

A study of Climatic Classification of Pudukkottai District, Tamil Nadu, India

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ABSTRACT

The present paper represents an attempt to study the Climatic Classification of Pudukkottai District, Tamil Nadu by using Geographical Information Systems (GIS). Pudukkottai district is one of the drought prone areas of Tamil Nadu and it has a long history of rainfall fluctuations of varying lengths and intensities. The aridity index ranges from 28% to 75% and the average is 59% and the mean annual moisture index of the study area is 40%. The entire study area is under megathermal regime of climate (A 4-7) conforming to the tropical pattern. Based on moisture index, seasonal variation of effective moisture, thermal efficiency and summer concentration of thermal efficiency, the district has been brought under 20 sub-types within 3 major climatic types. Out of 20 sub climatic types, only one type of Dry Subhumid (C1), 14 climatic combination from Semi Arid (D) and 5 unique types from Arid (E) climatic region. About 84% of the district fall under semi arid climate and distributed throughout the district.

1. Introduction

Climate is commonly defined as the weather, averaged over a long period of time. Climate encompasses the statistics of temperature, relative humidity, atmospheric pressure, wind speed and direction, sunshine, rainfall, atmospheric particle count and numerous other meteorological elements in a given region over long periods of time. The standard averaging period is 30 years, but other periods may be used depending on the purpose. The climate of a location is affected by its latitude, terrain, altitude, ice or snow cover, as well as nearby water bodies and their currents. Climates can be classified according to the average and typical ranges of different variables, most commonly temperature and precipitation. The most commonly used classification scheme is the one originally developed by Wladimir Koppen (1901). The Thornthwaite scheme, in use since 1948, incorporates evapotranspiration in addition to temperature and precipitation information and is used in studying animal species diversity and potential impacts of climate changes. There are several ways to classify climates into similar regimes. Originally, climates were defined in Ancient Greece to describe the weather depending upon a location's latitude. Modern climate classification methods can be broadly divided into genetic methods, and empiric methods, which focus on the effects of climate. Examples of genetic classification include methods based on the relative frequency of different air mass types or locations within synoptic weather disturbances. Examples of empiric classifications include climate zones defined by plant hardiness, evapotranspiration, or more generally the Koppen climate classification which was originally designed to identify the climates associated with certain biomes. A common shortcoming of these classification schemes is that they produce distinct boundaries between the zones they define, rather than the gradual transition of climate properties more common in nature.

Subrahmanyam et al (1965), has identified nine climatic types in India, based on the Koppen's classification of which, four fall under zone A, two each under zones B and C and one in zone D. Later, several authors have adopted this scheme and classified some Indian States. Murthy (1982) has reported the climatic types of Kerala and identified two climatic types of tropical zones namely, Tropical Monsoon and Tropical Savannah. In spite of the wide publicity it received, Koppen's system has very serious drawbacks as it lacks in a rational basis for the limiting values of temperature and precipitation and also lays less emphasis on the variations in moisture (Subrahmanyam et al.,1965). Thus, Koppen's scheme has failed to express the basic requirements of effectiveness of precipitation and efficiency of temperature.

The development of these concepts has been recognized by Thornthwaite (1943) who proposed a scheme based on fundamental considerations of thermal and moisture effectiveness (Thornthwaite, 1948). This classic scheme of Thornthwaite revolves around potential evapotranspiration (PE), a hypothetical expression that represents the water need of a place, and is derived from the temperature and the length of the day. Through PE, Thornthwaite has related the temperature and the unavoidable water loss to the atmosphere and has further added the soil factor, where in the capacitate role played by the soil in storing moisture is considered. He has evolved an elegant budgeting procedure (Water Balance) through which the water surplus and water deficit in relation to water need can be computed which gives a moisture index, on the magnitude of which different climatic provinces have been evolved. Positive indices represent humid climates-Perhumid (A), Humid (B) and moist sub humid (C2) while negative indices represented dry climates; Dry sub-humid (C1), semi-arid (D) and arid (E). This method has been later modified by Thornthwaite and Mather (1955) so as to improve it based on the later revelations of the field capacity of the soils in retaining the moisture. This improved version of the Thornthwaite and Mather (1955) has been widely accepted and followed till date.

