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Agro-Climatic Approach to Minimize Risk Associated With Water Scarcity in Different Locations of Matara District in Sri Lanka

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ABSTRACT. The research assessed the climatic risks in respect to onset, duration and magnitude of the rainfall using the climatic water balance approach and the rainfall probability concepts. The rainfall data for 45 consecutive years (1950 ~ 1995) were collected from nine stations in different agro-climatic regions of Matara district. Computer programs 'First' and 'CROPWAT' were used for the data analysis. Ten mm weekly rain < 75% probability and Hargreave's Moisture Availability Index (MAI)<0.34 in weekly basis were used to assess dry weeks of the area. Optimum date of crop commencement was simulated by least irrigation water requirement method, date of 100 mm forward accumulation of rainfall at 75% probability level, commencement of period with Hargreave's MAI>0.34 and onset date of 10 mm weekly rains >75% probability method.

The results revealed that the number of dry weeks in the selected regions except Thihagoda is closely related to the annual rainfall of the district. A bimodal pattern in distribution of the wet weeks was recorded in the regions except Dandeniya, which belongs to the IL_1 climatic region.

The planting dates of curry chillie <u>Capsicum annuum</u> var-Hungarian Yellow Wax in Yala and Maha seasons fall during 12^{th} ~ 17^{th} and 32^{nd} ~ 40^{th} meteorological weeks, respectively in all the selected regions. It is established that the commencement of the crop could be advanced in the locations where the annual rainfall is high.

INTRODUCTION

Home gardens play a vital role in the economy of the small holding agricultural sector in Sri Lanka. One of the major problems associated with intensification and optimization of the home garden agriculture is the water scarcity that couples with the high risk of temporal and special differences in rainfall. Water scarcity for irrigation is much acute even within the monsoon period. Hence, the identification of optimum cropping dates is of paramount importance to utilize the climate potential in different locations. Therefore, the analysis of rainfall data is important to determine the date of establishment of crops to obtain a better harvest. According to Panabokke and Walgama (1974), the arithmetic mean is usually calculated directly from rainfall figures, which does not take into account the inherent skewness of the raw data that resulting from a large amount of precipitation during heavy tropical downpours. Even the mean monthly averages proposed by Oldeman and Frere (1982) is a risky parameter to decide crop establishment period.

Krishnan (1980) considered the week as the unit of time period in tropics to analyse rainfall data, where rainfall is highly variable in intensity, amount and distribution. Therefore, decisions can be made based on the probability of receiving certain amount of rainfall during a week in selecting crops and identifying the ideal time of planting, while avoiding probable water stress periods and floods during sensitive phenological phases (Weerasinghe *et al.*, 1998). Same method has been applied by Robertson (1976), Virmani (1980), Virmani *et al.* (1982), Weerasinghe *et al.* (1990) and Weerasinghe (1993) to analyse the agro-climatologocal potential in different locations. These analyses show the existence of much acute water scarcity periods during the cropping seasons even within the monsoon period.

The optimum-cropping calendar indicates the best suitable time for the establishment of a seasonal crop to utilize the climatic potential effectively and maximize the yield while avoiding critical operations. As indicated by Weerasinghe *et al.* (1998), the need of irrigation for tea and rice in Nilwala areas could be minimized if the optimum planting date is selected using the 'CROPWAT' computer program.

The main objective of this research was to identify the optimum cropping calendar and planting time of curry chilies for home gardens in the selected regions of Matara district. Four assessment methods were used to identify the optimum planting date using the computer programs 'CROPWAT' and 'First'. Further, the research attempted to identify the number of dry weeks per year, critical water deficit periods and to determine the irrigation needs for curry chillie established in different time periods of the year.

MATERIALS AND METHODS

Location

The research was conducted in Matara district in southern Sri Lanka. The district has seven agro-ecological regions (The National Atlas of Sri Lanka, 1988) and located within latitude 6° – 6° 20' N and longitude 80° 23' – 80° 43' E covering an area of 1,282.5 km^2. Daily rainfall data available in nine rain gauge stations in Matara district representing all agro-ecological regions *viz.*, Anninkanda, Mawarala, Hiyare, Charley Mount, Mapalana, Thihagoda, Kekanadura, Dandeniya and Denagama, for 45 consecutive years (1950 – 1995) were used for the study.

