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RESEARCH ARTICLE

Adaptation to the vulnerability of paddy cultivation to climate change based on seasonal rainfall characteristics

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Abstract: This study was aimed at identifying adaptation measures to the vulnerability of paddy cultivation in the Dry and Intermediate Zones of Sri Lanka, based on rainfall. The spatial distribution of the onset time of rains, the length of the Yala and the Maha seasons and the number of dry weeks within seasons were determined using weekly rainfall data from 36 rainfall stations in the Dry and Intermediate Zones. Based on the seasonal rainfall characteristics, the cropping calendars for rice crops for each agro-ecological region (AER) were prepared. This study discloses a high spatial variability of the onset time of both the Yala and Maha seasons. Many AERs in the Dry Zone and some AERs in the Intermediate Zone do not have a distinct Yala season. The Yala rains in the Dry Zone are highly variable and the most probable length of the season may not exceed four weeks from the onset time. During the Maha season, there is enough rain water for paddy cultivation. The proposed cropping calendars can be used as a tool in farming activities from the land preparation to harvesting. Such information could assist to reduce the amount of irrigation water required and the frequency of water issued from the tanks in the respective regions without a wide margin of errors. It can also be used as a decision support tool in planning rainfed upland agricultural systems as well. The identification of dry periods within a season is necessary for the farmers to be aware and adapt to recent advanced technologies to reduce the water use for rice cultivation. Periodical checking and revision of the cropping calendars with future climate predictions are recommended.

Keywords: Climate change, cropping calendar, Maha season, seasonal characteristics, vulnerability, Yala season.

INTRODUCTION

Climate change is a global challenge and a serious threat requiring urgent response from all sectors. The potential and widespread effects of climate change on both humans and the environment makes it an important concern for the agricultural sector. The Intergovernmental Panel on Climate Change (IPCC, 2007) has identified South Asia as having the highest proportion of 'highly vulnerable' sectors in the Asia sub-regions. These include food, biodiversity, water, coastal ecosystems, human health and land degradation. Climate change affects all aspects of climate, making rainfall less predictable, changing the characteristics of the seasons, and increasing the likelihood or the severity of extreme events such as floods and droughts. In Sri Lanka agriculture is the most vulnerable sector to droughts.

Rice is the most important food crop occupying nearly 29 % of the total agricultural land in Sri Lanka and the cultivation accounts for the major part of the livelihood activities of the peasant agricultural sector. The gross total extent of paddy lands including the paddy lands of the North and East cultivated during both the Yala and Maha seasons in 2009 was nearly 980,000 ha. Rice is cultivated as a wetland crop in almost all the agro-ecological regions of the island below the elevations of 1,200 m MSL. It is grown under more diverse environmental conditions than any other food crop in Sri Lanka (Panabokke & Punyawardena, 2000). If the water conditions are appropriate, almost all kinds of soils could be used for rice cultivation (Panabokke, 1996). The rice lands are distributed in three main production systems: major irrigation schemes 41.6 %, minor irrigation schemes 24.3 % and rainfed schemes 34.1 % (Survey Department, 2007).

The high variability of rainfall due to climate change will adversely affect some agro-ecological regions, and hence affect the rice production- especially rainfed paddy cultivation comprising over 30 % of all rice paddies in

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the country. The major rice growing areas are in the Dry and Intermediate Zones. The Dry Zone, where nearly 70 % of the paddy is cultivated, is already showing an increasing number of consecutive dry days due to rainfall variability. Although about two thirds of the paddy is cultivated under irrigation, crop losses due to drought and shortage of irrigation water are of frequent occurrence. The Dry and Intermediate Zones are the most vulnerable to drought, with the districts of Jaffna, Killinochchi, Batticaloa, Polonnaruwa, Anuradhapura and Kurunegala having the highest probability of experiencing drought. The growth and yield of the paddy grown in these regions are largely determined by the variability of rainfall either positive or negative anomaly. This may cause serious socioeconomic impacts and imperil the future food security of the country (Ministry of Environment, 2011). Previous studies have clearly shown that paddy cultivation is highly vulnerable to climate change. Crop failures due to weather aberrations, viz. delayed onset of rains, early withdrawal of effective rains, and the occurrence of different degrees of drought at different stages of crop growth are common in these regions.

The implementation of adaptive measures will greatly help to reduce the adverse impacts of climate change and the farmers will be ready to cope with uncertainties brought about by climate change. They will be prepared to deal with the changes in precipitation and hydrology, temperature, the length of growing season and the frequency of extreme weather, which are all associated with climate change.

