Ceylon and the World Climatic Mosaic

TO the serious student of climatology, it comes as a surprise that the application of world climatic classifications to Ceylon has thus far been neglected.[1] Perhaps the reasons are not difficult to find; the small areal extent of the island and the common attribution to it, of a simple and single climatic type—Monsoonal or Tropical Rainy. There is perhaps still another reason—no student of climatology has been sufficiently interested in climatological research to give serious thought to such a consideration. Whatever the reason be, there is no doubt that their application to Ceylon is necessary from the climatological standpoint and it would prove of some value: from the standpoint of the classifications themselves, their validity and shortcomings in application to tropical environments; from the investigator's viewpoint, pointers for further study and research, leading perhaps to suggestions of modifications in the classifications.

One of the earliest world climatic classifications was attempted by the Greeks,[2] where the earth was divided into three 'climatic zones' giving five 'climatic regions'; since temperature was the only criterion used, these were in effect 'thermal zones'. The three zones were termed Torrid, Temperate and Frigid and essentially demarcated on a latitudinal basis. Supan[3] gave them quantitative definiteness; thus:

(*a*) Hot Belt (Torrid)—the boundary was the mean annual temperature of 20°C (68°F); this coincided with the temperature requirements for palm growth:

(*b*) Cold Caps—Polar zones—temperature of warmest month, less than 10°C (50°F); in the northern hemisphere this zone extends north of the Arctic Circle:

(*c*) Temperate Belts—the central zones between the Hot Belt and Cold Caps:

Supan also recognized 35 climatic provinces within this zonal division. The application of this classification would place Ceylon in only one 'province' which is only thermal and not 'climatic'.

1. However, in 1950 a research paper was prepared at the Geographical Laboratory, University of Western Australia, applying Thornthwaite to Ceylon. It will be discussed at a later stage. Also note Adm. Rep. of Conservator of Forests for 1952, G. 9.

2. A. Austin Miller, *Climatology* (2nd ed., London: Methuen, 1938), 54.

3. Ibid., 53-55; Thomas A. Blair, *Climatology* (New York: Prentice-Hall, 1942), 118.

The attempt of Rubner[4] may be briefly considered at this stage. He used a simple thermal criterion with a seasonal consideration. On the basis of the number of days with over 50°F average temperature, he envisaged five 'climatic' zones for Europe:—

Zone	*Number of 'warm' days* (over 50°F)
Subarctic	1- 60
Cool	61-120
Temperate	121-180
Warm Temperate	181-240
Warm	241-300

No tropical climates find place in this classification. Like that of the Greeks and of Supan, this again is a 'thermal' based classification, and thus would not warrant a 'climatic' aspect.

Pavari introduced a vegetative classification involving physiologic considerations.[5] Since this attempt was made with relation to Europe and very specifically investigated in the Alpine vegetation zone, it will be of no significance in Tropical latitudes. However, altitudinal relationship to vegetation and therefore the thermal significance has been demonstrated. Thus:—

Zones		*Annual Average temperature* (°F)	*Coldest month mean temperature* (°F)
(*a*) Alpine zone	—	below 36	below 4
(*b*) Spruce Forest zone	—	37-43	— —
(*c*) Beech zone	—	45-54	above 25
(*d*) Chestnut zone	—	50-59	,, 30
(*e*) Laurel zone	—	54-73	,, 37

About the third quarter of the 19th century, Drude introduced the phenological considerations as climatic factors, when he attempted a physiognomic vegetal classification. The length of the dry season was a determining criterion in his classification. Thus:—

Vegetal zones (dry season base)		*Physiognomic vegetal types*	*'climatic' aspect*
1. Hygrophytous	—	(*a*) Forest	Humid
		(*b*) Brush and shrub	
2. Tropophytous	—	(*c*) Grass and shrub	Sub-Humid
		(*d*) Steppe	Semi-Arid
3. Xerophytous	—	(*e*) Desert	Arid
		(*f*) Moss and Lichens	
		(*g*) Alpine and Polar	Deficient Heat

4. Blair, op. cit., 118.

5. Ibid., 121-123. The vegetal classifications are being introduced because of their important bearing on climatic classifications. This relationship is due to the simple fact that the 'biota' form direct expressions of climate. The edaphic and cultural factors, should not, however be neglected as being biota determinants.

Drude's climatic viewpoint of the phenologic relationship may be realized from the following statement of his :—

'In spite of the capacity for acclimatisation there still remains a considerable difference in the time at which a given stage of growth is entered upon by a plant in different climates. With increasing latitude and altitude, there is always a retardation of the stages of development in the same plant. This retardation when stated in *days*, may express the climatic differences of two places which are being compared more clearly than do the mean temperatures of these places, . . . '.[6]

In chronological sequence, Koppen[7] in 1884, was the next to propose a world classification, which underwent a series of modifications, both by him and by others.

The next one was that made by Hult[8] in 1892 ; his classification was superior to Koppen's original one, because Hult was the first to use a combination of climatic elements :

(*a*) average annual temperature,
(*b*) seasonal variations of temperature,
(*c*) winds,
(*d*) precipitation.

Koppen had used only temperature considerations. Hult recognized three (3) main 'classes'; nine (9) 'sub-classes' and thirty-three (33) 'provinces' of climate :

I. *Cold Climates* below 0°C mean annual ;
- (*a*) Cold summer—warmest month below 10°C ;
- (*b*) Warm summers, e.g., Siberia.

II. *Temperate Climates* 0°-20°C mean annual ;
- (*a*) Marine climate—westerly winds and rain all seasons,
- (*b*) Winter rains, dry summers,
- (*c*) Irregular winds, summer rains.

III. *Hot Climates* over 20°C, mean annual, small temperature range ;
- (*a*) One or two rainy seasons (solstices), e.g., E. Brazil,
- (*b*) Trade winds region, e.g., Polynesia,
- (*c*) Monsoons, e.g., India,
- (*d*) Heavy rains all months of the year.

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6. Julius Hann, *Handbook of Climatology* (Tr. by Robert De Courcy Ward, London : Macmillan, 1903), 85.

7. More detailed consideration will follow.

8. Renato Biasutti, *Il Paesaggie Terrestre* (Torino, Italy : Unione Tipografico, 1947), 43-44. Also see, Blair, op. cit., 123-125.

Thus Hult's classification as applied to Ceylon would give the island sub-classes and provinces within Class III. The main defect is the lack of quantitative criteria for precipitation, which he rectified to some extent in 1900.

The next world classification appeared in England in 1900 ; Ravenstein[9] used as his bases two main climatic elements, average annual temperature and average annual relative humidity. He recognized four (4) classes of each, and by a process of combination was able to specifically locate sixteen (16) climatic types as existing on earth, each type designated by a typical station.

I. *Temperature Classes* (average annual temperatures)

(*a*)	Torrid	over	24°C.
(*b*)	Warm		15-24°C.
(*c*)	Cool		0°C-14°C.
(*d*)	Cold	below	0°C.

II. *Relative Humidity* (average annual)

(*a*)	Very Humid	over	81 per cent.
(*b*)	Moderately Humid		66-80 per cent.
(*c*)	Arid		51-65 per cent.
(*d*)	Very Arid	below	50 per cent.

Some of his 'climatic types' in warm areas are :

(i) Hot and Very Humid.
(ii) Hot and Moderately Humid.
(iii) Hot and Arid.
(iv) Hot and Very Arid.

If applied to Ceylon only two 'types' could be recognized, namely,

(i) Hot and Very Humid, and
(ii) Warm and Very Humid.

The main defects of this system are its arbitrary nature, the unjustifiability of the boundaries and the lack of data on relative humidity ; the use of annual amounts alone again is to be deplored. Its application to Ceylon would have no significance.

An attempt to present a simple world classification has been made by Miller.[10] The use of quantitative criteria of temperature to demarcate the major zones and qualitative precipitation for demarcating the sub-zones are the noteworthy features. The use of the 'Monsoonal' criterion is also significant. However in the use of his quantitative criteria he warns against their

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9. E. G. Ravenstein, 'The Geographic Distribution of Relative Humidity', *Brit. Assoc. Adv. Sciences* (1900), 817 ff.

10. Miller, op. cit., 79-95. Refer figure 34 for the schematic assignment of his types on an Ideal Confinent.

climatological accuracy, 'The figures given are intended as approximate guides only and are not to be accepted literally . . . , the value of a single climatic element is seldom competent to define the limits of a zone, while the combination of more than one element, while giving a truer boundary, becomes cumbersome.[11] His classification may be outlined :—

A. Hot climates. Mean annual temperature more than 70°F.
- 1. Equatorial. Double maxima of rain.
- 1m. Equatorial. Monsoon variety.
- 2. Tropical, marine. No real dry season.
- 2m. Tropical, marine. Monsoon variety.
- 3. Tropical, continental. Summer rain.
- 3m. Tropical, continental. Monsoon variety.

B. Warm temperate or sub-tropical. No cold season, i.e. no month below 43°F.
- 1. Western margin (mediterranean). Winter rain.
- 2. Eastern margin. Uniform rain.
- 2m. Eastern margin. Monsoon variety. Summer maximum of rain.

C. Cool temperate. With cold season, i.e. 1-5 months below 43°F.
- 1. Marine. Uniform rain or winter maximum.
- 2. Continental. Summer maximum of rain.
- 2m. Continental. Monsoon variety. Strong summer maximum.

D. Cold climates. Long cold season, i.e. 6 or more months below 43°F.
- 1. Marine. Uniform rain or winter maximum.
- 2. Continental. Summer maximum of rain.
- 2m. Continental. Monsoon variety. Strong summer maximum.

