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A HUMAN CLIMATIC CLASSIFICATION FOR SRI LANKA

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INTRODUCTION

Sri Lanka is an Island situated on the northern edge of a zone which is commonly known as a belt of calm of the Doldrums. This belt lies close to the equator and extends to about 10° North and 10° South of the equator. The Island's extent is 25,000 sq.mile or 65,000 sq.km. Island of Sri Lanka lies between 5°.55'N and 9°.55'N latitudes and between 79°42' and 81° 52' East latitudes. Because of its latitude position, the sun can never (at midday) be lower than 57 degree above the horizon. The solar radiation always strikes the earth (Sri Lanka) at a high angle and is, therefore, relatively concentrated on any given area of Sri Lanka throughout the year. Although Sri Lanka is a small Island, it has a complex relief pattern—the mountainous area in the south central part ranges in elevation from about 3000 to 7000 feet, and is surrounded by an upland belt of about 1000 to 3000 feet, while the coastal plain occupies the rest of the Island. This plain on the south-west broadens out to a vast tract in the north. The central mountainous area plays an important role in determining Sri Lanka's physical (weather and climate) and cultural landscape.

Sri Lanka has four marked seasons in its climate, mainly based on its rainfall and meteorological controls of the Island. In the months of March-April and October-November, the Island's weather and climate comes under the influence of the inter tropical convergence zone (ITCZ). In other wards, due to the planetery movements, the northern convergence zone crosses Sri Lanka through the lowest layers of the atmosphere during the month of April on its northward journey and during October on its return. Climatologically the Island experiences the convectional seasons during these periods. Since they occur in-between two monsoons, they are also referred to as the inter Monsoon Seasons. When the northern convergence zone moves away to the north of Sri Lanka, the Island comes under the influence of equatorial air or the equatorial westerlies. This is the air stream of the south west monsoon. However, the south west monsoon is experienced in the weather of the Island only from latter half of May up to September. Sri Lanka comes under the influence of the north east monsoon which generally prevails over the Island from the beginning of December to the end of February.

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The term 'season' in Sri Lanka's context is entirely different to what the term means in the subtropical and polar regions. Here it depends purely on rainfall variation.

Although, several studies on human climatic classification have been done for the subtropical regions (Auliciems and de Freitas; 1976, de Freitas, 1979; Terjung, and Louie, 1971) there has not been a single study undertaken in the tropical environment. Several bio climatic methods such as heat stress, cold stress, clothing requirements have been used in those studies to give a quantitative interpretation of the body environment relationship. In this study, we have attempted to use the clothing requirement model for the human climatic classification of Sri Lanka. It is an obvious fact that the requirement of clothing is very minimal in Sri Lanka which has a tropical climatic environment, compared to a country in the subtropics which comes under the influence of the winter cold. However, it has remarkable variations in the seasonal and day and night clothing requirement.

Description of climate in terms of clothing requirements is by no means a new concept. It has been used by the Chinese who use the term 'two suit months' when referring to November. Broad zones of insulation needs were devised by the U.S.Army quarter master corps (Simple, 1949), with divisions such as one layer clothing zone (sub-tropical), and two layer clothing zone (sub-Artic). Apart from this past attempts to assess climate in terms of physical units of measurement have failed to provide direct required thermoregulatory activity of the amount of behavioral response (Auliciems and de Freitas, 1976). Because of the complexity of human response and man's inability to make physical measurement no satisfactory human climatic classification has been devised. Gregroczuk, (1966), has put forward a classification based on Air Enthalpy which relates physiological stress or behavioural patterns to the total content of the atmosphere. Terjung's (1966, 67, 68) works in this field has provided a comprhensive scheme of classification.

The present study is based on a scheme of classification which was originally introduced by Herrington, Winsiow and Gagge (1937). The scheme was substantally modified by Auliciems, de Freitas (1976), and de Freitas(1979) to overcome some of the shortcomings of previous classification scheme. This approach assumes the existence of a specific thermoregulatory state and then estimates the response in terms of clothing insulations required for the maintenance of that state in a given climate (Auliciems and de Freitas, 1976).

Clothing unit, Clo., is a widely used concept describing thermal resistance to dry heat flow along a temperature gradient (Auliciems, de Freitas, 1976). It is a physical unit defined in terms of a recognizable human scale which simplifies and standardizes discussion of thermal insulation of air layers, fabrics. (Gagge, Burton and Bszett, 1941).

