Optimizing planting schedule of sugarcane for saving irrigation water in Sevanagala and Udawalawe, Sri Lanka

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Optimising Planting Schedules of Sugarcane for Saving Irrigation Water in Sevanagala and Uda Walawe, Sri Lanka

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ABSTRACT

An analysis was carried to determine the most appropriate planting time in terms of minimum use of irrigation water for sugarcane cultivation at Sevanagala and Uda Walawe. Agro-meteorological data collected from 1984 to 2012 were used for this analysis. Monthly effective rainfall, crop water requirement, irrigation requirements and rainfall usage by the crop were assessed. The annual average rainfall at Sevanagala and Uda Walawe from 1984 to 2012 was1453 mm and 1532 mm respectively. The respective effective rainfall levels were 896 mm and 960 mm. The estimated annual average crop water requirement of sugarcane at Sevanagala and Uda Walawe were1421mm and 1397 mm respectively. With the change of planting date from January to December, it varied from 1385 mm to 1455 mm at Sevanagala and from 1352 mm to 1441 mm at Uda Walawe. The study revealed that when the crop was planted 10thJanuary to coincide with the first rainy season of the year, the total estimated annual irrigation water requirement in both locations was at minimum; 685 mm for Uda Walawe and 700 mm for Sevanagala. Similarly, when the crop was planted on 30th June, the grand growth period of sugarcane plant coincided with the second rainy season, and hence, the total estimated annual irrigation water requirement was at minimum in both locations; 619 mm for Uda Walawe and 649 mm for Sevanagala. Thusplanting sugarcane on 10thJanuary and 30thJune makes possible minimising the utilisation of limited available irrigation water by maximising the usage of rainfall at Sevanagala and Uda Walawe.

Keywords: Crop water requirement, Effective rainfall, Evapo-transpiration, Irrigation, Sri Lanka, Sugarcane

INTRODUCTION

Commercial cultivation of sugarcane in Sri Lanka is carried out in dry and intermediate zones where annual rainfall varies from 1500 mm to 1700 mm and 1750 mm to 2500 mm respectively with a bimodal pattern which has two rainy periods (Shanmugnathan, 1990). The first rainy period starts with the first inter-monsoonal rainfall from mid of March and continues till May. The second rainy season starts with the onset of second inter-monsoon and ends with the north-east monsoon from mid September to January. With this rainfall pattern, supplementary irrigation is required during dry months when crop water requirement cannot be supplied with rainfall for optimum growth (Shanmugnathan, 1990, Aloysius & Zubair, 1999). Rain fed-cultivation of sugarcane normally produces a low yield, and is about half of irrigated yield at Uda Walawe (De Silva, 2011). Even though Sevanagala (irrigated sector) and Uda Walawe sugarcane plantations are managed with irrigation supply at a rate of 151,000 m^3/day from Uda Walawe reservoir (Maaike, 2002), the frequency of water cut-offperiods have shown an increasing trend in the recent past. This leads to reduce not only potential yields of sugarcane but also total extent of irrigable land. Thus, adoption of irrigation water-saving practices has become important to increase cane yield as well as cropped area.

In general, net irrigation water requirement of a crop (In) is determined by effective rainfall (Pe) and crop evapo-transpiration (ETc) in a particular month. The length of a normal crop cycle of sugarcane under irrigation in tropical area is about 12 months (Wyseure, *et.al*, 1992) and crop water requirement (CWR) is 1200-1500 mm (Glyn,2004) per annum. The CWR depends on the local climatic conditions and the variety (FAO, 2002). Crop coefficients used to estimate crop evapo-transpiration varies from 0.4 to 1.25 (FAO, 1984), and accordingly the crop water requirement of different growth stages also vary. By planting sugarcane to coincide the growth stage where the crop water requirement is high and manipulation of other agronomic practices, the available rain water could be maximally utilised. This makes possible reduction of demand for irrigation. Commercial planting under irrigation can be carried out year around, and hence, planting date can easily be shifted to minimise the irrigation demand. The reduction of irrigation water use enhances the productivity of water, and hence, the sustainability of sugarcane farming under irrigation. This study was carried out to find out the best sugarcane planting dates in the two rainy periods aiming at minimising the irrigation water demand of sugarcane crop at Sevanagala and Uda Walawe.