2. The study area

Pudukkottai district was organized as a separate district on 14th January 1975 and it has comprising of the former Pudukkottai Division of Tiruchirappalli district with some additions from Thanjavur District. It is located almost in the mid southeastern part of Tamil Nadu in South India. The district lies between 9° 50' N to 10° 40' N latitudes and 78° 25' E to 79° 15' E longitude. It has covers an area of 4,663.29 sq.kms with a total coastline of 39 kms. The district is bounded by Tiruchirappalli district in the north, Thanjavur district in the northeast, Bay of Bengal in the east and Ramanathapuram and Sivaganga districts in the south. The temperature ranges

between 20.4° C in January and 38° C in May. The annual rainfall of the district is 860 mm of which the northeast monsoon contributes 47.7% followed by southeast monsoon 36.3 percent, summer 12% and winter 4% of the total the annual rainfall respectively. Vellar, Agniyar, Koraiyar and Ambuliar are the major non-perennial rivers of the district. The major soils of district are red fertile, river alluvium and saline coastal alluvium that account for 58.2, 32.4 and 9.4 percents respectively. Paddy, maize, groundnut, chilly, pulses, vegetables and coconut are the major crops. In 2011 Census, Population of the district is 16,18,725 of which 86.61% are rural and the rest are urban (**Fig.1**).



Fig.1

3. Materials and Methods

The present study is mainly based on secondary sources of data which is collected from various government organizations. The base map of Pudukkottai district has been prepared from Survey of India Toposheet which is on 1: 250,000 scale. In order to identify the prevailing climatic condition of Pudukkottai district, the long term (70 years) mean monthly rainfall data of 32 rainfall stations, Six temperature stations, and 31 soil types are considered. The centroid (polygons) of each geoclimatic unit is taken into account for computing Moisture Index (Im), Seasonal Variation of Effective Moisture (SVEM), Thermal Efficiency (TE) and Summer Concentration of Thermal Efficiency (SCTE) followed the book keeping procedure formulated by Thornthwaite and Mather (1955). This has been computed and used to determine the climatic types and sub types of Pudukkottai district of Tamil Nadu. All these data have been processed and analyzed by preparing various thematic maps using GIS software.

4. Results and Discussion

4.1. Climatic Classification of Pudukkottai District

According to Landsberg (1958), climate is the complete physical state of the atmosphere at a specified locality for a specific interval of time. The concepts of the general circulation of the atmosphere ascribe the origin of climate to the exchanges of energy between the earth's surface and the atmosphere in different geographical latitudes. Though climate is intricate when each of its variables is considered, there is no advantage in this view, because it leads to the conclusion that no points on the earth have exactly the same weather or climate. Such a limitless number of climates necessities grouping into classes and types for specific purposes of human activity. A meaningful classification of climate is capable of broad categorization or abstraction. The purpose of a climatic classification is to characterize regions in terms of principle elements, of which temperature and precipitation are the most important. There can, however, be no classification which can claim to be superior to another, as it is only the purpose to which it is put to use which determine the validity of a particular scheme. Temperature distribution alone formed the basis of

early attempts (Humboldt, 1817; Koppen, 1884) at a division of the earth into various climatic zones. Plant geographers, botanists and ecologists tried to map the distribution of vegetation in different parts of the world; the similarities between the temperature zones and vegetation zones led to more intensive studies of the distribution of climatic provinces in particular relation to vegetation types.

Koppen (1900) was the first to give serious thought to this problem and he greatly succeeded in evolving a general scheme of climatic classification based mainly on the critical temperature for the growth and maintenance of boundaries of his climatic zones were accordingly isotherms corresponding to the mean temperature of the coldest and warmest months of the year. Plant physiologists and ecologists amply demonstrated that moisture supply to a region is adequate within certain limits; the rate of plant growth and the abundance of vegetation vary directly with temperature. Similarly where thermal, edaphic and cultural conditions are favourable and constant, there is a direct relation between the abundance of vegetation on an area and effectiveness of precipitation. Thus, temperature efficiency and precipitation effectiveness are the prime favorable factors in the growth and development of vegetation. The merit of the Thornthwaite scheme is that they are linked with these active factors.