METHOD:

Burtan and Edholm (1955) have shown that the amount of insulation required to maintain thermal equlibrium between the human body and the environment without sweating or shirvering can be expressed by:

$$Icl = \frac{Ts - Ta}{H} - \frac{Ia\ (H+R)}{H} \qquad (1)$$

Where, Icl., is the resistance to thermal transfer through clothing, Ts is the skin temperature at comfort taken as 35°C. (Hardy, 1949), Ta is the air temperature. Ia is the resistance to heat loss of the boundary air layer at the clothing surface. H is the rate of dry heat transfer to the environment constant at approximately 75% of the metabolic rate (Dubois, 1927). R is the net solar heat load on the human body.

Considered together, the Icl and Ia terms represent the resistance in series to simultaneous convective and radiative heat loss from the body across the thermal gradient from skin to clothing and clothing to air. The standard formula in equation (1) is given by:

$$Ia = \frac{1}{0{\cdot}62 + 0{\cdot}19\ V^{0{\cdot}5}}\ \text{Clo.} \qquad (2)$$

Where, V is wind velocity in cm s^{-1} (Winslow, Gagge and Herrington, 1939, Burton and Edhalm, 1955), have shown that because of the partly off setting effects of air temperature on heat loss by radiation and convection, Epuation (2) affords a reasonable approximation over the normal range of low air temperatures encountered by man. It was originally developed by Harrington, Winslow and Gagge (1937) on the difference in temperature between the body and its surrondings, (Ts - Ta). Its application in the present context has been described in detail by Burton and Edholm (1955), Auliciems, de Freitas and Hare (1973), and de Freitas (1979).

The literature in bio-meteorology gives the metabolic rates for a great variety of activities (Christensen 1953, Spector 1956, Durnin and Passmore 1967). Energy expenditure rates range from 58Wm^{-2} for resting man, (110-175 Wm^{-2}) for slow working and light activity and between 460 and 1050 Wm^{-2} for heavy work.

The solar heat load on upright man (R) in the present circumstances may be calculated by:

$$R = (R_c \cos\alpha\, p^{m}\, a_r\, b) \qquad W/m^2 \qquad (3)$$

Where, R_c is the solar constant taken to 1390 W/m^2. α is the solar angle, p is the mean zenith path transmissivity of the atmosphere. This shows the marked latitudianal and seasonal distribution north of the sub-tropics in northern hemisphere. However, there is not much variation on this component in the Tropics, where Sri Lanka is situated. It was taken to be 0·6 for Inter Monsoon seasons and 0·7 for North East and South West Monsoon seasons.

m is the optical air mass which is the exponent of the mean zenith path transmissivity (p). In the present context, this can be calculated from the following formula. (Terjung, and Louie, 1971).

$$m = \sin\left\{ (90 - Z) + 0.15 \left[(90 - Z) + 3{\cdot}885 \right]^{-1{\cdot}253} \right\}^{-1} X(P_z P_o - 1) \quad (4)$$

Where, Z is the zenith angle of the sun. $P_z P_o - 1$ is the ratio of air pressure at height z to the air pressure at sea level P_o.

a_r is the combined solar heat load term related to the body surfacee receiving radiation and b is the absorptivity factor, a_r is the sum of direct diffuse and terrain reflected radiation. So that, the solar heat load on man will depend mainly on the above factors. In the absence of the solar radiation data, to calculate the solar heat load on man, procedure (2) was adopted. The total radiation absorbed by the body will vary according to the proportions a_r and b with the value of the former dependent on the relative contributions of the direct, diffuse and reflected component to the total solar input. The effective body area exposed to direct radiation (projected area) and the total body area expressed as a ratio of direct radiation is directly related to cos (Pugh and Chrenko, 1966), depending upon the body posture and orientation. In the absence of cloud cover diffuse radiation may be calculated from clear sky albedo varing according to Paltridge, (1974). Assuming an upright position facing the sun, approximately 40% of the body is exposed to direct radiation (Roller and Goldman, 1968). The diffuse radiation also plays an important role to increase the absorbing surface up to double this value, particularly in the case of reflected radiation, when fresh snow cover is present. As such, it is reasonable to assume a_r within the range of 40-80% (Auliciems and de Freitas, 1976). A similar absordtivity range for clothing (b) would apply (Burton and Edholm, 1955, Lee and Vangham, 1964). Several investigators, (Roler and Goldman 1968, Givoni, 1969) have shown that balanced estimates of the variable range of these factors provide a reasonably reliable prediction of the solar heat load on man. Given the degree of variability, it was decided that a combined total absorptivity factor ($a_r b$) of 60% was most suitable for the general classification. Therefore, the absorptivity factor of 0·6 was used for average conditions of maximum solar heat load and it will indicate the mean minimum resistance to thermal transfer through clothing.

