Rainfall Fluctuation and Changing Patterns of Agriculture Practices

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Abstract

Rainfall fluctuations and the resulting changes in agricultural practices are investigated in this study. The basis for the study is total rainfall and number of rainy days for the period 1961-2002 for 22 meteorological stations scattered throughout the country and the changing pattern of agricultural practices in the crop calendars of 15 reservoirs under the Mahaweli Authority from 1983-2008. From the regression analysis carried out for the 22 rainfall stations, the study recorded declining trends of rainfall in all the wet and intermediated zone stations that were considered, while only Jaffna, Pothuvil and Mulathivue recorded increasing trends. In terms of the number of rainy days, only the Nuwara Eliya station recorded an increasing trend, while all the other stations recorded declining trends. The spatial analysis indicates that the annual total rainfall, which is below 1,600 mm, tends to expand towards the central and south western part of the country. By inspecting the 'Crop Calendar' it was found that both *yala* and *maha* seasons start later, especially in the yala season. Also, in the irrigation schemes, the quantity of water issued and the number of days that it is issued for have declined over the years for both seasons.

Introduction

Rainfall is one of the influencing factors for human activities not only in agriculture-based regions, but also in industrialized urban areas. The rainfall received in any region can vary with physical factors as well as human interactions. The physical factors that can cause such variation could include micro-climatic phenomenon or global changes such as ozone depletion and global warming. Recent observations indicate that there are significant changes in rainfall patterns in both the dry and wet zones in Sri Lanka. Since average rainfall is highly influenced by the extreme cases of rainfall it is very difficult to identify the significant changes of average rainfall but it appears that average rainfall remains unchanged.

Rainfall fluctuations directly affect agricultural activities in any region. According to Prof. Thambyahpillay, "agriculture in the Indian areas is a gamble in the monsoon"; time and again, the monsoon has 'failed' either to appear on time or to produce the rainfall amount that is expected of it. Sri Lanka's main subsistence agriculture is paddy cultivation. Paddy cultivation is highly susceptible to variations in temperature, rainfall, soil moisture, and increases in the intensity and frequency of extreme events. Paddy cultivation is most liable to be affected by large-scale aspects of droughts and floods. The main environmental character that sets paddy apart from other crops is its high water requirement. The island's rainfall trend basically controls the paddy production.

During the past few decades, paddy production has been destroyed either by severe rainfall or the lack of timely rain; and variable rainfalls over the past two decades have pushed farmers to hold back paddy cultivation until the rains arrive. According to Dr. B. Poonyawardena, head of the Agro-climatology Division; the maha growing season usually starts in October and paddy is harvested in March but farmers now wait for the rains to arrive before starting cultivation. The *maha* crop is generally harvested in February, which is traditionally a dry month, but it is now harvested in mid-March.

There have been a number of changes in the harvesting practices due to changing patters of rainfall over the years. According to Mr. Nalin Munasinghe, Programme Associate at the Food and Agricultural Organization (FAO) in Colombo, the planting delays in October may be an indication that the farmers have already begun adjusting to the variation in the rainfall. The farmers may not have scientific knowledge, but they feel the practical need to change. This study attempted to examine the changing pattern of agricultural practices, as indicated by the 'Crop Calendar', in response to rainfall changes. The study especially strived to examine shifts in the cultivated seasons of *yala* and *maha.*

Objectives

The goal of this study is to examine the variations in the rainfall pattern in the country and to observe the impact of rainfall variations on the cultivation patterns for paddy. To examine the variation in the rainfall, only rainfall data was examined, including the monthly total rainfall and the monthly number of rainy days. To observe the changes in the cultivation pattern, the crop calendars of 15 catchments under the Mahaweli Authority were selected. This study attempts to examine the changes in rainfall patterns from different viewpoints using daily rainfall data collected at the 22 main meteorological stations of the Department of Meteorology. This paper identifies spatial and temporal trends in the rainfall received during the period from 1961 to 2002. The objectives of this paper are to:

- Examine the variations in rainfall for the periods 1961-2002, including - variations in the annual total rainfall, variations in the number of rainy days and spatial changes in the rainfall
- Investigate the variations in the 'Crop Calendar' - shifts in the start of *yala* and *maha* seasons and the harvesting dates, variations in water releases, and trends in the number of days of water release

Methodology

Data Sources

This study is entirely based on secondary data obtained from the Meteorology Department and the Mahaweli Authority. The monthly total rainfall and monthly number of rainy days data were obtained from the Meteorology Department for the period 1961–2002 for 22 meteorological stations scattered around the country (Table 1). The crop calendars were obtained from the Water Secretariat of the Mahaweli Authority from 1983–2008 for 15 main reservoirs. The crop calendars record the date of the beginning and end of water issue, which was considered to be the beginning and end of *yala* and *maha*. They also record the amount of water issued and the area under harvest.

Table 1. Data basis for study and research sources.

