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Aspects of aridity and drought in the monsoon climate of Sri Lanka

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ABSTRACT. Typical of the monsoonal rainfall conditions over Sri Lanka are the remarkable interannual and seasonal deficits of water, varying considerably in temporal and spatial aspects. Therefore, both the phenomena of aridity and drought are of great significance from the point of the general monsoon climate of Sri Lanka. This paper investigates the annual and monthly aridity by using the 'aridity index' of De Martonne Lauer (1926/1952) showing the increasing extent of aridity from the S.W. quarter to the N.W./N as well as S.E. of Sri Lanka. On the other hand, drought has been studied by the 'drought index' of Gibbs and Maher (1967) underlining a considerable interannual rainfall variability, being expressed by the incidence of heavily drought-stricken years as well as by the occurrence of completety drought-free years. It is pointed out that drought can be called a typical, however irregular and spatially limited phenomenon in the climate of Sri Lanka. All observations are based on 30-year rainfall data (1931-1960) of monthly and annual figures.

1. Introduction

The seasonally alternating regimes of two adjacent wind systems of the atmosphere resulting in periods of wet and dry weather are characteristic of all monsoon climates of the world. For South Asia including its southernmost island Sri Lanka, the equatorial westerlies in the summer season and the tropical easterlies in the winter season alternate, resulting in wet southwest monsoon and comparatively drier northeast monsoon conditions respectively.

2. Basic features of rainfall distribution in Sri Lanka

The two monsoons differ fundamentally in their structure, origin and composition of the airmasses, concerned: The southwest monsoon, as a part of the equatorial westerlies, is of unstable, moist maritime air, of strong intensity and of great vertical height reaching 6 to 7 km above Sri Lanka. On the contrary, the northeast monsoon is weaker, shallower and generally more stable. Its effect on rainfall is much less than the southwest monsoon. Broadly, rainfall conditions in Sri Lanka are first of all governed by the seasonally varying systems of the moist southwest monsoon on the one hand and the comparatively drier northeast monsoon on the other. Besides, regional and temporal variations of rainfall on Sri Lanka are the results of the wide-ranging influence of the Central Highlands, reaching upto 2524 m a.s.l. As to be seen clearly during the southwest monsoon, the Highlands cause, on the one hand, ample orographical rains on the windward side and — at the same time — remarkable föhn-effects, resulting in hot dry winds and less rainfall on the leeward side. Taking the average annual rainfall totals, the wettest part of Sri Lanka is situated on the lower western slopes of the Highlands, the driest regions are the peripheral northwestern and southeastern coastal lowlands (Fig. 1). From the aspect of seasonal rainfall activity, the intermonsoonal convectional thunderstorms in March/April and October/November, when the N.I.C.Z. crosses Sri Lanka, are as important as — at the same time — the depressional rains when cyclones from the Bay of Bengal (and seldom from the Arabian Sea) can result in heavy widespread rain over Sri Lanka.

Fig. 1. Average annual rainfall distribution on Sri Lanka (after Domrös 1974)

Taking into account these aspects it can be deduced that rainfall distribution in Sri Lanka varies in two directions: (*i*) in a spatial one, expressed by the large-scale differentiation of the annual rainfall totals into wet and comparatively dry regions (*See* Fig. 1), (*ii*) The more important direction is a temporal one, characterized by alternating wet and dry periods in the course of the year which vary regionally and temporally in their intensity and duration (*See* the climate diagrams of Colombo and Anuradhapura Fig. 2). Rainfall distribution in the first case expresses a long-term, more or less permanent condition of moisture, while in the second case it is a temporary, recurrent condition, dependent upon the annually varying rainfall efficiency of the monsoons. In climatological literature, the first case of moisture deficit is usually called aridity, the second case drought.

Both these phenomena will be investigated briefly from the climatological point of view, related to the monsoon climate of Sri Lanka, using various climatological methods — as a contribution to three major aspects: (1) to the regional climatology of Sri Lanka; (2) to the monsoon climatology in general; (3) to the important factors of aridity and drought in general climatology. [For the latter aspect see in particular the Special Environmental Report of the WMO on Drought (1975), the WMO Technical Note on Drought and Agriculture (1975), and the discussion on the Sahelian drought of 1971 to 1973].

