Use of rainfall patterns for effective management of rubber plantations in Eastern, North Central and Northern provinces of Sri Lanka

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Abstract

This study employed daily rainfall values of 10 meteorological stations in Anuradhapura, Vavuniya, Ampara, Kilinochchi and Mullaitivu districts covering Agro Ecological Regions (AER), DL1b, DL2a, DL2b, DL1e, DL1f and DL3. The methodology involved descriptive statistical techniques to derive yearly and monthly variations and probability calculations to derive frequency of dry spells. Incidence of consecutive wet weeks was analysed using Markov chain analysis. Except for Ampara, the rest of the locations analysed in this study recorded an average annual rainfall less than the minimum rainfall requirement for rubber. The AERs in the Dry zone are vulnerable to droughts especially during March to August. The chance of having long dry spells is less than 20% in all the sites during October, November and December. If cultural operations are carried out according to a proper plan the repercussions of drought conditions can be minimized to a considerable extent. Accordingly, holing operation which requires a moist soil should be done during 17th September to 30th September followed by planting during 22nd October to 04th November to catch the maximum possible length of the wet season to assure maximum establishment success. First, second and third fertilizer applications in the first year of planting need to be done during 17th to 31st December, 26th March to 8th April and 24th September to 7th October respectively, to avoid heavy rains and dry spells. It is inevitable to prevent any departures from these stipulated dates since, uncertainty stands as all these dates have been computed using the probability theory. Hence proper cultural operations and moisture management practices, viz. irrigation, mulching and intercropping throughout the immature phase of rubber are of great importance to assure a healthy rubber plantation with minimum vacancies and accepted growth rates.

Key words: Markov chain analysis, rainfall analysis, rubber

Introduction

Rubber is a crop which has its all operations connected with the rainfall pattern. Hence, for timely and efficient operation of agronomic practices from planting through felling, one needs a thorough understanding of the prevailing rainfall pattern of the area. There have been several reports on the rainfall pattern in traditional rubber growing areas in the Wet Zone of Sri Lanka. Yet, such reports on non-traditional rubber growing areas are limited except for studies reported by Wijesuriya *et al.* (2005 & 2010) focusing on Moneragala district. Through the recent development programmes under “*Regaining Sri Lanka*” such as, “*Nagenahira Navodaya*” and “*Uthuru Wasanthaya*”, the rubber tree has been introduced to Eastern and Northern provinces which come under Intermediate and Dry Zone areas (Rodrigo *et al.*, 2009). This move required more detailed analysis of rainfall in Northern and Eastern regions of Sri Lanka for better decision making to ensure sustainable rubber farming.

The ideal annual rainfall for rubber falls within the range of 1650 mm to 3000 mm. The tree performance is severely affected by prolonged periods of dry weather when rainfall over consecutive six months period recorded less than 500 mm, and also when rainfall is not uniformly distributed over the year (Yogaratnam, 2001). It has been observed that ideal rainfall conditions do not exist in non-traditional rubber growing areas in the drier areas

(Wijesuriya *et al.*, 2010). Vulnerability of different agro-ecological regions for droughts has been identified by Chithranayana & Punyawardene (2008). According to them, almost all regions of the island have a potential threat to droughts. However, the degree of vulnerability is more in the dry zone. Hence, rubber farming in drier areas is a challenge and need to handle carefully to avoid detrimental effects due to adverse environmental conditions.

The important information on rainfall with respect to agriculture are; the chance of rain, the start, end and length of the rainy season, amounts of rain that can be expected at specified probability levels and the risk of dry spells. Very simple to complicated statistical methods have been employed in analysis of rainfall. The probabilistic approach is very common and many studies have employed distribution free approaches. The pioneering work of Gabriel & Neumann (1962) was the starting point for Markov chain models which are helpful in defining probable occurrence of dry and wet spells. This method was employed for the wet zone rubber growing areas by Wijesuriya & Herath (2001). This paper employs simple descriptive methods and Markov chain analysis for several rainfall stations in Northern, North Central and Eastern provinces of Sri Lanka which are located in the areas where rubber is introduced on experimental basis as on-farm participatory trials. Optimal dates for different agro-management practices in rubber farming have been suggested

by Liyanage *et al.*, (1984) for Raigama estate, Ingiriya located in the Low Country Wet Zone (LCWZ). Later, Wijesuriya & Herath (2001) have reported an analysis of rainfall records in 14 Meteorological stations in LCWZ, Low Country Intermediate and Mid Country Wet Zone. The main emphasis of this study is to devise an effective management plan, employing appropriate statistical analyses for cultural operations in Eastern, North Central and Northern provinces of Sri Lanka for sustainable rubber farming.