It is no wonder then that the Thornthwaite's scheme of climatic classification (Thornthwaite, 1948 and 1955) has been

universally recognized as very sound and rational from an ecological angle. The unique feature of this system of classification is that both the moisture and thermal region of limits have been taken into account and blended for the evolution of indices for identifying different climates (Subrahmanyam and Sastri, 1969). Since this system of climate classification is already well-known and details are available in several publications (Subrahmanyam, 1956a and 1956b; Subrahmanyam, Subba Rao and Subramaniyam, 1965; Carter and Mather, 1966), only a broad outline of the revised scheme is given here. With the change in the expression for the moisture index of climate in 1955, only the changed limits for various dry climate types and seasonal variations of effective moisture of the original scheme (Thornthwaite, 1948) distinguish the 1955 Thornthwaite climatic classification.

The modified expression for the moisture index is, $I_m = I_h - I_a$

Where I_h = Humidity index which is the percentage ratio of the annual water surplus and the annual water need, and

I_a = Aridity index which is the percentage ratio of the annual water deficit and the annual water need.

On the basis of Thornthwaite and Mather's (1955) revised rational climatic classification scheme, the four relevant components (**Table 1**) are: 1. Moisture indices, 2. Seasonal Variation of Effective Moisture (SVEM), 3. Thermal Efficiency (TE), and 4. Summer Concentration of Thermal Efficiency (SCTE).

Table 1: Climatic Classification Scheme of Thornthwaite and Mather (Revised in 1955) with sub type Subramanian's

I MOISTURE INDEX	Moist Climate	Climatic Type / Symbol		Dry Climate	Climatic Type / Symbol	
	>100	Per humid	A			
80-100	Humid	B ₄		-33.3 to 0	Dry Sub-Humid	C1
60-80	Humid	B ₃		-66.7 to 33.3	Semi-Arid	D
40-60	Humid	B ₂		< -66.7	Arid	E
20-40	Humid	B ₁				
0-20	Moisture Subhumid	C ₂				
II SVEM	Aridity Index	(Water Deficiency)		Humidity Index	(Water Surplus)	
	0-10	Little or no water deficiency	r	0-16.7	Little or no water surplus	d
	10-20	Moderate summer water deficiency	s	16.7 - 33.3	Moderate winter water surplus	s
	10-20	Moderate winter water deficiency	w	16.7 - 33.3	Moderate summer water surplus	w
	20+	Large summer water deficiency	s ₂	33.3+	Large winter water deficiency	s ₂
20+	Large winter water deficiency	w ₂	33.3+	Large summer water deficiency	w ₂	
III TE (cm)	< 14.2	Forest	E'	MEGATHERMAL SUBTYPE (>114CM)		
	14.2 - 28.2	Tundra	D'			
	28.2 - 42.7	Microthermal	C' ₁	114.0 - 128.2	A' ₁	
	42.7 - 57.7	"	C' ₂	128.2 - 142.5	A' ₂	
	57.7 - 71.2	Mesothermal	B' ₁	142.5 - 156.7	A' ₃	
	71.2 - 85.5	"	B' ₂	156.7 - 171.0	A' ₄	
	85.5 - 99.7	"	B' ₃	171.0 - 185.2	A' ₅	
	99.7 - 14.0	"	B' ₄	185.2 - 199.5	A' ₆	
>114.0	Megathermal	A'	>199.5	A' ₇		
IV SCTE (%)	> 88.0		d'	SCTE SUB TYPE (<48%)		
	76.3 - 88.0		c' ₁			
	68.0 - 76.3		c' ₂	44.6 - 48.0	a' ₁	
	61.6 - 68.0		b' ₁	41.6 - 44.6	a' ₂	
	56.3 - 61.6		b' ₂	38.8 - 41.6	a' ₃	
	51.9 - 56.3		b' ₃	36.3 - 38.8	a' ₄	
	48.0 - 51.6		b' ₄	34.0 - 36.3	a' ₅	
	< 48.0		a'	31.9 - 34.0	a' ₆	
				29.9 - 31.9	a' ₇	
			<29.9	a' ₈		

Source: Compiled by Author.