Therefore, it is important to identify the seasonal rainfall characteristics in the Dry and Intermediate Zones and change the cropping calendar in each agro-ecological region as an adaptation measure to respond to the vulnerability of paddy cultivation to climate change.

METHODOLOGY

Study area

Figure 1 presents the agro-ecological regions (1a) (Punyawardena *et al*., 2003) and the major rice growing areas of Sri Lanka (1b). Among the three main climatic zones, namely, Wet, Intermediate and Dry, the major rice tracts are concentrated in the Dry and the Intermediate Zones. Although Figure 1b suggests that a considerable extent of rice lands are spread across the Wet Zone, the onset of seasonal rains in this region does not make significant impacts on the rice cultivation calendar owing to the availability of phreatic water throughout the region. Meanwhile, recent studies have clearly shown that farmers in the Wet Zone are weaning away from rice cultivation due to various physical and socio-economic reasons (Kendaragama & Bandara, 2000) in spite of its climatological conduciveness for rice cultivation in both seasons (Chithranayana *et al*., 2004). Therefore, this study limited its scope to the Dry and Intermediate Zones of Sri Lanka where the onset of rains in both the Yala and Maha seasons would have a significant effect on the rice cultivation calendars in the respective regions and consequently the national rice production.

Data summary

The weekly rainfall data collected from 36 stations scattered throughout the Dry and Intermediate Zones were selected for the study (Figure 2). In selecting these rainfall stations, emphasis was given to locations having long time series of data recorded during most recent times with a fair spatial coverage across all agro-ecological regions in both the Dry and Intermediate Zones. The periods between March to August and September to February were considered as the effective periods of the Yala and Maha seasons, respectively. Consequently, any standard week after the standard week No. 9 and 34 for the Yala and Maha seasons that satisfied the requirement of onset criteria given below, were chosen as the start of the respective seasons.

Determination of the onset and withdrawal of seasonal rains and mapping

If any consecutive three week period had a cumulative weekly rainfall of 20 mm or more in each week after a pre-specified week (week No. 9 and 34 for the Yala and Maha seasons, respectively) then, the first week of the said consecutive period was chosen as the onset of the seasonal rains. However, if the preceding week of the series had received a cumulative rainfall of 10 mm or more, then it was considered as the onset of the seasonal rains taking into consideration the fact that 10 mm of cumulative rainfall is adequate to soak the soil for land preparation activities. Meanwhile, if any consecutive three week period had a week with less than 20 mm of cumulative rainfall, but bounded on either side by 20 mm or more, then the first week of the said period was chosen as the start of the seasonal rains. This relaxation was highly applicable to the Yala season where a true onset of seasonal rains is not easily discernible. However, it was considered that the season is interrupted or the seasonal rains are withdrawn, if the cumulative weekly rainfall was below 10 mm for two weeks in a row. The growing season was considered as the period between the onset week and the withdrawal week. Any week within a season having less than 10 mm

