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Water Balance in the Rubber Growing Regions

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Climatological water balance of the rubber (*Hevea brasiliensis*) plantation in different agroclimates was studied. Most of the high productive commercial plantations in the equatorial and tropical region experienced below 150 mm annual evapotranspiration deficit. Also, these areas indicate positive water balance. The rubber grown under humid tropical climate in south Kerala experiences less than 300 mm of moisture deficits throughout their economic life period. However, plantations do exist in India experiencing deficits between 300 mm and 750 mm, except Dapchari (Konkan region). The moisture deficit experienced at Agartala (NE India) is comparable to that of south Kerala. Yield variations in different parts of Kerala are negatively correlated with moisture deficit conditions experienced by the rubber plantations. Thus, the distribution of rainfall is more important than the quantum received for introducing rubber to new areas under rainfed conditions.

Key words : Agroclimate, drought, evapotranspiration, *Hevea*, India, water balance, yield

INTRODUCTION

Rubber tree (*Hevea brasiliensis*), which produces latex, is indigenous to the rain forests of the Amazon basin and domesticated to humid tropical Asia, Africa and America (Watson 1989). It is perennial with 30-35 years of economic life period. Rainfall is the principal source of moisture to meet the crop water requirement. Areas of higher production are characterised by adequate rainfall and less fluctuations in temperature conditions (Sanjeeva Rao and Vijayakumar 1992). However, with increasing global demand for natural rubber, attempts have been made to extend this tree to marginal areas with varied climatic constraints (Sethuraj *et al.* 1989).

Rainfed rubber cultivation depends on the availability of adequate moisture in the root zone of the soil. The difference between the water requirement of the tree (ETc) and actual evapotranspiration (ETa) at a given period is the evapotranspiration deficit (ETd) or moisture stress experienced. Under well marked dry conditions young plants with life-saving irrigation exhibit growth inhibition in different agroclimates (Omont 1982, Saengruksowong *et al.* 1983, Sethuraj 1985, Vijayakumar *et al.* 1988, Sethuraj *et al.* 1989). Water deficits also affect yield and yield components (Buttery and Boatman 1976, Gururaja Rao *et al.* 1988, 1990). Besides the direct effect on laticeferous system, evapotranspirational deficits trigger biochemical changes (Premakumari *et al.* 1980). Recent experiments indicate that sufficient quantity of irrigation during stress period can increase the initial establishment of plants, reduce immaturity period and increase latex production (Haridas 1984, MohanKrishna *et al.* 1991).

An understanding of the water balance in the established rubber growing regions will provide the base-line data in resource inventory studies. Agronomically relevant agromanagement strategies could be formulated for better productivity. Studies on rainfall and water balance in the rubber growing regions are limited (Moraes 1977, Sanjeeva Rao *et al.* 1990). Hence, an attempt has been made to examine the climatic water balance in different agroclimatic conditions, the occurrence and frequency of annual moisture deficit and its relation with yield in the humid tropical climate of Kerala.

MATERIALS AND METHODS

The available agrometeorological data such as rainfall, maximum and minimum temperature, relative humidity, wind speed and sunshine from 17 stations in the natural rubber growing areas were collected from the respective rubber research organisations in Malaysia, Indonesia, Thailand, Sri Lanka, Ivory Coast, China and

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India. The period of data varied from 5 to 30 years. In addition to this, rainfall and crop yield data of eight districts during 1961-62 to 1986-87 were collected from the records of economics and planning divisions of Kerala State and the Rubber Board.

The climatological approach to the study of water balance requires knowledge of water requirement of the ecosystem, rainfall statistics and the water holding capacity of the soil. The changes in crop evapotranspiration (ETc) and the soil moisture were estimated considering soil, plant and atmospheric factors. The monthly potential evapotranspiration (ETo) were obtained with Penman model (Frere and Popov 1979, Rao *et al.* 1971). The ETc values were obtained as

$$ETc = ETo \times Kc.$$

Where Kc is the crop coefficient. The Kc varies between 0.4 and 1.2 depending on the stage of canopy and moisture availability (Haridas 1985, Haridas and Subramaniam 1985, Monteny *et al.* 1985). The soil moisture storage changes in the 100 cm root zone and the other components of water balance model were obtained according to Thornthwaite and Mather (1955). Correlation between yield and ETd in different agroclimatic conditions was also studied.