Variables	Source	Period	Description
Monthly total rainfall	Meteorology Department	1961-2002	Rainfall average for 22 meteorological stations in the country
Monthly number of rainy days	Meteorology Department	1961-2002	Monthly number of rainy days for the 22 meteorological stations
Crop Calendar	Water Management Secretariat; Mahaweli Authority of Sri Lanka	1983-2008	The crop calendars of 15 reservoirs under the Mahaweli Authority from 1983-2008

Data Analysis

Statistical as well as spatial analyses were carried out in this study using Microsoft Excel and Arcview GIS, respectively. In statistical analysis, time series analysis and regression analysis were carried out for monthly total rainfall and the total number of rainy days, and crop data. The total rainfall data was then exported to the Arcview GIS, and the Spatial Interpolation method was used to determine the spatial pattern of the total rainfall from 1961-2002.

Variations in the Annual Total Rainfall

Table 2 represents a summary of the regression analysis carried out for the 22 meteorological stations for the period of 1961 – 2002.

Table 2. Trends in total annual rainfall.

	Station	Slope	Intercept	R^2
	Wet Zone			
1	Colombo	-13.85	29,833	0.133
2	Katunayake	-12.69	27,334	0.124
3	Galle	-10.86	23,853	0.107
4	Ratmalana	-8.9111	20,128	0.072
5	Kandy	-2.784	7,553	0.02
6	Nuwara Eliya	-0.632	3,156	0.00
7	Ratnapura	-0.415	4,555	0.00
	Intermediate Zone			
8	Kurunegala	-7.361	16,637	0.06
9	Diyatalawa	-7.28	15,916	0.049
10	Badulla	-6.117	13,847	0.06

(continued)

Table 2. Trends in total annual rainfall. *(continued)*

	Station	Slope	Intercept	R^2
	Dry Zone			
11	Kankasanturai	-13.64	28,160	0.066
12	Vavuniya	-9.291	19,775	0.082
13	Trincomalee	-7.06	15,530	0.041
14	Hambantota	-6.874	14,645	0.111
15	Batticaloa	-5.077	11,695	0.015
16	Anuradhapura	-4.662	10,464	0.038
17	Mannar	-3.062	6,993	0.022
18	Puttalam	-2.256	5,654	0.009
19	Mahailluppallama	-2.035	5,412	0.006
20	Jaffna	0.732	-2.564	0.00
21	Mullaitivu	7.215	-13,130	0.012
22	Potuvil	28.62	-55,871	0.219

Note: Data have been arranged in descending order according to climatic zone

According to Table 2 it is evident that all stations, except three in the dry zone, show a decreasing trend in the total rainfall. The decreasing trend is especially manifest in the wet zone, where dramatic negative trends are recorded in the four stations of Colombo, Katunayaka, Galle and Ratmalana. In the dry zone all stations, except Jaffna (Figure 1), Mullaitivu and Potuvil, show negative trends. It is remarkable how these three stations show a positive trend, however Mullaitivu and Potuvil only have data records for 15 years due to the civil unrest in the country and, therefore, the projections for those stations cannot be deemed to be accurate. All the other stations in the dry zone record decreasing trends in total rainfall, with Kankasanturai and Vavuniya recording the highest decrease of -13.64 and -9.291 (Table 2). Hambantota, which is situated in one of the driest regions of the country, records a decrease of -6.874 in total rainfall for the period but the rainfall data for the past 5 years shows a slight increase. Anuradapura, Mahailluppallama record decreasing trends of -4.662 and -2.035, and the Mahailluppallama station (Figure 2) has the lowest decreasing trend from the dry zone.

Figure 1. Annual total rainfall of Jaffna.

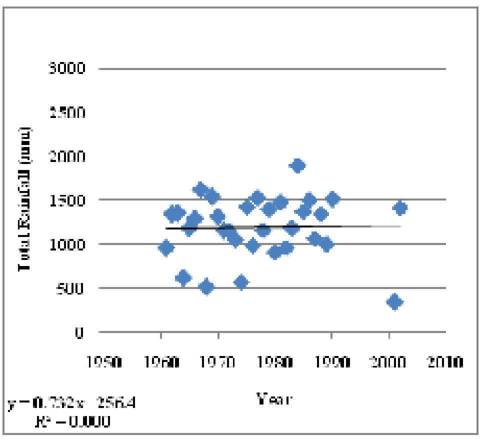
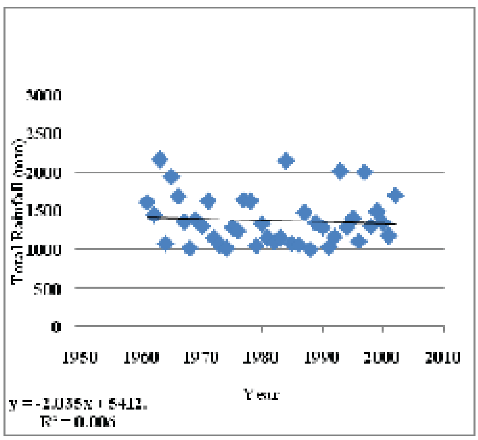


Figure 2. Annual total rainfall of Mahailluppallama.