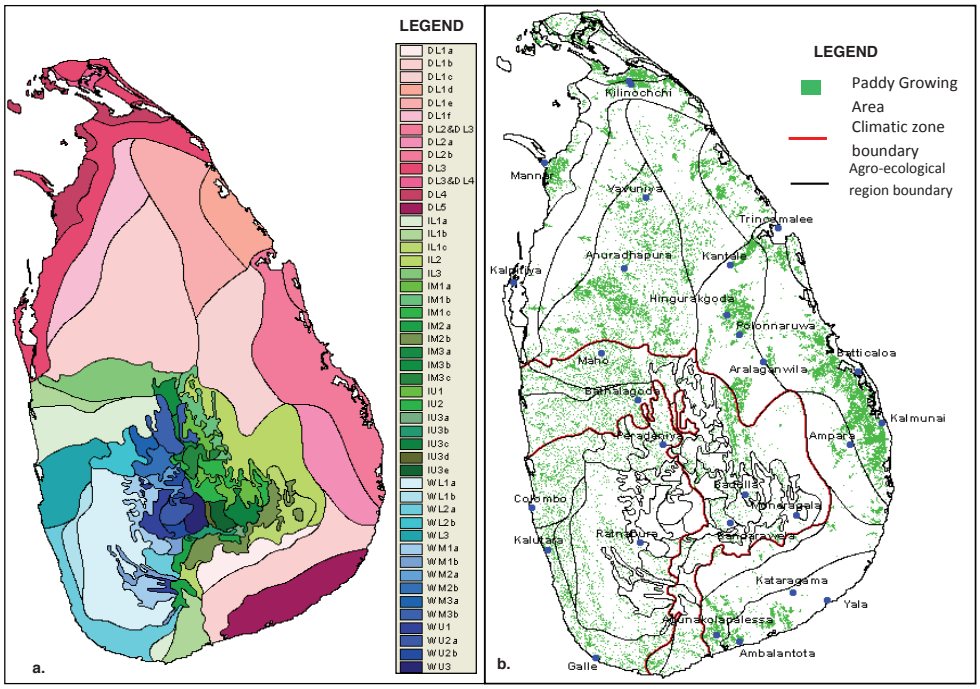

Figure 1: Agro-ecological map (a) and major rice growing regions in Sri Lanka (b)

of cumulative rainfall was considered as a dry week. Based on the above criteria, surfaces depicting the spatial distribution of the onset and the length of the growing season of each season were developed for the Dry and Intermediate Zones using ArcView GIS Software. Each surface was superimposed with the Dry and Intermediate Zones of the agro-ecological region map of Sri Lanka (Punyawardena *et al*., 2003) to ascertain the spatial relationship of the onset and the length of growing period of each season with the agro-ecology of the major rice growing regions of Sri Lanka.

Preparation of cropping calendar

The new cropping calendars for rice were prepared for each agro-ecological region based on the above seasonal characteristics. Most farmers in Sri Lanka use short duration (3 ½ months) rice varieties for both the Yala and Maha seasons. Therefore, the cropping calendars were prepared considering the short duration (3 ½ months) rice crop.

RESULTS AND DISCUSSION

Onset of the Yala season

This study reveals that the onset of the Yala season across the Dry and Intermediate Zones of Sri Lanka generally varies among standard week numbers 12 to 14, a period between 19th March to 2nd April. However, some agro-ecological regions (AERs) in the Dry and

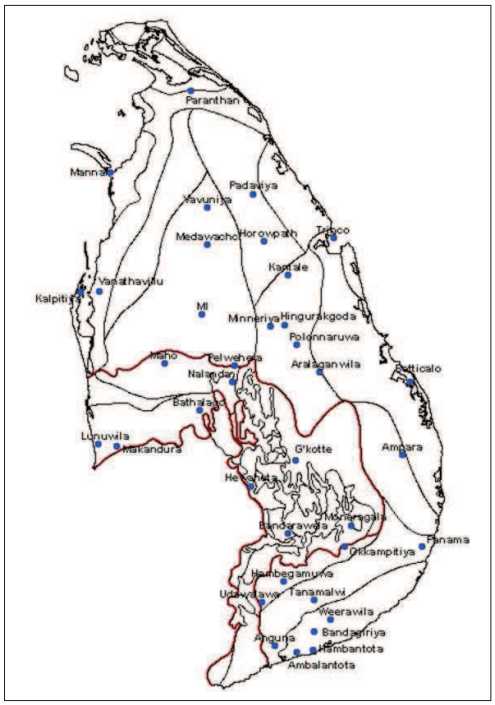

Figure 2: Selected rainguage stations for the study

Intermediate Zones do not have a distinct Yala season and has only a few weeks of rains, which just fulfills the requirements of the definition of the onset criteria used in this study. These regions include DL2a, DL2b AERs in the Digamadulla area, DL3, DL4, DL1c, DL1b (northern part), DL1e AERs of the Wanni region and DL5, DL1b (southeastern Dry Zone) in the Ruhuna area.

Figure 3a shows the spatial distribution of the onset time of the Yala season in the Dry and Intermediate Zones of Sri Lanka. It is clear that apart from an area in the IL1a AER, which is neighbouring the WM3a and WM3b AERs in the central highlands of the Wet Zone, in all other areas in the Low Country Intermediate Zone of the western half of Sri Lanka, the Yala season commences in the standard week 13, a period starting from 26th March onwards. However, the aforesaid area in the IL1a region, mainly in the eastern part of the Kurunegala District commences its Yala rains in the 12th week (19th March onwards). In fact, the most productive paddy tracts of the Kurunegala District are located in this region including the experimental fields of Rice Research and Development Institute (RRDI) of Sri Lanka. Meanwhile, in the IL2 AER in the eastern part of the Low Country Intermediate Zone, the Yala rains commences in the 14th week (2nd April onwards). However, these rains last only for a few weeks and hardly support any kind of cropping. All the other AERs of the Intermediate Zone located in the mid and up country regions begin to receive their expected Yala rains by standard week number 13, a period from the last week of March (Figure 3a).