In Equation (2), the component refers to solar angle, this can be calculated by using the latitude of a location (ϕ), solar declination (π), hour angle of sun (h). The standard formula is given in the following expression (List, 1963).

$$\sin\alpha = \sin\phi\sin\pi + \cos\phi\cos\pi \cos h. \quad (5)$$

Substituting for Ia (2) and Ts in equation (1) and coverting to Col. units description of the thermal environment in terms of clothing requirements for comfort is given in a final Equation as follows :

$$Icl = \frac{33 - Ta}{0{\cdot}155\ H} - \frac{H + 834 \cos\alpha\, 0{\cdot}6^{m}}{(0{\cdot}61 + 0{\cdot}19\ V^{0\cdot5}H} \text{ Clo} \quad (6)$$

Where, one cloth unit is defined in physical terms as the insulation that will allow the transfer of 1 Wm^{-2} with a temperature gradient of 0·155°C between the inner and outer boundaries of the insulating medium.

Employing the procedure explained, maximum clothing value were obtained using mean minimum monthly air temperature and lowest possible solar radiation (night time). Since there is no wind velocity data available in Sri Lanka for all meteorological stations it is necessary to use a standard night time wind velocity value found in the literature — a wind speed of 890 cm s^{-1}, a level repressentative of convective heat loss from the body. The insulation of air decreases very littte at wind speeds greater than 400 cm s^{-1}. The relationship between wind speed and insulation of air is graphically explained by Bedford, (1948).

Minimum clothing values were derived using mean maximum air temperature and solar heat load. Wind movement was taken to be 44 cm s^{-1} which is the minimum value allowing for free convection at the skin clothing surface and for body motion. R was calculated for clear sky condition at 1400 h, because the daily temperature maxima and the maximum solar heat load on the body would take place shortly after the greatest solar altitude at 1400 h.

Using the above model, day (minimum) and night (maximum) clothing requirement for the seasons were calculated. Thirty year (1931-60) average climatic data for 17 climatic stations have been selected for this study. The lower limit of the light activity class of work, 116 Wm^{-2} was selected as most suitable for general classification. With increased metabolism, man should be able to remove garments according to need, but the definition of clothing requirements for the most demanding situations (the ones involving least muscular activity) should facilitate the maintenance of the thermal equilibrium at all times, (Auliciems and de Freites, 1976). Therefore, the lower limits of the light activity class work, 116 W/m^{-2}, has been selected as most suitable for the purpose of the present classification. The appendix 1 gives the meteorological data used in this study.

RESULTS :

The generalized areal distribution of day time (minimum) and night time (maximum) clothing requirements are shown in figs. 1 – 8. To give a clear picture of clothing requirements clothing unit maps are given separately for day and night together with the contour lines. The variations of clothing requirements in this classification clearly reflects the effect of the rainfall seasons and the variation of relief which goes up to 8000 feet.

Figure 1 for the Inter Monsoon Season of March—April which has a day clothing values between +0·7,+0·09 shows that only a very small area over 6000 feet in hight in the central high lands requires 0 to 0·09 clothing.