Pan evaporation data of Mapalana meteorological station was used to calculate the potential evapotranspiration for all regions since there are no other data available in the region. The potential evapotranspiration was considered as 0.8 of the pan evaporation.

Assessment of dry weeks

In the present study, a weekly rainfall of 10 mm at 75% probability was considered as sufficient to satisfy the moisture requirement of the crop for three out of four years as confirmed by Virmani (1980), Virmani *et al.* (1982), Oldeman (1980) and Weerasinghe *et al.* (1998). The weeks receiving 10 mm rains less than 75% probability are considered as the dry weeks.

The adequacy of rainfall to meet the potential evapotranspiration (PET) gives a better understanding of the climatic water balance. The Moisture Availability Index (MAI) suggested by Hargreaves (1971) was used to calculate the number of dry weeks per year. The calculation was done by assessing the ratio between weekly dependable precipitation and weekly potential evapotranspiration. According to Hargreaves (1971), a MAI of 0.34 could be considered as the lower value for dry land crops. Therefore, the weeks which MAI value is less than 0.34 were considered as the dry weeks which was confirmed by Krishnan (1980). The distribution of dry weeks throughout the year in the study area was demarcated using these two methods.

Optimum time of crop establishment

Optimum time of crop establishment for *Yala* (shorter) and *Maha* (longer) rainy seasons was calculated using four assessment methods, namely considering the week of forward accumulation of 100 mm rainfall at 75% probability after the dry period, commencement of wet weeks after end of prolong series of dry weeks assessed in respect to 10 mm weekly rain at 75% probability, Hargreave's weekly MAI and the water balance method using 'CROPWAT' computer program. Different planting dates are selected for the same crop under the same climatic conditions. When the planting date is changed, the irrigation requirement is also changed. Therefore, the optimum date of planting is selected on the basis of the least irrigation requirement throughout the season.

Apart from the rainfall and the potential evapotranspiration data, irrigation water requirement for curry chillie grown under water saving irrigation systems (Navaratne *et al.*, 1997) was used to calculate crop coefficients.

The computer programme 'First' developed by Weerasinghe *et al.* (1990) for hydrological frequency analysis based on Markov Chain Procedure was used to determine the probability of receiving 10 mm weekly rain. The 100 mm accumulation of rainfall in each location was carried out from 1st March and 1st August for *Yala* and *Maha* seasons respectively. A survey was conducted in all selected regions to find the present commencement period of vegetable crops in *Yala* and *Maha* seasons.

RESULTS AND DISCUSSION

Assessment of dry weeks

Table 1 shows the number of dry weeks per year, which was assessed considering 10 mm weekly rainfall less than 75% probability, the Hargreave's weekly MAI less than 0.34, and the annual rainfall of all the regions.

Even though, the mean annual rainfall received in selected locations were high (ranging from 1656–3867 mm), seasonality of rainfall created a large number of dry weeks, more than 10 weeks in each location, which agrees with the earlier study conducted by Weerasinghe (1989) for selected stations of Matara, which pursues the irrigation need of the crops. The dryness is very much high in Dandeniya, Kekanadura, Thihagoda and Denagama where 39 – 43 weeks received less than 10 mm rain at 75% probability level.

The dry weeks of each region are related to the mean annual rainfall of the respective region.

Table 1. Number of dry weeks and annual rainfall in different locations.

Location	Dry weeks year^{-1}		Annual rainfall (mm)
	10 mm rainfall at 75% probability	MAI < 0.34	
Anninkanda	10	12	3867
Mawarala	22	23	3041
Hiyare	31	24	2796
Mapalana	34	30	2352
Tihagoda	43	41	2041
Kekanadura	43	40	1656
Charley Mount	27	26	2527
Dandeniya	43	43	1685
Denagama	39	39	1863

* Correlation - 0.96 ** R^2 - 0.9692

Number of dry weeks in all the selected locations computed under both methods showed a significant correlation with rainfall (R^2 = 0.97 and $P<0.0001$) indicating the practicability of application of 10 mm rainfall limit to identify wetness of the region when potential evapotranspiration data are not available.