In Kurunegala, the total rainfall has declined by -7.361 slopes, but by looking at Figure 3, extreme cases of high rainfalls are also evident during this period. The greatest decline in rainfall, of -13.85, in the 22 stations analyzed was recorded in Colombo (Figure 4). Colombo, Galle, Ratmalana and Katunayake are situated in the western windward slope of the central highlands and Nuwara Eliya and Ratnapura are situated in the eastern windward side of the central highlands, which recorded the highest rainfall in the country. The stations on the western windward slope record mediocre declining trends, with Nuwara Eliya recording a decline of -0.632, while Ratnapura on the eastern windward side recorded -0.415 decline trend.

Figure 3. Annual total rainfall of Kurunegala.

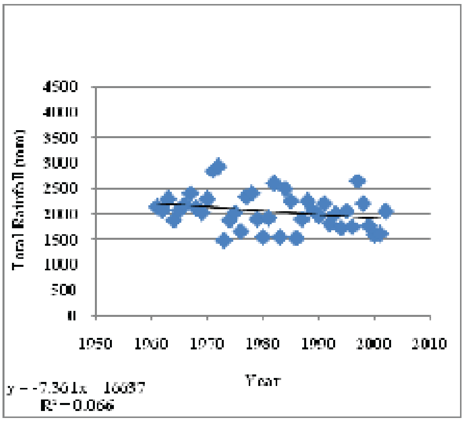
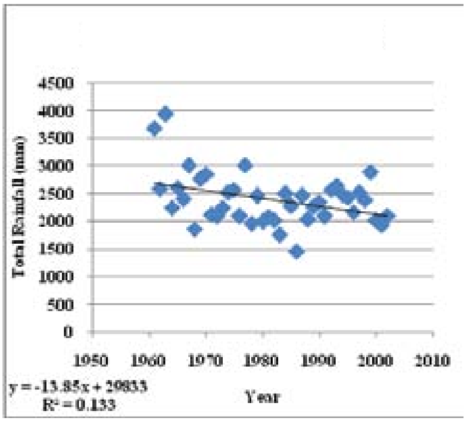


Figure 4. Annual total rainfall of Colombo.



Variations in the Number of Rainy Days

The number of recorded rainy days per month is taken into analysis; the annual total number of days is calculated by adding the total number of days in a year.

The number of rainy days has decreased in all stations except in Nuwara Eliya (Table 3), for which the regression parameter records an increase of 0.047, which is only a slight increase as can be noted from Figure 5. The number of rainy days per year in Nuwara Eliya has not exceeded 250 days but has not dropped below 150 days since the 1980s.

Table 3. Trends in number of rainy days.

	Station	Slope	Intercept	R^2
	Wet Zone			
1	Nuwara Eliya	0.047	107	0.001
2	Kandy	-0.065	312.7	0.002
3	Ratnapura	-0.302	833.2	0.073
4	Ratmalana	-0.376	926.9	1.04
5	Galle	-0.4	991.9	0.098
6	Colombo	-0.537	1,238	0.179
	Intermediate Zone			
7	Badulla	-0.3	753.3	0.048
8	Diyatalawa	-0.13	420.5	0.006

(continued)

Table 3. Trends in number of rainy days. *(continued)*

	Station	Slope	Intercept	R^2
9	Kurunegala	-0.706	1,566	0.27
	Dry Zone			
10	Jaffna	-0.058	193.8	0.001
11	Mahailluppallama	-0.28	675.8	0.066
12	Trincomalee	-0.321	738.2	0.061
13	Mannar	-0.347	757	0.106
14	Batticaloa	-0.355	810	0.074
15	Puttalam	-0.425	946.8	0.095
16	Hambantota	-0.433	970.2	0.099
17	Anuradhapura	-0.458	1,015	0.117
18	Kankasanturai	-0.487	1,040	0.66
19	Vavuniya	-0.488	1,072	0.13
20	Mullaitivu	-0.818	1,714	0.034
21	Potuvil	-0.971	2,013	0.064

Note: Data have been arranged in ascending order according to climatic zone

All the other stations in the wet, intermediate, and dry zones show a declining trend throughout this period (Table 3). The greatest decline in rainy days in the wet zone is recorded in Colombo (regression trend -0.537). The number of rainy days dropped below 200 in the early 1960s and more recently even greater variation is seen (Figure 6). Other wet zone stations such as Galle, Ratmalana, Ratnapura and Kandy also recorded declines in the total number of rainy days in the regression equation. This is of importance as these stations are situated on the windward side of the central highlands, which records a high rainfall during the South West Monsoon period. In the intermediate zone, the number of rainy days has decreased in all three stations, namely Badulla (Figure 7), Diyatalawa and Kurunegala. Kurunegala records a moderate decline in the number of rainy days (regression trend -0.706).

Figure 5. Total number of rainy days in Nuwara Eliya.