E. Arctic climates. No warm season, i.e. 12 months below 50°F.

F. Desert climates. Less than 10 inches of rain.
- 1. Hot deserts. No cold season, i.e. no months below 43°F.
- 2. Cold deserts. With cold season, i.e. one or more months below 43°F.

G. Mountain climates.

In this scheme, Ceylon is being assigned to A_1m, i.e., Equatorial Monsoon variety.[12] This climatic type is valid only from a general viewpoint.

In 1931, appeared a classification involving new ideas, by Thornthwaite.[13]

11. Miller, op. cit., 107-114. Refer figure 33, for the geographical assignment of his climatic types. Ceylon's position is also clearly assigned.

12. Ibid., 93-94.

13. More detailed consideration will soon follow.

The latest classification is that proposed by Strahler[14] in 1951, on the basis of air masses. Its application to Ceylon invariably will be limited because it recognizes only very broad ' climatic zones '.

Various modifications of Koppen's classification have appeared, purporting to introduce significant 'climatic regions'; two of them are those by Trewartha[15] and Blair.[16] Modifications of certain aspects of Koppen's system have also appeared from time to time.[17]

The main concern in this paper is to apply the two outstanding world classifications in use today, namely, Koppen's and Thornthwaite's. It may be mentioned to the unwary reader that one of the main limitations of applying these systems to Ceylon is the fact that only 16 meteorological stations[18] have records of both temperature and precipitation ; the reliability of the records, however, is satisfactory.

The Koppen Climatic Classification

Today, the classification of Koppen has been so much modified that it bears little trace of the original, propounded in 1884 ; it was based only on average annual temperatures[19] and bears a close resemblance to that of Supan. Three ' climates ' were recognized :

I. *Tropical* over 20°C,
- (*a*) all 12 months, e.g. Batavia.
- (*b*) sub-tropical 4-11 months.

II. *Temperate* 10°-20°C,
- (*a*) warm summers (Rome).
- (*b*) cold winters (Paris).
- (*c*) (Messina).

III. *Polar* below 10°C.

For about half a century, Koppen continued to modify his original classification ;[20] thus :

(i) In 1900, temperature and moisture were considered ;

14. Arthur N. Strahler, *Physical Geography* (New York : John Wiley, 1951), 343-391.

15. Glenn T. Trewartha, *Introduction to Weather and Climate* (New York : McGraw-Hill, 1943), 305-521.

16. Blair, op. cit., 116-465.

17. These modifications are in effect 'refinements' of the Koppen classification, adding to its value rather than being negatively critical of such a worthy system. The references mentioned here are not complete, however. Refer C. W. Thornthwaite, 'The Climates of North America according to a New Classification', *Geog. Rev.*, XXI (October, 1931), 633-635 ; Harry P. Bailey, 'Proposal for a Modification of Koppen's Definitions of the Dry Climates', *Yearbook, Assoc. of Pacific Geog.*, X (1948), 33-38.

18. Refer Table I, and Plate I.

19. Biasutti, op. cit., 41-42.

20. Preston E. James, *An Outline of Geography* (New York : Ginn, 1943), 371.

(ii) In 1918, a completely revised scheme was published, and assumed somewhat its present form ;

(iii) Along with Geiger, he published a wall map incorporating important revisions ; certain changes made in this map were later discarded, leading to much confusion in the process of its being reproduced.

(iv) In 1931, appeared the classification, in almost the final form it has assumed today ; the *Handbook of Climatology*[21] was begun to be completed in five volumes, of which the first one was by Koppen.

The classification that will be applied to Ceylon is the 1931 system. Since it is well known and can be referred to in standard geography books,[22] only those sections applicable to the island will be considered in detail.

In 1874, there appeared de Candolle's work on a vegetation classification of the world[23] ; he recognized five plant groups in terms of their general climatic ' determinants '.

A. *Megatherms*—high temperature and abundant moisture ;
B. *Xerophytes*—short hot season, tolerance of dryness ;
C. *Mesotherms*—moderate heat and moderate moisture ;
D. *Microtherms*—less heat and moisture ; tolerance of shorter summers and colder winters ;
E. *Hekistotherms*—polar zone beyond forest limits.

Koppen utilized these vegetal zones as the basis of his climatic regions ; he gave them quantitative temperature-rainfall critical limits, both on an average basis, as well as on seasonal characteristics.

Thus, to briefly summarize his classification :

A. *Rainy Climates* (Megathermal)—temperature of coldest month over 18°C (64·4°F) ; no winters (cool or cold season).
B. *Dry Climates* (Xerophytic)—arid or semi-arid ; the distinction of this climate is in terms of ' precipitation effectiveness ' which is determined by the use of formulae.

21. W. Koppen, ' Das Geographische System der Klimate ', Vol. I, Part C of W. Koppen and Geiger, *Handbuch der Klimatologie* (Berlin : Gebruder Borntraeger, 1936). Also refer B. Hauritz and J. A. Miller, *Climatology* (New York : McGraw-Hill, 1944), 109-130 and 135-156.

22. James, op. cit., 370-379.

23. de Condolle, A. ' Les Groupes Physiologiques dans le regne vegetal ', *Rev., Scientifique*, Ser. 2, XVI (1875), 364-372. Views have been expressed deploring Koppen's use of de Condolle's physiologic vegetal base. That Schimper's physiognomic base would have been more suited for a climatic classification is felt among many climatologists ; the writer agrees with the latter view. See A. F. Schimper, *Pflanzen-Geographie auf Physiologischer Grundlage*, 1894 (trans. into English and edited by Percy Groom and I. Bayley Balfour in 1903).

C. *Humid Climates* (Mesothermal) with mild winters—temperature of coldest month less than 64·4°F but warmer than 26·6°F (-3°C) ; warmest month above 50°F (10°C) ; short winters.
D. *Humid Climates* (Microthermal) with severe winters—temperature of warmest month above 50°F, coldest month below 26·6°F ; severe long winter ; ground frozen for several months.
E. *Polar Climates* (Hekistothermal)—no warm season ; warmest month temperature below 50°F.

These major climates are further subdivided in terms of specific precipitation and temperature characteristics ; combinations of the various symbols designate climatic types. The merit of this classification is its scientific character ; the use of distinctive quantitative criteria of climatic elements ; the use not only of average annuals, but also of seasonal considerations ; the use of vegetation as a basis for the choice of the climatic values ; the use of symbols to designate, simply and effectively, the innumerable climatic types—a minimum of two and a maximum of four symbols for the designation of any climatic type. The modifications that were introduced are not to discredit the classification but to lend it more refinement, in terms of increasing data and verification of the limiting boundaries.

Only the A, B and C climates will be considered here. The A and C types occur in Ceylon ; the B climate will be discussed because ' dryness ' is an important consideration in the Island's climate.

The A climates are subdivided on precipitation considerations :

f : rainfall of driest month is at least 2·4 inches (6 cm.).
m : short dry season exists but is compensated by heavy rains during the rest of the year ;
w : dry season exists, which is not compensated during the rest of the year ; dry season comes during the low-sun period of the hemisphere ;
w′ : used if the rainfall maximum is in the autumn of hemisphere ;
w″ : used if there are two distinct maxima of rainfall, separated by two dry seasons ;
s : used when dry season comes during the high-sun period.

The distinction between m and w (w′, w″, and s) is made on the relationship between the rainfall of the driest month and the total annual rainfall ; this involves the compensation idea. A table has been prepared for this purpose by Kendall.[24]