Table 2 gives the probability of receiving 10 mm rainfall in each standard week for the selected regions. The distribution of dry weeks in each region is highlighted. The regions such as Anninkanda and Mawarala received 10 mm rainfall weekly at higher probabilities than all the other regions. Lower probability of receiving 10 mm rain weekly occurred in Kekanadura, Dandeniya and Denagama regions.

The distribution of dry weeks in each region throughout the year based on weekly MAI <0.34 is shown in Table 3. Virmani (1980), Virmani *et al.* (1982) and Krishnan (1980) successfully used this methods to delineate dry periods in India. Both methods showed a similar dry weeks distribution pattern. The lowest number of dry weeks can be found in northern part whereas the highest is recorded in southeastern part of Matara district (Fig. 1 and 2).

Optimum date of crop establishment

Irrigation requirement of the crops based on the crop commencement date of curry chillie for *Yala* and *Maha* seasons in selected regions is given in Fig. 3 and 4. The same method has been applied by Weerasinghe *et al.* (1998) to identify irrigation requirement for rice and tea in Nilwala Basin in southern Sri Lanka.

Table 2. Initial probability of weekly rains (Limit 10 mm).

Week	Anninkanda	Mawarala	Hiyara	Mapalana	Tihagoda	Kek'dura	Charley	Dandeniya	Denagama
1	77	53	63	51	40	28	51	27	51
2	77	63	65	63	54	42	63	54	60
3	70	56	39	46	30	33	48	38	54
4	59	60	63	44	35	17	44	38	49
5	68	56	51	51	30	36	51	40	39
6	61	49	51	40	40	19	46	32	44
7	66	60	53	40	37	42	41	22	47
8	70	74	63	46	30	33	51	41	53
9	86	63	72	53	49	33	61	38	49
10	82	67	67	51	30	25	56	22	60
11	86	76	74	58	19	28	54	35	56
12	95	79	67	62	43	28	61	54	53
13	93	81	79	49	54	31	44	57	56
14	95	88	74	72	57	55	76	57	74
15	84	74	76	60	59	42	59	54	70
16	95	86	86	74	68	50	85	59	84
17	95	95	86	84	76	61	78	62	77
18	91	90	81	77	76	75	78	73	67
19	86	86	81	74	70	69	76	67	67
20	89	83	83	77	62	72	78	81	65
21	91	88	81	74	68	64	78	70	81
22	91	86	81	81	68	81	83	76	86
23	86	88	84	88	70	69	87	73	81
24	79	86	84	76	73	72	78	62	67
25	84	77	79	72	65	72	76	68	72
26	86	74	72	74	81	78	76	73	63
27	75	70	67	65	62	67	73	65	56
28	81	81	81	74	59	69	83	54	74
29	81	65	72	65	54	64	76	59	63
30	70	60	74	70	56	58	66	65	56
31	68	72	67	65	51	42	59	65	51
32	79	74	70	63	78	64	73	54	67
33	73	74	70	63	70	69	66	57	60
34	68	63	72	58	54	53	59	59	49
35	75	70	74	63	59	53	61	68	63
36	82	65	60	58	51	53	68	57	60
37	81	79	76	77	70	61	78	70	67
38	84	86	91	77	70	64	83	81	72
39	86	81	79	83	81	75	83	70	74
40	84	76	79	74	70	69	73	73	70
41	86	79	67	79	65	69	88	78	72

Continued ....

Table 2. Cont'd ....

Week	Anninkanda	Mawarala	Hiyara	Mapalana	Tihagoda	Kek'dura	Charley	Dandeniya	Denagama
42	84	79	72	81	70	72	83	76	79
43	84	88	74	76	86	75	93	81	81
44	95	93	74	88	81	89	93	86	98
45	95	86	72	81	76	92	88	81	95
46	100	88	81	91	78	83	93	76	93
47	86	88	81	84	73	75	80	73	86
48	89	83	81	79	65	69	80	57	81
49	93	88	74	84	62	53	71	49	91
50	80	70	65	63	49	44	61	35	63
51	89	88	70	67	49	58	71	35	67
52	93	81	79	63	59	58	76	54	74

The shaded area represents the dry weeks.

