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Climatic Classification for Agricultural Potential in Peninsular Malaysia

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Abstract
Papadakis system of climate classification give special consideration into ecological requirements of the different agricultural crops and such that the classification indicates the agricultural potential and limitation in a region. This system also enable a useful interpretation of the possible land utilization types. An advantage of this system is that the meteorological data required for the classification are generally available in the country. A global system of classifying world climate such as Papadakis system has shown that this system can be used to classify the climate of Peninsular Malaysia to a great level of detail.
Keywords: Climate, Papadakis, classification, Peninsular Malaysia

Introduction

The best known system of classifying world climate is that of Koppen (1928). In the Koppen system, Peninsular Malaysia falls within Afi. This implies that the average monthly temperature is above 18^0C and rainfall more than 60mm and the difference between the hottest and coldest months is usually being less than 5^0C, thus isothermic(i). The climatic classification of Papadakis (1970) is a system which a classification of climates and ecological classification of crops fit one another and has been prepared with special reference to agricultural potentialities. The Papadakis system has been used by a great number of scientists in various parts of the world and it has always given satisfactory results (Sys et. al., 1991).

In the Papadakis system has recognized 10 fundamental groups of climate being tropical, tierra fria, desert, subtropical, pampean, mediterranean, marine, humid continental, steppe and polar alpine. The classification of the climate is defined on the basis of the winter type, summer type and humidity regime.

Six fundamental winter type have been recognized and these have been subdivided to give a total of 13 winter types. The type of winter is defined on the basis of the average daily minimum, average daily maximum and or absolute minimum temperatures of the coldest months.

Nine fundamental summer types have been recognized and these have been further subdivided to give a total of 13 summer types. The criteria used are minimum, available and average frost-free seasons, temperature conditions of the warmest months and the month of occurrence of the highest monthly potential evapotranspiration.

Six fundamental humidity regimes have been defined and these have been subdivided to give a total of 14 types of humidity regimes. The characteristics of the humid months, non-humid months, dry months, humidity indices, rainfall, potential evapotranspiration and the average daily maximum temperature and criteria that are considered in this classification.

The other subdivision within the climatic groups are based on special diagnostics such as the length of the humid, non-humid, dry and non-dry months. Features concerning the annual humidity index, the humidity condition in summer, winter, spring, autumn are considered. The month of the starting of the dry season is also taken into consideration.

Papadakis system of climate classification give special consideration into ecological requirements of the different agricultural crops and such that the classification indicates the agricultural potential and limitation in a region. This system also enable a useful interpretation of the possible land utilization types. An advantage of this system is that the meteorological data required for the classification are generally available in the country.

Materials and Methods

The methodology of Papadakis (1970) was used for the classification of climate. The climatic data from nine Malaysian Meteorological Services Department between 2005 to 2015 were used in this study. They are Alor Star (Kedah), Ipoh (Perak), Kuala Lumpur, Malacca (Malacca), Kluang (Johore), Senai (Johore), Kuantan (Pahang), Kuala Krai (Kelantan) and Tanah Merah (Kelantan). These nine stations are situated within the five rainfall regions (Dale, 1959). Only one example of the climatic data of these stations is presented as shown in Table 1 as it involved the same calculation.

The methods for calculation was based on elemental climatic data being averaged of the lowest, average daily minimum and average daily maximum temperature, vapour pressure and rainfall. Average monthly temperatures are necessary to determine the coldest months. The monthly potential evapotranspiration in mm

was calculated by the following formula PET equal 5.625(ea_{tmax}-ed) where ea_{tmax} equal saturation vapour pressure that corresponds to average daily maximum. This value can be found in standard table (Doorenbos and Pruitt, 1970), ed equal actual vapour pressure. This value is not always given in meteorological statistics but it may be computed on the basis of relative humidity, ed equal ea_{tmax} multiply RH_{mean} divided by hundred and ea_{mean} equal this value can be found in standard table (Doorenbos and Pruitt, 1970)