The aspects of aridity and drought in Sri Lanka have not been investigated in detail so far. Jameson (1932) has dealt with only the climatological aspects of droughts in Colombo. On a drought symposium on South Asia, held in Poona in 1972,

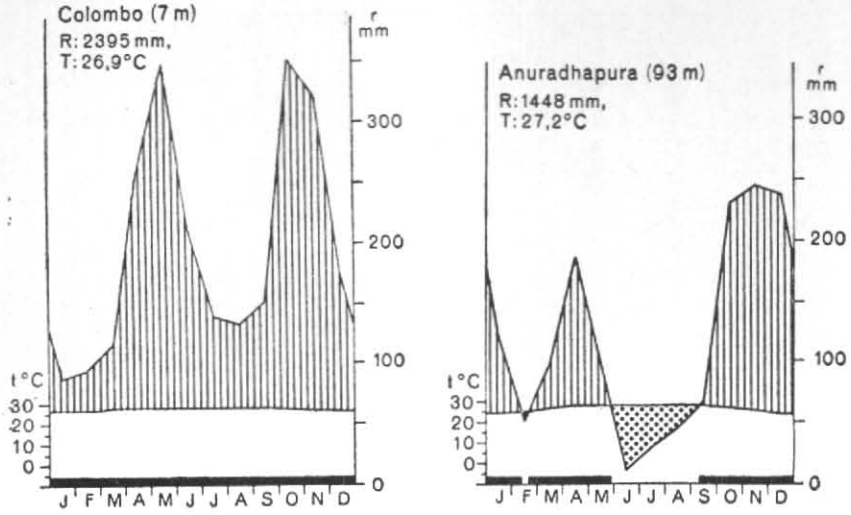


Fig. 2. Climate diagrams for Colombo and Anuradhapura on the basis of the aridity index of De Martonne/Lauer (after Domrös 1974)

Jayamaha has presented "An analysis of droughts over Sri Lanka" in which he has studied mainly the climatological aspects of droughts. On this occasion Ramaswamy, in his paper on droughts in the Asiatic monsoon area, has stressed briefly the synoptic pattern of the serious drought over Sri Lanka in February 1972 (cf. Proceedings of the Indian National Science Academy, Vol. 42, Part A, Nos. 2 and 3, 1976). The so far poor scientific attention of the present aspects is also underlined by the fact that text-books on general climatology and meteorology so far scarcely give any substantial information on the aspects of aridity and drought in the monsoon climates so that these aspects need further investigation.

3. Definitions

In climatological literature two terms are mainly used to express the lack of sufficient water or moisture to meet certain requirements : drought or dry period on the one hand, and aridity on the other. The requirement of water is dependent upon population and mode of life, cultivation of crops and land-use.

The lack of water may result either from an unusually small water supply or an unusually large water demand. Thus drought and aridity are terms of insufficient water supply or of abnormal water demand. The requirement of water for a certain purpose is therefore the decisive criterion for the definition of drought respectively aridity.

Due to the large variability of water requirements for different purposes, an objective and universally acceptable definition of drought and aridity has not been developed so far and does not seem possible at all. However, the distinction between drought and aridity is generally accepted : *Drought* means a temporary condition of lack of water, it represents a recurrent phenomenon, being an integral, if irregular, component of climate. From the spatial point of view, drought is uaually not an isolated phenomenon, but often widespread over a large area. *Aridity*, on the opposite, expresses a more or less permanent condition of lack of water or of low average rainfall bringing about deserts as the typical companion land form. It is usually restricted to regions of high temperature whereas drought is possible in virtually any temperature and rainfall regime.

In practice, the most frequently drought-affected areas are the transition zones between truly arid areas and moister regions with more reliable rainfall which are often called semi-arid. In these regions, drought occurs often in connection with or as a part of the typical high rainfall variability. From the point of the general circulation of the atmosphere the endangered areas are particularly situated at the fringes of the semi-permanent subtropical high pressure cells; an outstanding example of this being the disastrous drought in the Sahelian region in the most recent past. Other regions, less frequently involved, but still notably affected, are parts of the world where summer

monsoonal circulations are the principal rain bringers. It must, however, be pointed out that no region is absolutely free from drought. On the opposite, it is also true that even arid areas occasionally may be flooded.

It can be noted finally that the incidence of drought and aridity depends very much upon the definition used. Besides, lack of water is basic to drought and aridity; both terms express a relative rather than an absolute condition.