Table 3. MAI values of selected stations.

St Weeks	Anninkanda	Mawarala	Hiyara	Mapalana	Tihagoda	Kek'dura	Charley	Dandeniya	Denagama
1	0.15	0.11	0.08	0.00	0.00	0.00	0.00	0.00	0.00
2	0.14	0.03	0.09	0.04	0.00	0.00	0.13	0.00	0.00
3	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.01	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00
5	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	0.84	0.29	0.05	0.00	0.00	0.00	0.00	0.00	0.00
9	0.62	0.19	0.16	0.06	0.00	0.00	0.07	0.00	0.00
10	1.11	0.09	0.11	0.00	0.00	0.00	0.00	0.00	0.07
11	1.08	0.32	0.07	0.00	0.00	0.00	0.00	0.00	0.00
12	1.74	0.31	0.06	0.00	0.00	0.00	0.00	0.00	0.00
13	0.84	0.48	0.16	0.00	0.00	0.00	0.00	0.00	0.00
14	1.62	0.67	0.21	0.25	0.00	0.22	0.45	0.02	0.00
15	1.38	0.30	0.23	0.0-9	0.00	0.00	0.11	0.00	0.00
16	1.36	0.68	0.69	0.20	0.16	0.17	0.51	0.00	0.00
17	1.02	0.76	0.83	0.55	0.31	0.14	0.22	0.04	0.14
18	1.20	1.35	1.40	0.51	0.39	0.66	0.47	0.07	0.00
19	1.01	1.05	0.92	0.23	0.22	0.23	0.33	0.00	0.00
20	1.42	0.53	1.15	0.44	0.37	0.31	0.72	0.29	0.34
21	0.88	1.04	1.20	0.40	0.40	0.00	0.73	0.30	0.12
22	0.82	1.03	1.41	0.61	0.37	0.80	0.70	0.45	1.42
23	0.76	0.76	0.81	0.71	0.14	0.26	0.83	0.24	0.09

Continued ....

Table 3. Cont'd ....

St Weeks	Anninkanda	Mawarala	Hiyara	Mapalana	Tihagoda	Kek'dura	Charley	Dandeniya	Denagama
24	0.86	0.69	0.88	0.44	0.21	0.41	0.61	0.23	0.61
25	0.41	0.38	0.70	0.30	0.11	0.37	0.43	0.19	0.09
26	0.77	0.44	0.56	0.38	0.34	0.54	0.56	0.42	0.16
27	0.55	0.31	0.30	0.22	0.11	0.21	0.26	0.15	0.00
28	0.40	0.62	0.58	0.34	0.28	0.30	0.46	0.18	0.00
29	0.32	0.16	0.60	0.16	0.03	0.22	0.35	0.00	0.00
30	0.74	0.16	0.51	0.23	0.00	0.18	0.27	0.00	0.00
31	0.25	0.28	0.32	0.17	0.12	0.00	0.24	0.00	0.11
32	0.22	0.33	0.34	0.13	0.08	0.22	0.35	0.14	0.26
33	0.36	0.22	0.30	0.07	0.00	0.25	0.19	0.20	0.09
34	0.15	0.17	0.22	0.06	0.08	0.08	0.08	0.06	0.00
35	0.34	0.16	0.30	0.07	0.19	0.00	0.00	0.04	0.00
36	0.87	0.18	0.23	0.03	0.00	0.05	0.28	0.00	0.00
37	1.05	0.52	0.62	0.41	0.32	0.29	0.49	0.13	0.13
38	0.56	0.70	0.89	0.44	0.30	0.27	0.53	0.28	0.28
39	1.03	1.19	0.70	0.53	0.56	0.50	0.42	0.45	0.11
40	1.37	0.47	0.69	0.37	0.18	0.29	0.60	0.36	0.64
41	2.07	0.65	0.47	0.54	0.23	0.32	0.70	0.56	1.33
42	2.77	1.11	1.03	0.90	0.12	0.34	0.82	0.22	0.93
43	2.23	0.91	0.63	0.62	0.43	0.39	0.86	0.29	0.47
44	2.73	1.68	1.73	1.26	0.97	1.00	1.48	0.99	0.79
45	1.33	1.48	1.47	1.19	0.86	1.09	1.41	0.72	0.71
46	0.90	1.84	2.02	1.54	1.24	0.99	1.41	0.61	1.00
47	1.59	0.77	0.36	0.59	0.79	0.40	0.69	0.47	0.79
48	0.80	0.69	0.74	0.53	0.25	0.29	0.63	0.20	0.43
49	0.88	0.94	0.23	0.43	0.19	0.05	0.28	0.00	0.44
50	0.72	0.14	0.09	0.21	0.00	0.05	0.16	0.00	0.00
51	0.00	0.69	0.22	0.11	0.00	0.00	0.26	0.00	0.00
52	0.00	0.55	0.55	0.10	0.11	0.00	0.55	0.00	0.00