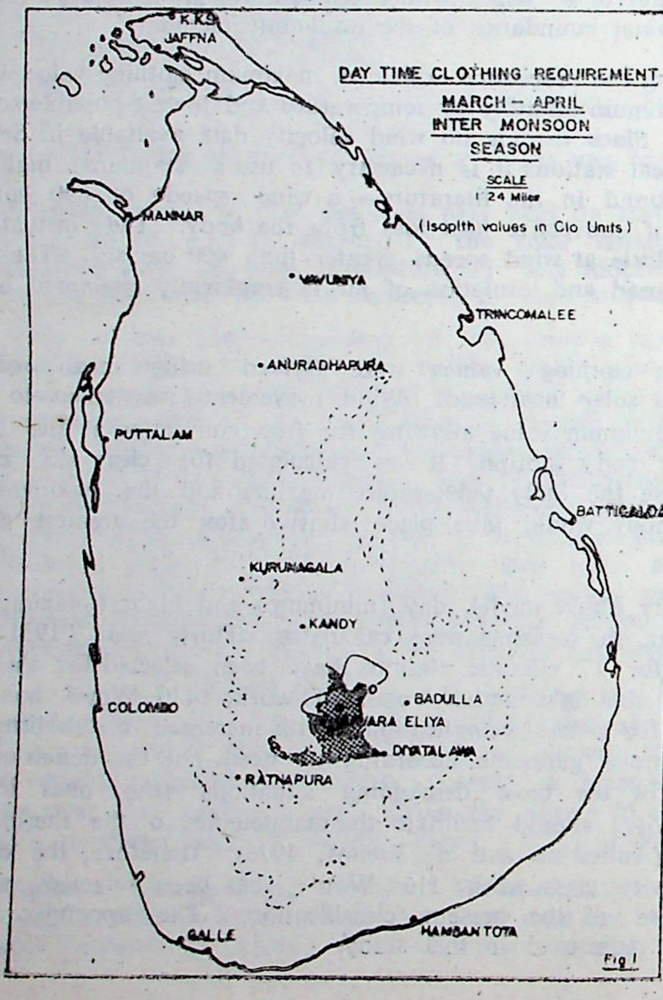


Fig. I

Except this, the dry high land (Diyatalawa, −0·13, Badulla, −0·29), the mid land region (over 1000 feet) requires -0·4 clothing while the low land indicated increasing negative values up to (-0·8). The reasons for these differences, appears to be largely the result of the solar radiation intensity during this season. Since there are no monsoonal currents in March - April, intermonsoon season, the clothing units isolines do not show the influence of winds. It is notable that in the case of the South West and North East monsoon the isolines show the influence of winds in one particular directions i-e south west or north east. Decreasing negative clothing value towards the central high lands show the influence of elevation. The night clothing requirements of this season is shown in Fig. 2. Although, noticeable similarity

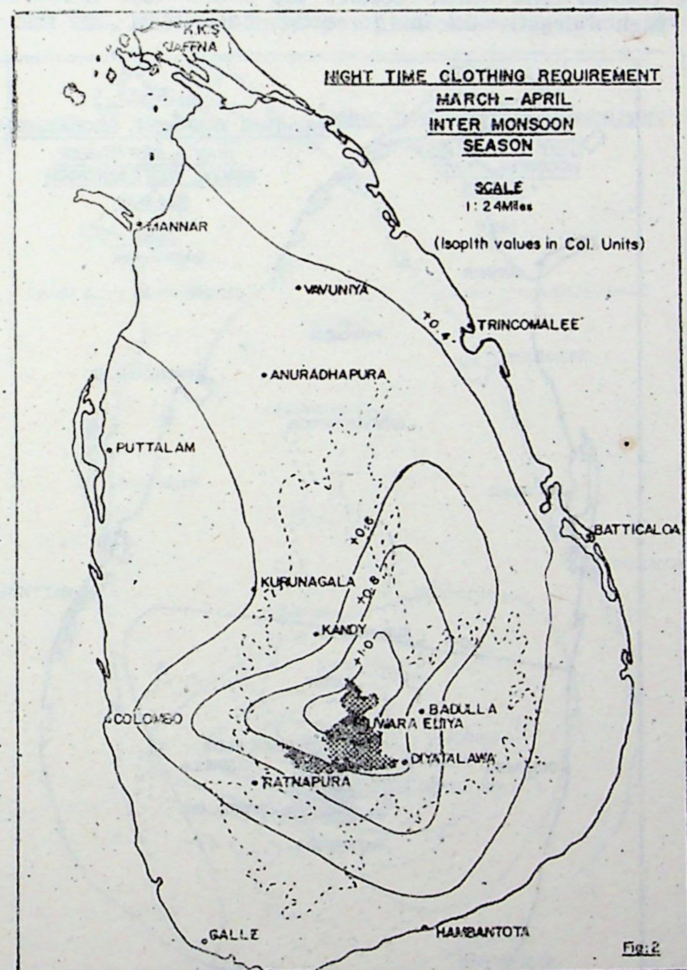


Fig: 2

can be seen in the areal distribution between Figs.1 and 2, a remarcable change in clothing unit exists all over the Island for the night time. The gradual positive increase in clothing from the coastal stations towards the high lands clearly indicate the role of elevation and effect on clothing. All coastal areas require less than + 0·4 clothing in night time.

Following the March - April inter-monsoon season, the south west monsoon period prevails for five months in the Island's weather pattern in which the day clothing requirement nicely corresponds with the wind direction of the south west monsoon Fig. 3. The south west quarter of the island comprise with −0·4 clothing value curve and within this area an increase of clothing requirement according to hight can be seen. Positive clothing units are indicated above 6000 feet. The south west coastal land which receives the south west monsoon shows comparatively higher negative clothing requirements than the rest of the low land