Due to the definitions, both drought and aridity are *qualitative* terms for the lack of water to meet requirements. From this point of view it is understandable that there is no overall valid precise definition of drought and aridity in the climatological dictionary.

4. Aridity and drought indices

Since water supply or water demand are taken as the decisive criterion of aridity and drought, it follows that delineation of aridity and drought occurrence depends on the nature and amount of water-need. Therefore only from the aspect of water supply which is necessary for a certain purpose it can be decided which definition out of the very large number of attempts to defining *quantitatively* the phenomena of drought and aridity, is valid or not. In practice, aridity and drought are most commonly investigated from the point of agricultural, climatological and hydrological aspects.

Since the lack of sufficient water is used as the basic criterion for aridity and drought, rainfall is generally taken as the most useful *single* index in defining and delineating the occurrence and extent of aridity and drought. Because rainfall is non-continuous in time and space, its statistical description is quite complex and the common statistical measures of the mean and standard deviation are often poor indicators of rainfall distribution and probability. Also the most usual and easily applicable element, used for representation of climate, the average precipitation is, often the most misleading and of poor practical importance.

In attempting to involve the many other climatological elements as well as hydrological factors, both together or separately related to the water requirements with respect to certain purposes, a great variety of aridity and drought indices has been developed.

A summary of the widely used drought and aridity indices has been given by the WMO : (*i*) in the Technical Note No. 138 "On Drought and Agriculture", 1975; appendix 1, where the indices have been classified under the following aspects : (1) rainfall, (2) rainfall with mean temperature, (3) soil-water and crop parameters, (4) climatic indices and estimates of evapotranspiration; (*ii*) in the Special Environmental Report No. 5 on "Drought", 1975, Table 1. However, in both publications a clear distinction between drought indices on the one hand and aridity indices on the other is missed and further studies on this topic are necessary.

In the present paper, aridity and drought in Sri Lanka have been investigated from the climatological point of view, using the following indices :

Aridity : The well known and often applied "aridity index" of De Martonne/Lauer (1926/1952):

for computing annual aridity : $\left(i = \frac{P}{T+12} \right)$

for computing monthly aridity : $\left(i = \frac{12p}{t+10} \right)$

where P (p) is the average annual (monthly) rainfall (mm), T (t) the mean annual (monthly) temperature (°C). An index of less than 20 indicates aridity with regard to annual (monthly) conditions. By use of the monthly aridity index the number of arid months per year and station and thus a spatial differentiation of Sri Lanka according to the number of arid months can be worked out.

Drought : The index of Gibbs and Maher (1967), defining drought as the amount of annual rainfall in the first decile range which — as a result of studies made in Australia—roughly coincides with drought conditions. With the aim of this index the temporal and spatial distribution of drought can be analyzed by working out (1) for each year under investigation those areas getting the first decile range of rainfall respectively drought, (2) for the total observation period and total study region the frequency of drought occurrence and the extent of drought-affected regions.

5. Results

(a) *Aridity in Sri Lanka*

By use of the *annual* aridity index of De Martonne/Lauer (1926/1952) all observation stations in