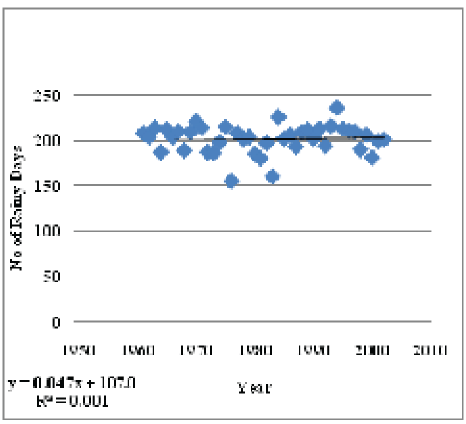
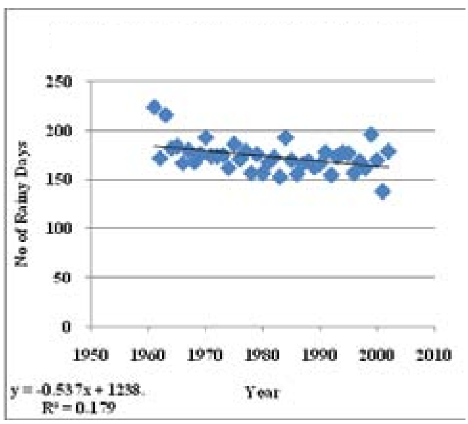


Figure 6. Total number of rainy days in Colombo.



In the dry zone, the highest decline is recorded in Potuvil at -0.971, followed by Mullaitivu and Vavuniya. The lowest decline is recorded in Jaffna, Mahailluppallama and Trincomalee as -0.058, -0.28 and -0.321, respectively. Figure 8 demonstrates the decrease in the number of rainy days in Mahailluppallama. Hambantota, situated in the south of the island, records a moderate decline of -0.433 in number of rainy days. In both Mahailluppallama and Puttalam, there has been a steady decline apart from few deviations between certain years. In both stations, the number of rainy days has not exceeded 150 days since the 1960s.

Figure 7. Total number of rainy days in Badulla.

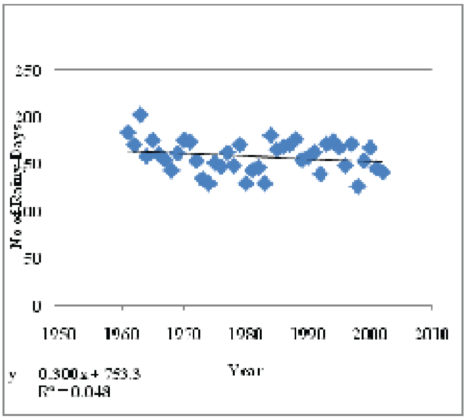
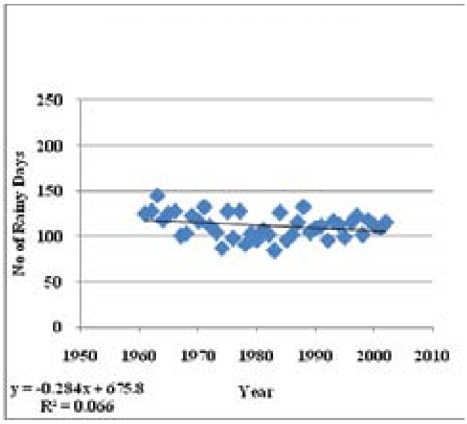


Figure 8. Total number of rainy days in Mahailluppallama.

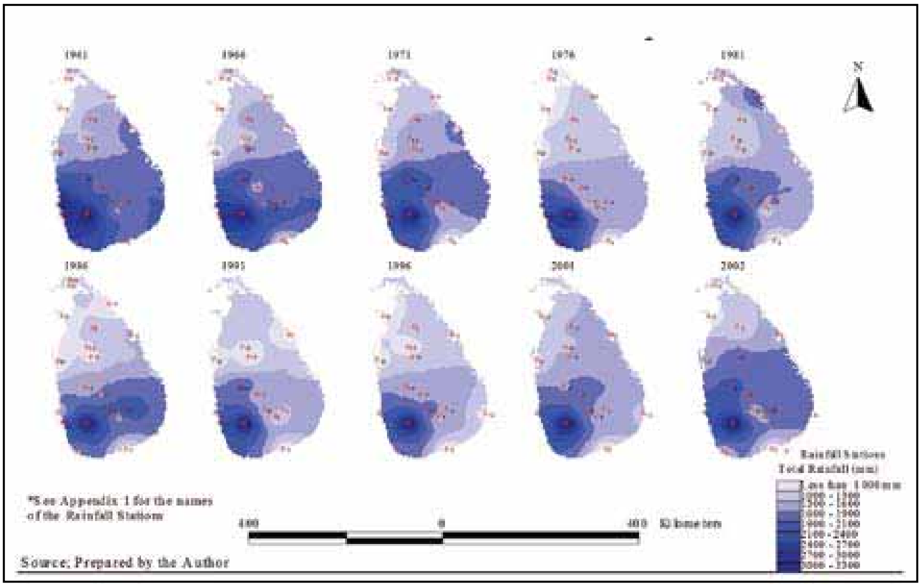


Spatial Analysis

Sri Lanka is an agrarian country and any shift in the climatic zones can have adverse agricultural and socioeconomic impacts. By observing the spatial changes in rainfall patterns, a clear perception can be obtained of the severity of the problems that may occur. The total rainfall data for each of the 22 rainfall stations were exported to Arcview GIS, and the rainfall data was interpolated for the 42-year period of each station, to examine the spatial changes in rainfall. From the interpolated surfaces, the variations in rainfall can be observed visually, as illustrated in Figure 9.