Water storage in the soil was calculated based on the difference between rainfall and potential evapotranspiration. Humidity index is equal to rainfall divided by potential evapotranspiration. Leaching rain (Ln) was calculated based on the difference of rainfall of humid months and potential evapotranspiration of humid months. Draught stress is the difference between potential evapotranspiration and rainfall during the non-humid months

Table 1: Climatic Data for Alor Star (Average over 10 years)

Criteria \ Months	J	F	M	A	M	J	J	A	S	O	N	D	Annual mean	Total
Mean temp.(^{0}C)	26.8	27.5	27.7	27.3	27.8	27.6	27.0	26.8	26.7	26.5	26.3	26.3	27.0	
Mean daily max.temp (^{0}C)	33.0	34.2	34.4	33.6	32.3	32.0	31.7	31.4	31.2	31.3	31.3	31.3	32.3	
Mean daily min. temp (^{0}C)	22.2	22.5	23.1	24.1	24.5	24.2	23.8	23.5	23.6	23.5	24.0	22.7	23.5	
Mean rainfall (mm)	10.5	45.0	123.5	171.3	225.3	126.6	195.7	181.5	248.2	257.1	163.0	111.6		1859.0
Rain days	3.0	4.0	10.0	15.0	19.0	12.0	17.0	19.0	20.0	22.0	22.0	17.0		
Rainfall intensity	3.5	11.2	12.3	11.4	11.8	10.5	11.5	9.5	12.4	11.7	9.6	16.0		
Sunshine (hrs month^{-1})	273.0	257.6	263.5	255.0	232.5	213.0	210.8	193.5	171.0	168.0	183.0	217.0		2640.0
Mean relative humidity (%)	73.4	72.6	78.0	82.4	85.1	86.0	86.0	87.1	85.6	87.0	85.5	81.8	82.5	
Length of dry season (month year^{-1})														1.0

Results and Discussion

The climatic characteristics, diagnosis and classification of the regions according to Papadakis (1970) are shown in Table 2 to Table 10

Table 2: Climatic Characteristics, Diagnosis and Classification of Alor Star by the Papadakis System

Variables \ Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	17.40	18.10	18.30	21.10	21.20	21.10	20.90	20.80	21.10	20.80	20.00	19.50
Av. daily min temp (^{0}C)	22.10	22.50	23.10	24.10	24.50	24.20	23.80	23.50	23.60	23.50	24.00	22.70
Av. daily max temp (^{0}C)	33.00	34.20	34.40	33.60	32.30	32.00	31.70	31.40	31.20	31.30	31.30	31.30
Mean temp (^{0}C)	26.80	27.50	27.70	27.30	27.80	27.60	27.00	26.80	26.70	26.50	26.40	26.30
RH mean (%)	73.40	72.60	78.00	82.40	85.10	86.00	86.00	87.10	85.60	87.00	85.50	81.80
e_a (mbar)	34.60	36.40	36.30	36.10	36.70	36.50	35.70	34.60	34.50	34.20	34.10	34.00
e_d (mbar)	25.40	26.40	28.30	29.70	31.20	31.40	30.70	30.10	29.50	29.70	29.10	27.80
e_{max} (mbar)	50.30	53.50	53.80	51.20	48.00	47.60	46.00	45.50	45.20	45.30	45.30	45.30
PET (mm month^{-1})	151.30	152.40	143.40	121.00	94.50	91.10	86.10	88.60	79.30	87.70	91.10	98.40
Rainfall (mm month^{-1})	10.50	45.00	123.50	171.30	225.30	126.60	195.70	181.50	248.20	257.10	163.00	111.60
W. Storage (mm month^{-1})	0.00	0.00	0.00	50.30	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	0.07	0.29	1.00	1.41	2.38	1.39	2.27	2.05	3.13	2.93	1.79	1.13

Drought stress (s) = 268.1 mm, Leaching rain (Ln) = 842.5 mm or 186 % of the annual PET.