Aridity Index (I_a) = $WD/PE \times 100$

Where WD = Water Deficit + Potential Evapotranspiration.

So, Aridity Index will keep always an inversely related with the humidity index. Index of aridity on annual basis can be taken to study the drought severity, frequency and pattern.

4.2. Moisture indices

Moisture indices can be estimated through the following four components and it represents the spatial – temporal coherence between the climatic parameters viz., precipitation, potential evapotranspiration, actual evapotranspiration and soil moisture holding capacity.

Moisture Adequacy Index: As discussed earlier the AE represents in a way the absolute amount of water that is actually from the soil for use by vegetation. AE will be high in place where there is adequate moisture and it may even equal the PE under conditions of saturated soil, while in dry areas, it will be proportionately lower, in spite of large values of PE. Thus either the AE or PE is considered independently in different places, the ratio between Actual evapotranspiration and Potential evapotranspiration with available moisture in the soil. This is termed the “Index of Moisture Adequacy”. Subramaniyam et al., (1979) have used the term moisture adequacy index. It can be obtained by using the equation given below.

Index of Moisture Adequacy = $AE/PE \times 100$

Moisture Index: Since water surplus and water deficiency occur in different seasons at most places, both factors must be considered in the form of an index of Moisture deficiency in another except when the moisture may be stored in the soil. This stored moisture in soil to a certain extent contributes seasonal water additions to subsoil moisture and ground water. *The moisture index is an appropriate tool which can decide the degree of aridity or humidity of a region. Moist climate have positive values of I_m while dry climates have negative values.* Thornthwaite’s expression of moisture index mainly used to separate the humid and arid region with sub regions. The moisture index is calculated by using the formula given below:

Index of Moisture (I_m) = $I_h - I_a$

Where

I_h = is humidity index and

I_a = is aridity index

4.3. Major Climatic Types Based On Index of Moisture

Based on moisture index, (I_m) = $I_h - I_a$, Moisture Index of the Pudukkottai district fall under three Climate types such as 1. Sub humid dry (C1), 2. Semi arid (D) and Arid climate (E). About 84% of the district (**Fig.2**) fall under semi arid climate and distributed throughout the district. The southeastern part of Ponnamaravathi area fall under Dry sub humid for one percent. The arid is distributed for 15% of the total area of the district over Kilanilai in the south, Malaiyur and Adanakottai in the northeast and Nagudi, Ayingudi and Aranthangi in the southeast.

Humidity Index: Where there is only a water surplus, and no water deficit, the relation between water surplus and water need constitutes an index of humidity. Generally, humidity index again records the water surplus in percent and it can be computed using the following formula.

Humidity Index (I_h) = $WS/PE \times 100$

Where

WS = Water surplus and PE = Potential Evapotranspiration.

By using this humidity index, Thornthwaite classified the seasonal variation of surplus moisture in dry and wet climate using symbols. It is an important parameter to distinguish the periodical occurrence of wet and dry spells. In dry climate if the Humidity index is:

< 17% - the water surplus is little or nil.

17 - 33% water surplus is moderate

33% - water surplus is large

If the seasonal extent is in winter then it is coded as S moderate and S2 for large surplus. Similarly W and W2 coding is used to represent moderate and large summer water surplus.

Aridity Index: As the humidity index represents the water surplus, the aridity index represents the water deficit. Therefore it represents the percentage ratio of the total water deficit (WD) to the total water need (WN).