The total rainfall in the country has declined during the years of observation, especially in the north and south of the country (Figure 9). The area around Hambantota has experienced the greatest decline. The expanse of areas, which record a total rainfall below 1,600 mm, has gradually increased from 1961 onwards, but this expansion is more evident from 1971 onwards. By 1976, almost three quarter of the island, from Puttalam up to Galle, recorded a total annual rainfall below 1,600 mm. Also, from 1986, the stations in Kurunegala and Galle recorded a value below 1,600 mm in the majority of years. The southwestern quarter of the island recorded a total rainfall that was above 2,500 mm in 1961, with a few areas surrounding Potuvil also having recorded the same values of total rainfall. But from 1967 onwards, the area in the island recording total rainfall under 2,500 mm or less has declined steadily. The area that recorded a total rainfall of more than 2,500 mm in 1961 is concentrated in Colombo, Nuwara Eliya, Ratnapura, Galle, and even Kurunegala. In 1966 the area around Nuwara Eliya recorded rainfall less than 2,500 mm, but again in 1971, total rainfall increased to more than 2,500 mm. From 1971 onwards, again the Nuwara Eliya station recorded a total rainfall that was less than 2,500 mm until 1986, at which point it recorded a high aggregate of annual rainfall but again from 1991 onwards till the year 2002 it recorded a total rainfall that was less than 2,500 mm. Also, the area surrounding the southwestern parts of the island showed a decline in the total rainfall.

Figure 9. Rainfall distribution across Sri Lanka (1961-2002).



Investigating the Variations in the 'Crop Calendar'

The climatic variations across Sri Lanka mean that there is a need to study the spatial variation impacts of climate change on paddy cultivation.

Shifts in the Start and End of the Yala and Maha Seasons

The cropping calendars record the start and end of the *yala* and *maha* seasons for 25 years. Traditionally the *yala* season is cultivated from March to September (First Inter- Monsoon) and *maha* season from early October to February (South West Monsoon). Using the crop calendar the first days of the *yala* and *maha* seasons were analyzed to investigate whether these have changed over the years and whether they relate to water availability. As there is these dates are rarely recorded, the first and last days of irrigation water issues were taken as proxies. The amount of water issued and the total number of days that the water was issued were also considered.

Figures 10 and 11, respectively, represent the beginning and end of the *maha* season in the Kalawewa LB Reservoir, while Figures 12 and 13, respectively, represent the beginning and end of the *yala* seasons in the same reservoir.

Over the years a clear shift can be seen in the time at which the *maha* seasons started and ended in the Kalawewa LB Reservoir irrigated area. The *maha* season, traditionally starting from early October to February, has shifted to late October or sometimes to November and the harvesting days have moved to as late as March in most years, when it would traditionally have been considered to be February (Figures 10 and 11) The harvest only took place in February for 5 out of the 25 years that were recorded.

Figure 10. Kalawewa LB Reservoir's beginning day of *maha* season.

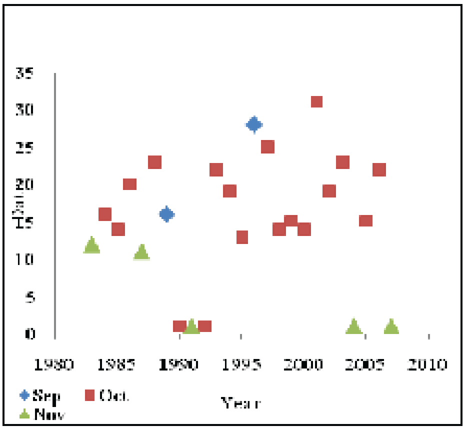
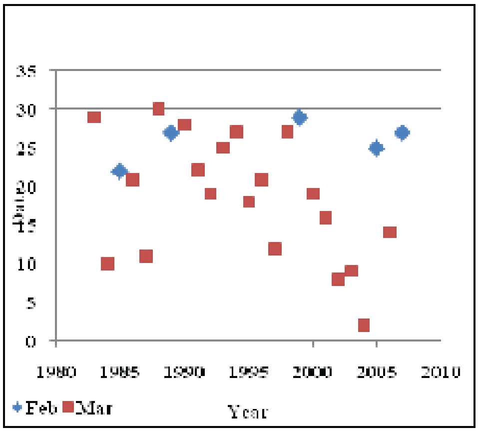


Figure 11. Kalawewa LB Reservoir's end day of *maha* season.