Table 3: Climatic Characteristics, Diagnosis and Classification of Ipoh by the Papadakis System

Variables / Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	17.80	19.30	18.90	21.00	20.90	19.90	19.70	19.90	20.30	20.50	20.10	19.90
Av. daily min temp (^{0}C)	22.70	23.00	23.30	23.80	24.00	23.80	23.30	23.20	23.20	23.10	23.10	22.70
Av. daily max temp (^{0}C)	32.50	33.70	34.00	33.60	33.40	33.30	33.00	32.70	32.70	32.40	32.10	32.30
Mean temp (^{0}C)	26.60	27.00	27.30	27.30	27.50	27.50	27.60	26.80	26.80	26.40	26.30	26.30
RH mean (%)	79.50	79.00	80.50	82.70	82.10	80.70	79.60	81.70	82.30	84.30	85.10	84.10
e_a (mbar)	34.40	35.70	36.10	36.10	36.40	36.40	36.50	34.60	34.60	34.10	34.00	34.00
e_d (mbar)	27.30	28.20	29.10	29.80	29.90	29.40	29.00	28.30	28.50	28.70	28.90	28.60
e_{max} (mbar)	48.30	51.40	53.20	51.20	50.90	50.70	50.30	48.60	48.60	48.20	47.20	48.00
PET (mm month^{-1})	118.10	130.50	135.60	120.40	118.10	119.80	119.80	114.20	113.10	109.70	103.30	109.10
Rainfall (mm month^{-1})	126.00	133.60	177.00	272.70	236.20	152.30	173.30	189.30	219.00	317.70	251.70	279.00
W. Storage (mm month^{-1})	8.00	11.00	52.50	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	1.07	1.02	1.30	2.26	2.00	1.27	1.45	1.66	1.94	2.90	2.44	2.56

Drought stress = Nil, Leaching rain (Ln) = 1096.1 mm or 77.6 % of the annual PET.

Table 4: Climatic Characteristics, Diagnosis and Classification of Subang by the Papadakis System

Variable / Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	18.60	18.10	18.70	21.20	21.00	18.90	20.00	20.00	20.30	20.20	20.60	20.00
Av. daily min temp (^{0}C)	22.70	23.00	23.30	24.00	24.10	24.00	23.30	23.20	23.40	23.30	23.30	23.00
Av. daily max temp (^{0}C)	32.10	32.80	32.10	32.50	33.00	32.60	32.30	32.10	32.20	32.00	31.70	31.40
Mean temp (^{0}C)	26.50	27.00	27.20	27.30	27.70	27.30	27.00	27.00	27.00	27.00	26.50	26.30
RH mean (%)	81.00	80.00	81.00	83.00	82.00	81.30	79.00	80.50	80.60	82.60	84.30	83.30
e_a (mbar)	34.20	35.70	36.00	36.10	36.60	36.10	35.70	35.70	35.70	35.70	34.20	34.00
e_d (mbar)	27.70	28.60	29.20	30.00	30.00	29.30	28.20	30.30	30.70	29.50	28.80	28.30
e_{max} (mbar)	47.70	48.80	47.70	48.30	50.30	48.50	48.00	44.70	47.90	47.60	46.00	45.60
PET (mm month^{-1})	112.50	113.70	104.10	103.00	114.20	108.00	111.40	81.00	96.70	101.70	96.70	97.30
Rainfall (mm month^{-1})	194.50	163.00	278.50	244.30	237.70	166.00	115.00	193.70	205.00	245.80	300.00	307.20
W. Storage (mm month^{-1})	82.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	1.73	1.43	2.67	2.37	2.08	1.54	1.03	2.39	2.12	2.42	3.10	3.16

Drought stress (s) = Nil, Leaching rain (Ln) = 1410.4 mm or 113.7 % of the annual PET.