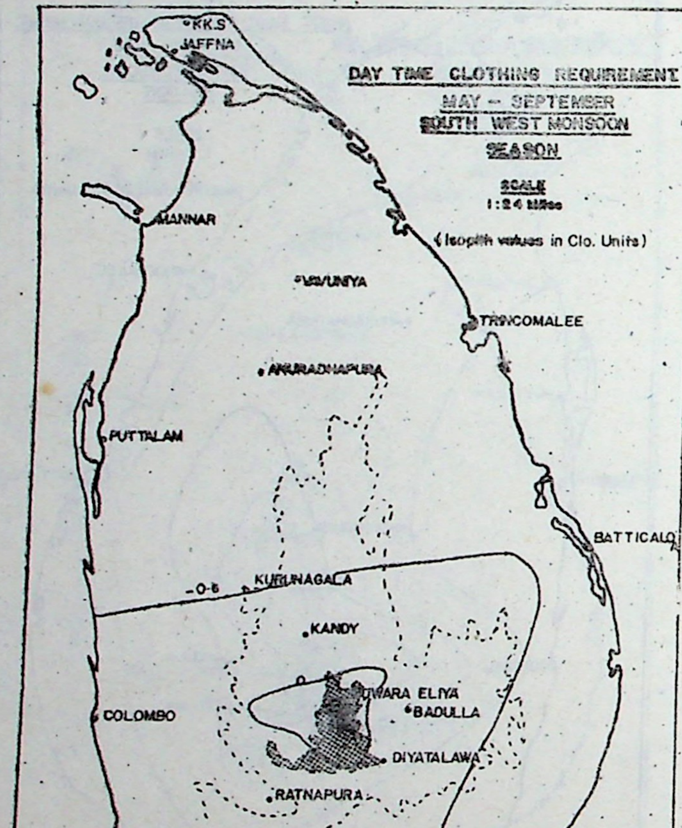
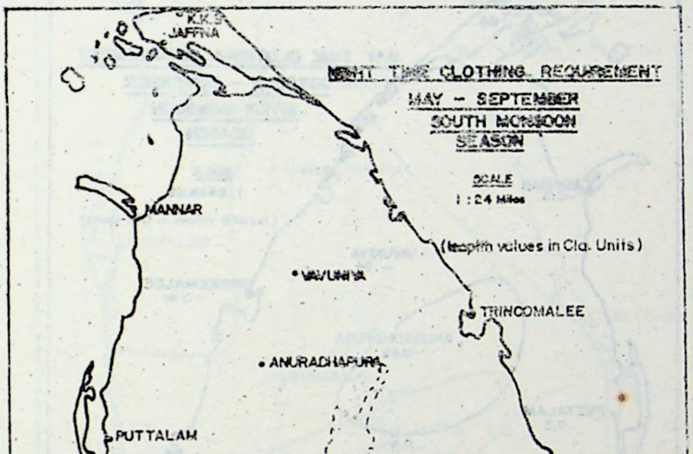


Fig. 3

where the values range from - 0·4 to - 05·2. These differences although slight, between the above two regions, the positive effect of cloud on the incomming solar radiation in the south west coast during this period would have reduced the thermal effect by cloud albedo.

Positive increase in clothing towards the windward side, and negative increase in the leeward side of the central high land are remarkable features in front and rare side of central massive. For example, Badulla and Diyatalawa which experiences the leeward effects of south west monsoon and which are the two stations represent the dry hill land (Uva basin) shows realistic clothing figures of - 0·36 and - 0·12 respectively. Figure 4 shows the night time clothing reqirement. It reveals that, while low lands of the island postulate positive colothing



values, there is a gradual increase in clothing requirement from 1000 feet countour up to the highest elevation. At the hight of 6000 feet, Nuwara Eliya exhibits a higher clothing value of + 1·2. This value clearly illustrats the relationship between diurnal variation of temperature and clothing requirement during night in the hill country.

This situation is changing considerably during the following inter-monsoon season. During the day time, except arround Nuwara Eliya, rest of the Island demands negative requirement see Fig. 5. As in the case figure one, in this season also the isolines of ciothing units do not explicite the influence of