The shaded area represents the dry weeks.

The minimum water requirement occurred if the curry chillie is planted in 12^{th} – 13^{th} meteorological week in Mawarala, Hiyare, Charley Mount and Mapalana regions while 15^{th} – 17^{th} meteorological week in Thihagoda, Kekanadura, Dandeniya and Denagama regions for the *Yala* season. Therefore, the optimum planting time for curry chillie should be between 12^{th} – 17^{th} standard weeks for all the regions except the high rainfall regions such as Anninkanda. Any planting date could be adopted through out the season, as these high rainfall regions have no irrigation requirement.

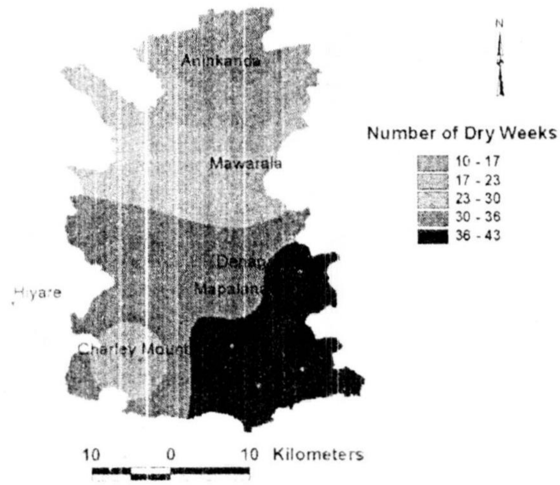

Fig. 1. Annual distribution of dry weeks in Matara District based on receiving 10 mm weekly-rain less than 75% probability.

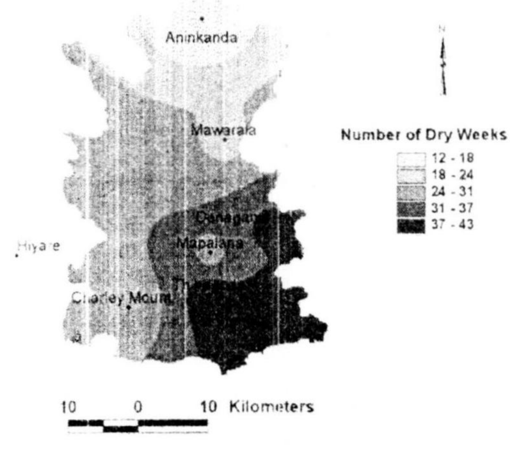

Fig. 2. Annual distribution of dry weeks in Matara District based on weekly MAI values less than 0.34.

The minimum water requirement for *Maha* season occurred in all the selected regions when curry chilies are planted in 32nd – 39th meteorological week. Morris and Zandstra (1978) presented a method to determine the onset of cropping season using an accumulation of a certain amount of rainfall, which helps to moisten the topsoil. The rainfall of the year is summed forward until the amount of rainfall interested by the user is accumulated. Morris and Zandstra (1978) selected 75 mm accumulation of rainfall as the onset time for the growing season of dry seeded crops in Malaysia. They indicated that in the areas where the dry weeks appeared in the cropping seasons frequently, 75 mm accumulation of rainfall is not sufficient to demarcate the cropping seasons. Therefore, 100 mm accumulation of rainfall at 75% probability is selected as a method of identifying the onset time for curry chilies in the present research for the Matara district.