Table 5: Climatic Characteristics, Diagnosis and Classification of Malacca by the Papadakis System

Variables / Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	20.10	20.30	19.60	21.00	21.00	19.50	20.30	20.40	20.70	20.90	20.60	19.80
Av. daily min temp (^{0}C)	23.00	23.00	23.40	23.60	24.00	23.50	23.00	23.00	23.10	23.20	23.10	23.00
Av. daily max temp (^{0}C)	31.70	32.60	33.00	32.50	32.10	32.00	31.20	31.10	31.20	31.60	31.30	31.00
Mean temp (^{0}C)	26.40	27.00	27.10	27.30	27.30	27.20	27.00	26.50	27.00	27.00	26.30	26.10
RH mean (%)	78.60	79.00	81.10	84.20	85.00	85.00	85.00	85.20	85.20	84.60	86.30	84.00
e_a (mbar)	34.10	35.70	35.80	36.10	36.10	36.00	35.70	34.20	35.70	35.70	34.00	33.70
e_d (mbar)	26.80	28.20	29.00	30.40	30.70	30.60	30.30	29.20	20.40	30.20	29.30	28.30
e_{max} (mbar)	46.00	48.50	50.30	48.30	47.70	47.60	45.20	45.00	45.20	45.80	45.30	44.90
PET (mm month^{-1})	108.00	114.20	119.80	100.70	95.60	95.60	83.80	89.00	83.20	87.70	90.00	93.40
Rainfall (mm month^{-1})	74.00	81.00	158.00	213.50	205.30	171.30	185.00	169.00	217.80	183.00	251.30	132.70
W. Storage (mm month^{-1})	66.00	33.00	38.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	1.00	1.00	1.32	2.12	2.15	1.79	2.21	1.90	2.62	2.09	2.79	1.42

Table 6: Climatic Characteristics, Diagnosis and Classification of Kluang by the Papadakis System

Variables / Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	19.30	20.00	20.40	20.60	21.10	20.00	19.50	20.40	20.00	20.80	20.80	20.50
Av. daily min temp (^{0}C)	22.70	23.00	23.30	24.00	24.10	24.00	23.30	23.20	23.40	23.30	23.30	23.00
Av. daily max temp (^{0}C)	32.10	32.80	32.10	32.50	33.00	32.60	32.30	32.10	32.20	32.00	31.70	31.40
Mean temp (^{0}C)	26.50	27.00	27.20	27.30	27.70	27.30	27.00	27.00	27.00	27.00	26.50	26.30
RH mean (%)	84.50	84.40	84.60	86.60	87.50	86.70	87.00	88.00	87.00	84.00	88.30	87.60
e_a (mbar)	34.20	35.70	36.00	36.10	36.60	36.10	35.70	35.70	35.70	35.70	34.20	34.00
e_d (mbar)	26.40	30.10	30.40	31.30	32.00	31.30	31.00	31.40	31.00	30.00	30.20	29.80
e_{max} (mbar)	44.70	48.80	44.70	48.30	50.30	48.50	48.00	47.70	47.90	47.60	46.00	45.50
PET (mm month^{-1})	103.00	105.20	80.40	95.60	103.00	96.70	95.60	91.70	95.00	99.00	88.90	88.30
Rainfall (mm month^{-1})	169.50	129.00	179.00	239.10	219.00	147.20	139.30	176.80	151.10	208.60	211.10	289.30
W. Storage (mm month^{-1})	66.50	90.30	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	1.64	1.23	2.23	2.50	2.13	1.52	1.46	1.93	1.59	2.11	2.37	3.28

Drought stress (s) = Nil, Leaching rain (Ln) = 1115.5 mm or 97.6 % of the annual PET.

Table 7: Climatic Characteristics, Diagnosis and Classification of Senai by the Papadakis System