4.4. Seasonal Variation of Effective Moisture (SVEM)

In hydrological, agricultural as well as ecological investigation, it is important parameters to distinguish wet condition in one season and dry in another season from continuously wet or continuously dry. The moisture index reflects annual quantity of moisture and it indicates only how humid or arid the climate is. It cannot distinguish between climates with seasonal moisture variation. Thornthwaite has considered the seasonal variation of effective moisture which can be estimated based on the Humidity Index and Aridity Index. *The aridity index, typically exceeds 33 percent over the district and is marked by either large summer water deficiency (S2) or winter water deficiency (W2). Further, it is interesting to note that in dry climate the humidity index ranges between 0 to 17% which occurs throughout the study area. Hence maximum parts of the district comes under little or no water surplus during the year and are coded as ‘d’.* Contribution to the ground water reservoir from this region are normally absent except that greater rainfall causes local water surplus for a brief period and significantly contributes to groundwater resources.

4.5. Thermal Efficiency (TE)

Thornthwaite has expressed potential evapotranspiration as an index of Thermal Efficiency. It shows the amount of energy present at a particular place in terms of water, if easily available, can be evaporated by the energy. On the basis of thermal efficiency, Thornthwaite has defined nine climate types and Subramanyam (1956) has further sub-divided the

‘Megathermal climate’ (one among the nine) into seven sub types for Indian condition. Thermal efficiency interval of 15 cm divides the thermal regimes. From the (Fig.3) it can be seen that almost the entire region under study has megathermal regime of climate (A 4-7) conforming to the tropical pattern.