24. James, op. cit., 377.

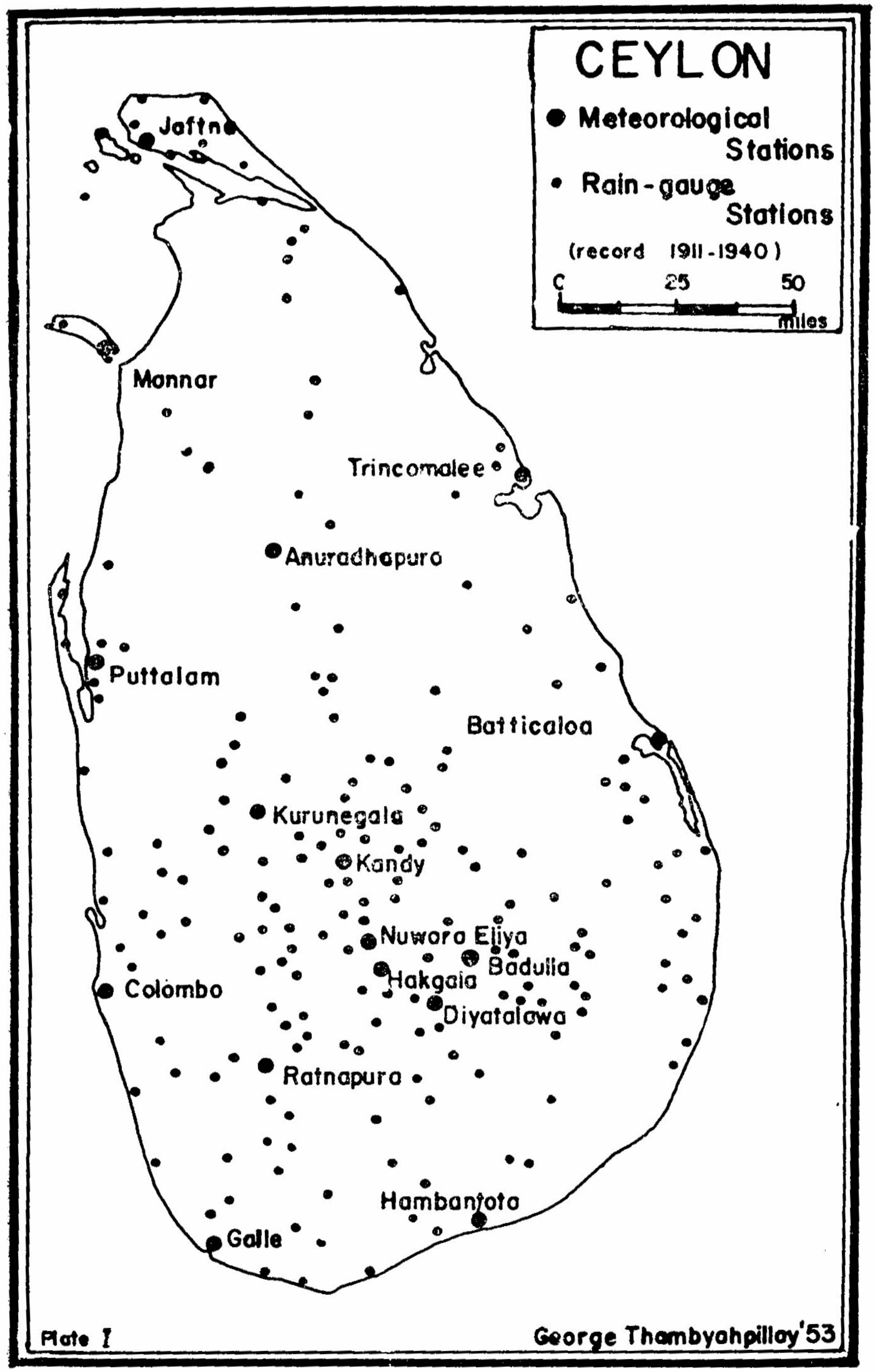

Plate I

Temperature criteria :

- i : range of temperature (annual) less than 9°F ;
- g : hottest month comes before the solstice.

The *C Climates* are subdivided in terms of temperature and rainfall :

- f : no dry season ; precipitation difference between driest and wettest months, less than that required for s or w ; if winter rain and summer drought, driest summer month receives more than 1·2 inches (3 cm.) ;
- s : dry season in summer ; rainiest month of winter receives at least three times as much as driest month in summer ; driest summer month has less than 1·2 inches ;
- w : dry season in winter ; rainiest summer month receives ten times as much as in driest winter month ;
- a : hot summers ; temperature of warmest month over 71·6°F (22°C);
- b : cool summers ; temperature of warmest month below 71·6°F ;
- c : cool, short summers ; only 1-3 months above 50°F ;
- i : temperature range (annual) less than 9°F ;
- x : maximum rainfall in spring or early summer ;
- s′ : maximum rainfall in autumn ;
- n : frequent fogs.

B Climates. The formulae for demarcating the Dry climates from the Humid climates (B/SH) depend on the seasonality of the rainfall. The boundary (BW/BS) between the Arid (Desert) and Semi-Arid (Steppe) climates is determined by formulae similar to that for the B/SH determination, except that the values are halved. The three formulae have been suggested to allow for compensation of rainfall during the summer and winter seasons, and for even distribution.

	BS/H	BW/BS
(*a*) Rainfall chiefly in summer	$r = 2(t+14)$	$r' = t+14$
(*b*) Rainfall evenly distributed	$r = 2(t+7)$	$r' = t+7$
(*c*) Rainfall chiefly in winter	$r = 2t$	$r' = t$

r : annual average rainfall in centimeters
t : annual temperature in °C.

Their application in terms of inches and °F has been made convenient by Meyer ;[25] tables for use in determining the respective boundaries, BS/H and BW/BS, have been prepared by Kendall.[26]

25. James, op. cit., 373.

	BS/H	BW/BS
(*a*) Rain chiefly in summer	r : ·44(t-7)	r′ : ·22(t-7)
(*b*) Rain evenly distributed	r : ·44(t-19·5)	r′ : ·22(t-19·5)
(*c*) Rain chiefly in winter	r : ·44(t-32)	r′ : ·22(t-32)

26. Ibid., 374-375.

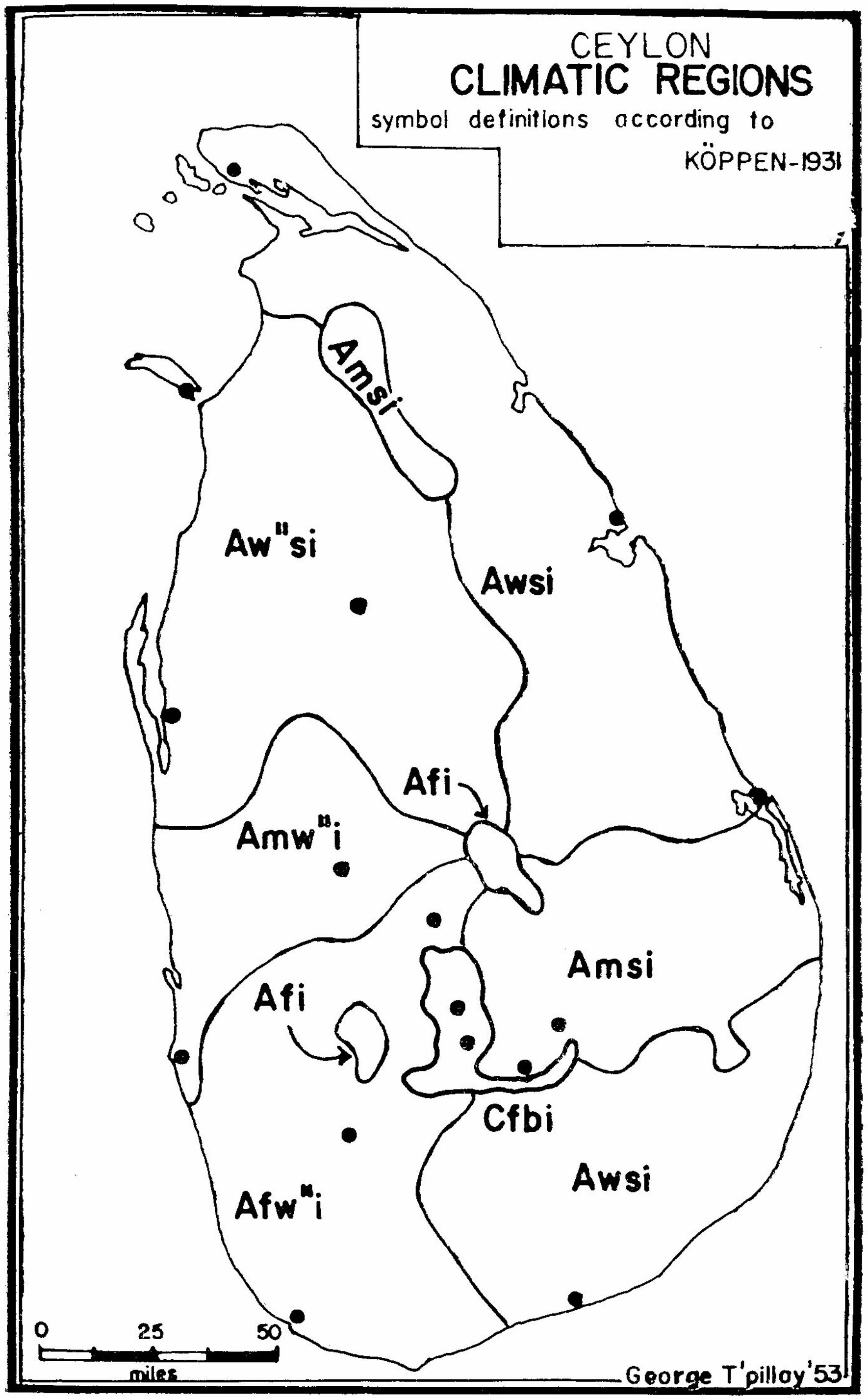

Plate II

Since recorded temperatures were available for only 16 stations, a method of interpolating the temperatures of other stations was adopted by the writer[27] which enabled the use of over 200 stations, for which reliable recorded rainfalls are available (for over 30 years at least) in assigning the Koppen classification symbols. The result showed six climatic types (Plate II).

The whole island shows isothermal tendencies (using 9°F as the criterion) ; there are two ' climates '—the A or Tropical Rainy Climate and the C or Humid Mesothermal Climate.

The C climate is confined to the central highland, and coincides with the 5-6,000 foot contour and includes the west-east and the north-south aligned ridges. The Namunukula Range in the east also exhibits this climate. This zone fulfills the characteristics that designate it a *Cfbi climatic type,* i.e., Humid Mesothermal : no dry season with no month receiving less than 1·2 inches and cool ' summers ' with temperature of the warmest month being less than 71·6°F. Typical stations are Nuwara Eliya and Hakgala.

The A Climatic types cover the rest of the island and the following are recognizable :

(i) *Afi climatic type :* It occurs in two localities, to the south-west and north-east of Kandy. Though both exhibit similar types yet, by virtue of their ' aspects '—facing south-west and north-east—their rainfall characteristics are contrasted in terms of the period of occurrence. The south-west area is that around Watawala[28] which receives an annual rainfall of over 218 inches, of which 65 per cent falls during the months of the SW Monsoon, yet no month receives less than 3·5 inches ; a single maximum regime during the ' summer ' is the marked feature. St. Martin's Estate, Rangala, which is the type station in the other area exhibiting Afi characteristics, has a north-eastern aspect and is located on the flanks of the Knuckles Range ; its rainfall is again of the single maximum type as that of Watawala, with one significant difference—the occurrence is during the ' winter ' months (the prevalence of the NE Monsoon) when over 83 per cent of its total of 173·4 inches is received. There is no dry season, because no month receives less than 4 inches. The vegetation in both areas is of the typical Tropical Rainy Forest type.