Variable / Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	18.30	18.40	18.20	20.10	20.30	20.00	19.70	20.20	20.00	20.50	20.40	19.50
Av. daily min temp (^{0}C)	22.50	22.40	22.50	23.10	23.30	23.30	22.70	22.50	22.80	23.00	23.00	22.50
Av. daily max temp (^{0}C)	31.20	31.20	32.30	33.00	32.80	32.50	32.10	31.40	31.70	32.00	31.60	30.80
Mean temp (^{0}C)	25.80	25.70	26.00	26.50	26.60	26.60	26.40	25.80	26.30	26.10	26.00	25.60
RH mean (%)	83.80	85.50	85.60	86.60	87.70	87.00	85.20	87.50	86.00	86.00	87.10	86.10
e_a (mbar)	32.70	32.60	33.60	34.20	34.40	34.40	34.10	32.70	34.00	33.70	33.60	32.50
e_d (mbar)	27.40	27.90	28.80	29.60	30.20	30.00	29.00	28.60	29.20	29.00	29.30	28.00
e_{max} (mbar)	45.20	45.20	48.00	50.30	48.80	48.20	47.70	45.50	46.00	47.60	45.80	43.50
PET (mm month^{-1})	100.10	97.32	108.00	116.40	104.60	102.40	105.20	95.00	94.50	104.60	92.80	87.20
Rainfall (mm month^{-1})	164.00	143.00	203.50	243.00	171.10	151.10	220.10	179.30	217.00	247.10	262.70	250.00
W. Storage (mm month^{-1})	64.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	1.64	1.47	1.88	2.09	1.63	1.47	2.09	1.89	2.30	2.36	2.83	2.87

Drought stress (s) = Nil, Leaching rain (Ln) = 1, 243 mm or 103 % of the annual PET.

Table 8: Climatic Characteristics, Diagnosis and Classification of Kuantan by the Papadakis System

Variables / Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	16.80	17.40	17.30	18.80	21.10	20.00	19.90	20.30	20.20	20.10	20.20	19.40
Av. daily min temp (^{0}C)	22.00	22.10	22.60	23.30	23.60	23.40	23.20	23.10	23.10	23.00	23.00	22.50
Av. daily max temp (^{0}C)	29.40	30.40	31.40	32.60	33.00	32.10	32.00	32.00	31.70	30.50	30.00	29.20
Mean temp (^{0}C)	25.00	25.40	26.10	27.00	27.30	27.10	27.00	27.00	26.60	26.30	25.50	25.00
RH mean (%)	85.60	85.00	84.50	84.20	84.50	83.50	83.50	83.60	84.50	86.00	89.40	88.40
e_a (mbar)	31.70	32.20	33.70	35.70	36.10	35.80	35.70	35.70	34.30	34.00	32.30	31.70
e_d (mbar)	27.10	27.40	28.50	30.00	30.50	29.90	29.80	29.80	29.00	29.20	28.90	28.00
e_{max} (mbar)	40.60	43.00	45.50	48.50	50.30	47.70	47.60	47.60	46.00	43.10	42.40	40.40
PET (mm month^{-1})	76.00	87.80	95.60	104.10	111.30	101.10	100.10	100.10	95.60	78.20	76.00	69.70
Rainfall (mm month^{-1})	318.40	105.20	207.10	149.30	180.50	147.60	130.00	188.30	229.00	237.00	567.00	574.00
W. Storage (mm month^{-1})	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	4.18	1.20	2.17	1.43	1.62	1.46	1.30	1.88	2.39	3.03	7.46	8.23

Drought stress (s) = Nil, Leaching rain (Ln) = 1,937.8 mm or 177 % of the annual PET.

Table 9: Climatic Characteristics, Diagnosis and Classification of Kuala Krai by the Papadakis System

Variables / Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	17.90	17.60	19.00	21.20	21.30	20.60	20.50	20.40	20.60	20.20	20.40	18.90
Av. daily min temp (^{0}C)	21.30	21.40	22.20	23.00	23.00	23.00	22.50	22.40	22.30	22.50	22.50	21.80
Av. daily max temp (^{0}C)	30.50	32.20	33.40	34.70	34.10	33.70	33.20	33.00	33.00	32.40	30.50	30.00
Mean temp (^{0}C)	25.00	25.00	26.30	27.20	27.00	27.00	26.40	26.20	26.00	26.00	25.20	24.70
RH mean (%)	87.30	84.40	85.00	84.00	86.00	86.10	86.30	87.10	88.00	89.00	91.30	90.10
e_a (mbar)	31.70	31.70	34.00	36.00	35.70	35.70	34.10	33.80	33.60	33.60	31.90	30.70
e_d (mbar)	27.70	26.70	28.90	30.20	30.70	30.70	29.40	29.40	29.60	30.00	39.10	27.70
e_{max} (mbar)	46.10	47.90	50.90	54.30	53.30	51.40	50.60	50.30	50.30	48.20	43.10	42.40
PET (mm month^{-1})	103.50	119.20	123.70	135.50	127.10	116.40	119.20	117.60	116.40	102.40	78.80	83.00
Rainfall (mm month^{-1})	125.60	49.10	92.30	86.50	133.00	163.00	150.00	173.30	278.10	234.50	447.00	477.00
W. Storage (mm month^{-1})	22.00	0.00	0.00	0.00	6.00	53.00	84.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	1.21	0.41	1.00	1.00	1.05	1.40	1.26	1.47	2.39	2.29	5.67	5.75