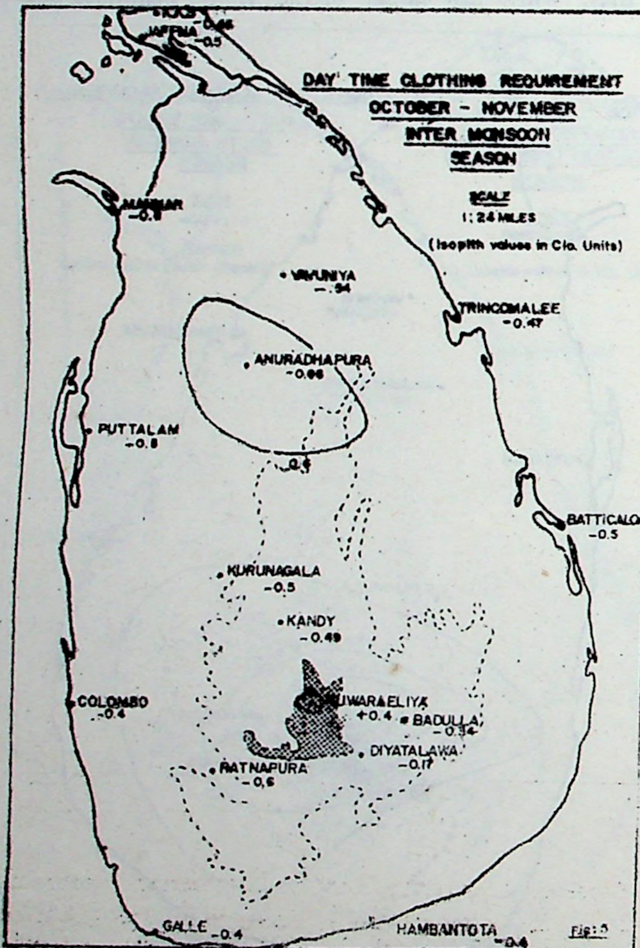
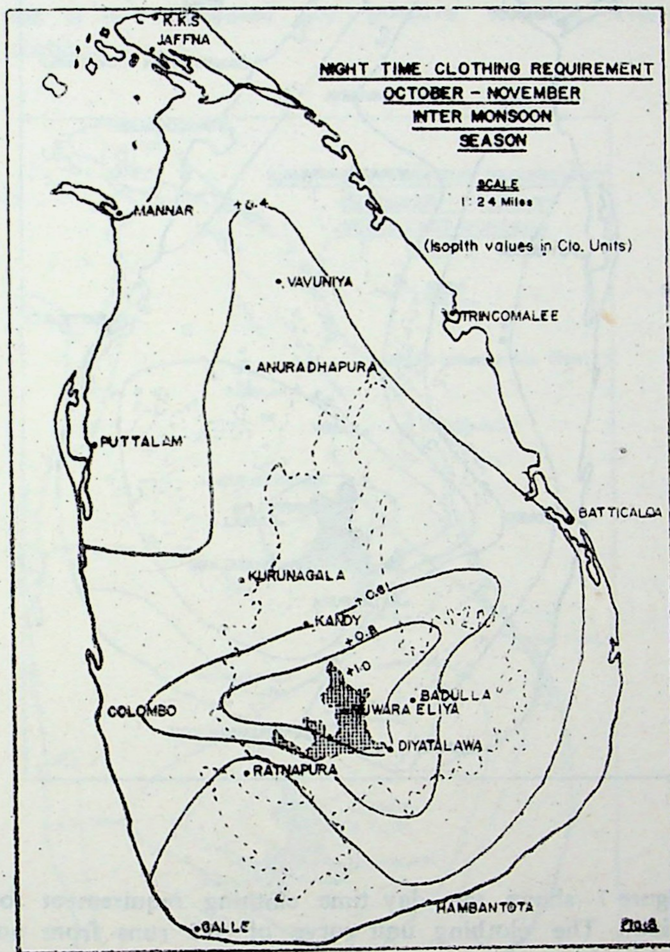


Fig: 5

winds particularly from any one direction. A minimum clothing units require during this month except in high land over 6000 feet, where, this region requir positive clothing even during daytime. However, remarkable change in clothing requirement can be visualized during night time in figure six.



A conic increase of positive clothing requirement according to the hight has been shown in the above figure. The values of clothing units ranges from +0·29 arround the coastal plane to 1·1 at a hight of 6000 feet.