The onset of the Yala season in the Dry Zone generally delays by one or two weeks than in the Intermediate Zone. However, in most parts of the Dry Zone of Sri Lanka the Yala rains commence by the first week of April (standard week number 14). In DL1a region of the Dry Zone the Yala season commences two weeks prior to the other areas of the Dry Zone (Figure 3a). This area stretches as a strip sandwiched between DL1b AER of the southern Dry Zone and, foothills of southeastern edge of the central hills and IL1c AER. Despite being able to identify the start of the Yala rains by the first week of April in the eastern and southeastern parts of the Dry Zone, the continuation of the rains to support a crop growth during the season cannot be guaranteed due to well established climatological reasons.

Onset of the Maha season

The spatial distribution of the onset of Maha rains in the Dry and Intermediate Zones of Sri Lanka is shown in Figure 3b. Unlike in the Yala season, the onset of seasonal rains in major rice growing regions of Sri Lanka ranges from standard week number 37 to 41, a period from 10th September to 8th October with a five-week span. The earliest onset of the Maha rains in the standard week number 37, 10th September onwards is recorded in IL1a region in the Low Country Intermediate Zone along with most of IU regions. The other parts of the Low Country Intermediate Zone, namely IL1b, IL1c, western part of the IL2 region and all IM regions begin to experience effective Maha rains a week later, a period from 17th September onwards. The rest of the IL2 region that adjoins the Dry Zone along with the IL3 region commence the Maha rains by the 39th week, 24th September onwards.

Even though it is customary to presume that the onset of the Maha season rains occur only after early October in the Dry Zone, some regions such as DL1a region, southern part of the DL1b region and a part of the DL1c region that neighbours IL2 region begin to experience effective Maha rains from 24th September onwards (standard week 34). Meanwhile, the rest of the Dry Zone receives its effective Maha rains between standard weeks 40 and 41, October 1st and 8th, respectively (Figure 3b). The late start of the Maha rains (standard week 41) occurs in the northern, northwestern and southeastern parts of the Dry Zone including the entire DL5 regions. The Rajarata region (area between Deduru oya and Mahaweli river) of the Dry Zone along with the northern part of the DL2b region begins to receive Maha rains on 1st October, the conventionally accepted onset time. In fact, this is the area where Sri Lankan hydraulic civilization was most pronounced with cascades of tanks during ancient times. Nevertheless, within this region a lens-shaped strip of area starting from the meeting point of the Dry, Wet and Intermediate Zones in the Matale District towards the northeastern direction up to Kantale is discernible where the onset of the season is delayed by a week (Figure 3b).

Length of the Yala season

Under average conditions the length of the growing season is useful in determining the crop cycle duration and the cropping calendars. Figure 4a shows the spatial distribution of the length of the Yala season. It clearly shows that many AERs in the Dry Zone and some AERs in the Intermediate Zone do not have a distinct Yala season. The length of the Yala season in the Dry and Intermediate Zones ranges from 1 to 22 weeks. The length of the Yala season increases from northeast to southwest due to the southwest monsoon wind direction.

The longest Yala season, more than 17 weeks, is recorded in the eastern part of IL1a in the Low Country

Intermediate Zone along with the IU2 in the Up Country Intermediate Zone. The western and southern parts of the IL1a region and IM3c region have a 12 − 16 week long Yala season. However, the Mid Country Intermediate Zone exhibits less variability in the growing periods. All AERs in the Mid Country Intermediate Zone except IM3c region, all AERs in the Up Country Intermediate Zone except IU2 region, IL1b and the southwestern part of IL1c regions in the Low Country Intermediate Zone have 8 – 11 week long