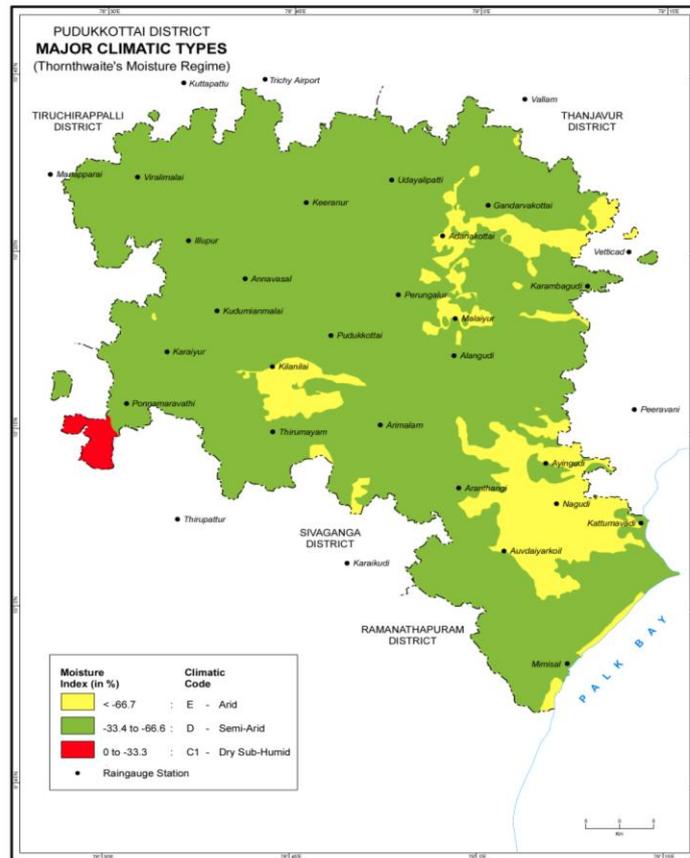


Fig.2

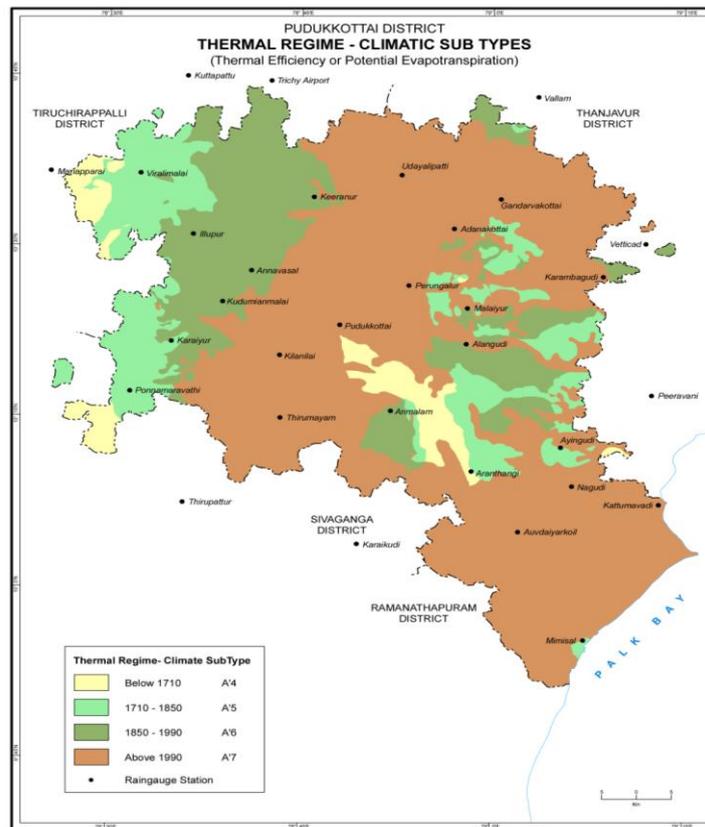


Fig.3

4.6. Summer Concentration of Thermal Efficiency (SCTE)

Seasonal variation in thermal efficiency is due to variation in temperature and day duration. At the equator, where day length is the same throughout the year and where temperature is also uniform, seasonal variation of potential evapotranspiration of any three consecutive months will constitute 25% of the annual total. On the other hand, in the Polar Regions, where the growing season is entirely within the three summer months, the PE of these months will constitute 100% of the total. On the basis of thermal concentration of thermal efficiency, Thornthwaite has defined eight climatic types and Subramanyam (1956) has further divided Thornthwaite’s ‘a’ type climate (one among eight) into sub-types. The whole district is megathermal climate. The summer concentration of thermal efficiency, a 4-8 are shown in (Fig.4), inspite of inadequate total thermal stimulus on an annual basis for the growth of tropical forests. The seasonal distribution of thermal efficiency is so highly uniform and hence climatically ideal conditions are available for the most efficient development of forest type of vegetation, provided however, the hygric and edaphic factors are favorable, of course. These favorable features of thermal regime in conjunction with those of moisture regime have profound influence on the ecoclimatology of Pudukkottai district of Tamil Nadu with special reference to the development and distribution of natural vegetation.

5. Climatic Sub Types of Pudukkottai District

In concurrence to Thornthwaite’s scheme, there are four relevant information obtained for rational classification of climate with the help of potential evapotranspiration, water surplus and water deficit. They are moisture index, seasonal variation of effective moisture, thermal efficiency and summer concentration of thermal efficiency. On their basis, the district has been classified in to 20 sub types as of 3 major climatic types shown in Table 2 Climatic types have been symbolized with four letters.

- the first is based on moisture index,
- the second on thermal efficiency index,
- the third on the seasonal variation of effective moisture and
- the fourth on the degree of summer concentration of the thermal efficiency.

If the climatic symbol is DA’7 d a’7, represents that, semi arid Megathermal seventh with little or no water surplus and summer concentration of thermal efficiency of the seventh of Megathermal type.

Table 2: Area under Climatic Types and Sub Types – Areal Units of Pudukkottai District

Climatic Types	Climatic code	No. of sub types combination	No. of Geoclimatic Units	Area	
				Sqkm	in%
Dry Subhumid	C1	1	66	41	0.88
Semi Arid	D	14	430	3907.29	83.79
Arid	E	5	8	715	15.33
Total		20	504	4663.29	100.0

Out of 20 sub climatic types, only one is under Dry Subhumid (C1), 14 climatic combination from Semi Arid (D) and 5 unique types from Arid (E) climatic region. It has been shown in **Table 3** and **Fig.5**.

Notably Dry Subhumid zone characterized by wider Thermal zone A4 and seasonal moisture class varies with no water surplus (d) to larger summer water surplus (W2) and here the Megathermal subtypes ranges a8 moderate water surplus is observed southwestern part of Ponnamaravathi block which is covers an area is 0.8%.