Methodology

Selection of sites

Selection of sites was done to represent the areas where rubber is recently introduced through various development programmes by Rubber Research Institute of Sri Lanka (RRISL) and

Rubber Development Department (RDD). Table 1 lists the stations considered against the agro-ecological regions (AER) and the duration of data availability. The geographical distribution of meteorological/rainfall stations is depicted in Fig. 1.

Organizing data and analysis of rainfall records

Daily records were summarized into annual, monthly and standard week bases for all the stations. Descriptive analyses including mean, minimum, maximum, standard deviation (SD) and coefficient of variation (CV) were done on annual, monthly and standard week basis. For yearly and monthly totals, the 75% exceedance probability value was chosen by ranking the series from lowest to highest and selecting the 25th percentile point of each series.

Table 1. Details of the meteorological stations selected for the study

District	Station	Agro-ecological zone	Data availability
Anuradhapura	Anuradhapura	DL 1b	1980 - 2012
	Elayapattuwa	DL 1b	2004 - 2012
	Medawachchiya	DL 1b	1995 - 2012
Vavuniya	Pawatti Kulam	DL 1b	1993 - 2012
	Vavuniya	DL 1b	1980 - 2012
Ampara	Ampara Tank	DL 2b	1980 - 2012
	Uhana	DL 2a	2008 - 2011
Kilinochchi	Akkarayan Kulam	DL 1f	1980 - 2012
	Iranamadu Tank	DL 3	1980 - 2012
Mullativu	Muthuiankadu Kulam	DL 1e	1989 - 2012

Fig.1. Geographical locations of selected meteorological stations

Specific terms/criteria used in analysis

Dry day - A threshold value of rainfall $<0.5 \text{ mm day}^{-1}$ was taken to define a dry day. This value was employed in detecting the onset of rains.

Onset of rains - Defining the onset of rains is difficult due to the wide variability of the specific nature of the rainfall pattern in Sri Lanka. A rainy day is defined as having a rainfall greater than or equal to 0.5mm. The start of rains is defined using three specific components as follows.

- i. The onset of rains is considered, after 1st of March and 1st of August for the 1st rain spell and 2nd rain spell, respectively.
- ii. A potential start date will be the first occurrence of at least 30mm of rain summed over three consecutive days with at least two rainy days.
- iii. The potential start could be a false one if there is a seven-day dry spell within next twenty days after the potential start.

Cease of rains - The end of rains is also difficult to decide due to the intermittent and patchy nature of rains in Sri Lanka. The definition of the cease of rains also depends on the particular application. The components that define the cease of rains are termed as follows.

- i. The end date of rains is considered after 1st July and 15th January for the 1st rain spell and 2nd rain spell, respectively.
- ii. The first 3-day dry spell is considered as a potential end of rains.
- iii. This day is a false one if the total rainfall over next 20 days exceeds 100mm.

Wet week – A total of 20mm or more is considered as a wet week since the average Potential Evapo-transpiration (PET) of the Dry zone is around 3mm/day (Punyawardene, 1998).

Analysis of occurrence of dry spells

For different months of the rainfall series, the occurrence of dry spells of different lengths, viz. 10, 15 and 20 days were counted. Subsequently, the occurrences were presented as probability of occurring dry spells of different lengths for different months.

Analysis of occurrence of wet weeks

The data set organized on standard week basis was employed in the analysis. For each year, using the total rainfall for the 52 standard weeks, the events were defined as 1, if rainfall equals or exceeds 20 mm and 0, otherwise. The probability

values of receiving a wet week for each standard week were calculated accordingly.

Markov chain analysis

The first-order, two-state Markov probability matrix consist of four probabilities; probability of having a Wet week after a wet week (W/W), probability of having a dry week after a wet week (D/W), probability of having a wet week after a dry week (W/D) and probability of having a dry week after a dry week (D/D). This study was limited to finding the probability of receiving a wet week after a wet week (W/W) as it is expected to find the most suitable times for agro-management practices which requires sufficient amount of moisture retaining in the soil. The data set employed in analysis of occurrence of wet weeks was used to calculate the probability of having a wet week after a wet week (W/W).