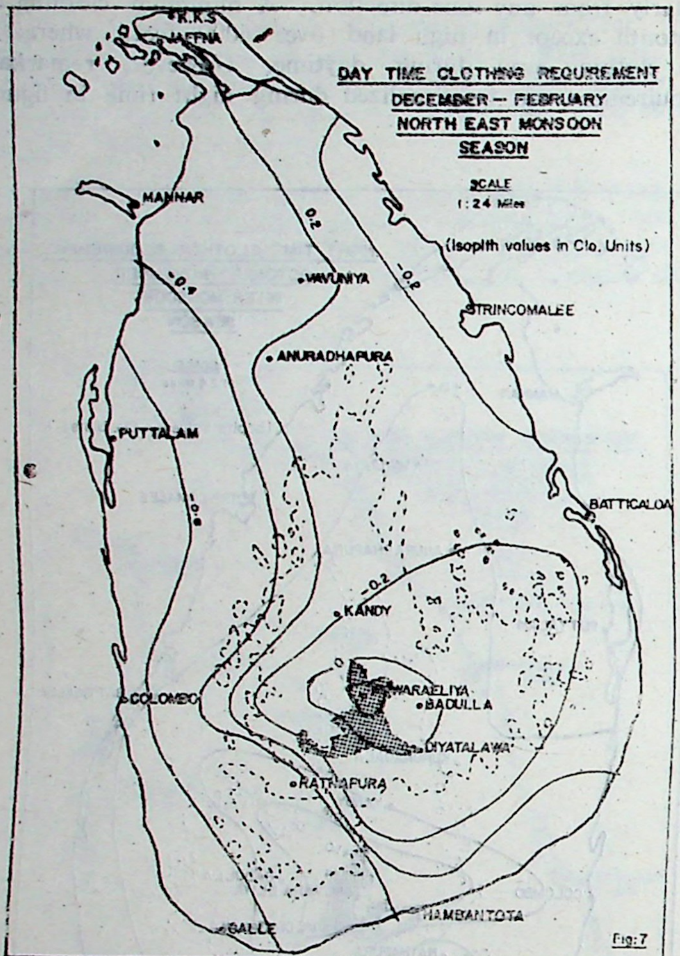


Fig:7

The figure 7 shows the day time clothing requirement for north east monsoon period. The clothing unit curve of $-0{\cdot}3$ runs from north to south deviding the island into east to west. The eastern half of the area includes central high land eastern low land shows the minimum negative values of clothing compared to western half, where the values increases upto $-0{\cdot}78$. The reason for this remarkable feature would be the presence of north east monsoon which brings cooler air currents from Himialayan hills through the deep vallies of Ganga during this winter season. The north east monsoon is generally cool, dry and stable wind and it is received by the eastern low land of Sri Lanka. However, west and south west pants of Sri Lanka have a minimum effects of the north east monsoon due to mountain barrior of central high and. The effect of relief has clearly been illustrated in figure 7. The zero (O) clothing isoline includes Badulla and Diyatalawa only in this season. The figure clearly illustrates that the dry high land gets the positive effects of north-east monsoon and it is elucidated by positive clothing requirement of these high land stations.

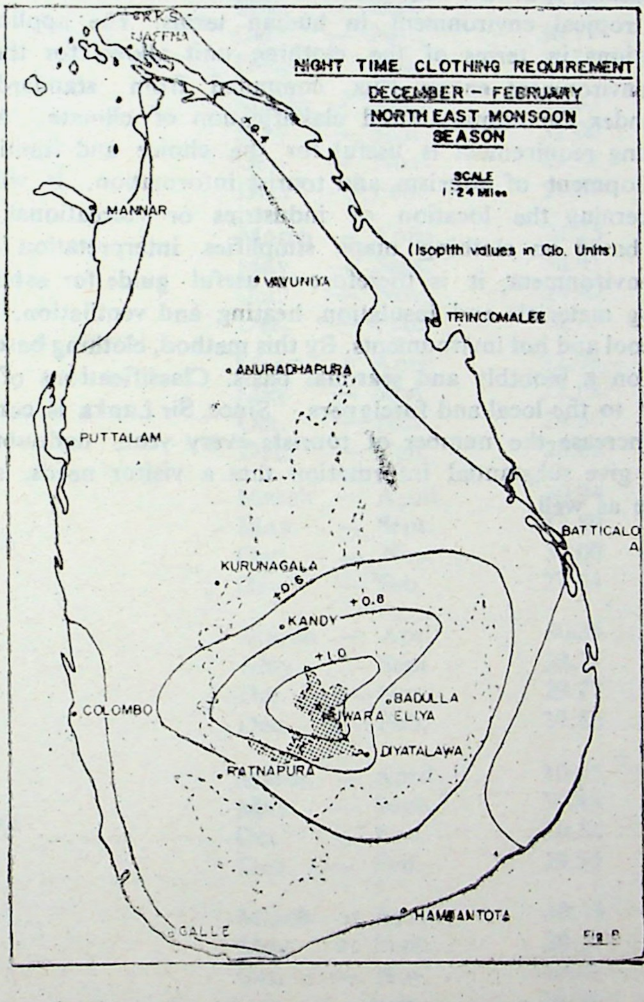


Fig. 8

The clothing requirement is changed during night. Since, it is a winter season for northern hemisphere, all weather stations show high positive clothing requirement figures in a wider area. The island requires clothing values between +0·3 to 1·2. Increasing clothing requirements towards the relief peak is clearly illustrated by +0·4,+0·8,+1·0 isolines and these isolines include wider areas than the night clothing requirement of previous seasons. Very cold air currents which flow from Jammu-Kashmir region through the Ganga Valley must have contributed tremendously to the higher clothing requirement.