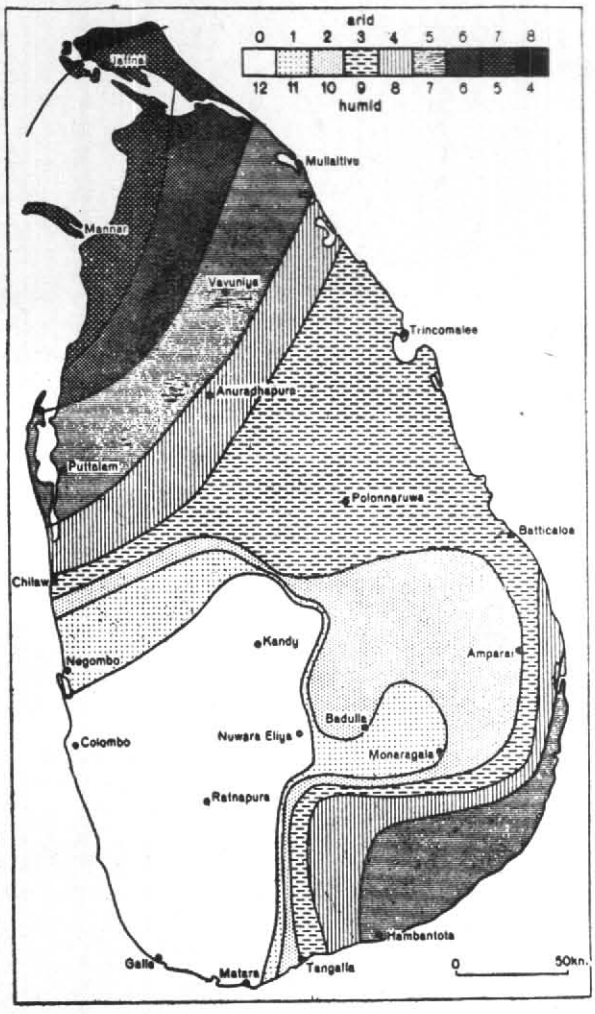


Fig. 3. Number of arid resp. humid months in Sri Lanka, according to the index of De Martonne/Lauer
After Domrös 1974)

Sri Lanka and thus all parts of the island clearly exceed the aridity limit of 20. Even in the case of both the driest stations of the island in the southeastern and northwestern coastal lowlands the aridity index distinctly exceeded the aridity limit, as to be seen in the following values :

Maha Lewaya Saltern/Hambantota (P=929mm, T=27,1°C*), i=25; Marichchukkaddi (P=950 mm, T=27, 8°C*, i=25.

That means that from the aspect of the average annual rainfall and temperature conditions no part of Sri Lanka can be classified as arid.

However, for a more detailed analysis of the temporal and spatial incidence of aridity in Sri Lanka the use of the *monthly* aridity index of De Martonne/Lauer seems to be more efficient. It enables the calculation of the number of arid or humid months per year and thus to work out the spatial variation of Sri Lanka according to monthly or seasonal aridity. By doing so, the number of arid or humid months per year has been computed for the 30-year standard period from 1931 uptil 1960, the result is given in Fig. 3. Showing the average number of arid and humid months on Sri Lanka, the map clearly underlines the existence of seasonally arid conditions in Sri Lanka; two major results become obvious: (1) the remarkably high spatial variation of the number of arid months in Sri Lanka reaching from a maximum of 8 arid months in the north Jaffna Peninsula to a minimum of not a single arid month in the southwest quarter of the island; (2) the gradually increasing extent of aridity from the southwest quarter to the northwest/north as well as southeast of the island.