Drought stress (s) = 150.5 mm, Leaching rain (Ln) = 1,217.1 mm or 90.9 % of the annual PET.

Table 10: Climatic Characteristics, Diagnosis and Classification of Tanah Merah by the Papadakis System

Variables / Months	J	F	M	A	M	J	J	A	S	O	N	D
Av. of lowest temp (^{0}C)	17.60	18.20	18.60	21.40	21.60	20.30	20.60	20.20	20.50	20.10	20.30	17.80
Av. daily min temp (^{0}C)	21.20	21.10	22.00	22.20	23.10	22.80	22.50	22.50	20.30	22.40	22.20	21.80
Av. daily max temp (^{0}C)	30.00	31.50	33.20	34.60	34.00	33.40	33.00	32.70	32.60	32.10	30.10	29.00
Mean temp (^{0}C)	24.20	26.20	27.50	28.60	28.80	28.30	27.80	27.60	26.30	26.20	24.70	22.70
RH mean (%)	84.70	80.00	78.20	76.50	77.50	80.00	80.00	80.50	83.20	81.50	86.40	87.10
e_a (mbar)	30.00	33.80	36.40	38.60	38.90	38.20	36.70	36.50	34.00	33.80	30.70	27.20
e_d (mbar)	25.40	27.00	28.50	29.50	30.10	30.60	29.40	29.40	28.30	27.50	26.50	23.70
e_{max} (mbar)	42.40	45.60	50.60	54.10	53.20	50.90	50.30	48.60	48.50	47.70	42.50	40.10
PET (mm month^{-1})	95.60	104.70	123.80	138.40	130.00	114.20	117.60	108.00	113.60	113.60	90.00	92.30
Rainfall (mm month^{-1})	171.00	65.40	105.70	111.00	222.70	238.00	242.20	257.00	327.10	346.00	571.00	517.00
W. Storage (mm month^{-1})	75.00	36.00	18.00	0.00	93.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Hum. Index	179.00	1.00	1.00	1.00	1.71	2.08	2.05	2.38	2.88	3.04	6.34	5.60

Drought stress (s) = 84.8 mm, Leaching rain (Ln) = 1,917.1 mm or 143 % of the annual PET.

The summary of Papadakis classification of climate and its interpretation for the regions in Peninsular Malaysia is shown in Table 11.

Table 11: Papadakis Classification of Climate and its Interpretation for the Regions in Peninsular Malaysia

Region	Classification
Alor Star	1.1 Ec, G, MO 47, 53, 96, 97, 101, 176, 190*, 204*
Ipoh	1.1 Ec, G, HU 47, 98, 101
Subang	1.11 Ec, g, HU 98
Malacca	1.12 Ec, g, Hu 47, 82, 97, 190*, 202*
Kluang	1.11 Ec, g, HU 47, 98, 101
Senai	1.11 Ec, g, HU 47, 98, 101
Kuantan	1.11 Ec, g, HU 98, 99
Kuala Krai	1.12 Ec, G, Hu 47, 53, 83, 98, 102, 191*, 204*
Tanah Merah	1.12 Ec, G, Hu 47, 53, 83, 98, 99, 102, 191*, 204*