MATERIALS AND METHODS

The maximum and minimum temperatures, relative humidity, wind velocity, bright sunshine hours and rainfall during the last 29 years from 1984 to 2012 collected at weather stations in Lanka Sugar Company Limited, Sevanagala (6°23'47"N, 80°54'45"E) and Sugarcane Research Institute, Uda Walawe (6°24',32"N; 80°50',23"E) were used for this analysis. These two agro- meteorological stations are located at a distance of 8.14km. The Uda Walawe and Sevanagala sugarcane lands are located in DL_{1a} and DL_{1b} agro-ecological zones, respectively.

Crop water requirement (CWR), which is equal to crop evapo-transpiration was estimated by multiplying reference evapo-tratspiration (ET_o) values with crop factor (Joss, 2009). The reference evapo-transpiration values were estimated based on agro-climatic data in Sevanagala and Uda Walawe using the Modified Penman method (FAO, 1984).

The reference evapo-transpiration (ET_0) was estimated with the following equation (Equation 1) (FAO, 1984) using CROPWAT software v 8.

$$\mathbf{ET_0 = C\ [W.Rn + (1\text{-}w).\ f\ (U).\ (ea - ed)]} \qquad \text{Equation 1}$$

where, Rn = net radiation in equivalent evaporation expressed as mm/day, W=temperature of altitude related factor, f(U) = wind-related function, ea–ed= vapour pressure deficit (m. bar), C=the adjustment factor (ratio of U day to U night), Rn (0.75-Rns), ea=Saturated vapour pressure (mb), ed=mean actual vapour pressure of the air (mb).

The crop evapo-transpiration of sugarcane crop was estimated by equation (2) shown below (FAO, 1984):

$$\mathbf{ET_c = K_c * ET_o} \qquad \text{Equation 2}$$

where, ET_c – evapo-transpiration, Kc – crop coefficient depending on the crop growth stage, ET_0 reference evapo-transpiration.

The irrigation requirement was determined by field water balance approach (Equation 3). Field water balance (soil moisture deficit or surplus) was calculated for 10-day intervals by subtracting effective rainfall (Pe) from crop-evapo-transpiration (ET_C), assuming evapo-transpiration is the only way of removing water from the root zone soil and no capillary rise takes place from groundwater table. It was assumed that deep percolation loss is zero, since the root–zone depth of sugarcane is considered as 90 cm. The irrigation depth was calculated at 50% moisture depletion level.

$$\mathbf{In = ETc - (Pe + Ge + Wb)} \qquad \text{Equation 3}$$

where, In-net irrigation requirement, ETc – crop evapo-transpiration, Pe- effective rainfall, Ge- ground water contribution, Wb- soil moisture level before irrigation.

The effective rainfall (Pe) in Sevanagala and Uda Walawe was determined according to the FAO/AGLW formula (FAO, 1984).

Field water balance analysis showed excess rainfall in some months and deficits in others. Even though excess water is available, plants consume only the fraction equal to crop evapo transpiration. Accordingly, the amount of rainfall that could be utilised by the crop ($RF_{utilise}$) can be calculated as follows:

If, effective rainfall (Pe) $\leqslant$ Crop evapo-transpiration (ET_{Crop}) then,

$$RF_{utilise} = Pe$$

Else,

$$RF_{utilise} = ET_{Crop}$$

RESULTS AND DISCUSSION

Rainfall and effective rainfall

Sevanagala and Uda Walawe areas received an annual average rainfall of 1452.7 mm and 1531.6 mm respectively with a unique bimodal pattern of distribution in *Yala* (March to May) and in *Maha* seasons from September to January (Figure 1).

The estimated monthly effective rainfall (*Pe*) for sugarcane crop of Sevanagala and Uda Walawe were 896.2 mm and 959.7 mm respectively (Table 01).

Variations of crop evapo-transpiration and irrigation requirements

The estimated crop evapo-transpiration (ET_c), irrigation requirement (In) and rainfall utilised by the crop ($RF_{utilise}$) varied with the change of planting date (Table 2). Further, variation of irrigation water requirement (In) showed a bimodal pattern (Figure 02) as the pattern of rainfall distribution.