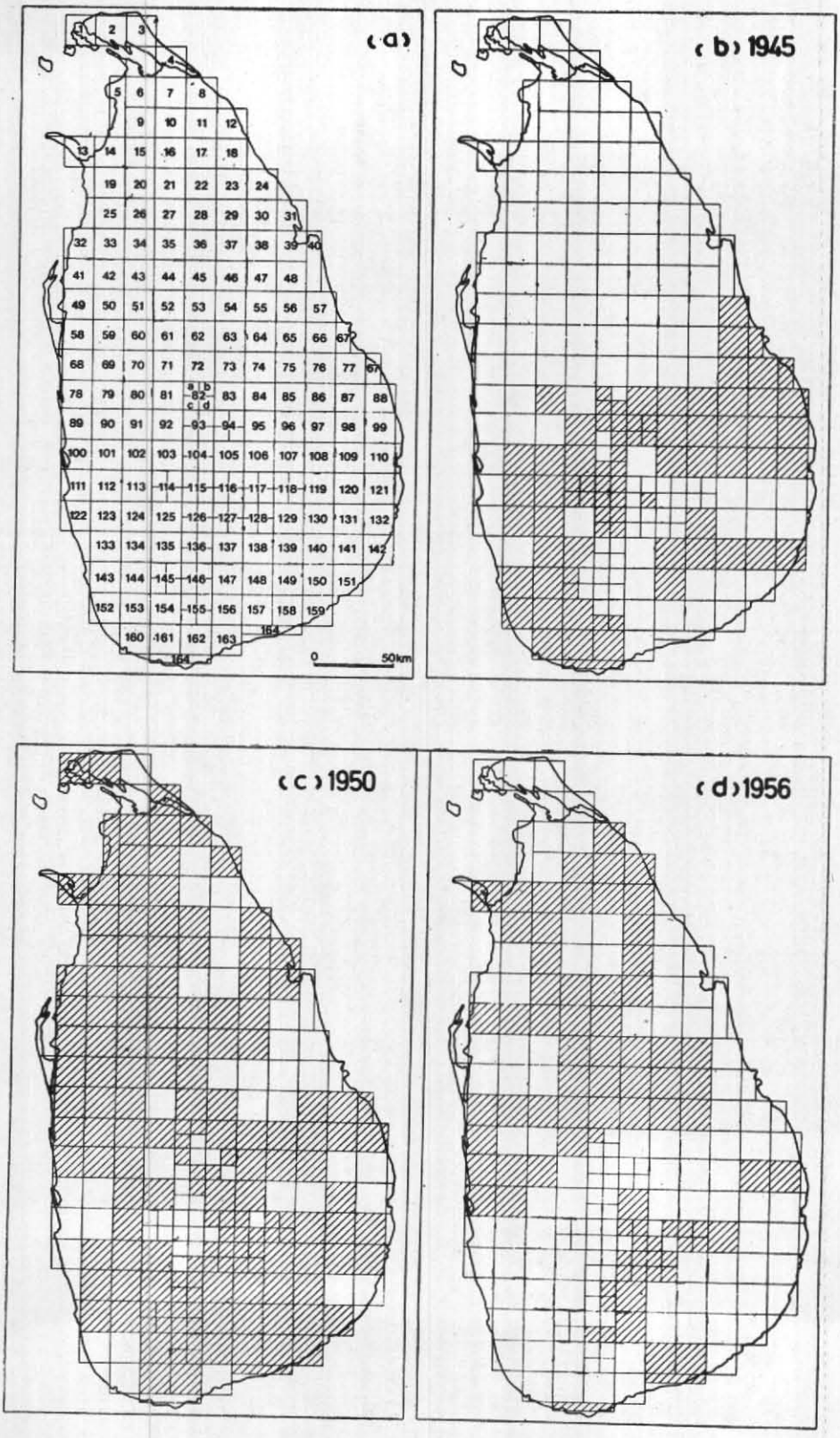
Due to these observations, in no part of Sri Lanka can the climate of the whole year be described as arid. However the climate in those regions of the island, showing seasonally or monthly existing aridity, may be characterized as *semi*-arid or *semi*-humid, in accordance with the different number of arid or humid months. Hence regions with a distinct, long seasonal period between 7 and 9 arid months (resp. 3 to 5 humid months) are often called *semi-arid.* According to this, a small section of Sri Lanka may truly be described as semi-arid, namely the northwestern and northern coastal lowlands, including the Jaffna Peninsula which are characterized by 7 and at the most 8 arid months.

(*b*) *Drought in Sri Lanka*

A few introductory remarks from the methodological point of view should be mentioned in advance, when applying the drought index of Gibbs and Maher (1967) :

(1) In respect of an easy as possible calculation of drought-affected regions of Sri Lanka, the island was divided into 164 squares each of them measuring 20 by 20 km, respectively corresponding to 0, 61 per cent of the total area of the island. As an attempt to consider the remarkable orographical variations and thus the meso- and topo-climatic differences in the Central Highlands 16 squares were divided again into 4 sub-squares each.

*The temperatures values used are those of adjacent temperature recording stations, Hambantota Observatory resp. Mannar Observatory.



Figs. 4 (a-d). Division of Sri Lanka into squares and sub-squares as the basis of the drought index of Gibbs and Maher 1967 (Fig. 4a); maps of Sri Lanka showing drought in 1945 (Fig. 4 b), 1950 (Fig. 4c) and 1956 (Fig. 4d), defined by the lower decile range of annual rainfall

TABLE 1

Rainfall stations under investigation (*see* **Fig. 4a**)