RESULTS

Climatological water balance

The components of mean annual water balance experienced by the rubber plantations in various parts of the World are given in Table 1. The cumulative ETc in the equatorial region varies between 1350 mm and 1500 mm. In these regions the annual ETd is below 80 mm and comparatively higher amounts of water surplus are noticed. Relatively higher ETd, ranging between 179 mm and 344 mm, and lower quantity of water surplus were observed at the remaining locations. Monthly distribution of the components of water balance at four selected rubber growing areas in the World are shown in Fig. 1. Bimodel rainfall distribution in the equatorial regions (Ex: Senai, Malaysia and Sembawa, Indonesia) indicate either zero or lower moisture deficit. However, short dry spells may occur in these areas, which have not seriously affected rubber growth and production. Climatological conditions prevailing at Phuket (Thailand) and Danxian (China) indicate that rainfall is seasonal, with distinct dry period. The annual deficit is below 350 mm. Variations in the length of moisture availability and the intensity of dry period may be the factors regulating growth and productivity in different agroclimatic conditions.

Table 1. Components of water balance (mm) of rubber plantations in various parts of the world

Station	No. of years	P	ETc	ETa	ETd	WS
Senai	11	2360	1388	1388	0	972
Dartonfield	11	4131	1364	1364	0	2767
Sembawa	5	2361	1376	1358	18	1003
Anguededov	30	1866	1363	1290	73	576
Alor Star	11	1978	1511	1435	76	543
Chumphon	10	1889	1903	1724	179	165
Phuket	10	2152	1776	1542	234	610
Qiong Hai	20	2005	2059	1823	236	182
Abidjan	30	2131	1700	1435	265	696
Danxian	30	1826	2027	1683	344	143

P = Rainfall, ETc = Crop Evapotranspiration, ETa = Actual Evapotranspiration, ETd = Water deficit, WS = Water surplus

In India, rubber is being cultivated in areas with annual rainfall below 2000 mm to above 4000 mm (Table 2). Higher rates of ETc at Dapchari (Konkan region of Maharashtra, Western India) and Palghat (Kerala, southern India) when compared to other areas (below 1500 mm) may be due to the prevailing higher temperature, vapour pressure deficits and moderate wind. Lowest ETa was observed at Dapchari. This is due to the concentration of rainfall during the monsoon period (Fig. 2). Whereas the rainfall distribution at Chethackal (Southern Kerala) indicates that the moisture availability is adequate for rainfed rubber cultivation.

Low temperature in the winter months experienced in the extra-tropical regions show lower ETc and hence results comparatively lower deficits. The moisture deficit experienced at Agartala (North-Eastern India) is comparable to that of southern parts of Kerala. However, plantations raised at Dapchari experience severe water deficits of the order of 1100 mm under rainfed cultivation.

Frequency of moisture deficits in the traditional rubber areas of Kerala

During the past 30 years, in two consecutive years 1982 and 1983, rubber plantations at Kottayam area experienced water deficits of the order of above 300 mm