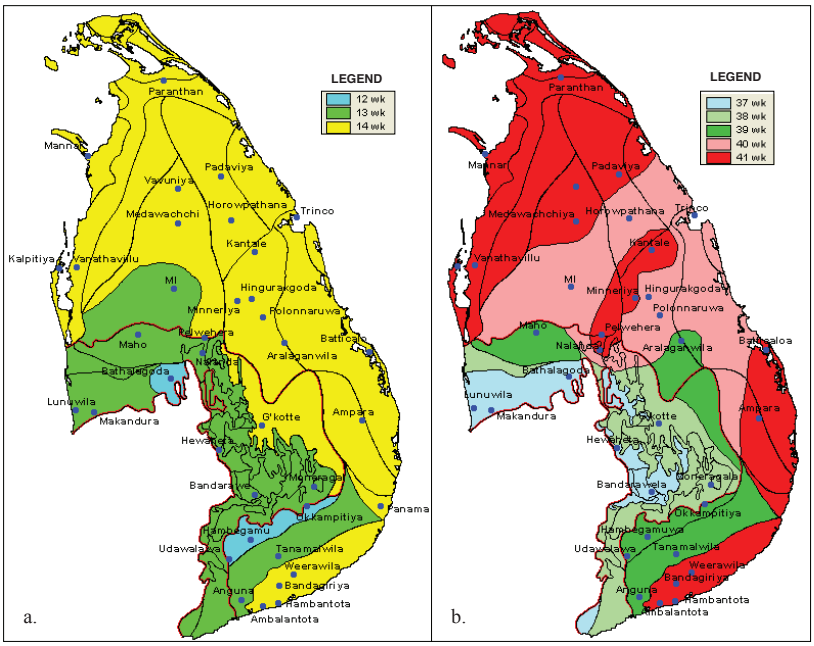

Figure 3: Spatial distribution of the onset time of Yala season (a) and Maha season (b) in the Dry and Intermediate Zones of Sri Lanka.

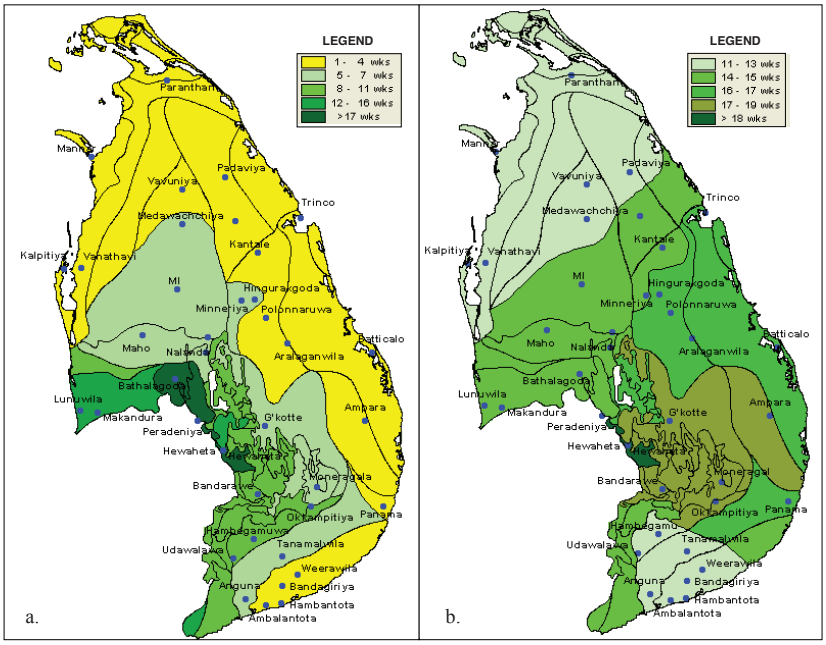

Figure 4: Length of the Yala season (a) and the Maha season (b) in the Dry and Intermediate Zones of Sri Lanka

Yala seasons; the rest of the IL1c region along with the IL2 and IL3 display a Yala season of 5 − 7 weeks.

The Yala rains in the Dry Zone are highly variable and most probably the length of the season may not exceed four weeks from the onset time except some parts of the DL1b region and the western part of the DL1c region. DL1b region and the western part of the DL1c region exhibit a length of 5 – 7 weeks due to the impact of the southwest monsoon. Therefore, any type of cultivation during the Yala season in the Dry Zone and some parts of the Intermediate Zone needs irrigation for both paddy lands and other highlands. If irrigation water is not guaranteed, high yields are not assured due to the high risk involved.