1 Kayts
2 Jaffna
3 Point Pedro
4 Paranthan
5 Mannar
6 Paranthan
7 Paranthan
8 Mullaitivu
9 Paranthan
10 Mankulam
11 Nedunkeni
12 Mullaitivu
13 Mannar
14 Mannar
15 Mannar
16 Mankulam
17 Nedunkeni
18 Nedunkeni
19 Akathimurippu
20 Akathimurippu
21 Vavuniya
22 Vavuniya
23 Nedunkeni
24 Trincomalee
25 Marichchukkaddi
26 Akathimurippu
27 Vavuniya
28 Vavuniya
29 Horowupotana
30 Trincomalee
31 Trincomalee
32 Marichchukkaddi
33 Marichchukkaddi
34 Anuradhapura
35 Anuradhapura
36 Horowupotana
37 Horowupotana
38 Kantalai
39 Trincomalee
40 Allai
41 Kalpitiya
42 Kalpitiya
43 Anuradhapura
44 Anuradhapura
45 Anuradhapura
46 Kantalai
47 Kantalai
48 Allai
49 Puttalam
50 Puttalam
51 Galgamuwa
52 Kalawewa
53 Maradankadawela
54 Minneriya
55 Minneriya
56 Topawewa
57 Vaganeri
58 Puttalam
59 Galgamuwa
60 Galgamuwa
61 Kalawewa
62 Dambulla
63 Topawewa
64 Topawewa
65 Topawewa
66 Vaganeri
67 a, c Vaganeri
67 b, d Batticaloa
68 Palugaswewa
69 Palugaswewa
70 Flensburg
71 Galewela
72 Nalanda
73 Nalanda
74 Topawewa
75 Topawewa
76 Unnichchai
77 Batticaloa
78 Horakele
79 Berna
80 Kurunegala
81 Lenawihara
82 a Lenawihara
b Gammaduwa
c Matale
d Nillomally
83 Gammaduwa
84 Horaborawewa
85 Maha Oya
86 Maha Oya
87 Unnichchai
88 Batticaloa
89 Horakele
90 Andigama
91 Poromadala
92 Kegalle
93 a Matale
b Nillomally
c Peradeniya
d Rajawella
94 a Nillomally
b Hendon
c, d Rangalla
95 Horaborawewa
96 Horaborawewa
97 Maha Oya
98 Amparai
99 Amparai
100 Negombo
101 Hunumulla
102 Yataderia
103 Aranayake
104 a Peradeniya
b, c Kirimetiya
d Sogama
105 Meeriatenne
106 Arawa
107 Bibile
108 Bibile
109 Nethai
110 Timitar
111 Colombo
112 Dompe
113 Dunedin
114 a Ingoya
b Watawala
c Ingoya
d Watawala
115 a Sogama
b Labookelle
c Dimbula
d Labookelle
116 a Gonapitiya
b Liddesdale
c Nuwara Eliya
d Ambagasdowa
117 a Ledgerwatte
b Keenakelli
c Attampettia
d Badulla
118 a Mahadowa
b Medagama
c, d Passara
119 Medagama
120 Lahugala
121 Lahugala
122 Colombo
123 Rayigam
124 Eheliyagoda
125 Carney
126 a Wanarajah
b Holmwood
c Maskeliya
d Campion
127 a Upper Ohiya
b Dyraaba
c, d Needwood
128 a Dyraaba
b Newsburgh
c Pita Ratmalie
d Meeriabedde
129 Buttala
130 Monaragala
131 Lahugala
132 Panama
133 Gikiyanakanda
134 Ratnapura
135 Ratnapura
136 a Pelmadulla
b Wikiliya
c Pelmadulla
d Wikiliya
137 Uggalkaltota
138 Hambegamuwa
139 Buttala
140 Buttala
141 Panama
142 Panama
143 Sirikandura
144 Sirikandura
145 a Kokkawita
b Depedene
c Kokkawita
d Depene
146 a, b Godakawela
c Anningkande
d Panilkande
147 Embilipitiya
148 Hambegamuwa
149 Tanamalwila
150 Yala
151 Yala
152 St. Leonards
153 St. Leonards
154 Mawarella
155 a Anningkande
b Panilkande
c Mawarella
d Kirama
156 Embilipitiya
157 Ridiyagama
158 Tissamaharama
159 Tissamaharama
160 Galle
161 Hali Ela
162 Ella Wela
163 Tangalla
164 a, b Hambantota
c, d Kekanadure

TABLE 2
Per cent of area of Sri Lanka under drought conditions based on period 1931-1960

(The table shows those drought years only, striking at least 5 per cent or Sri Lanka)

Year	Per cent of Sri Lanka	Year	Per cent of Sri Lanka
1932	11	1947	6
1934	16	1948	8
1937	10	1949	9
1938	13	1950	74
1939	8	1952	15
1940	6	1953	10
1943	7	1956	41
1945	33	1958	15

Completely drought-free years : 1931, 1941, 1954, 1959

(2) For each square or sub-square one representative rainfall station was selected, totally 213 stations. In the case of sparsely populated, jungle-covered regions in parts of the north and east of Sri Lanka rainfall stations of adjacent squares have been taken over. The dense network of stations was possible thanks to a larger number of rainfall recording stations on plantations, mainly in the High-lands, outside the official network of stations under the Meteorological Department of Sri Lanka. Rainfall data of these stations have been obtained from the stations concerned, the observations of most of the stations however were made available at the Department of Meteorology, Colombo.

