particularly in the Dry Zone (Fig. 3).

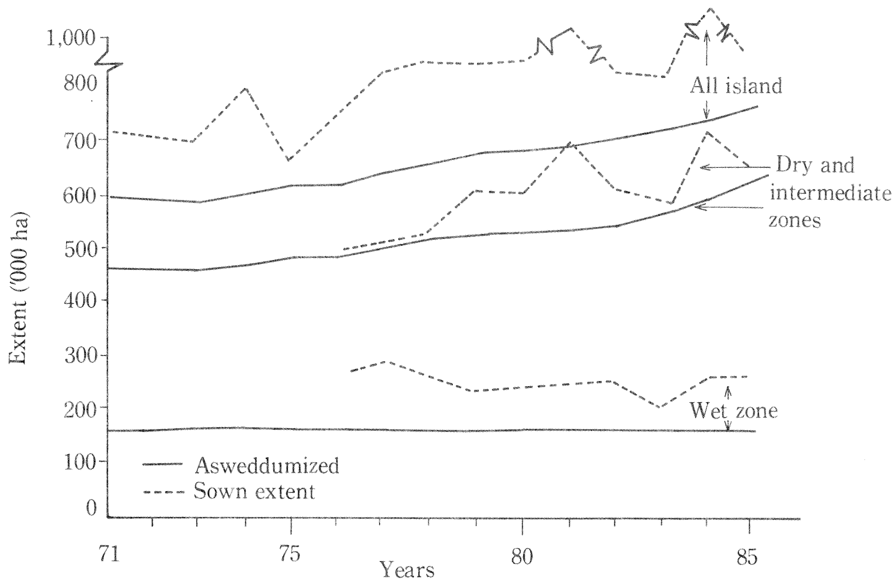


Fig. 2 Sri Lanka, asweddumized and sown extents.

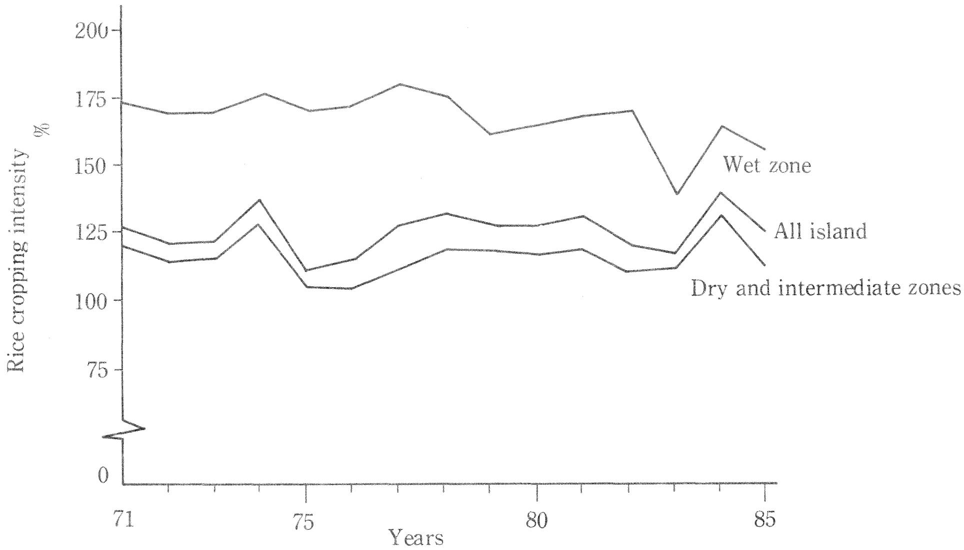


Fig. 3 Sri Lanka: Rice cropping intensity 1971 - 1985.

Some views on development investment vs rice production

Two views expressed in relation to investment are noteworthy. In the Agricultural Plan of 1958, MOAF (1958) quoted Professor KALDOR as having said "Large scale schemes for the development of food production by means of irrigation schemes, etc. are bound to be very wasteful in comparison with large scale schemes for the development of plantation agriculture ...... In the long run the employment problem can only be successfully tackled through industrialization and large scale construction projects associated with industrial development than by agricultural colonization schemes", (ALWIS, 1982). WYATT (1966), an FAO expert on the Mahaweli Ganga Project had a different view. He stated "..... agriculture will remain the basis of the national economy ...... The ultimate development of agriculture in the country is tied to development in the Dry Zone. The ultimate development of agriculture in the Dry Zone depends entirely on the amount of water available for irrigation".