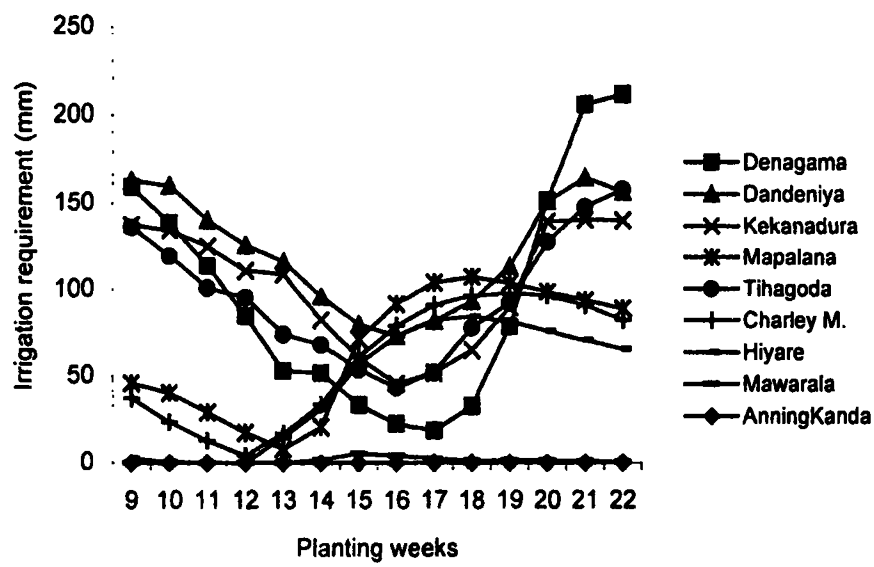

Fig. 3. Simulated water requirement of curry chilies in different regions for *Yala* season when the planting dates are changed.

The optimum crop commencement for *Yala* and *Maha* seasons with respect to four assessment methods and weekly MAI are given in Table 4. The applicability of Hargreaves monthly MAI to delineate the cropping seasons has been tested by Weerasinghe (1989) for Mapalana, Sri Lanka, and Virmani (1980), Virmani *et al.* (1982) and Krishnan (1980) for India.

The optimum planting date for curry chillie in *Yala* season may vary from 12th to 21st week for all the regions except more wet regions such as Anninkanda. The optimum planting date for *Maha* season would vary from 34th – 42nd week for all the regions. The present research reveals that the beginning of *Maha* season is somewhat earlier than normally practised in all the regions other than Denagama.

All four assessment methods indicated similar crop commencement weeks for a particular region. The crop establishment period could be advanced in the regions where annual rainfall is high.

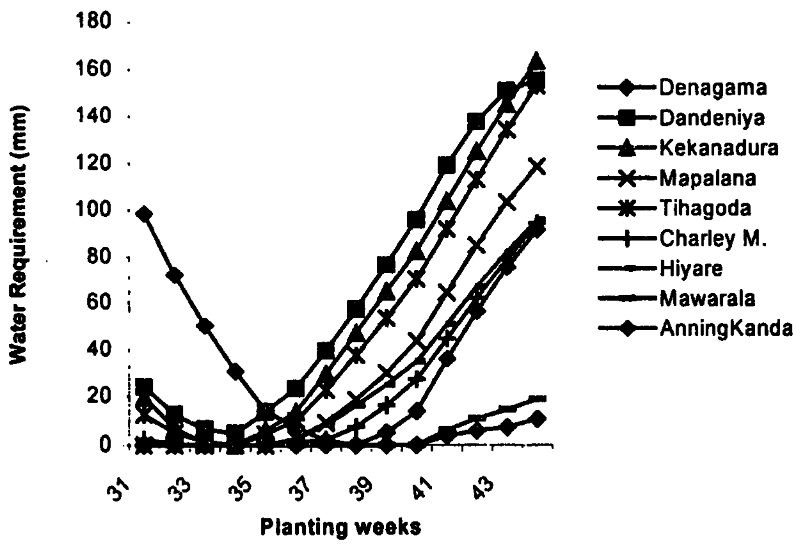

Fig. 4. **Simulated water requirement of curry chillie in different stations for *Maha* season when the planting dates are changed.**

Table 4. **Crop commencement time for different regions with respect to four assessment methods.**