(3) The division of Sri Lanka into squares and subsquares is shown in Fig 4(a), whereas Table 1 gives the names of the rainfall stations used.

(4) The observation period corresponds for all stations with the standard period of 1931 upto 1960. Thus, for each station the first decile range of annual rainfall represents the three lowest annual rainfall totals out of the 30 values in total.

The analysis and presentation of drought, defined by annual rainfall in the first decile range, has been made in two directions : (*i*) by preparing a simple tabular matrix containing station by station the occurrence of drought years; (*ii*) by drawing a map for each year under investigation showing the spatial distribution and extent of drought-stricken squares or regions in Sri Lanka.

The *drought matrix* gives clear evidence of the occurrence and frequency of droughts in the various years under investigation (Fig. 5). This clearly shows the incidence of heavily drought-sricken years as well as the occurrence of completely drought-free years. The maximum percentage of the area of Sri Lanka under drought in a single year amounted to 74%, however in one out of 30 years only (1950). The second highest percentage was 41, the third 33% (1956 resp. 1945), followed by much lower percentages of drought-affected areas. On the other hand, there have occurred only 4 completely drought-free years out of 30 years (1931, 1951, 1954, 1959).

The percentage of the area of Sri Lanka under annual drought conditions, studied for the period from 1931 uptil 1960, are shown in Table 2. It can be seen from this that drought can be called a typical although irregular and spatially limited phenomenon in the monsoon climate of Sri Lanka. Drought years never strike the whole island, they only occur in comparably small parts of Sri Lanka. Any periodicity of drought occurrence could not be observed. Also droughts in consecutive years were unusual.

According to the frequency of occurrence of drought between 1931 and 1960 the following probability (per cent) of annual drought over given percentages of the total area of Sri Lanka has been calculated:

	% of area											
	91-100	81-90	71-80	61-70	51-60	41-50	31-40	21-30	11-20	5-10	<5	Nil
% probability of drought	0	0	3, 5	3, 5	3, 5	7	10	10	30	53, 5	73, 5	13, 5