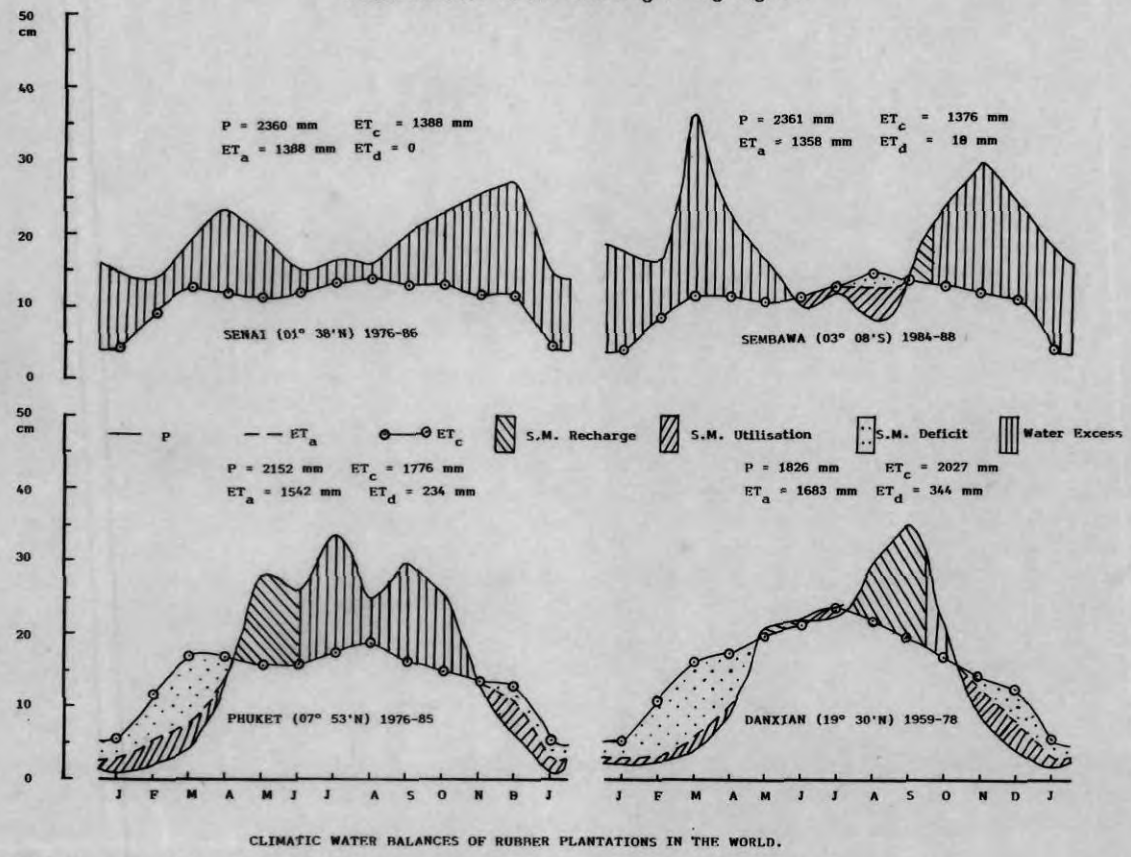

Fig. 1. Climatic water balances of rubber plantations in the world.

Table 2. Components of water balance (mm) of rubber plantations in various parts of India

Station	No. of years	P	ETc	ETa	ETd	WS
Chethackal	6	3509	1489	1439	50	2070
Punalur	30	2690	1415	1284	131	1406
Kottayam	30	3028	1489	1357	132	1671
Agartala	9	1963	1430	1292	138	671
Balusseri	30	4498	1498	1245	253	3253
Palghat	30	2125	1632	1202	430	923
Dapchari	6	2175	2034	924	1110	1251

P = Rainfall, ETc = Crop Evapotranspiration, ETa = Actual Evapotranspiration, ETd = Water deficit, WS = Water surplus

(Fig. 3). Also, during 1981-1990 period, these areas experienced above 150 mm of ETd for seven years, indicating that rubber trees are exposed to alternative wet and dry seasonal conditions.

The frequency distribution of annual ETd experienced by the rubber plantations in three distinct agroclimatic conditions are given in Table 3. At Kottayam in about 93 per cent of the years, ETd was below 300 mm. Whereas in the northern parts of Kerala (Balusseri, Calicut region) rubber plantations are prone to moisture stress of the order of 300 mm to 500 mm, once in two years. However, plantations in the Palghat region experiences above 300 mm and upto 750 mm of ETd during the life cycle (30-35 years) of the plantation. These results indicate that a mean of 150 mm of moisture deficit may be considered as a threshold limit for rainfed rubber cultivation. Beyond this limit growth and productivity of rubber plantations are affected.

Influence of moisture stress on yield

The moisture deficit experienced at Palghat, Kozhikode and Cannanore districts in Kerala lie between 350 mm and 450 mm. Except for the Trivandrum district, the water surplus is of the order of 1200 mm, indicating the possibility of conservation and reuse during the dry period.

The mean yield of rubber during 1961-62 to 1986-87 period varies from 872 kg ha^{-1} (Quilon district, Southern Kerala) to 650 kg ha^{-1} (Cannanore and Palghat district, North and Central Kerala). The variations in yield observed in the rubber growing regions in Kerala