Length of the Maha season

The Maha season is the main growing season in Sri Lanka. Figure 4b shows the spatial distribution

Table 1: Number of dry weeks in different agro-ecological regions within the Yala and Maha seasons

Agro-ecological region	Maha		Yala	
	Season length (wks)	No. of dry weeks	Season length (wks)	No. of dry weeks
IU1	16 − 17	0	8 − 11	0
IU2	18 − 22	0	17 − 22	1
IU3a	17 − 19	0	8 − 11	0
IU3b	17 − 19	0	8 − 11	0
IU3c	17 − 19	0	8 − 11	0
IU3d	17 − 19	0	8 − 11	0
IU3e	17 − 19	0	8 − 11	0
IM1a	17 – 19	0	8 − 11	0
IM1b	14 − 17	0	8 − 11	0
IM1c	17 − 19	0	8 − 11	0
IM2a	14 − 15	0	8 − 11	0
IM2b	14 − 19	0	5 − 11	0
IM3a	16 − 17	0	8 − 11	0
IM3b	14 − 15	0	5 − 7	0
IM3c	17 − 19	0	12 − 16	0
IL1a	14 − 15	0 − 2	12 − 18	0 − 2
IL1b	14 − 15	0	8 − 11	0 − 1
IL1c	17 − 19	0	5 − 7	0
IL2	17 − 22	2	5 − 7	0
IL3	14 − 15	0	5 − 7	0
DL1a	12 − 18	0	8 − 11	0 − 1
DL1b	11 − 15	0 − 1	1 − 7	0 − 1
DL1c	14 − 16	0 − 2	1 − 7	0 − 2
DL1d	14 − 16	0	1 − 4	0 − 2
DL1e	12 − 15	0	1 − 4	0 − 2
DL1f	11 − 13	0	1 − 4	0
DL2a	17 − 19	0	1 − 7	1
DL2b	15 − 18	0 − 1	1 − 4	1
DL3	11 − 13	0 − 1	1 − 4	0
DL4	11 − 13	0	1 − 4	0
DL5	11 − 14	1 − 2	1 − 4	0 − 3

of the lengths of the Maha season for the Dry and Intermediate Zones. The length of the Maha season in the Dry and Intermediate Zones ranges from 11 – 22 weeks. The map shows a decrease in the duration of the season towards the north and south. An increase from southwest towards northeast due to the prevailing monsoon wind direction is clear.

The Dry Zone and about two thirds of the Intermediate Zone display growing periods exceeding 14 weeks, while nearly one third exhibits periods of over 16 weeks (Figure 4b). The longest Maha season, more than 18 weeks, is recorded in the IU2 region while the shortest Maha season, 11 − 13 weeks, is recorded in the western part of DL1a, DL1b and DL5 regions, northern part of DL1b, DL1d and DL1e regions, DL1f, DL3 and DL4 regions. The Dry Zone shows different durations of growing periods ranging from 11 weeks to 19 weeks. All AERs in the Up Country Intermediate Zone except IU2 region and the AERs in the eastern part of the Mid Country Intermediate Zone and eastern part of the Low Country Intermediate Zone have 17 − 19 weeks long Maha seasons. Western and southern parts of the Low Country Intermediate Zone (IL1a, IL1b, IL3 and southern part of IL1c), eastern part of the DL5 region and southern parts of the DL1b, DL1d, DL1f and northern part of DL1c in Rajarata region display a length of 14 − 15 weeks. Although the AERs in the southern part of the Mid Country Intermediate Zone exhibits a 14 − 15 week long growing period, the length of the Maha season in AERs in the eastern part is 16 − 19 weeks due to the impact of monsoon wind direction.

Number of dry weeks within the seasons

The number of dry weeks within the Yala and Maha seasons is shown in Table 1. The number of dry weeks within a season varies from 0 – 3 weeks. It is common in the AERs in the Dry Zone in the Yala season except DL3 and DL4. This information is important in irrigation scheduling and timely water supply. The rainfall patterns are gradually becoming unpredictable and the rainy season is becoming shorter. Although the inter-monsoonal rains allow the farmer to plant rice, unexpected dry spells as long as three weeks may occur at critical stages of growth after establishment of the crop. Without irrigation, the long dry spells within a rainy season would affect rice production severely. The shorter Yala season may also limit rice cropping in some areas in the Dry Zone limiting rice cultivation to one season per year. If water from previous rains can be stored for supplementary irrigation during dry periods, crop failures can be avoided and successful double cropping can be practiced.

Cropping calendar

The proposed cropping calendars for short duration (3 ½ months) rice crops for each AER in the Dry and Intermediate Zones are shown in Figure 5 and 6, respectively. The cropping calendars indicate diagrammatically when the land preparation and sowing should start, the harvest period and the end of the season.