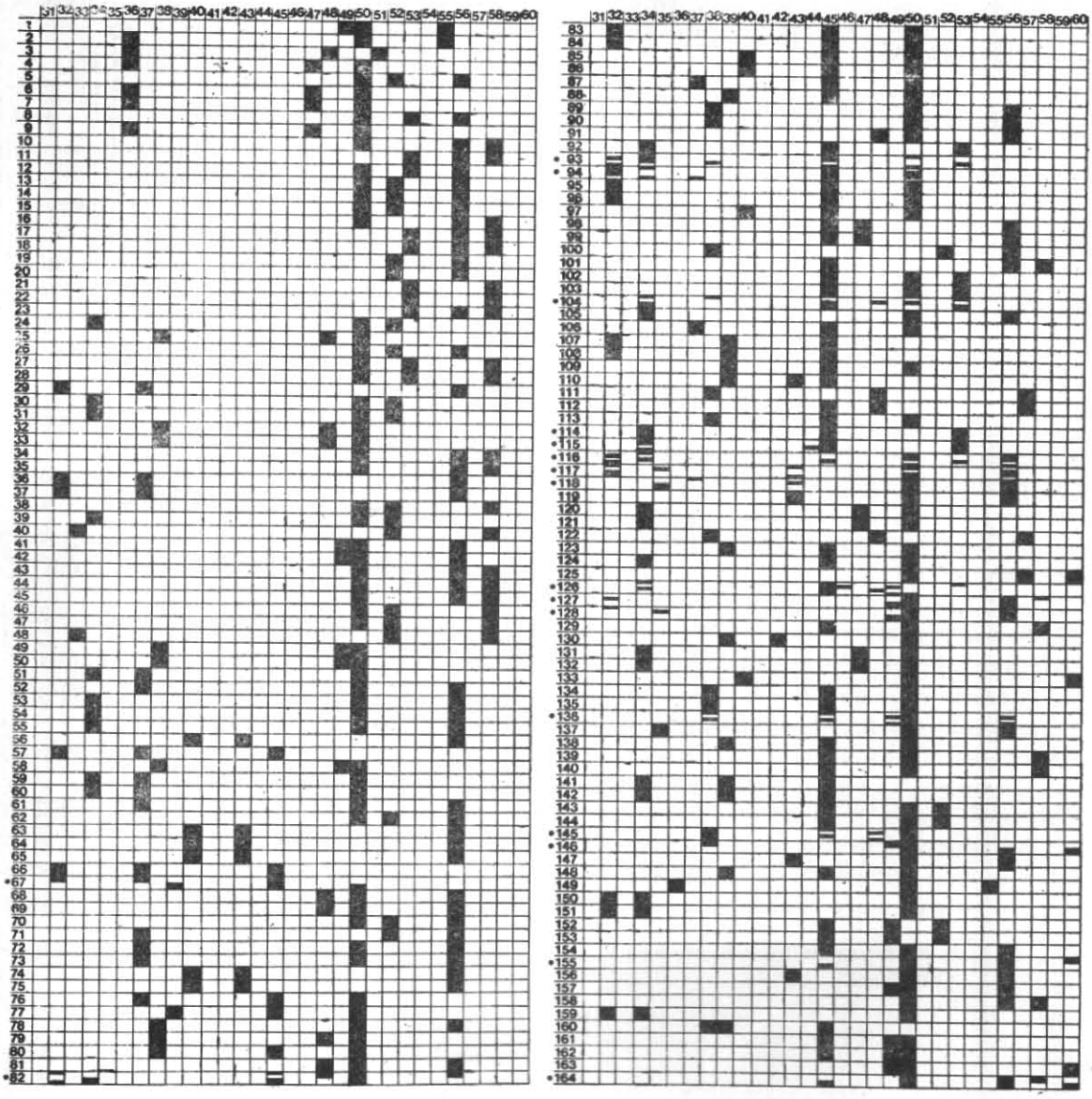


Fig. 5. Drought matrix of Sri Lanka ('drought' as defined by Gibbs and Maher 1967).

From this it can be seen that drought can be expected as a small-scale phenomenon only, confirmed by the observation that in about 3 years out of 4 less than 5 per cent and in about every second year only 5 to 10 per cent of the area of Sri Lanka are drought-stricken. It is most unlikely that more than 40 per cent of the island would be drought-affected in any one year, and also in 10 years out of 100 an area of 20 to 30% can be expected to be drought-stricken. Completely drought-free conditions for Sri Lanka would occur in one out of 7 to 8 years.

A detailed presentation of the spatial occurrence of drought can be given on *maps* showing drought in individual years. As example, maps of the most seriously drought-stricken years 1945, 1950 and 1956 have been drawn (Figs. 4b, 4c and 4d). Although these maps cannot be discussed in detail, they clearly show as a major result of the spatial distribution of drought regions, that drought — in the case of its incidence — may occur both as an isolated or as a large-scale phenomenon.

6. Conclusion

This paper has dealt with two characteristic aspects of the monsoonal rainfall conditions in Sri Lanka, namely aridity and drought. Typical of both is lack of water, in the first case a more or less permanent condition, in the latter case a temporary one. Comparing both phenomena from the climatological point of view, drought can be described as the more important one in Sri Lanka.

Aridity is restricted to seasonal occurrence, showing the greatest number of arid months in the north and northwest of the island from where the length of the arid season decreases gradually towards the non-arid southwest sector of Sri Lanka.

Drought, on the contrary, could be proved as a typical, although irregular phenomenon in Sri Lanka. It is limited, as a rule, to small parts of the island. Completely drought-free climatic conditions over the whole island are seldom experienced.

The drought index of Gibbs and Maher (1967), having been applied, can be taken in fact only as a crude index of drought; however, it gives a useful introduction into this problem. A weakness of the method is that drought occurrence does not necessarily coincide with the calender year so that the lower decile range of annual rainfall does not always give the full temporal picture of drought. In addition, it is doubtful whether actually the lower decile range of rainfall expresses drought conditions or not; in any case, these values indicate abnormally low rainfall totals in relation to the average conditions.

Further studies should investigate also the aspects of seasonal drought and could include, too, the phenomenon of so-called "semi-drought", defined by the second decile range of rainfall. Important for practical purposes of land use is an investigation of the spatial frequency of droughts in order to define regions of different drought risk.

The paper has shown both aridity and drought as typical elements of the monsoon climate of Sri Lanka, and underlining its great variability with respect of the moisture and rainfall conditions in temporal as well as spatial aspects.

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