Key

1. Tropical
1.1 Humid equatorial
Ec Equatorial zone. Average daily minimum of the coldest month > 18^0C
G Gossypium zone. Minimum frost season > 4.5 months; average of the daily maxima of the six warmer months > 25^0C; average daily maximum of the warmest month > 33.5^0C
g Gossypium zone. Idem; but average daily maximum of the warmest month < 33.5^0C; it cannot be c
Mo Rainy monsoon. Ln > 20% of annual potential evapotranspiration and or annual humidity index > 0.88
HU Ever-humid humidity regime. No month is dry; annual humidity index > 1.0; Ln > 20% of annual potential evapotranspiration. All months are humid.
Hu Humid humidity regime. Idem; but one o more months is non-humid
47 Eight or more humid months
53 One to three dry months
81 One non-humid month
82 Two non-humid months
83 Three non-humid months
96 Annual humidity index > 1.0
97 Ln < 1000 mm where Ln refers to the seasonal excess of rainfall
98 Ln > 1000 mm
99 Ln < 2000 mm
100 The humid months form one continuous humid season
101 The humid season is divided into two or more segment
176 The dry season begins with March or early
190* The non-humid month begins in January
191* The non-humid month begins in February
200* S is less than 25 mm, where S refers to the drought stress
201* S is between 26 and 50 mm202* S is between 51 and 75 mm
203* S is between 76 and 100 mm204* S is more than 100 mm
Note: Number with * are additions based on suggestions in this thesis.

It is important to know the degree of stress during the non-humid months. This is designated as drought stress (S) by Papadakis (1970). The following details are suggested to be included into the system of Papadakis (1970).

Drought stress conditions
200 S is less than 25 mm
201 S is between 26 and 50 mm
202 S is between 51 and 75 mm
203 S is between 76 and 100 mm
204 S is more than 100 mm

The main distinction between the regions in Peninsular Malaysia are in the humidity regime and the special diagnostics. The amount of rainfall exceeds potential evapotranspiration for every month are Subang, Kluang, Senai and Kuantan. These four towns are unique in that Kuantan has a very high seasonal excess of rainfall (Ln) followed by Subang, Senai and Kluang, Senai being almost double that of Kluang.

In Alor Star, Malacca, Kuala Krai and Tanah Merah there are months where precipitation is less than potential evapotranspiration. Alor Star has three non-humid months which occurs in January, February and March. Of these January and February are dry months. Malacca has two non-humid months which occur in January and February while Kuala Krai and Tanah Merah have three non-humid months in February, March and

April. Of these February is a dry month.

The seasonal excess of rainfall (Ln) for Alor Star and Malacca is less than 1, 000 mm while that of Ipoh, Subang, Kluang, Senai and Kuala Krai is more than 1, 000 mm. In Kuantan and Kuala Krai, the seasonal excess of rainfall (Ln) is close to 2, 000 mm.

Four climatic groups exist in Peninsular Malaysia being Ec, G, Mo; Ec, G, Hu; Ec, g, HU; Ec, g,Hu. The first climatic group does not exist in Papadakis classification of climate for the humid equatorial type.

The areas classified as Ec, G, Hu climate are Ipoh, Kuala Krai and Tanah Merah and as Ec, G, MO climate is Alor Star. The regions with a summer type 'G' with characteristic of very high maximum temperatures are not the features of humid equatorial zones.

It is seen that the average maximum temperature of the warmest month is above 33.5^0C for the month of February for Alor Star and Ipoh, the month of April, May and June for Kuala Krai and the month of April and May for Tanah Merah (Table 9). The temperature value of 33.5^0C is a threshold value to separate the summer types 'G'and 'g'.