(ii) *Afw"i climatic type.* This covers the whole of the south-west quadrant of the island except for the small Afi zone, mentioned before and the extension of the Cfbi zone. Heavy rainfalls of over 90-200 inches occur annually, while the main contribution is from the SW Monsoon (May to September) ' summer ' rains—over 40 per cent of the total ; the rest is divided

27. George Thambyahpillay, *The Climates of Ceylon,* (M. A. Thesis ; University of California, Los Angeles, 1952), Figure I.

28. Ibid., Chapter III, Part D.

equally between the NE Monsoon and the Convectional rains. The stations exhibit a double maxima, the 'peaks' of rainfall occurring about April-June and October-November; while the contribution of the SW Monsoon is not to be neglected during the earlier 'peak', the effect of the convectional circulation during the 'near-equinoctial' period is clearly in evidence. Galle, Ratnapura and Kandy, though situated at varying distances from the coast, reflect the 'double maxima'. The vegetation, though still of the Tropical Rainy type, has marked differences from that in Afi.[29]

(iii) *Amw''i climatic type.* This is a fairly small area, lying north of the Afw''i zone; its northward extension reflects the decreasing rainfall in that direction from the south-west 'centre'. The annual rainfall is from 60-90 inches and the tendency for lower rainfall during the SW Monsoon and markedly higher during the NE Monsoon ('winter') has increased; the double-maxima characteristic still prevails. The vegetation begins to include occasional deciduous trees among the evergreens;—toward the northern border, this tendency increases.

(iv) *Amsi climatic type.* In somewhat counterpart relationship to that of the Amw''i is this zone; covering a larger area, and including the Uva Basin (the western corresponding area is the Hatton Plateau in the Afw''i zone), this zone reflects the effect of the NE Monsoon 'winter' rain dominancy as opposed to the SW Monsoon 'summer' dominancy in the Amw''i zone. The total rainfall, however, is smaller because of the lesser moisture carrying capacity of the NE Monsoon, while the strong SW Monsoon as it spills over the Central Ridge is a dry wind which warms adiabatically in its descent to blow over this area as a 'parching' wind. The vegetation exhibits more deciduous trees while the evergreens occur sparingly; the 'dry' season from June to August, which comes during the high-sun period of the hemisphere, becomes marked enough to acquire a clear distinction.

An elongated Amsi climatic zone occurs peculiarly in the northern lowland; its NNW/ESE alignment has a special explanation. This zone corresponds to the belt of the frequent passages of cyclonic storms from the Bay of Bengal and the east Indian Ocean; the annual rainfall amounts to about 65 inches, of which 50-60 per cent falls during the months of November and December. The 'dry' season is compensated for, by this heavy rainfall.

(v) *Aw''si climatic type.* The entire western part of the northern half of the island (with the exception of the Amsi zone in the north-east) comes within this zone. The rainfall is low (35-60 inches), a slight double maxima, with one of the dry seasons more marked than the other; the two rain 'peaks' are due to the convectional and the NE Monsoon rains (the latter in the 'winter'

29. Thambyahpillay, op. cit., 145-152; Chapter V.

season). The vegetation is characteristically deciduous, with the evergreens almost entirely absent; in the north-west some xerophytic features prevail. Around Mannar and the central part of the Jaffna peninsula, only xerophytic vegetation occurs; however, this is due perhaps more to edaphic factors (the underlying limestone) rather than to the climatic features.

(vi) *Awsi climatic type.* The eastern half of the northern lowland has a slightly different climatic type from the western half (Aw''si), mainly reflected by the single maximum rain 'peak' in 'winter'; this of course is due to the strong NE Monsoon dominancy (50-60 per cent. of the total rainfall of slightly over 60 inches). The 'dry season' rainfall is less marked than in the Aw''si zone and the vegetation, as a result, does not reflect xerophytic characteristics to the degree shown in the western zone. Deciduous forest type prevails with occasional evergreens.

A region around the Hambantota-Yala-Southern Platform exhibits climatic characteristics to warrant its being assigned to the Awsi zone; low rainfall (annual rainfall about 40 inches), and dry seasons during the high-sun period. However, to assign to it a similar climatic zone as that of the eastern part of northern low-land seems unjustified; the marked 'winter' rains in the Trincomalee-Batticaloa zone and the dry season are significantly absent. But, in terms of the climatic classification adopted here, it has no other assignable type. The rainfall in this zone is comparable to that of the Aw''si zone (43 inches) but it lacks the w'' character; its vegetational type (xerophytic tendency) is also comparable.

The B climates do not appear in Ceylon according to this system. But characteristics of such climates are reflected by the vegetation of the Aw''si zone, and the Hambantota environs[30] (south and south-east); to what extent the vegetation is a reflection of edaphic, rather than purely climatic factors is yet to be ascertained.

The problem of assigning the Hambantota zone to a satisfactory climatic type is one of the problems confronted in applying the Koppen classification to a tropical island like Ceylon. Since the application of this system has been studied in detail only in non-tropical latitudes, many of the symbols suggested do not serve to specify satisfactorily climatic 'types' in tropical latitudes.

Two modifications that are fundamental may be suggested. First, with regards to the A/C boundary; there is no doubt that montane vegetation in tropical latitudes exhibits features distinct from lowland Rainy Forest types, reflecting the effect of temperature. The 'below 64·4°F coldest month

30. During field investigations in the Mohave Desert, (Koppen-BWh) California, in the summer of 1952, the writer noted the striking similarity of the desert vegetation (cacti; creosote bush) to that in the Mannar and Hambantota environs.

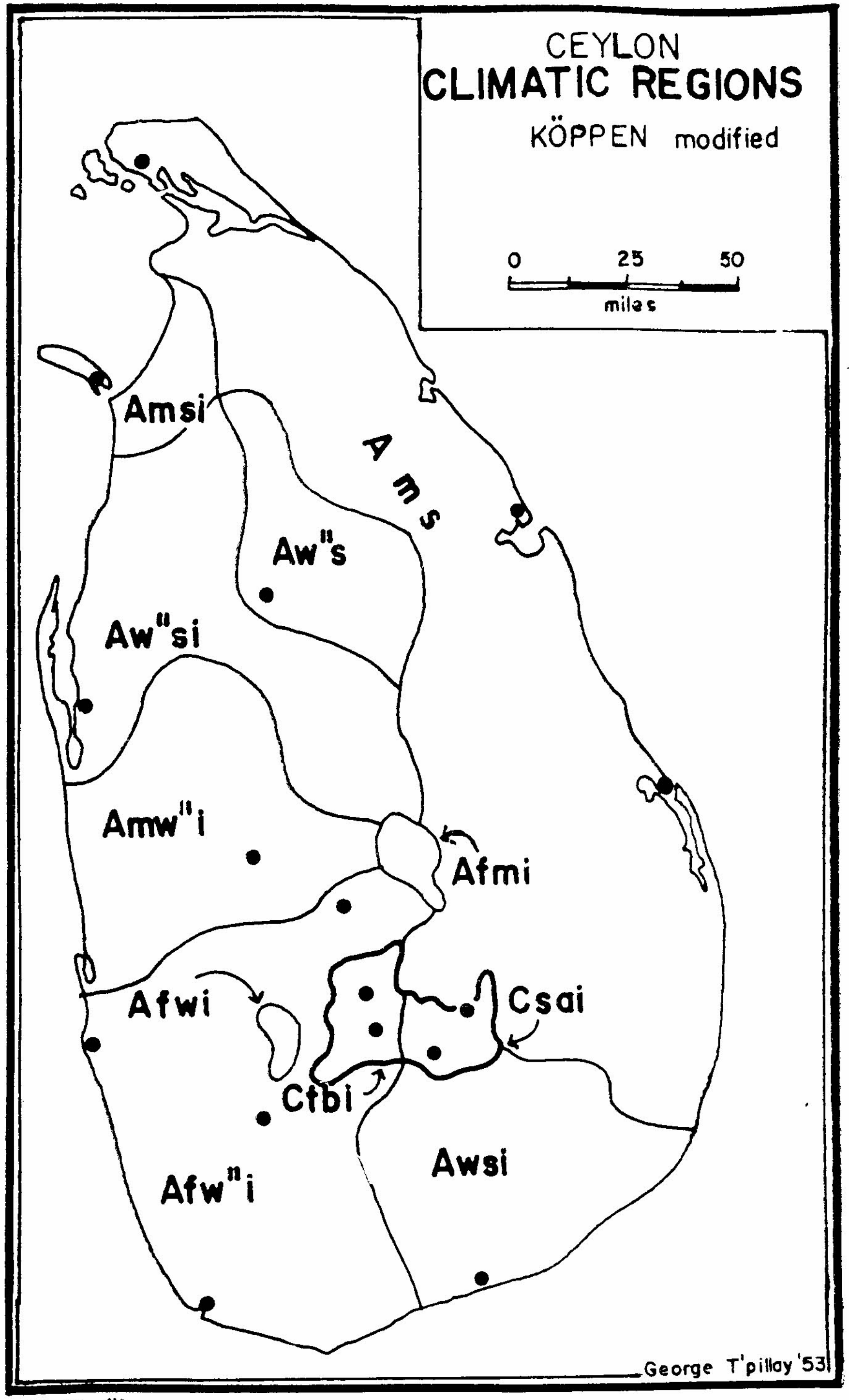

Plate III

temperature ' criterion has been designated for the A/C boundary. According to the Oxford School of Forestry Studies, 70°F (average annual) seems to accord fairly remarkably with the zone of contact between the ' montane ' and the ' lowland ' forest types. Other studies[31] too have substantiated this temperature-vegetal relationship. Of course, the seasonal temperatures also should be taken into consideration, in suggesting new criteria to designate the climatic boundary between the montane and lowland vegetation, in the tropical latitudes. A case in point was revealed during the application of Koppen to Ceylon. Certain vegetal zones in the highland area, according to the present system, fall under the A climates because no month exhibits less than 64·4°F, though the vegetation is of the montane type.[32] The lack of more temperature records in the highland zone makes it difficult to compare this isotherm with other stations ; however, by a process of ' interpolation ' the 3,000 foot contour seems to coincide satisfactorily with the 70°F isotherm, as well as with the contact zone between the montane and lowland vegetation. According to the 64·4°F criterion, only areas above 6,000 feet can be categorized as C climatic types.