According to the results, the estimated annual crop water requirement varied from 1384.6 mm to1454.8 mm and from 1352.3 mm to 1441.1 mm in Sevanagala and Uda Walawe respectively. The annual average values were 1420.5 mm and 1396.5 mm for Sevanagala and Uda Walawe respectively (Table 2). Moreover, as monthly effective rainfall varied (Table 1), the irrigation water requirement also varied (Figure 2).The analysis showed that planting

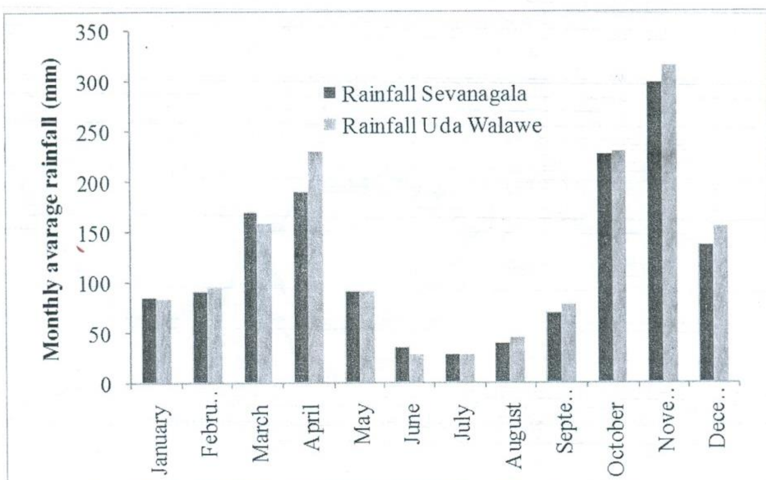

Figure1 Distribution of mean monthly rainfall (from 1984 to 2012) at Sevanagala and Uda Walawe

Table 1 Variation of monthly affective rainfall (mm) in Sevanagala and Uda Walawe

Month	Sevanagala	Uda Walawe
January	43.5	42.5
February	48.6	52.2
March	111.1	102.5
April	127.1	159.4
May	47.8	48.6
June	10.6	6.0
July	6.1	6.0
August	13.6	16.9
September	31.6	37.6
October	157.4	159.4
November	214.2	228.6
December	84.6	100.0
Total	896.2	959.7

June which resulted in a minimum irrigation water requirement for a total crop cycle. The analysis for Sevanagala showed the irrigation requirement has reduced to 700.4 mm/year when planting was done on 10th January and to 649.3mm/year if planted on 30th June. For Uda Walawe, these two minimum irrigation water requirement levels were at 685.2 mm/year and 619.1mm/year respect to planting on10th January and 30th of June .The grand growth period which has a maximum daily crop evapo-transpiration starts at 95 days after planting. If planting is done on the 10th of January, the maximum amount of rainwater can be utilised by the crop during this grand growth period, which starts on 6th of April. At this time, *Yala* rainy season is well established. If planting is done on 30th June, the grand growth period starts from 3rd of October. Usually, the 2nd inter-monsoonal rainfall for Sevanagala and Uda Walawe area starts in late September (Figure 1). The *Maha* rainfall continues till end of December for a period of three and a half months. Hence, the maximum amount of rainwater can be utilised by the crop during this period. Starting the planting on 30th of June facilitates the grand growth period of sugarcane crop to coincide with this heavy rainy season that has adequately available soil moisture. Considering the fraction of rain water used, month of January and (1st planting season) and from June to July (for 2nd planting season) are most suitable for planting sugarcane in both Sevanagala and Uda Walawe areas.

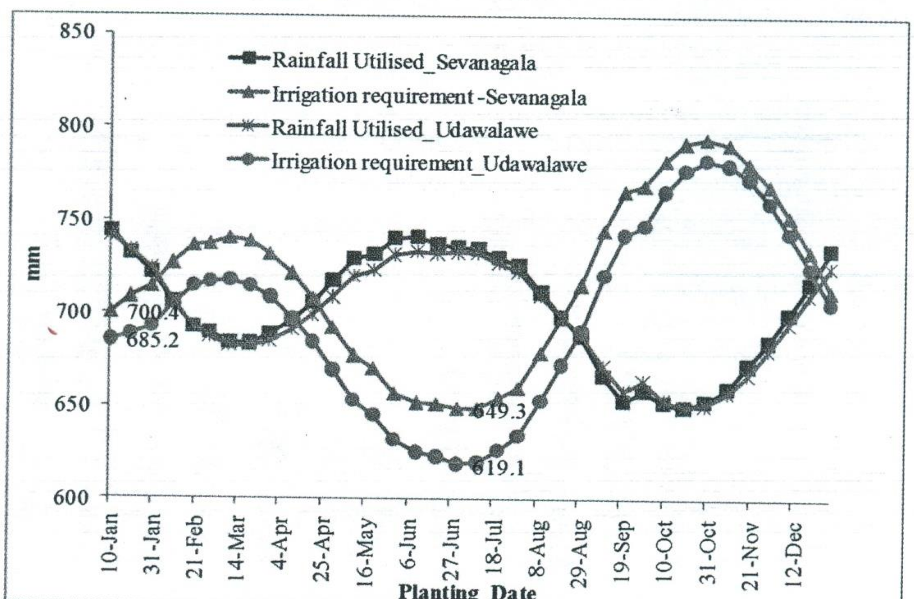

Figure 2 Variation of rainfall utilised by the crop ($Rf_{utilise}$) and irrigation requirements (In) for a 12-month crop cycle at Sevanagala and Uda Walawe