The results illustrate the thermal demands of environment and human activity in a tropical environment in human terms. The application of energy balance Equations in terms of the clothing unit allows for the interpretation of the body-environment energy flux, computed from standard meteorological data as an index for human based classification of climate. A knowledge of average clothing requirement is useful for the choice and limiting of outdoor activity, development of tourism and tourist information. It will help to make decisions concerning the location of industries or recreational sites. Since a classification based on clothing maps simplifies interpretation of the thermal demands of environment, it is therefore a useful guide for establishing housing needs, building materials and insulation, heating and ventilation, or airconditioning needs for cool and hot invironments. By this method, clothing based classifications can be done on a montbly and seasonal basis. Classifications of this kind gives greater insight to the local and foreigners. Since, Sir Lanka is concern to develop tourism and increase the number of tourists every year, undoubtedly a study of this kind will give substantial information that a visitor needs, so that it has a practical value as well.

APPENDIX I

STATIONS	SEASONS	Tair °C (Max.)	Tair °C (Min.)
1. Colombo	March — April	31.03	23.83
	May — Sept.	29.69	25.03
	Oct. — Nov.	29.47	23.36
	Dec. — Feb.	30.22	23.31
2. Puttalam	March — April	32.11	23.64
	May — Sept.	30.64	25.82
	Oct. — Nov.	30.11	23.61
	Dec. — Feb.	30.17	22.17
3. Mannar	March — April	32.03	24.86
	May — Sept.	31.00	26.48
	Oct. — Nov.	29.72	24.77
	Dec. — Feb.	28.39	24.02
4. Jaffna	March — April	31.25	25.58
	May — Sept.	30.41	26.83
	Oct. — Nov.	29.42	24.64
	Dec. — Feb.	28.76	23.33
5. K. K. S.	March — April	32.08	24.19
	May — Sept.	32.13	25.91
	Oct. — Nov.	29.86	24.28
	Dec. — Feb.	28.02	22.64
6. Trincomalee	March — April	30.94	25.14
	May — Sept.	33.59	25.66
	Oct. — Nov.	30.00	24.08
	Dec — Feb.	27 44	24.17
7. Batticaloa	March — April	30.36	24.42
	May Sept.	32.77	24.07
	Oct. — Nov.	29.77	23.81
	Dec. — Feb.	27.83	23.20
8. Hambantota	March — April	30.75	24.11
	May — Sept.	30.43	24.83
	Oct. — Nov.	29.86	24.06
	Dec. — Feb.	29.56	22.78
9. Galle	March — April	30.11	24.16
	May — Sept.	28.51	25.07
	Oct. — Nov.	28.47	23.81
	Dec. — Feb.	28.98	23.00

STATIONS	SEASONS	Tair °C (Max)	Tair °C (Min.)
10. Ratnapura	March — April	33.19	22.83
	May — Sept.	30.73	23.52
	Oct. — Nov.	33.60	25.50
	Dec. Feb.	32.09	31.83
11. Anuradhapura	March — April	33.22	22.50
	May — Sept.	32.82	24.36
	Oct. — Nov.	30.86	22.53
	Dec. — Feb.	29.28	20.88
12. Vavuniya	March — April	33.08	22.44
	May — Sept.	32.64	23.91
	Oct. — Nov.	31.11	22.08
	Dec. — Feb.	30.74	20.52
13. Kurunagala	March — April	33.31	22.94
	May — Sept.	30.72	24.06
	Oct. — Nov.	30.58	22.53
	Dec. — Feb.	28.78	21.15
14. Maha-Illupalama	March — April	33.22	22.31
	May — Sept.	31.83	23.89
	Oct. — Nov.	30.64	22 14
	Dec. — Feb.	29.07	20.76
15. Kandy	March — April	31.31	20.22
	May — Sept.	28.10	20.92
	Oct. — Nov.	28.30	19.83
	Dec. — Feb.	28.35	18.37
16. Badulla	March — April	28.58	18.50
	May — Sept.	29.90	18.66
	Oct. — Nov.	27.36	18.64
	Dec. — Feb.	25.52	17.78
17. Diyatalawa	March — April	25.61	15.25
	May — Sept.	25.53	16.78
	Oct. — Nov.	24.13	15.69
	Dec. — Feb.	22.76	14.76
18. Nuwara-Eliya	March — April	21.83	8.97
	May — Sept.	19.38	12.52
	Oct. — Nov.	19.86	11.06
	Dec. — Feb.	20.22	8.68

Temperature averages are taken for the standard period of 1931—1960
Wind data were derrived from the standard average of (1936—1960) 25 years.

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