The Semi- Arid, the major climatic type of the district spreads over 83% of Pudukkottai with 14 sub types characterized by Megathermal. Seasonal water surplus is highly localized and occurs during October, November and December and is distributed over Kattumavadi, north of Keeranur, Kudumianmalai, and west of Ponnamaravathi and northwest of Viralimalai. The summer concentration of TE ranges from sub types of a4a8 and higher thermal efficiency (a8) is associated with the low latitude interior plains as well as east coastal region. Arid climate zone covers an area of 15% with 6 sub types endorsed with megathermal (A4-A7).

Table 3: Area under Climatic Types and Sub-Types and Their Occurrences

Rank	R Code	No. of Station	Sub Types	Area Sq.km.	Area in %	Occurrences
1	C1	1	C1A'4da'8	41.00	0.88	Ponnamaravathi Block
			DA'4da'7	120.00	2.57	Thiruvankulam Block Aranthangi Block, Arimalam Block
		2	DA'4da'8	63.00	1.35	Aranthangi Block
		1	DA'5da'6	9.00	0.19	Karambakkudi Block
		2	DA'5da'7	61.00	1.31	Thiruvankulam Block, Karambakkudi Block, Pudukkottai Block, Gandarvakkottai Block
		9	DA'5da'8	596.00	12.78	Viralimalai Block, Annavasal Block, Ponnamaravathi Block, Thiruvankulam Block, Karambakkudi Block, Pudukkottai Block, Gandarvakkottai Block
2	D	1	DA'6da'4	27.00	0.58	Gandarvakkottai Block
			DA'6da'6	2.00	0.04	Karambakkudi Block West
			DA'6da'7	1.00	0.02	Pudukkottai Block Central
		12	DA'6da'8	865.29	18.56	Karambakkudi Block, Thiruvankulam Block, Arimalam Block, Ponnamaravathi Block, Annavasal Block, Viralimalai Block
		1	DA'7da'4	16.00	0.34	Manamelkudi Block Gandarvakkottai Block
		7	DA'7da'5	876.00	18.79	Gandarvakkottai Block, Pudukkottai Block, Karambakkudi Block, Thiruvankulam Block, Arimalam Block, Thirumayam Block, Aranthangi Block, Manamelkudi Block, Auvdaiyarkoil Block.
		7	DA'7da'6	942.00	20.20	Gandarvakkottai Block, Pudukkottai Block, Karambakkudi Block, Thiruvankulam Block, Arimalam Block, Thirumayam Block, Aranthangi Block, Manamelkudi Block, Auvdaiyarkoil Block, Manamelkudi Block
		5	DA'7da'7	273.00	5.85	Thirumayam Block, Ponnamaravathi Block, Annavasal Block, Kunnandarkoil Block
		4	DA'7da'8	149.00	3.20	Kunnandarkoil Block, Pudukkottai Block, Karambakkudi Block, Thirumayam Block, Annavasal Block, Ponnamaravathi Block
				4000.29	85.78	
3	E	2	EA'7da'4	2.00	0.04	Pudukkottai Block, Aranthangi Block,
		4	EA'7da'5	459.00	9.84	Avudaiyarkoil Block, Manamelkudi Block, Aranthangi Block, Arimalam Block, Thiruvankulam Block, Karambakkudi Block, Pudukkottai Block, Gandarvakkottai Block
		3	EA'7da'6	154.00	3.30	Gandarvakkottai Block, Pudukkottai Block, Gandarvakkottai Block, Thirumayam Block, Arimalam Block
			EA'7da'7	1.00	0.02	Thirumayam Block
			EA'7da'8	6.00	0.13	Ponnamaravathi Block
				622.00	13.34	
Grand Total				4663.29	100	