Despite these divergent views and the issue of low returns to capital, for instance the return to capital from Gal Oya Project is said to be 3% (Central Bank, 1969), Dry Zone colonization schemes have made an impressive impact on paddy prodution. In 1945 the Dry Zone accounted for about 200,000 metric tons of paddy, 42% of the rice area and the yield was 1,500 kg/ha. By 1985 paddy production increased to 1.6 million metric tons (8 fold increase), the rice area to 62% and the average yield was 3,600 kg/ha (140% increase) with some areas giving over 5,200 kg/ha. However, the share of total population increased slowly, from 24% of the total population in 1945 to 28% in 1980. The most disappointing and negative feature was the low cropping intensity i.e. $\frac{\text{Annual sown extent}}{\text{Annual asweddumized extent}} \times 100 = \text{Cropping intensity (\%)}$. In the period 1976 - 1985, for instance, the average cropping intensity for the Dry Zone as a whole was only 117% compared with 167% for the Wet Zone (Fig. 3). The low cropping intensity, has had adverse effects on employment generation, family labor utilization and incomes. Poverty still prevails in the Dry Zone, even in major colonization schemes.

In terms of paddy production, there is little doubt that the Dry Zone with 3/5 of the total annual production plays the dominant role for achieving self-sufficiency in rice. For instance, with a requirement of 175 kg paddy/capita/year (BALASURIYA, 1982; EDIRISINGHE and POLEMAN, 1976). and a projected mid-year population of 15.6 million in 1985, the paddy production required for self-sufficiency was 2,782 million metric tons of paddy. Hence, the 1985 total annual paddy production of 2.661 million metric tons (127,552,000 bushels), 60% of which was from the Dry Zone, brought the country to 96% self-sufficiency in rice, excluding seed paddy requirements.

Some aspects of rice double cropping in Sri Lanka

In this section greater attention will be given to the Dry and Intermediate (D and I) rainfall zones, as they together contain 72% of the rice area, dominate paddy production and carry the largest potential for rice double cropping.

1 All island

The island's overall average annual cropping intensity in the past 15 years (1971 - 1985) was 126% with a range of 112% to 140%, the main reason being the low intensity of rice double cropping in the Dry Zone.

2 The Dry and Intermediate Zones

Reliable information is not available on rice double cropping during ancient times. However, in the recent past the rice cropping systems in the D and I Zones during the wet *Maha* season were: (1) Lowland rice, with supplementary irrigation, in major and minor irrigation schemes, (2) Rainfed upland rice in "Chenas", and (3) Rainfed, dry-seeded rice in the northern and eastern regions, called "Manawari" cultivation.

Traditionally, with the onset of the monsoon rains in late September or October the rainfed upland rice was broadcast-sown. Next, after an assessment of the available water in the tank farmers by mutual consent agreed on the extent to be cultivated. The lowland rice was broadcast-sown in November-December. Village varieties of medium (120-135 days) or short (105 days) duration were grown, the actual choice of variety depending on the availability of irrigation water and the rainfall pattern in the area. Also, the use of medium duration varieties appears to be an adaptation to unstable environments, as the longer vegetative phase enables better adaptation to unpredictable stress, than short duration varieties. The village varieties had good early vigor and weed competitive ability but were prone to disease and lodging when fertilized, particularly with nitrogen. Their yields were low, being less than 1,500 kg/ha. The *Maha* crop was harvested in the period February-March, depending on the cropping system. In general, no rice crop was grown in the dry *Yala* season. However, in favorable rainfall years a 90 day or 105 day (3 or 3½ months) "Heenati type" variety was sown. However, there was no assurance that a second crop could be grown. Hence, rice single cropping was the predominant practice.