The *yala* season demonstrates an extreme case of transformation with the traditional start of the season shifting to April and in a majority of the years as May and June. This clearly reveals that the cultivation patterns in the country are now in the process of alteration (Figure 12). The end days of the *yala* season do not show any evidence of change (Figure 13).

Figure 12. Kalawewa LB Reservoir's beginning day of *yala* season.

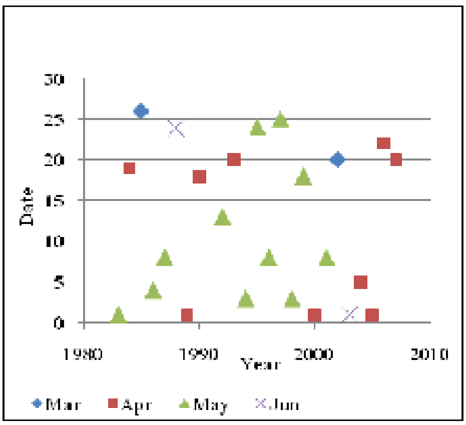
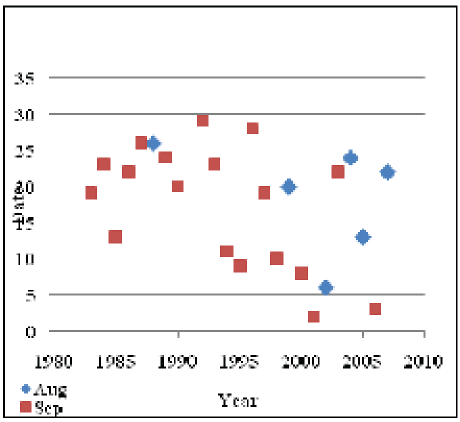


Figure 13. Kalawewa LB Reservoir's end day of *yala* season.



From the 15 reservoirs studied, 5 reservoirs (Maduru Oya, Kalawewa, Nachchaduwa, Nuwarawewa and Huruluwewa) demonstrate shifts in the *maha* cultivation days. Figures 14, 15, 16 and 17 illustrate the shifts in the beginning and end days of the *maha* and *yala* seaasons in the Huruluwewa.

Figure 14. Huruluwewa Reservoir's beginning day of *maha* season.

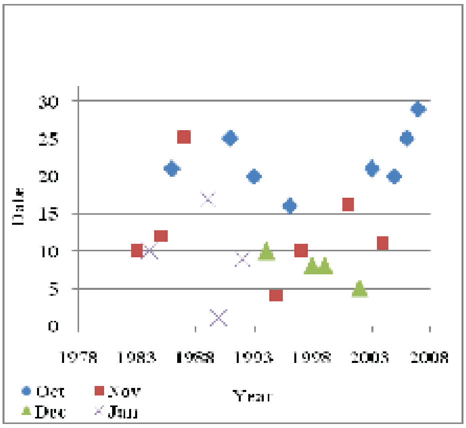


Figure 15. Huruluwewa Reservoir's end day of *maha* season.

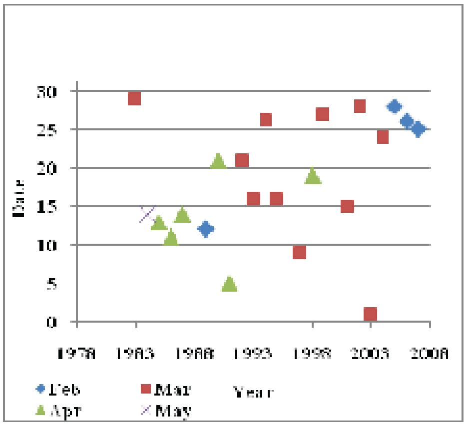


Figure 16. Huruluwewa Reservoir's beginning day of *yala* season.

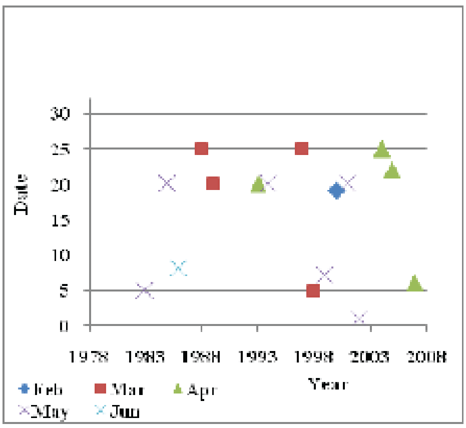
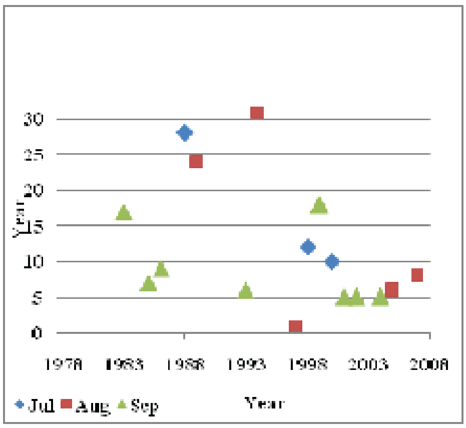


Figure 17. Huruluwewa Reservoir's end day of *yala* season.