Source: Compiled by Author based on V. P. Subramaniyam

Description: C1: Subhumid Dry Climate Megathermal subtypes: A₁, A₂, A₃, A₄, A₅, A₆, A₇
D: Semi Arid Summer concentration of Thermal efficiency: a₁, a₂, a₃, a₄, a₅, a₆, a₇, a₈
E: Arid d: Little or no water surplus

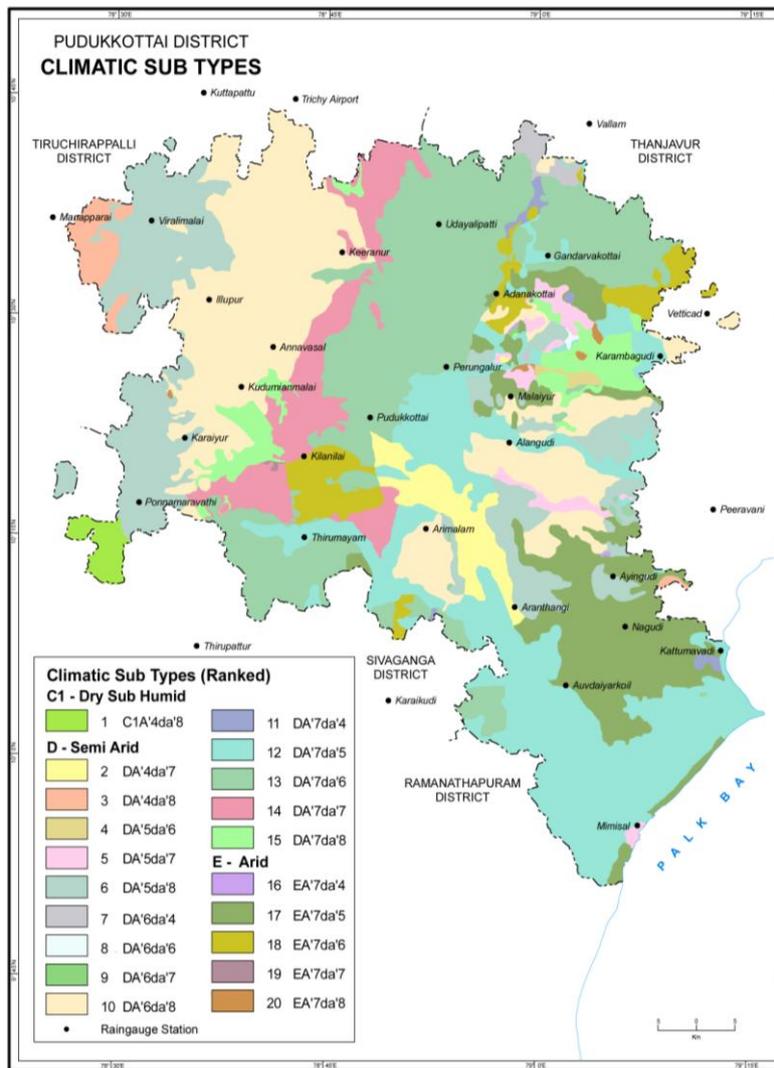


Fig-5

6. Conclusion

The main conclusions resulting from this study are:

- Based on Moisture index, 84% of the study area is under Semi arid (D) type of climate, 15% Arid climate (E) and 1% dry sub humid climate.
- The entire study area is under megathermal regime of climate (A 4-7) conforming to the tropical pattern. The seasonal distribution of thermal efficiency is so highly uniform in this area and hence, larger scope for forest type of vegetation/natural vegetation.
- Based on moisture index, seasonal variation of effective moisture, thermal efficiency and summer concentration of thermal efficiency, the district has been brought under 20 sub-types within 3 major

climatic types. Out of 20 sub climatic types, only one type of Dry Subhumid (C1), 14 climatic combination from Semi Arid (D) and 5 unique types from Arid (E) climatic region.

- Although the district is often prone for drought as the people are having the notion for longtime, no study has been reported in detail as of now to understand the climatic characteristics. The present study concludes that the areas under **no risk zone** of about 30.5 under **semi-arid climate** and as well as under **dry sub-humid** are free from limitations for agricultural operations and variety of crops can be grown.

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