Table 2 Variation of the estimated crop evapo-transpiration (ET_c), rainfall utilised by the crop ($Rf_{utilise}$) and irrigation requirement (In) for a crop cycle of sugarcane at Sevanagala and Uda Walawe

	Sevanagala			Uda Walawe		
Planting date	ET_{crop} (mm/yr)	Rainfall utilised(mm/year)	Irrigation requirement (mm/yr)	ET_{crop} (mm/yr)	Rainfall utilised (mm/yr)	Irrigation requirement (mm/yr)
10-Jan	1444.3	743.9 #	700.4 *	1426.4	741.2 #	685.2 *
20-Jan	1440.6	732.0	708.6	1421.4	733.1	688.3
30-Jan	1436.5	721.9	714.6	1416.3	723.9	692.4
10-Feb	1432.4	705.7	726.7	1411.2	706.3	704.9
20-Feb	1429.1	692.4	736.7	1407.0	692.5	714.5
28-Feb	1426.8	689.4	737.4	1403.7	686.9	716.8
10-Mar	1424.4	684.0	740.4	1400.0	682.4	717.6
20-Mar	1422.4	683.4	739.0	1396.7	682.2	714.5
30-Mar	1420.7	688.8	731.9	1393.4	684.8	708.6
10-Apr	1417.3	696.0	721.3	1388.2	691.1	697.1
20-Apr	1414.1	705.8	708.3	1383.4	699.2	684.2
30-Apr	1410.4	717.6	692.8	1378.2	708.8	669.4
10-May	1406.7	729.4	677.3	1373.6	720.2	653.4
20-May	1402.5	732.0	670.5	1368.6	723.3	645.3
30-May	1398.0	740.8	657.2	1363.6	731.4	632.2
10-Jun	1393.1	741.1 #	652.0	1358.8	733.5 #	625.3
20-Jun	1388.9	737.4	651.5	1355.1	732.2	622.9
30-Jun	1385.3	736.0	649.3 *	1352.3	733.2	619.1 *
10-Jul	1384.6	735.2	649.4	1352.4	732.7	619.7
20-Jul	1384.8	730.4	654.4	1353.8	727.4	626.4
30-Jul	1386.4	726.0	660.4	1357.0	722.9	634.1
10-Aug	1391.1	711.9	679.2	1363.5	710.1	653.4
20-Aug	1396.9	698.8	698.1	1371.0	698.4	672.6
30-Aug	1403.8	688.0	715.8	1380.0	689.4	690.6
10-Sep	1411.9	666.4	745.5	1381.5	700.3	720.7
20-Sep	1419.9	653.2	766.7	1401.0	658.5	742.5
30-Sep	1428.0	658.5	769.5	1411.3	663.8	747.5
10-Oct	1435.3	652.3	783.0	1419.8	653.7	766.1
20-Oct	1442.2	650.2	792.0	1427.5	649.8	777.7
30-Oct	1448.3	653.4	794.9	1434.3	651.3	783.0
10-Nov	1452.0	660.5	791.5	1438.4	658.2	780.2
20-Nov	1454.1	672.6	781.5	1440.6	667.3	773.3
30-Nov	1454.8	685.0	769.8	1441.1	680.7	760.4
10-Dec	1453.5	700.2	753.3	1439.0	695.1	743.9
20-Dec	1451.1	717.0	734.1	1435.6	710.8	724.8
30-Dec	1448.0	735.0	713.0	1431.5	725.8	705.7

Note: "maximum rainfall use" and "minimum irrigation requirement" are demarcated in # and *

Conclusion

The findings of this study could be used as a guideline to plan planting program for efficient utilisation of limited available irrigation water by maximum utilisation of rainfall. However, this finding was merely based on the estimated values using climatic data of the area. Further studies based on field trials have to be carried out for a better understanding of performance of new planting schedules in respect of yields, sugarcane quality, sugar recovery percentages and pest and disease incidence, etc.

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