Results and Discussion

Annual rainfall

Five of the selected stations are found in agro-ecological region DL1b, which receives an overall rainfall of more than 900mm annually with 75% probability (which means in 3 out 4 years, the annual rainfall exceeds 900 mm). The analysis of 75% expected rainfall for these stations revealed that the highest value was recorded in Medawachchiya while the lowest was observed in Pawatti Kulam (Table 2). The station at Ampara tank belongs to DL2b with expected rainfall of 1100 mm at 75% probability.

However, this location receives an annual rainfall more than 1417 mm at 75% probability. Akkrayan Kulam, Iranamadu tank and Muthuiankadu Kulam which belong to DL1f, DL3 and DL1e, respectively receive more than 800 mm with 75% probability. Yet, according to the analysis the station at Iranamadu tank receives more than 1128 mm with 75% probability. It was also noted that the coefficient of variation (CV%) is lower in DL1b areas compared to the other stations indicating a lower variability in annual rainfall.

Monthly rainfall

Monthly variation in rainfall is depicted in Fig. 2 to Fig. 6 for meteorological

stations in Anuradhapura, Vavuniya, Ampara, Kilinochchi and Mullaitivu districts, respectively. In Anuradhapura district, the bimodal pattern of rainfall exists with peaks that coincide in April and November. A slight departure was observed in Medawachchiya where the peak rainfall occurs in December. However, the pattern observed for 75% expected rainfall is similar for both stations (Fig. 2). It is also noted that 100 mm is exceeded with 75% probability in April, October and November for Anuradhapura, while in Medawachchiya, there is a chance to exceed 100 mm in December too.

Table 2. Descriptive statistics of annual rainfall in selected locations

Station	Agro-ecological zone	Average annual rainfall (mm/year)	75% expected rainfall (mm/year)	Min.	Max.	Coefficient of Variation (CV%)
Anuradhapura	DL 1b	1269	1097	849	1878	19.3
Elayapattuwa	DL 1b	1159	*	838	1594	*
Medawachchiya	DL 1b	1429	1201	812	2037	19.4
Pawatti Kulam	DL 1b	1064	820	675	1622	24.5
Vavuniya	DL 1b	1320	1167	812	2229	21.6
Ampara Tank	DL 2b	1764	1417	992	3273	26.7
Akkrayan Kulam	DL 1f	1216	995	547	1964	28.4
Iranamadu Tank	DL 3	1247	1128	733	2242	27.7
Muthuiankadu Kulam	DL 1e	1316	962	511	2389	33.0

* Not enough data to compute the statistics

Monthly rainfall distributions in Vavuniya and Pawatti Kulam stations which belong to Vavuniya district exhibit similar patterns with peaks that coincide in April and November. Although Pawatti Kulam and Vavuniya stations are found in close proximity, Vavuniya receives more rains during October to December (Fig. 3).

The bimodal rainfall pattern does not exist in stations located in Ampara and Uhana. There is a chance to exceed 100 mm at 75% probability during October

to January. December receives the highest rainfall (Fig. 4). Akkarayan Kulam and Iranamadu which belong to DL1f and DL3 regions, have their peaks in November and there is a chance to exceed 100 mm at 75% probability during October, November and December (Fig. 5). Muthuiankadu Kulam located in agro-ecological region DL1e also has its peak coinciding November but there is a chance to exceed 100 mm at 75% probability only in November and December.

Fig. 2. Distribution of monthly average and 75% expected rainfall in stations located in Anuradhapura district

Fig. 3. Distribution of monthly average and 75% expected rainfall in stations located in Vavuniya district

Fig. 4. Distribution of monthly average and 75% expected rainfall in stations located in Ampara district

Fig. 5. Distribution of monthly average and 75% expected rainfall in stations located in Kilinochchi district

Fig. 6. Distribution of monthly average and 75% expected rainfall in stations located in Mullaitivu district

Occurrence of dry spells

The probability of occurrence of dry spells of different lengths in different months is depicted in Fig. 7 to Fig. 11. It is evident that probability of having long dry spells is less than 20% in all the sites during October, November and December. The chance of having dry spells more than 20 days is also less than 0.2 in April for stations located in agro-ecological region DL1b, in Ampara located in DL2b and in Iranamadu in DL3. There is only a

chance 20% to occur dry spells more than 20 days during January and September too, for Ampara.