Knowledge about the occurrence of the non-humid months is of great importance in agriculture because this season is associated with periods of low precipitation. This indicates the month of the year of moisture stress and possibly irrigation is needed. These months of low precipitation are ideal for partial burning in area where it is difficult and dangerous to use machines especially on steep slopes or the areas that are affected by pests and diseases like bag worms. However partial burning programmes should be approved by the Department of Environment. Open burning technique was widely used in the beginning of the initial land development until the late 1970's. Under the Environmental Act 1974 and the Environmental Quality Act 1978, this technique is not allowed. The Department of Environment has been enforcing the act and stopped or at least minimized this practice as to avoid air pollution. Zero burning technique to replace open burning technique is already being used in the programme of jungle clearing and replanting from an oil palm to oil palm by the estates in Peninsular Malaysia and this is practiced in the months of low precipitation.

It is also important to know the degree of stress during the non-humid months. There are differences in drought stress conditions, Alor Star having 268 mm, Ipoh, Subang, Kluang, Senai and Kuantan has no drought stress while Kuala Krai 150 mm and Tanah Merah 85 mm.

The analysis indicates that Papadakis system of classifying climate when used with some modifications such as drought stress conditions has shown a remarkable precision in defining the climatic regions in a humid tropical regions like Peninsular Malaysia.

The nine meteorological stations were chosen on the basis of the rainfall regions in the country according to Dale (1959). The climatic classification of Papadakis for the stations confirmed well to the rainfall regions of Dale. Kuantan, Kuala Krai and Tanah Merah region represent the East Coast type which have a very high rainfall.

Table 12: Mean Maximum Temperatures (^{0}C) of the Warmest Months in Alor Star, Ipoh, Kuala Krai and Tanah Merah

Station\ Month	J	F	M	A	M	J
Alor Star	33.0	34.2	34.4	33.6	32.3	32.0
Ipoh	32.5	33.7	34.0	33.6	33.4	33.3
Kuala Krai	30.5	32.2	33.4	34.7	34.1	33.7
Tanah Merah	30.0	31.5	33.4	34.6	34.0	33.4

Ipoh and Subang are two stations selected from the West rainfall region. The results showed that all the months are humid and this would put the climate of Ipoh to be similar to that of Subang.

Malacca which is representative of the Port Dickson-Muar region is known to have a distinct dry season (Dale, 1960; Nieuwolt, 1965). This is shown in the climatic classification of Papadakis where two non-humid months with a total drought stress of 67 mm occur. Alor Star which is representative of the North-West rainfall region has the largest amount of drought stress (268 mm).

It is impossible to arrive at the climatic classification of the country based on a study of only nine meteorological stations. However as an approximation for the lowlands of Peninsular Malaysia which lies between 0 to 150 m above sea level, the classification of climate according to Papadakis is that the North-Western part of the country has Ec, G, MO; its lower boundary corresponds approximately within a line following Kedah river and passing through Alor Star, Jitra (Kedah), Hat Yai and Songkla (Thailand). Symington (1943) reported that this part of the country reflect a monsoon type of climate based on phytogeographical grounds. The West region has Ec, G, HU for Ipoh and Ec, g, HU for Subang. The South-West region has Ec, g, Hu while the Port Dikson-Muar region has Ec, g, Hu type of climate. The eastern part of the country has Ec, G, Hu type of climate although there may be limited areas within the East rainfall region where an Ec, g, HU climate exists as for example around Kuantan.

Papadakis (1970) reported that the climatic group 1.11 Ec, g, HU as exemplified by that of Subang,

Kluang, Senai and Kuantan is good for cultivation of coconut, oil palm and rubber but it is too humid for cocoa. The climatic group 1.12 Ec, g, Hu is also suitable for coconut, oil palm and rubber but cocoa is grown in areas where Ln is less than 1, 000 mm. As such the region of Ipoh has a suitable climate for the cultivation of coconut, oil palm, rubber and cocoa. The North-West part of the country has Ec, g, MO climate and it is considered to be good for coconut, oil palm and rubber.

A global system of classifying world climate such as Papadakis system has shown that this system can be used to classify the climate of Peninsular Malaysia to a great level of detail.

Conclusion

The results showed that Papadakis system of classifying climate for agricultural potential when used with some modifications such as drought stress conditions has shown a remarkable precision in defining the climatic regions in a humid tropical regions like Peninsular Malaysia.

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