The optimum time for sowing in the Yala season in many AERs of the Dry Zone and in many AERs in the Intermediate Zone is between the 1st week of May and the last week of April, respectively. The time of cultivation is more variable in the Maha season than that in the Yala season, especially in the Dry Zone due to the variability of onset of rains. Sowing time in the Maha season varies from the 1st week of October to the 2nd week of November while in the Yala season it is from the 2nd week of April to the 1st week of May. However, early pre-monsoon rainfall can be used effectively for crop establishment during the early stage of crop growth. Later in the season, when the reservoirs have been filled and irrigation has begun, the crop can be irrigated as needed. Hence, the early crop establishment results in less water use from the reservoirs in the wet season while saving water for the dry season.

In the proposed cropping calendars, 4 weeks are allocated for land preparation (Figure 5 and 6). However, if the time taken for land preparation can be minimized to about 2 – 3 weeks, it would help to conserve irrigation water. The maximum utilization of rainwater by timely cultivation increases the potential for increased rice production. It will also maximize the irrigation water use efficiency. Therefore, strict policy decisions on timing of crop establishment is needed to avoid late planting and excess water use. This would even allow the cultivation of 4 month duration rice.

All harvesting operations of rice are planned to be completed during the driest months, February/March, for the Maha season and August/September for the Yala season. The harvesting time of Maha season varies from zone to zone. In the southern Dry Zone, eastern part of IL2 region and IL3 region, harvesting can be started in the 3rd week of February to be over by the end of the month. However, in the northern Dry Zone, the harvesting could begin in the 1st week of March to be generally over by mid-March. In AERs in the Up Country Intermediate Zone and IL1a region, the crop can be harvested in the 1st week of February. In all AERs in the Mid Country Intermediate Zone except the northern part of IM1b region, 2nd week of February is the harvesting time. In the Yala season, for many AERs in the Intermediate

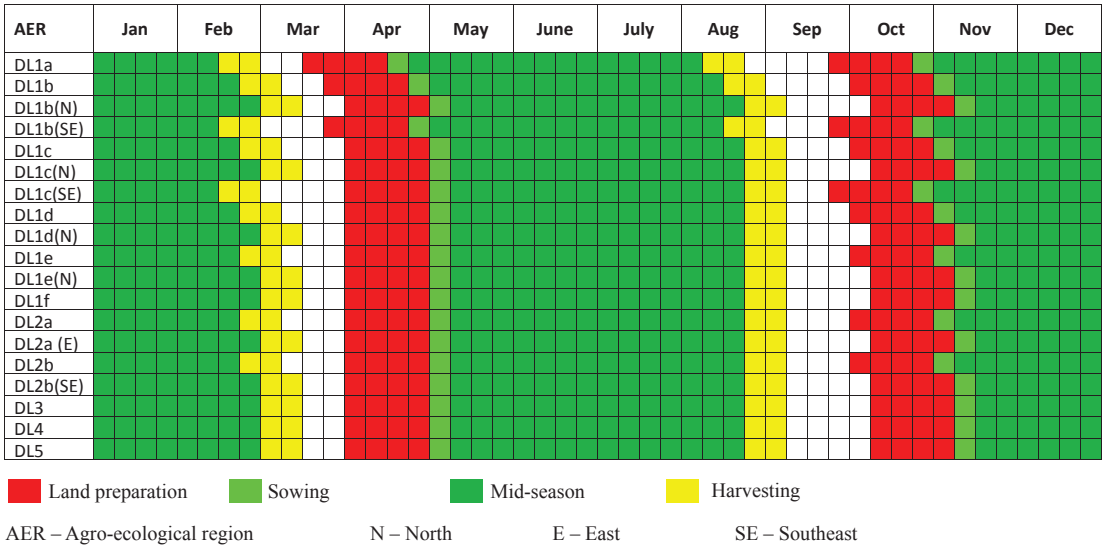

Figure 5: Proposed cropping calendar for the rice crop in each agro-ecological region in the Dry Zone of Sri Lanka