Location	Crop commencement time (St. Weeks)							
	Yala				*Maha*			
	1st Mtd.	2nd Mtd.	3rd Mtd.	4th Mtd.	1st Mtd.	2nd Mtd.	3rd Mtd.	4th Mtd.
Anninkanda	-	11	9	6	32-39	35	34	35
Mawarala	12	12	10	14	32-39	35	36	37
Hiyare	12	14	12	15	32-35	35	36	37
Mapalana	13	14	16	16	32-35	35	36	37
Tihagoda	15	16	16	17	34	37	39	39
Kekanadura	16	18	17	21	34	37	39	39
Charley	12	14	15	15	34--36	35	36	37
Dandeniya	16	18	20	21	34	37	37	39
Denagama	17	17	15	19	38	39	42	40

1st Mtd. - Water balance analysis using 'CROPWAT'; 2nd Mtd. - Forward accumulation date of 100 mm rainfall at 75% probability; 3rd Mtd. - Initial probability of weekly rains at 10 mm limit; 4th Mtd. - Weekly MAI >0.34

The relationship between crop commencement period calculated by 'CROPWAT' and other methods are shown in Boxes 1 and 2. Date of crop establishment calculated by 'CROPWAT' has already been tested by several authors and the results have indicated that it may be the best method to calculate crop establishment time.

Box 1: For *Maha* season;

$a = 2.6703x - 17.572$; $r^2 = 0.869$	$b = 1.3626x - 2.2198$; $r^2 = 0.738$	$c = 1.9176x - 9.6319$ $r^2 = 0.757$

Box 2: For *Yala* season;

$a = 0.9595x + 3.7703$; $r^2 = 0.387$	$b = 1.1622x - 5.0811$; $r^2 = 0.658$	$c = 1.9595x - 32.23$ $r^2 = 0.693$

where;

x = 'CROPWAT' method
a = MAI method
b = 100 mm rainfall accumulation method and
c = 10 mm initial probability method

Irrigation need for the crops with optimum planting date

The optimum planting time is scheduled considering the minimum irrigation requirement of crops for *Yala* and *Maha* seasons. The irrigation water requirement for curry chillie throughout the season when planting is done considering the minimum irrigation requirement is given in Table 5.

Table 5. Optimum planting date and irrigation need of curry chillie.

Location	Optimum planting date		Irrigation need (mm)	
	Yala	*Maha*	*Yala*	*Maha*
Anninkanda	-	32-39	0.0	0.0
Mawarala	12	32-39	0.0	0.0
Hiyare	12	32-35	0.0	0.0
Mapalana	13	32-35	20.2	0.0
Tihagoda	15	34	59.2	3.0
Kekanadura	16	34	66.2	30.4
Charley Mount	12	34-36	7.2	0.0
Dandeniya	16	34	119.1	7.6
Denagama	17	38	34.4	8.4

The highest irrigation need for *Yala* is in Dandeniya among all the selected regions (119.1 mm) and the highest irrigation need for *Maha* season is in Kekanadura (30.4 mm) for the curry chillie.

Even though there is considerable number of dry weeks appeared in the selected regions, the irrigation need for a particular crop can be minimized when planting is done on the optimum planting date. It is important to note that an extended crop establishment period could be observed in *Maha* in wet regions when compared to the dry regions such as Tihagoda, Kekanadura, Dandeniya and Denagama.

CONCLUSIONS

Weekly rainfall of (10 mm at 75% probability level and weekly Hargreave's MAI$\leq$0.34 could be equally applied to identify the prevailing dryness in different regions. The methods of water balance analysis using 'CROPWAT', 100 mm forward accumulation of rainfall at 75% probability, weekly MAI>0.34 and receiving of 10 mm weekly rain >75% probability levels could be successfully used to assess the optimum crop commencement period of curry chillie in Matara district of Sri Lanka. A 100 mm forward accumulation rainfall at 75% probability method and 10 mm weekly rains at 75% initial probability method can be used to calculate crop establishment period in the regions where the potential evapotranspiration and crop data are not available. Adaptation of optimum planting date based on the water balance approaches would help to reduce the irrigation requirement of the particular crop.

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