With improvement in the supply of irrigation water more regular *Yala* cropping was possible and gradually rice double cropping was firmly established, especially in the major irrigation schemes. In the meantime, the development and release of OIVs, particularly H_4 and H_{105} (medium-aged) and H_7 (short-aged) in the late 1950s, together with the new improved varieties (NIVs) of the Bg series made rice double cropping economically attractive to farmers. Presently, the NIVs have spread to 85% of the irrigated rice areas in the D and I Zones, and OIVs to the major part of the rainfed areas.

In spite of the heavy investment in irrigation and settlements and impressive increases in paddy production, the annual cropping intensity in the D and I Zones in the period 1971-1985 was 117%, with a range of 105%-132%. Therefore, in the D and I Zones, as a whole, there is an average annual unutilized rice double cropping potential equivalent to 83% of the total extent of 570,000 ha. This indicates that in many areas of the Dry Zone only a single rice crop is grown, despite the availability of land for double cropping. Inadequate water supplies is the key critical factor for low cropping intensities.

With 269,000 ha in the major irrigation schemes (1984) and an average annual cropping intensity of 140% (WICKRAMASEKARA, 1982), there is an annual average of 161,000 ha available for double cropping. Moreover, an additional estimated 167,000 ha out of the 176,000 ha under minor irrigation too would be available, thus, a total of 328,000 ha per annum. The non-cultivation of these lands, at an average yield of 3,800 kg/ha, amounts to a loss of 1.2 million metric tons of paddy per annum. This loss of production potential is the major cause of rural poverty and poor returns to irrigation investments in the Dry Zone and the country's delayed self-sufficiency in rice. Hence, the scarcity of water for rice cultivation, which bedevilled the ancients has emerged as the most critical constraint for developing rice double cropping in Sri Lanka and the development of the Dry Zone itself.

In the D and I Zones there are about 125,000 ha of rainfed "Manawari" and upland rice areas where no double cropping is possible owing to the lack of irrigation water.

3 Wet Zone

The Wet Zone (WZ) receives rain from both South-West and North-East monsoons, which coincide with the *Yala* and *Maha* rice cropping seasons. This enables two lowland rice crops to be cultivated each year, with some supplementary irrigation from river anicuts (weirs) and springs. Hence, rice double cropping is the usual practice. In the 15 year period, 1971-1985, the average annual rice cropping intensity was 167%, with a range of 180% (1977) to 140% (1983). The wide variation in annual double cropping is clear evidence of an unstable water supply for predominantly rainfed rice. For instance, the cropping intensity in the period 1971 to 1978 was 176% while that from 1979 to 1985 was 162%; a decline of 14% mainly due to poor rainfall conditions (Fig. 3). In fact, in *Yala* 1986, the South-West monsoon failed.

In spite of the Wet Zone being a relatively small area, about a quarter of the island, there is a considerable variation in the total annual rainfall within the rice-growing areas of the region. For instance, the average annual rainfall in Kalutara on the coast (Low-Country) is 2,768 mm, while that of Kandy (Mid-Country) is 2,021 mm, a difference of 27%. In fact, the Wet Zone has nine agro-ecological regions compared with only four for the Dry Zone (PANABOKKE and HUSSAN, 1980), a good indication of the climatic diversity in the Wet Zone. Moreover, poor distribution of the seasonal rainfall makes much of the seasonal rainfall ineffective. Short spells of heavy rains cause sudden flooding of rice fields, frequently followed by periods of droughty weather lasting 2 to 3 weeks. The strong winds and high temperature (27°C-28°C) cause fields to quickly run dry. This results in profuse weed growth and serious yield loss if the water stress occurs during the reproductive and heading stages of the crop, as it frequently does. On the other hand, unexpected rains at heading (anthesis) results in a high percentage of unfilled or partially filled grains. In the Low-Country Wet Zone (up to 300 meters, above Mean Sea Leve (MSL) the average yield is 2,700 kg/ha, mainly due to the unstable water regime) whereas in the Mid-Country Wet Zone (between 300m and 1,000 above MSL), where supplementary irrigation is available, the yield is around 3,500 kg/ha. While it is not possible to prevent rain, the adverse effects of drought could be relatively easily remedied by providing irrigation from the numerous perennial rivers and streams in the Wet Zone. In fact, surveys have shown the existence of 2,970 village tanks in the Wet Zone, with the largest number in the Galle and Matara districts, (Economic Review, 1986). However, a large majority is now virtually abandoned.