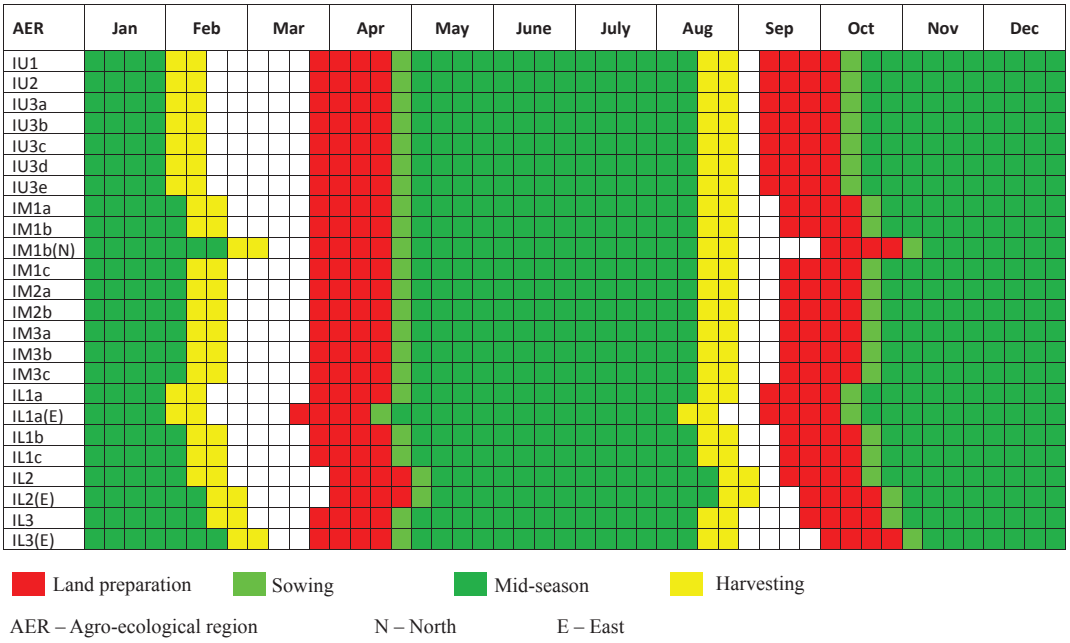

Figure 6: Proposed cropping calendar for the rice crop in each agro-ecological region in the Intermediate Zone of Sri Lanka

Zone, the 2nd week of August is the peak harvesting time and for many AERs in the Dry Zone, it is started in the 3rd week of August.

The optimal time of cultivation can be considered as an important part in maximizing the economic yield while optimizing the resource-use efficiency (Dhanapala, 2000). However, most farmers do not adhere to optimum timing due to various avoidable and/or unavoidable reasons. The loss in yield due to delayed sowing cannot be compensated (Weerakoon, 2011). Timely cultivation with maximum use of rainwater, especially during the major season could save the irrigation water, which could be used to expand the cultivated land extent and production in the minor season (Yala).

CONCLUSION AND RECOMMENDATIONS

This study has shown that there is a high spatial variability of the onset time of both the Yala and Maha seasons. Many AERs in the Dry Zone and some AERs in the Intermediate Zone do not have a distinct Yala season. The Yala rains in the Dry Zone are highly variable and the most probable duration of the season may not exceed four weeks from the onset time. The length of the Maha season in the Dry and Intermediate Zones ranges from 11 – 22 weeks. The map shows a decrease in duration of the season towards the north and south. During the Maha season, there is usually enough water to sustain the cultivation of almost all rice fields, nevertheless in the Yala season water is available for cultivation of about half the land extent.

The proposed cropping calendars can be used as a guideline in rice farming activities from the early stage of land preparation to the stage of harvesting and the next planting cycle. Such information could assist irrigation system managers in the relevant authorities to reduce the amount of irrigation water that will be required during the subsequent seasons to meet crop water demand and to issue water from the tanks in the respective regions without a wide margin of errors. It is also helpful to access and make available quality seeds of specific rice varieties for a particular agro-ecological region at the appropriate sowing or planting time. A prudent user can also make use of the above information as a decision support tool in planning rainfed upland agricultural systems as well. Timely cultivation with the onset of monsoon rains is essential to reduce the risk of terminal drought. Farmers are encouraged to follow a uniform cultivation calendar without any overlapping of different growth stages in a given region. The dry periods during crop season necessitates the farming community to be aware and adapt to recent advances on reduced water use for sustained rice production. However, water loss becomes higher when farmers take a long time to complete land preparation. Although 4 weeks are allocated for land preparation in the proposed cropping calendars, if the time taken for land preparation can be minimized to about 2 − 3 weeks, it would help to conserve irrigation water. This information needs to be made available to farmers through agricultural extension or relevant authorities. The cropping calendars should be subjected to periodical checking and revision. Based on the above seasonal characteristics, developing detailed cropping calendars for rice with optimum time for farm activities such as land preparation, dates of sowing/planting, manuring/ fertilization, weeding, irrigation/drainage, disease/pest control, harvesting etc., is recommended. This work provides the farmers more opportunities to reduce the risks and make them more resilient to climate change.

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