A second modification suggested is that the Monsoon regimes in the tropical latitudes, especially in South-east Asia, have a strong 'opposite-seasonal' orientation. The Am/Aw boundary criterion needs modification, as the compensatory principle does not prove satisfactory. The adoption of ' effective rainfall ' criteria would prove more satisfactory. Many of the stations with a high incidence of ' Monsoon tendency ' (contributing 40 per cent. to 60 per cent of the total rainfall) on the Koppen compensatory criterion, fall under the Aw climatic type. There must also be a method of indicating the dominant ' Monsoon season '. The only possibility of so doing under the present basis is in terms of the ' dry ' season during the ' low-sun ' period of the particular hemisphere. In the equatorial latitudes, the ' low-sun ' period has little significance, with regards to the Koppen climatic consideration.

In terms of Ceylon, therefore, minor modifications to the Koppen classification have been made, and a map prepared (Plate III) to compare with the one made using the Koppen classification (Plate II) in its strict sense. In making the above comment about the need for modifications to satisfy tropical areas, the writer is aware of the difficulty of making a world climatic classification which would be applicable to all parts of the world with perfect

31. *Ceylon Yearbook*, 1950 (Ceylon : Government Press, 1951), 140-141. Also refer Thambyahpillay, op. cit., 215-219.

32. Diyatalawa has an annual average temperature of 68°F, with three months below 66°F and one month with 64·4°F. Only three months record over 70·4°F.

satisfaction.[33] There is no doubt that this classification still stands out with distinction in many respects in its application to tropical areas.

Four important modifications are embodied in the map (Plate III) :—

(*a*) The letter 'i' according to the original Koppen criterion designates 'an annual temperature range of less than 9°F'. It is found that in Ceylon, all the climatological stations would therefore be assigned the 'i' characteristic. However, from local considerations, it is revealed that the stations Anuradhapura, Batticaloa and Trincomalee exhibit annual ranges distinct from those revealed by the rest of the island ; therefore, these stations must be distinguished from the others. The use of the letter 'i' to designate 'annual temperature ranges less than 7°F' would satisfactorily bring this distinction out. Thus :—

Trincomalee — Ams   Anuradhapura — Aw''s
Batticaloa — Ams

(*b*) Many of the stations according to the original Koppen assignments are designated Awsi, e.g., Mannar, Batticaloa and Trincomalee ; however these stations undoubtedly exhibit marked monsoonal characteristics. Using the Koppen Compensation Principle, this monsoonal feature is not revealed (Plate II). These stations in the north-eastern lowland have therefore been assigned to the Ams climatic type (Plate III). These stations also exhibit 'drought' conditions and thus warrant being assigned the letters 's' and 'w' (to indicate 'dry' season during the 'high-sun' period and the 'low-sun' period respectively). Thus the following stations are assigned accordingly (Plate III) :—

Kurunegala — Amw''i
Mannar — Amsi
Trincomalee — Ams

This monsoonal feature is also revealed by the station already designated Afi, e.g., St. Martin's Estate, Rangala. According to the new assignment, this station has been designated, Afmi (Plate. III).

(*c*) A third modification is that in connection with the use of the letters 'w' and 's' together. This seems contradictory, since they seem to indicate 'dry' seasonal characteristics, during 'winter' ('low-sun period') and 'summer' ('high-sun period'). However, their combined designation to the one and same single station is warranted from the standpoint that 's' if indicated for both A and C climates would be confusing, because they do not mean the same climatic feature. Thus in this paper, 'w' indicates that the 'dry-season' rainfall is not compensated by the 'wet-season rainfall'. The letter 's' of course designates the occurrence of the 'dry season' during the 'high-sun period'. The designation of the As climatic type would seem logical.

33. More than any other classification, Koppen's has gained wide acceptance from a world consideration. However for critical opinions refer A. E. Ackerman, 'The Koppen Classification of Climates in North America', *Geog. Rev.*, XXXI (January, 1941), 105-111 and F. K. Hare, 'Climatic Classifications' in *London Essays in Geography*, ed. L.D. Stamp and S. W. Woolridge (London: Longmans, 1951), 111-134.

However, the writer feels justified in using the combined designation, from the climatic standpoint.

(*d*) The fourth modification is the one dealt with already, namely the inclusion of Diyatalawa and Badulla within the C climatic region. According to the original Koppen assignments, these two stations are assigned to the Amsi type, thus not in the least indicative of the Montane climatic characteristics of these environs. The biota as well are certainly not of the Tropical Rainy Forests, but unmistakably those of the Montane or at least sub-Montane characteristics. These stations are now assigned (Plate III) the Csai designation and which is justified.

The 'simplified and modified form of the Koppen' climatic classification by Trewartha[34] has not introduced any changes as far as Ceylon is considered. The island falls under two types :

Am—Monsoon Littoral sub-type of the Tropical Rainy Forest Climates ;
BS—Tropical Steppe.

Since it is a simplification of Koppen, its shortcomings are further increased.

The Blair[35] classification only makes a pretense of being a 'new' classification ; there is no doubt that it is based on Koppen. According to Blair, Ceylon has two climatic types :

TRm—Tropical Rainy (Monsoon subtype).
TS—Tropical Savanna.

This system is less definitive and has less value in designating 'general' climates ; the inadequacy of expressing the climatic features in terms of definite climatic 'types' is evident. In this it offers a contrast to Koppen, which latter is more satisfactory.

The Thornthwaite Classification of Climates

In 1931, there appeared a 'new' classification of climates[36] which was to stand out in comparison with the prevailing, widely-accepted Koppen classification. While the latter was based on Vegetation Zones to which were designated critical climatic quantitative values, the new classification introduced the 'effectiveness' criterion as its basis.

The concept of 'effectiveness' introduced by Thornthwaite is not a new one. Since the turn of the 20th century, studies have been made increasingly in relation to this concept, in terms of phytoclimatological considerations. Vegetation has long been recognized as the expression, of the interaction of climatic elements ; the effect of the latter on the type of vegetation development

34. J. Paul Goode, *Goode's School Atlas* (New York: Rand McNally, 1950), 8; Trewartha, loc. cit.

35. Blair, op. cit., 128-129, 302, 320-322.

36. Thornthwaite, op. cit., 633-655.

was recognized by Koppen,[37] to be used in his formulation of a climatic classification. The use of formulae, to determine and define the BS/H and BW/BS boundaries in terms of temperature and precipitation (differing in terms of the seasons) was a clear indication of the significance that the 'effectiveness' concept had to Koppen; his demarcation of the major 'Climates' itself is further evidence of its significance. The role of evaporation was, therefore, brought into focus; an attempt was made to express its determination in terms of the temperature-precipitation relationship; as a result, numerous studies were made and formulae computed to express this ratio. Various workers[38] in this field of investigation introduced 'indices' and 'factors'; thus for example, Transeau's 'index of precipitation effectiveness' (1905), the 'rain factor' of Lang (1915), 'index of aridity' of De Martonne (1926), the N-S quotient of Meyer (1926), *le quotient hygrometrique* of Szymkiewiez (1925).

In his study,[39] Thornthwaite attempted to introduce a method of computing the precipitation-evaporation (P/E) quotient, by utilizing only the mean, monthly temperature and monthly precipitation. His idea was to formulate a classification of climates on the basis of the precipitation-evaporation quotient; but since evaporation measurements were available only in a few stations, he looked for a means of using readily available data. He recognized, however, that although other factors influencing evaporation, 'such as vapour tension, wind and atmospheric pressure, have not been taken into consideration, the resulting error makes no significant difference in the results'.[40]

From the data of evaporation, monthly temperature and precipitation of 21 stations in the Western United States, Thornthwaite obtained the following values:

(i) $\frac{\text{Monthly precipitation}}{\text{Monthly evaporation}}$ = P-E (precipitation-evaporation) ratio

(ii) $\frac{\text{Total annual precipitation}}{\text{Total annual evaporation}}$ = P-E quotient

(iii) Sum of 12 monthly P-E ratios = P-E index

The quotient P-E is considered the 'precipitation effectiveness' ratio of a single month; the sum of the 12 monthly P-E ratios gives the 'precipitation effectiveness' of the station. From these, Thornthwaite defined the following 'Humidity Provinces' (as applied to the United States):

Humidity Province	*Characteristic Vegetation*	*P-E Index*
A (Wet)	Rain Forest	above 128
B (Humid)	Forest	64-127
C (Sub-humid)	Grassland	32-63
D (Semi-arid)	Steppe	16-31
E (Arid)	Desert	less than 16

37. Koppen applied quantitative definiteness to de Candolle's Vegetation Zones, on a basis of their growth conditions, as determined by temperature and precipitation. Refer Victor Conrad, *Methods in Climatology* (Cambridge, U.S.A.: Harvard University Press, 1946), 196-198.