High variation is recorded for the start time of *maha*, in the period of the study, with the start days shifting from the traiditional month of October, to November and December and in some years, as late as January. The end days of the *maha* season show an extreme shift from February, to March, April, and May. During the last 10 years, the start has shifted to late October and even early November. The *yala* season also demonstrates variations like in all other reservoirs but the end days of the *yala* season do not show any specific alteration, except for ending in periods earlier than in other reservoirs under study.

In all 15 of the reservoirs studied, the most pronounced shift in the cultivation pattern is observed in the *yala* season, with the beginning of the season shifting to April and in some years to May as well. But the end days of *yala* do not show a shift.

Variations in Water Issues and the Number of Water Issue Days in Yala/ Maha

During the period of the study, there has been a variation in the number of days in which water is issued. From the early 1990s onwards, a declining trend is observed for both seasons. In most of the reservoirs taken studied, the number of days on which water is issued has fallen below 160 days from the early 1990s as seen in figures 18,19,20 and 21.

Figure 18. The number of days in which water is issued in the Kalawewa LB Reservoir during the *maha* season.

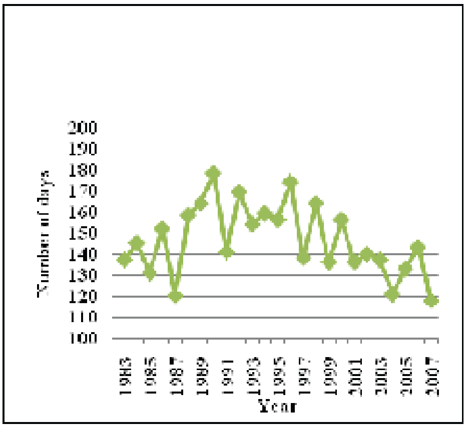


Figure 19. The number of days in which water is issued in the Kalawewa LB Reservoir during the *yala* season.

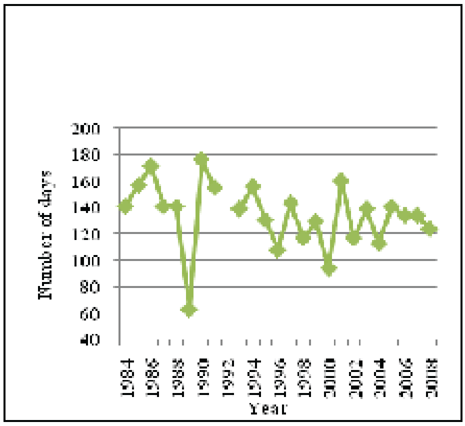


Figure 20. Amount of water issued in the Kalawewa LB Reservoir during the *maha* season.

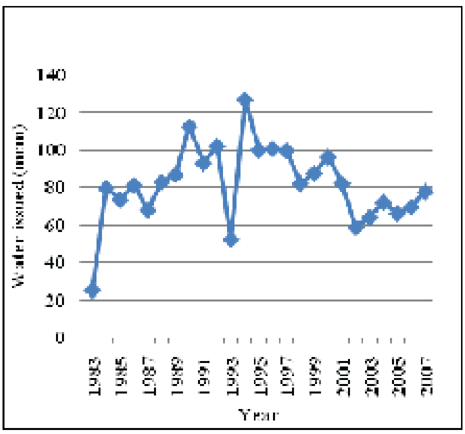
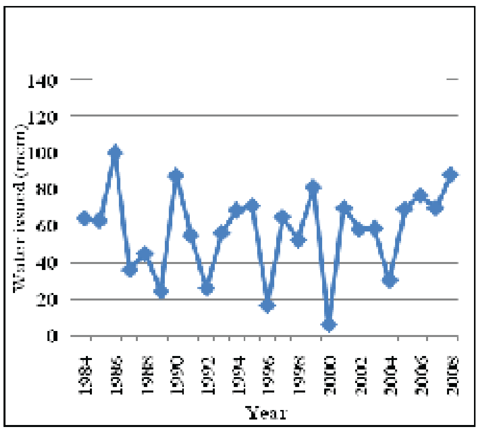


Figure 21. Amount of water issued in the Kalawewa LB Reservoir during the *yala* season.



As regards the amount of water issued from the Kalawewa LB Reservoir in both cultivation seasons, the water volume has increased slightly during the past 25 years but there are large variations, especially in *yala*.

In the Parakrama Samudraya Reservoir, the number of days in which water is issued has also declined throughout the years during both the *maha* and *yala* periods, but the amount of water issued has actually increased slightly overall (Figures 22, 23, 24 and 25).

Figure 22. The number of water issued days in the Parakrama Samudraya Reservoir in the *maha* season.