The need for stabilizing the water supply for rice cultivation in the Low-Country Wet Zone has been largely over-looked and is a serious constraint for stabilizing double rice cropping at an annual cropping intensity around 180% and increasing productivity.

The rainfall, hydrology and soils of the Wet Zone present unfavorable conditions of varying magnitude. These in turn affect the cropping intensity and productivity, the main constraints being flash flooding, poor drainage, intermittent drying of fields, iron toxicity and low phosphate availability. In addition, within the belt of coastal low-lying lands, generally in areas below 0.1 m (2 ft) above MSL during dry weather, coastal salinity, inland salinity and transitory acid sulfate conditions, the latter condition often confused with coastal salinity by farmers as it occurs during dry weather (BALASURIYA, 1984), hamper rice cultivation.

In the Wet Zone the present average seasonal yield is about 50% lower than in the Dry Zone. Nevertheless, with a high level of double cropping the annual productivity is around 5.200 kg/ha/year, whereas, in the Dry Zone, with a low cropping intensity, in the major part (83%) only a single rice crop is cultivated annually, hence the productivity is only around 3,900 kg/ha/year. Increasing the double cropping area in the Dry Zone carries the potential for increasing pest and disease problems. This could not only decrease yields but further increase the high cost of chemical pest control, create environment pollution problems and even health hazards, since rural people use water from irrigation and drainage canals for domestic purposes. In fact, the heavy chemical spraying of the rice crop by farmers during the outbreak of ragged stunt in the Hambantota District in *Yala* 1984 is a case in point, although on a small scale. Hence, only time will tell whether in the long run the productivity/ha/year in the Dry Zone would be significantly higher than in the Wet Zone and what would be the consequences of extensive rice double cropping on the environment.

Some efforts and prospects for increasing rice double cropping

The largest potential and greatest need for increasing rice double cropping is in the major and minor irrigation schemes in the Dry and Intermediate Zones. This has drawn the attention of policy makers and promoted rice research since the 1960s. The critical limiting factor was water and not land. Many studies have revealed that the main constraints for increasing double cropping in irrigated areas of the Dry Zone are erratic rainfall, deficiencies in design, construction and maintenance of irrigation systems and excess and inequity in the use of irrigation water by farmers. The emphasis was on developing technologies for conserving water in *Maha* for raising a second dry season rice crop in *Yala*, headworks and on-field water management and greater farmer participation in water management through users' organizations.

In the 1960s the Special Projects Model was tried where productivity and cropping intensity were to be improved by channelling inputs at the required time and in proper quantities. It was found that this required a heavy commitment by officials and was not a viable system for extension. Moreover, lack of assured irrigation for double cropping was a major constraint. (JOGARATNAM, 1971).

The findings of the cropping systems research in the Walagambahu Minor Tank Project, from 1978-1982, indicated that improved short-aged varieties (i.e. 3 and 3½ months) when dry-seeded in September or October, prior to the main *Maha* rains, rather than the customary sowing in November-December could save sufficient water in the tank for raising a second short-aged rice crop in *Yala* or less water-consuming non-rice crops. However, extending this to other areas and the Tank Irrigation Modernization Project (TIMP) did not prove popular among farmers, the main reasons being the high cost of dry tractor tillage, uneven plant stand from erratic early season rains, high cost of controlling weeds; all together the high costs and risk were unacceptable to small farmers. Moreover, this technique required short-aged varieties with high drought resistance and weed competitive ability, as in case of low early rainfall there would be insufficient water in the tank for irrigation. The view was also expressed that early sowing of short-aged varieties would expose the crop to low solar radiation and limit yields to around 2,300 kg/ha and also that medium-aged varieties with a longer vegetative phase would be better able to recover from stress conditions than short-aged varieties (SENADHIRA, 1981).