38. Thornthwaite, op. cit., 635-636.

39. Ibid., 633-655. Also see Hauritz and Austin, op. cit., 130-134.

40. Ibid., 636.

(These were compared with the indices of plant growth in the United States).

Realizing the effect of seasonal variations, Thornthwaite also attempted to express 'the seasonal distribution of precipitation effectiveness'. Using P-E index for the abscissa and the sum of the three P-E ratios of summer or winter (depending upon which is greater) for the ordinate, four sub-types were recognized by means of a chart. Thus:

r : moisture abundant at all seasons—P-E index must be more than 48 and highest seasonal effectiveness less than half the total;

s : moisture deficient in summer—Winter effectiveness index more than 16 and more than half P-E index (less than 128);

w : moisture deficient in winter—Summer effectiveness index more than 16 and more than half P-E index (less than 128);

d : moisture deficient at all seasons—Highest seasonal effectiveness less than 16 or less than half total; P-E index less than 48.

Precipitation effectiveness was thus expressed as an accumulated sum of the effectiveness ratios of individual months; a similar method of expression was introduced for an equivalent coefficient for temperature efficiency. He thus defined the following:

T-E ratio: monthly coefficient of thermal efficiency;

T-E index: the sum of the 12 monthly ratios.

The 'limiting and stimulating' temperatures for plant growth were expressed as 'temperature efficiency' coefficients, comparable to the P-E indices. Six 'Temperature Provinces' were recognized:

Temperature Province	*T-E Index*
A′ (Tropical)	above 128
B′ (Mesothermal)	64-127
C′ (Microthermal)	32-63
D′ (Taiga)	16-31
E′ (Tundra)	1-15
F′ (Forest)	0

To this 'thermal efficiency' seasonal considerations were introduced; the summer concentration was found to alter the effectiveness of the precipitation and thus a relationship was established between the thermal efficiency accumulation of the three summer months and the total thermal efficiency. The ratio between these was expressed in percentage, and was used as the criterion for the thermal sub-provinces :

Sub-province	*Per cent. (%) Summer Concentration*
a	25-34
b	35-49
c	50-69
d	70-99
e	100

Thus, recognizing precipitation effectiveness (P/E) and thermal efficiency (T/E) as being the most significant of climatic elements (the relative importance of each depending upon its limiting effect) Thornthwaite attempted a classification of climates from these considerations.

He first applied it to North America (1931), and subsequently to the world.[41] In all, thirty-two climatic types were recognized by a process of combination.

The use of complicated and detailed formulae to determine the demarcating limits of the climatic types may be considered one of the deterrent factors in its being widely utilized. The empirical nature of the derived criteria also vitiates the value of this classification. Thornthwaite has himself referred to the fact that evaporation is dependent, not only on temperature and precipitation, but also on many other significant factors, although he considers the latter to affect the results in no marked degree.[42]

He has made the determination of the P-E ratio (by the computation process) easy, by the use of the nomogram.[43] Corresponding data for Ceylon for the 16 meteorological stations have been used by O'Dwyer[44] for the determination of the precipitation-effectiveness indices. On this basis, a map has been prepared (Plate IV).

(i) Two Temperature Provinces are recognized :—

A' (Tropical)	*T-E Index : 128 and above*	*Av. Annual Temperature °F*
Stations : Mannar	150	82·1
Trincomalee	150	82·1
Anuradhapura	147	80·9

41. C. Warren Thornthwaite, 'The Climates of the Earth', *Geog. Rev.* (July, 1933), 433-440.

42. Thornthwaite, 'The Climates of North America', op. cit., 636.

43. Average annual temperature and annual precipitation are the co-ordinates of a logarithmic graph. Then the determination of the P-E ratio is easy.

44. Douglas O'Dwyer, *The Climates of Ceylon*, Research Report, No. 14 (University of Western Australia : Geographical Laboratory, April, 1950), p. 8, 1 Pl.

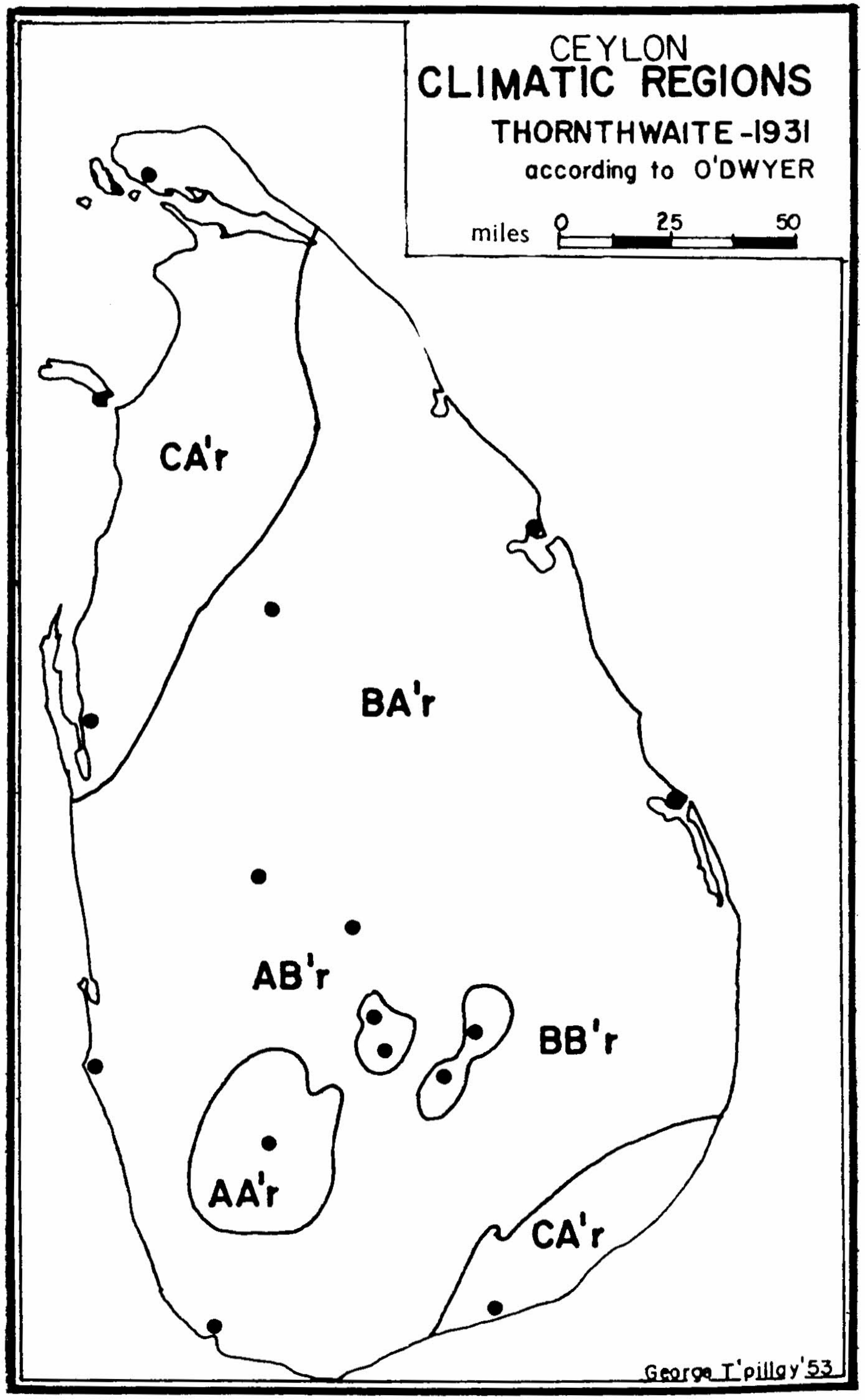

Plate IV

A (*Tropical*)	*T-E Index:* 128 *and above*	*Av. Annual Temperature* °F
Stations: Batticaloa	147	81·4
Jaffna	147	81·5
Puttalam	147	81·0
Ratnapura	146	80·8
Hambantota	146	80·7
Kurunegala	145	80·6
Colombo	144	80·5
Galle	143	80·0
Kandy	135	77·0
B′ (*Mesothermal*)	*T-E Index:* 64–127	
Stations: Badulla	125	73·5
Diyatalawa	108	68·2
Hakgala	90	63·1
Nuwara Eliya	83	59·5

No thermal sub-provinces are recognized.