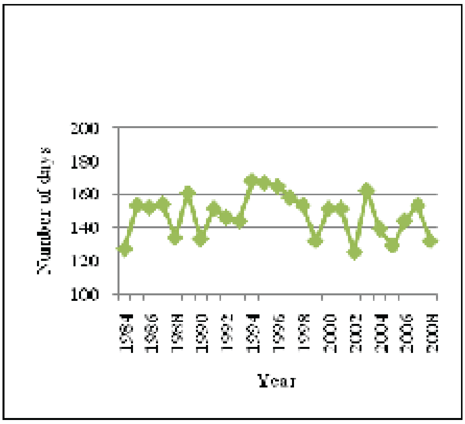


Figure 23. The number of water issued days in th Parakrama Samudraya Reservoir in the *yala* season.

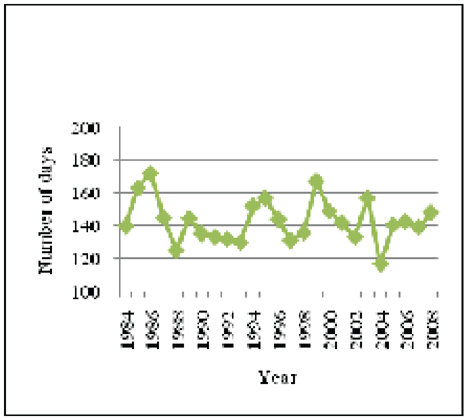


Figure 24. Amount of water issued in the Parakrama Samudraya Reservoir in the *maha* season.

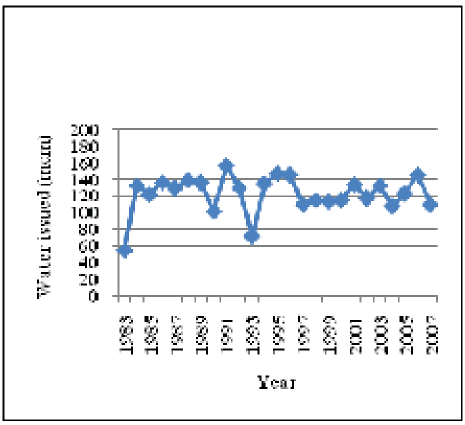
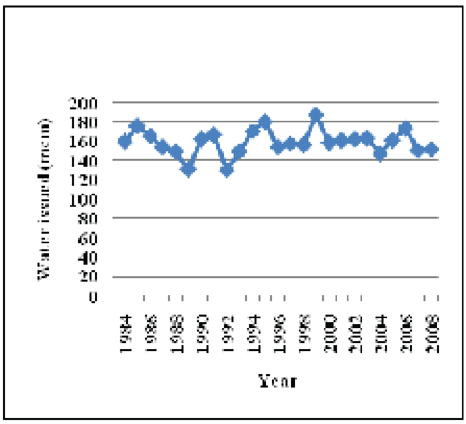


Figure 25. Amount of water issued in the Parakrama Samudraya Reservoir in the *yala* season.



Note: The area of cultivation is constant during the period of study

In all the 15 reservoirs under study, the number of days in which water is issued seems to be declining, with the days declining below 150 days after the 1990s in both the *yala/maha* seasons. However, the amount of water issued has increased in some reservoirs, especially during the *yala* season. Girithale, Minipe, Ulthitiya Rathkinda, Huruluwewa, Udawalawe LB, Maduru Oya and Parakrama Samudraya show slight increases in the amount of water issued in the *yala* season, while Minipe, Ulhitiya Rathkinda, Maduru Oya, Kalawewa LB, Parakrama Samudraya and Udawalawe LB recorded a slight increase in the amount of water issued in the *maha* season. The amount of water issued has only increased slightly and it has not affected the starting days of *yala* season.

Conclusion

The study found that although the number of rainy days has declined at all, but one, of the meteorological stations, the annual total rainfall has not declined in all the stations. The total annual rainfall has actually increased in the Jaffna, Potuvil and Mullaitivu stations, but has declined in all the other stations in the dry, intermediate, and wet zones. The spatial analysis highlights this decline in total anual rainfall as the areas with high rainfal (over 2,500 mm per year) have reduced and are now limited to the southwestern parts of the central highlands. The lowlands of the southwestern parts of the island record a declining expanse of the area recieiving total rainfall in the amount below 2,500 mm. This could indicate that the intensity of rainfall events may have increased and that the duration of dry spells has inceased, especially in the dry zone. Further studies are needed to investigate the relationship between the numbers of rainy days and total rainfall within seasons.

The changes in the 'Crop Calendar', which indicate a shift in the start and end of the cultivation seasons, show that there are delays in the arrival of rainfall and a reduction in the number of days in which water is issued from the irrigaiton scheme This data provides evidence that droughts and dry spells can affect paddy cultivation practices. Further studies are needed to investigate the delays in seasonal rainfall and the impact of such delays. Such studies could provide invaluable guidance to decision-making in agricultural practices and water management.

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