In the five major tank TIMP project (1978) the emphasis was on modernization and minimizing distribution losses in the conveyance system, such as cementing distributory channels, and providing equitable water issues to farmers on a seven day rotation. It appears that despite an expenditure of US$9.5 million the project was not considered a major success for rehabilitating and improving major irrigation schemes (Ministry of Lands, 1983; ABEYSEKERA, 1985).

In the Gal Oaya Rehabilitation Project (1979) improving water management for rice through increased farmer participation in organizing water supplies and distribution at the tertiary or field level was tried. This approach is being extended to other major schemes.

The experience from the initiatives mentioned, and others, together with the statement that in only 2 out of 5 years could favorable weather be expected for rice cropping in the Dry Zone (Research Highlights, 1982) suggests that there was no practical or acceptable alternative for increasing rice double cropping in the Dry Zone other than providing assured irrigation water. The Mahaweli Division Project together with its acceleration, is meant to provide assured irrigation to 100,000 ha of existing rice lands and 268,000 ha of new lands. Thus, the problem of low rice cropping intensity in the irrigated areas of the Dry Zone would be a thing of the past.

In many Dry Zone irrigation schemes well-drained soils in the upper reaches are used for rice cultivation. These soils require large amounts of water to maintain submergence. Moreover, this water seeps into the lower fields causing water-logging and salinity. These well-drained lands should be utilized for low water consumption non-rice crops and the water saved utilized to extend rice double cropping.

In the Intermediate Zone, for instance Kurunegala District, low rainfall in the *Yala* season frequently results in the death of rice crops on higher slopes of valleys and considerable damage even in valley bottoms too. The development and release of the 2½ months variety Bg 750 for cultivation in the valley bottoms and lower slopes has reduced the risk of crop failure. The higher slopes can be better utilized for non-rice crops.

In the Wet Zone coastal low-lying lands, between the elevation 0.3 m (1 ft) and 1.5 m (5 ft) above MSL, there are approximately 33,000 ha–36,000 ha of lands where rice double cropping is practiced but owing to unfavorable hydrologic conditions often only a single crop is grown. In addition, below 0.3 m (1 ft) above MSL, but mainly between 0.3 m and mean sea level, there are about 8,900 ha–11,000 ha where a single long-aged crop is grown owing to flooding and water-logging thus a total of 42,000 ha–47,000 ha could be double-cropped with appropriate reclamation systems, namely, the "Polder System", flood control or controlled flooding, improved drainage, coastal salinity control, prevention of acid–sulfate conditions and inland salinity and irrigation during dry weather .

Sri Lankan rice breeders are burdened with maintaining and increasing paddy production in stable environments where the rice crop is threatened by a multitude of pests and diseases. Hence, it would be unrealistic to expect breeders to combine high yield, adequate resistance to serious insect pests and virus, fungal and bacterial diseases and good grain quality with resistance or tolerance to all the physical environment-related stresses, toxicities and deficiencies. For instance, for many years breeders have not been able to replace single cropping with long-aged varieties with double cropping in flood-prone, poorly drained lands of the Wet Zone. However, in the Nilwala Ganga Flood Protection Scheme, by applying an engineering solution to the problem of flooding and drainage, rice double cropping was introduced for the first time in *Yala* 1986. Also, it would be quite appropriate to provide irrigation water in dry weather in low-lying coastal areas to prevent soil drying and development of inland salinity and acid sulfate conditions, rather than use a plant breeding solution. Therefore, it would be advisable to extend the multidisciplinary approach to rice breeding to a multiprofessional approach for rice double cropping and seek engineering solutions too, such as for increasing rice double cropping in the coastal low-lying lands. This would enable rice breeders to concentrate on combating pests and diseases, improving grain quality and raising yields for which genetic improvement is the only practical solution.

The development of low cost, and low risk technology would be advantageous, in the context of small farmers, when extending rice double cropping into unstable areas. The use of rice straw for recycling potassium and nitrogen and azolla for biological nitrogen are two such examples. The development of pest- and disease-resistant varieties with good weed competitive ability, and high nitrogen and phosphate efficiency is highly desirable too.