(ii) Three Humidity Provinces are recognized:

A (*Wet*)	*P-E Index:* . 128 *and above*	*Total annual rainfall (inches)*
Stations: Ratnapura	208·2	153·5
Hakgala	179·1	100·0
Nuwara Eliya	171·7	90·5
B (*Humid*)	*P-E Index:* 64–127	
Stations: Galle	123·2	94·5
Colombo	118·9	93·0
Kandy	113·0	87·0
Badulla	100·4	72·0
Kurunegala	106·1	84·7
Diyatalawa	99·5	65·5
Batticaloa	92·0	69·0
Trincomalee	81·9	65·0
Anuradhapura	73·1	57·0
Jaffna	69·1	53·0
C (*Sub-humid*)	*P-E Index:* 32–63	
Stations: Puttalam	53·4	44·0
Hambantota	49·4	43·0
Mannar	47·8	40·0

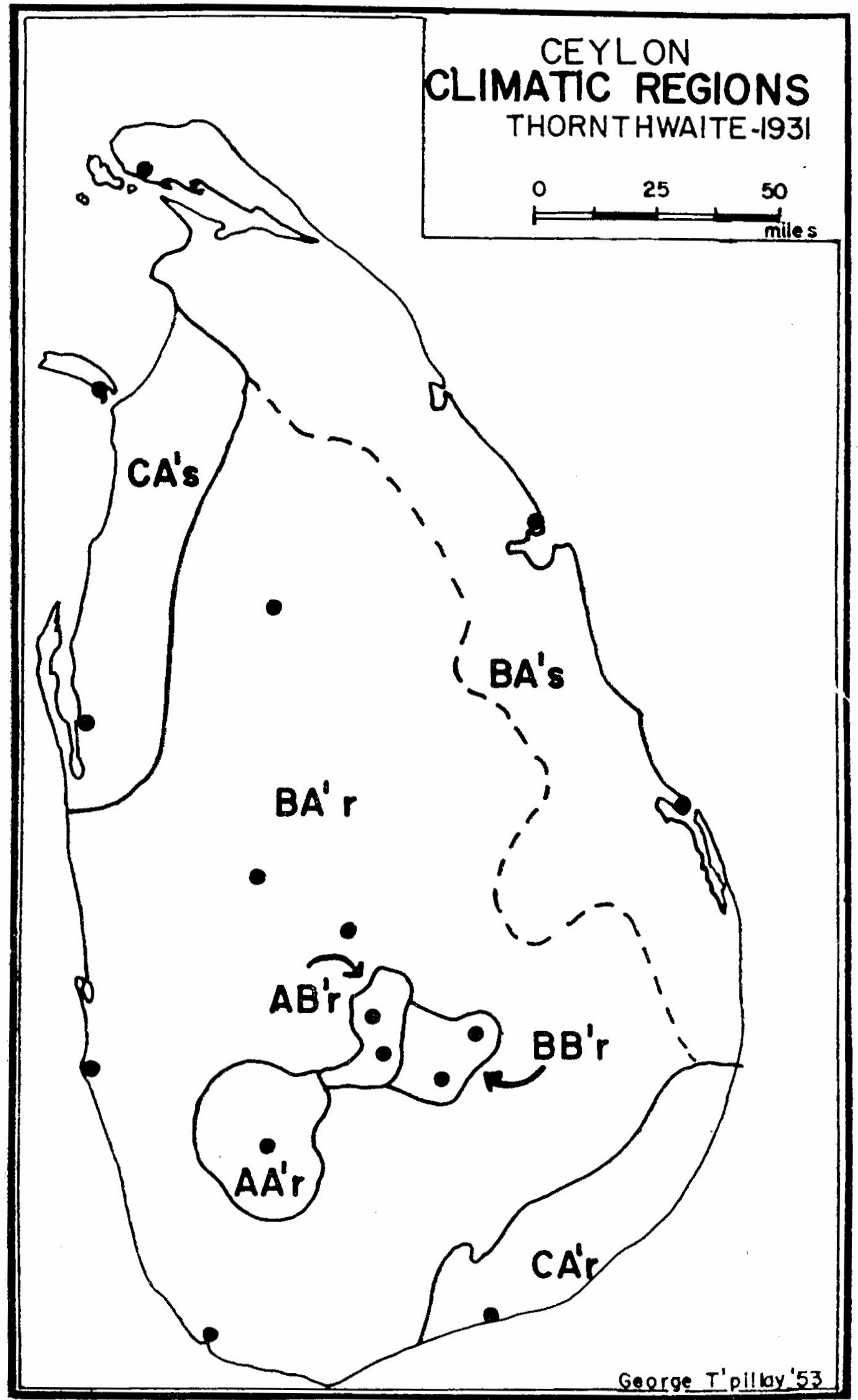

Plate V

There is some confusion regarding the assignment of the sub-types. In the table, O'Dwyer assigns ' r ' to all the stations, while in the text, Batticaloa and Puttalam are considered ' s ' in some connections.

There is, of course, the problem of the ' summer ' and ' winter ' considerations in tropical latitudes ; these terms are therefore not applicable to Ceylon in their strict sense. The Monsoonal control masks even these tendencies ; in some places the NE Monsoon rains in the ' winter ' season are heavier than the ' summer ' rains.

However, ' s ' (moisture deficient in summer) can be assigned to Batticaloa, Jaffna, Mannar, Puttalam and Trincomalee. Thus, the following climatic types and provinces can be recognized, (Table II) on the basis of the 1931 Thornthwaite classification, as applied to the sixteen stations :

(i) AA'r — Ratnapura
(ii) AB'r — Hakgala and Nuwara Eliya
(iii) BA'r — Anuradhapura, Colombo, Galle, Kandy, Kurunegala
(iv) BA's — Batticaloa, Jaffna, Trincomalee
(v) BB'r — Badulla, Diyatalawa
(vi) CA'r — Hambantota
(vii) CA's — Mannar, Puttalam

According to O'Dwyer's map[45] only five provinces are indicated : Jaffna, though tabulated under BA'r, appears on the map within the CA'r zone ; no sub-province types are indicated, and no ' s ' type is assigned to any station in the table. Therefore, a map (Plate V) to incorporate the modifications and refinements has been prepared by the writer.

AA'r—Wet Tropical Climate (with no ' dry ' season) : This corresponds to the ' Evergreen Multi-canopied Forest Zone ' of vegetation[46] ; heavy rainfall (over 125 inches, annual) and high temperature (over 80°F annual) characterize this zone. It occurs around the Watawala-Ratnapura-Padupola environs.

AB'r—Wet Mesothermal Climate (with no dry season) : This covers a small area, about the zone over 6,000 feet in the central highland. Nuwara Eliya and Hakgala are representative—the thermal efficiency index is less than 90 and the temperature average an annual of about 60°F ; the vegetation corresponds to the ' montane forest zone '.

BA'r—Humid Tropical Climate (with no dry season) : This type reflects the greater part of the island's climatic characteristics. According to O'Dwyer, the eastern coast with a marked ' dry ' season is also included in this zone. The annual rainfall varies from about 87 inches (Kandy) to 57 inches (Anuradhapura) ; the temperatures are high, slightly below 81°F (average annual). The vegetation reflects deciduous characteristics, the ' evergreens ' occurring only towards the central highland.

45. The map has demarcating boundaries of climatic regions, not in accordance with the data ; it is also a poor map.

46. Thambyahpillay, op. cit., 149-151 ; Plate XXV.

BA's—Humid Tropical Climate (with marked ' summer ' dry season) : This zone has been separated from the general BA'r zone because of the marked dry season that is reflected in the vegetation ; xerophytic tendencies appear, and ' evergreens ' are rare. The rainfall is everywhere less than 70 inches though a 60-inch annual rainfall appears to be characteristic. The rains during the ' winter ' period contribute 50-60 per cent of the total.

BB'r—Humid Mesothermal Climate (no dry season) : This occurs within a restricted zone, and is determined by the climatic characteristics of the elevation and the leeward position of the Uva Basin. The north-south Central Ridge acts as an effective ' climatic ' barrier to the SW moisture-laden winds ; having deposited their moisture on the windward slopes of the highland, the winds spill over into this basin as ' dry ' winds.[47] The rain-shadow effect is clearly evident ; the annual rainfall is 65-70 inches, the ' summer ' rain amounting to only 20 per cent of the total. The lower temperatures, however, counteract the low rainfall, thus making the rainfall more ' effective ' than would be otherwise.

CA'r—Sub-humid Tropical Climate (no dry season) : This zone corresponds to the so-called ' Arid Zone ' of the south-west ; the rainfall is low (43 inches at Hambantota) ; the rainfall and the precipitation effectiveness are evenly distributed, permitting a ' seasonal ' effectiveness. Xerophytic-Palm association, and deciduous trees form the vegetation.

CA's—Sub-humid Tropical Climate (with marked dry season) : This is the north-western part of the ' Arid Zone ',—the counterpart of the ' Hambantota ' area. A marked ' dry ' season during ' summer ' prevails in this area, the seasonal precipitation effectiveness thus becoming a significant feature. The annual rainfall varies from 40-50 inches ; the ' summer ' rainfall incidence is very low, only 12 per cent of the total. Xerophytic vegetal associations are typical, with low shrubs. The underlying limestone bedrock has, to some extent, accentuated the xerophytic tendency.

The lack of temperature data for a larger number of stations for which reliable long-period rainfall records are available, vitiates the satisfactory application of this system to the island. The number and the zonation of ' climatic provinces ' would present a more true picture for the island, if temper-

47. George Thambyahpillay, ' Climate Controls in Ceylon ', *Ceylon University Review*, XI, 3 and 4 (July-October, 1953), 171-180. Adiabatic warming due to descent make the winds drier, so that the little moisture content they might have had at the time of the ' spill-over ' does not ' precipitate '. These are the ' foehn ' winds—locally the *kachchan*, when it blows over the northern and eastern lowlands.

6298—C

ature data is available. It is strongly felt that the demarcations on the map do not present the complete picture; the system is not to be considered at fault. However, certain anomalies are evident:

(*a*) The Humid Mesothermal Climatic (BB'r) type indicated for the Uva Basin is not in accord with the vegetation actually found there; grassland practically covers the complete area,[48] while forest occurs only in favoured localized belts, along river valleys, etc.[49]

(*b*) The Sub-humid Tropical Climate (CA'r) of grassland is inapplicable to the assigned two zones, where in effect xerophytic vegetation dominates the landscape; in the north-west, edaphic factors (limestone base) may be cited, but in the south-west, it is the climatic factors that are perhaps responsible.