The driest month is June in all the locations studied except for Anuradhapura where August has more chance to receive dry spells greater than 20 days. The chance exceeds 80% in Medawachchiya, Pawatti Kulam, Akkarayan Kulam, Iranamadu and Muthuiankadu Kulam (Fig. 7 to Fig. 11).

Fig. 7. Monthly distribution of frequency of dry spells of different lengths in Anuradhapura district

Fig. 8. Monthly distribution of frequency of dry spells of different lengths in Vavuniya district

Fig. 9. Monthly distribution of frequency of dry spells of different lengths in Ampara district

Fig.10. Monthly distribution of frequency of dry spells of different lengths in Kilinochchi district

Fig. 11. Monthly distribution of frequency of dry spells of different lengths in Mullaitivu district

As stated by Chithranayana & Punyawardene (2008) DL1f and DL3 regions exhibit mild drought during the Maha season with Moisture Availability Index (MAI) less than or equal to 0.33 in January and February. The areas that belong to DL1e are vulnerable to drought conditions during February. The agro-ecological regions DL2a and DL2b to which Uhana and Ampara areas belong to have no threat of drought during September to February. However, these areas are vulnerable to severe drought conditions during March to August (Fig. 4).

Onset of rains

Knowledge on onset of rains is a basic necessity in devising plans for agro-

management practices. The dates of onset for 1st and 2nd rain spells for different locations are given in Table 3. Based on the criteria used for detection of onset and cease, the dates for onset and cease for the 1st rain spell could be detected in the DL1b areas (Table 3). Further, the start of the 2nd rain spell is about a week earlier than the areas in DL2b, DL1e, DL1f and DL3. There is 80% chance to cease the rain spell before 19th January in 3 of the locations, 20th January, 22nd January and 6th February in other locations (Table 3). The length of the 2nd rain spell in Ampara is comparatively long compared to other locations.

Table 3. Dates of onset and cease of rains in selected locations in the dry zone

Station	Agro-ecological zone	1 st rain spell		2 nd rain spell	
		80% chance to commence before	80% chance to cease before	80% chance to commence before	80% chance to cease before
Anuradhapura	DL 1b	2 nd April	15 th July	27 th October	22 nd January
Vavuniya	DL 1b	15 th April	4 th July	28 th October	19 th January
Ampara Tank	DL 2b	-	-	04 th November	6 th February
Akkarayan Kulam	DL 1f	-	-	07 th November	20 th January
Iranamadu Tank	DL3	-	-	03 rd November	19 th January
Muthuiankadu Kulam	DL 1e	-	-	03 rd November	19 th January

Chance of receiving consecutive wet weeks

The probability of receiving a wet week after a wet week (W/W) can be used in finding suitable time periods for agro-management practices in rubber planting. The results obtained by the Markov chain analysis are depicted in Figs. 12 to Fig. 15. A comparison of probabilities of receiving W/W (≥ 20 mm) is depicted in Fig. 16. It is apparent that in Anuradhapura and Medawachchiya (DL1b) there exist a considerably long wet period during the standard weeks 13-17, which can be effectively used for agro-management practices although it is not strong compared to the year-end wet period. However, in Vavuniya and Pawatti Kulam although belong to DL1b, this period is limited for 3 weeks (15-17) and 2 weeks (16 and 17), respectively. There appeared a chance of 50% or more to have consecutive 2 wet weeks

for a fairly long period in DL1b areas except Pawatti Kulam, which has only 3 weeks which receive consecutive 2 wet weeks during the latter part of the year (Fig. 16).

As depicted in Fig. 14, the probabilities of receiving W/W (20 mm) in Muthuiankadu Kulam which is more towards the East coast of Sri Lanka (DL1e) during the latter part of the year is high compared to Iranamadu (DL3) and Akkarayan Kulam (DL1f). This phenomenon is also clearly depicted in Fig. 16.

The situation in Ampara is somewhat different as depicted in Fig. 15. The probabilities of receiving W/W (20 mm) is 0.3 – 0.49 during 39 to 42, ≥ 0.5 from standard weeks 43 to 52 and extends to the 1st week in the next year and followed by 4 more weeks with a probability between 0.3 – 0.49 (Fig. 16).