It is the speaker's view, that at the present time, inadequate and unstable water supplies and pest and disease control are the major constraints for rice double cropping in Sri Lanka. For instance, it was found that the brown planthopper (BPH) resistant variety Bg 379-2 when grown for five consecutive seasons became susceptible to this pest (Research Highlights No. 20). This may require several BPH-resistant varieties for growing in different seasons. The development of low cost, low risk and convenient technology, together with low environment damage, for small rice farmers requires greater attention. Technology which requires considerable financial commitment by small farmers requires in addition an economic evaluation too. Therefore, at this juncture a multiprofessional approach is appropriate for further development of rice double cropping in Sri Lanka involving plant breeders, agronomists, engineers, ecologists and even economists.

References

1) ABEYSEKARA, W.A.T. (1985): Improvement of irrigation system performance in Sri Lanka: The experience of Mahavilachchiya settlement. PhD Thesis, Cornell University, Ithaca, New York, USA. 295 pp.
2) ALWIS, J. (1982): Water management in major irrigation schemes. *In*: Wimaladharma (ed.). Land Settlement Experiences In Sri Lanka. Pub. Karunaratne and Sons Ltd., Colombo, Sri Lanka.
3) BALASURIYA, I (1982): Development of coastal poorly drained lands for rice cultivation in the Wet Zone of Sri Lanka. M.S. Thesis. Cornell University, Ithaca, New York, USA. 303 pp.
4) BALASURIYA, I. (1984): Kiralakelle drainage and reclamation scheme: Salinity and acidity conditions, *Yala* 1983 and Detection of transitory acid sulphate conditions. Department of Agriculture, Sri Lanka. (Unpublished).
5) BROHIER, R. L. (1934): Ancient irrigation works in Ceylon. Part I. II & III. Government Press, Ceylon, Sri Lanka.
6) Economic Review (Feb.) (1986): Village irrigation. People's Bank Pub. Sri Lanka. p. 3-15.
7) EDIRISINGHE, N., and POLEMAN, T. T. (1976): Implications of government intervention in the rice economy of Sri Lanka. Cornell International Agriculture. Mimeograph 48. NY State College of Agric. and Life Sci., Cornell Univ., Ithaca, New York, U.S.A. 106 pp.
8) HUKE, R. (1976): Geography and climate of rice. *In*: International Rice Research Institute. Climate and Rice. Philippines. p. 31-50.
9) JOGARATNAM, T. (1971): A survey of nine colonization schemes in Sri Lanka. Peradeniya: University of Sri Lanka.
10) MENDIS, G. C. (1938): The Early History of Ceylon. Calcutta. Y.M.C.A.
11) MOAF (1958): Agriculture Plan, First Report, Ministry Planning Committee, Ministry of Agriculture and Food, Colombo, Sri Lanka.
12) Ministry of Lands and Land Development (1983): Resource development, 1978-1982. Colombo, Sri Lanka.
13) PANABOKKE, C.R., and HUSSAN, N. (1980): Application of agrometeorology to some aspects of rice research in Sri Lanka. Proc. Symp. on the Agrometeorology of the Rice Crop. The International Rice Research Institute, Los Banos, Philippines. p. 115-120.
14) Research Highlights (1982): Number 8. Mimeograph. Department of Agriculture, Sri Lanka.

15) Research Highlights (1984): Number 20. Mimeograph. Department of Agriculture, Sri Lanka.
16) SENADHIRA, D. (1981): *Research Highlights,* Number 6. Mimeograph. Department of Agriculture, Sri Lanka.
17) WICKRAMASEKARA, P. (1982): Aspects of labor use in paddy cultivation in land settlement schemes. *In*: WIMALADHARMA (ed.). Land Settlement Experiences In Sri Lanka. Pub. Karunaratne and Sons Ltd., Colombo, Sri Lanka.
18) WYATT, W.R.M. (1966): A note on the axiom of water utilization in the Dry Zone of Ceylon. *In*: ABEYGUNAWARDANA (ed.). Research and Production of Rice in Ceylon. Ceylon Association for the Advancement of Science, Colombo.
19) YAMADA, N. (1959): Analysis of the yield potential of the indica hybrid, H-4. *Tropical Agriculturist,* **115,** 173-178.