In 1948,[50] Thornthwaite introduced a 'new' concept into climatological investigations, as a follow-up upon his earlier classification. This 'approach' towards a rational classification attempts to do away with empirical considerations of the 1931 system;

> Superficially the present system is similar to its predecessor in that the same factors are employed; namely a moisture factor, a heat factor, and the seasonal variation of the two. Actually, the two systems are fundamentally different. In the earlier classification, climatic types were identified, and boundaries are determined by the data.[51]

The main defect of his earlier classification (i.e., empirical considerations) is expressed in the above statement.

'Potential evapotranspiration' is the new concept which Thornthwaite introduces as the basis of his classification; this, he considers, will lift climatology from the present role it exhibits, namely, 'statistical meteorology'. The combined evaporation from the soil surface and transpiration from plants is called 'evapotranspiration'; it represents the transport of water from the earth back to the atmosphere—the reverse of precipitation. Even if an area receives sufficient soil moisture so as to develop the 'climax' vegetation, evaporation will still continue to operate; this evaporation from the soil surface, vegetation, etc., Thornthwaite refers to as 'potential evapotranspiration'. The 'potential evapotranspiration' would thus be entirely a function of climate (depending, of course, on the vegetation type in different areas). By comparing

48. R. A. de Rosayro, 'Notes on the Patanas of Ceylon', *Bull. Ceylon Geog. Soc.*, II, 2 (June, 1947), 36-42.

49. These forest 'tongues' ascending up valley slopes are because of soil moisture along the river courses.

50. C. Warren Thornthwaite, 'An Approach Toward a Rational Classification of Climate', *Geog. Rev.*, XXXVIII (January, 1948), 55-94.

51. Ibid., 88.

potential evapotranspiration and precipitation, he attempts to obtain 'a rational definition of the moisture factor'.[52] Potential evapotranspiration is obtained by instrumental observations alone. By the study of such records in a particular vegetal environment, Thornthwaite was able to derive certain 'ratios'. With these he computed the potential evapotranspiration amounts at a particular place; from these data, a graphical method of deriving it by means of a nomogram was devised.[53] The results have been used to determine indices of aridity and humidity, as expressed by the amounts of water deficiency and water surplus, respectively. From these, 'moisture indices' were derived by a simple formula:

$$Im = Ih - {\cdot}6Ia \text{ or } Im = \frac{100s - 60d}{n}$$

Im = moisture index; Ih = Humidity index; Ia = Aridity index;
s = water surplus; d = water deficiency; n = water need.

From this formula, the derived moisture results were graded to give moisture indices, to designate climatic types for the new classification. He calls these 'rational indices of moisture regions' because they are revealed in the nomograms. He also concedes that the climatic types so designated are the same and have the same meaning, as those proposed in the earlier classification (1931); however, whereas the limits in the previous system were determined empirically by study of vegetation, soils, drainage patterns, etc., the limits of the present classification, 'are rational and are established solely in terms of the relation between potential evapotranspiration and precipitation'.[54] It is possible to convert the present moisture index I to the old P-E index, by a simple equation:

$$P\text{-}E = {\cdot}8I + 48$$

In all, nine Humidity Provinces were demarcated. The aridity and humidity indices were further used in order to designate 'seasonal efficiency' types; the aridity index was used to designate the 'types' within the moist climates and *vice versa*.

Potential evapotranspiration is an index of thermal efficiency expressing growth in terms of the water-need for it; it relates thermal efficiency to precipitation effectiveness. Thermal efficiency indices were used to designate and define nine types, under five major groups. Further, 'summer concentration' indices (percentages) were derived to designate the subtypes.

To designate a climate, four symbols are used; they are considered adequate to describe the climate satisfactorily. These symbols, it is claimed, designate

52. Thornthwaite, 'An Approach toward a Rational Classification . . .', op. cit., 56.

53. Ibid., 89-94. The recommended logarithm paper is Keuffel and Esser No. 359-112L (Logarithmic, 2 × 3 cycles).

54. Ibid., 88.

essentially the climatic 'aspects' of an area and not simply 'vegetation regions climatically determined'; the earlier classification was essentially the latter, namely, classification of 'vegetation regions' with climatic imprint.[55]

This classification is not claimed to be the final product; it is a 'method of approach'. The author himself suggests the need for more data and more investigations; a better method of determining potential evapotranspiration (which is the basis of this one) needs to be developed; more data needs to be obtained from tropical and high latitudes to modify and revise the present formula; in effect, even to devise a new and more rational formula. The author makes no pretense, therefore, of the limitedness of this classification, in terms of its validity as a basis for world application, as well as regards the satisfactory character of the formulae and the demarcation indices used in the present classification. He only claims a 'new approach' and the 'rationality' of it.

The very basis of the classification, and the 'uncertain validity' of the formula in terms of its possible application to tropical latitudes are obvious reasons to not attempt its application to Ceylon. The conditions, both climatic and vegetation, under which the instrumental recordings were made, are essentially different from those prevailing in Ceylon; to apply it to such an area, using the only *modus operandi* possible—the computation process—would invariably be without justification. However, the discussion of the 'new approach' is not unwarranted, in this paper.

At present the writer is engaged in the continuation of climatic studies in the island. More detailed field investigations would inevitably lead to modifications in the regional assignments of climatic types so far discussed, i.e., Koppen and Thornthwaite. The results will appear in a subsequent paper.[56]

55. For a critical analysis of the Thornthwaite Classification refer Hare, op. cit., 121-132; Hare's schematic representations are highly commendable.

56. For suggestions for a new classification for Ceylon, see Thambyahpillay, 'Climates of Ceylon', op. cit., 211-229. The following Plates in this work may be considered:— IX, XV, XX, XXX and XXXI.

Table I

Main Meteorological Stations

Station	*Height above mean sea level (feet)*	*Years of observation*[a]	
		Rainfall	*Temperature*
Anuradhapura	295	83	24
Badulla	2225	80	26
Batticaloa	26	84	25
Colombo	24	84	25
Diyatalawa	4104	52	26
Galle	13	85	24
Hakgala	5581	69	20
Hambantota	61	85	24
Jaffna	14	83	26
Kandy	1611	84	25
Kurunegala	381	74	24
Mannar	12	84	28
Nuwara Eliya	6170	85	24
Puttalam	27	85	26
Ratnapura	113	85	25
Trincomalee	24	84	25

[a]Observations up to 1952 on this table.
Source: *Reports of the Colombo Observatory*, Ceylon.

Table II

Precipitation Effectiveness Indices—Thornthwaite, 1931
(Computed from data : 1911-1940)

Station	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*P/E Index*	*T/E Index*	*Climatic Provinces*
Anuradhapura	7·5	2·0	4·8	7·5	4·0	0·8	1·4	1·8	4·2	12·5	14·6	10·0	73·1	147	BA'r
Badulla	16·3	4·3	6·7	9·4	6·0	1·9	2·6	4·3	5·8	12·7	15·5	17·9	100·4	125	BB'r
Batticaloa	18·5	5·1	4·0	2·6	2·0	1·0	1·1	2·3	2·6	8·5	19·3	25·0	92·0	147	BA's
Colombo	4·7	3·0	5·3	11·2	20·5	10·8	6·6	4·7	8·3	18·9	18·0	6·9	118·9	144	BA'r
Diyatalawa	10·8	3·4	5·8	9·6	8·6	2·6	2·6	4·2	6·3	14·6	17·5	13·5	99·5	108	BB'r
Galle	4·8	3·8	6·4	10·9	16·8	10·7	7·7	7·4	11·4	16·5	16·7	10·1	123·2	143	BA'r
Hakgala	25·0	6·7	10·7	11·6	14·5	11·0	11·1	8·1	11·0	20·5	23·2	25·7	179·1	90	AB'r
Hambantota	4·9	1·6	3·9	4·4	5·0	2·2	2·3	1·7	3·1	5·6	9·7	7·0	49·4	146	CA'r
Jaffna	5·4	1·9	1·7	2·3	2·2	0·3	0·5	1·2	2·8	11·6	24·6	14·6	69·1	147	BA's
Kandy	8·3	2·8	4·7	8·2	9·5	11·8	9·7	7·4	8·3	15·0	15·7	11·6	113·0	135	BA'r
Kurunegala	6·3	1·3	7·3	12·4	9·1	8·2	4·6	4·2	6·6	20·6	17·0	8·5	106·1	145	BA'r
Mannar	4·6	2·0	2·1	3·8	1·9	0·3	0·3	0·6	1·3	7·7	13·2	10·0	47·8	150	CA's
Nuwara Eliya	14·0	3·5	7·0	8·6	15·5	20·2	21·4	14·0	15·6	18·8	17·6	15·5	171·7	83	AB'r
Puttalam	4·2	1·5	3·5	5·6	4·2	1·6	1·1	0·6	1·8	9·0	13·4	6·9	53·4	147	CA's
Ratnapura	7·6	6·3	13·2	15·0	30·0	26·2	17·2	15·2	20·1	25·5	20·4	11·5	208·2	146	AA'r
Trincomalee	11·0	3·1	2·6	2·2	3·5	1·0	1·8	4·0	3·7	12·1	19·5	18·3	81.9	150	BA's

T/E = Temperature Efficiency
P/E = Precipitation Effectiveness