Fig. 12. The probabilities associated with occurring a wet week after a wet week in Anuradhapura and Medawachchiya in Anuradhapura district (DL1b)

Fig. 13. The probabilities associated with occurring a wet week after a wet week in Vavuniya and Pawatti Kulam (DL1b) in Vavuniya district

Fig. 14. The probabilities associated with occurring a wet week after a wet week in Akkarayan Kulam (DL1f), Iranamadu (DL3) and Muthuiyankadu Kulam (DL1e) in Kilinochchi and Mullaitivu districts

Fig. 15. The probabilities associated with occurring a wet week after a wet week in Ampara (DL2b)

Optimal dates for major agro-management practices of rubber planting

The major agricultural operations of rubber farming considered in this study are holing, planting and fertilizer application. Planting is the most important operation in rubber cultivation. Hence, it is important to time this operation properly to attain maximum possible establishment success. There is no option other than planting rubber in October/November period with the onset of 2nd rain spell in the locations considered in this study.

In areas which belong to agro-ecological region, DL1 there is 80% of chance to begin the 2nd rain spell before the end of October. The average onset date for Anuradhapura is 10th October and for Vavuniya it is 11th October. The average end date for both these locations is 19th January and the length of the rain spell is 101 days. During the

months, October to December the risk of having long dry spells (>20 days) is very low (Fig. 7 & Fig. 8). Hence, planting can be commenced after 22nd October (43rd standard week) in these areas. There will be minimal risk of receiving dry spells until the end of the year for these areas. However, it is important to complete planting during 43rd and 44th weeks (22nd October to 04th November) because the 1st fertilizer application need to be done when there is sufficient moisture in the soil.

Holing is usually carried out in the Wet zone areas during late March when scattered showers are set in. A moist soil is generally required for this operation and holing should be done about 1 to 1½ months before planting. Therefore, to match with the planting dates holing can be done during 38th or 39th standard weeks (17th September to 30th September).

Fig. 16. Periods associated with different probabilities for receiving wet after a wet week (> 20 mm) in different locations

As stated above, the 1st fertilizer application is due 2 months after planting coincides with the 51st or 52nd week. This period is usually without heavy showers and has sufficient moisture retained in the soil from the 2nd rain spell which is more effective in these areas. For the 2nd application of fertilizer, 13th or 14th weeks are suitable (26th March to 8th April) and the next application should coincide with 39th or 40th weeks (24th September to 7th October) before heavy rains begin to occur in the 2nd rain spell.

The average onset date of the 2nd rain spell in Ampara area which belongs to DL2b is 14th October and the average end date is 25th January and has an average length of 103 days which is quite similar to DL1b areas. Holing, planting and fertilizer applications can be done in DL2b areas according to the dates suggested for DL1b areas. However, it should be noted that the risk of experiencing a 20 days dry spell is more (20%) compared to DL1b areas during April and hence more thought should be given to moisture conservation measures.

According to Fig. 16, a similar agro-management plan can be employed in rubber planting in the areas that belong to DL1f, DL1e and DL3. It is further supported by Fig. 11. Yet, the probability of receiving consecutive wet weeks in Akkarayan Kulam (DL1f) is very low during the latter part of the year.

Conclusions

The AERs in the Dry zone are vulnerable to droughts especially during March to August. However, if cultural operations are carried out in a timely manner the repercussions of dry spells can be minimized to a considerable extent. Holing operation which requires a moist soil is best be done during 38th or 39th standard weeks (17th September to 30th September). Planting of rubber should coincide with 43rd and 44th weeks (22nd October to 04th November) to catch the maximum possible length of the wet season to assure optimal establishment success. First, second and third fertilizer applications in the first year of planting need to be done respectively, during 51st/52nd (17th to 31st December), 13th/14th weeks (26th March to 8th April) and 39th/40th weeks (24th September to 7th October) to avoid heavy rains and dry spells. All these dates have been computed using the probability theory in various ways. Hence, it should be noted that it is impossible to prevent any departures from these stipulated dates. Yet, through proper cultural operations and moisture management practices in rubber plantations, *viz.*, irrigation, mulching and intercropping throughout the immature phase of rubber, one can assure a healthy rubber plantation with minimum vacancies to reach the tappable status.

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