PyAEZ Module I Climate Regime

Introduction to the Climate Agro-Climatic Indicators and generate those using PyAEZ

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1. Introduction to Agro-Climatic Indicators

Thermal Regimes

To cater for **differences in thermal requirements of crops**, an adequate characterization of the temperature regimes is required, applicable for a wide range of locations. The characterization of the temperature regimes in the present approach comprises five parts:

A. Thermal climates that indicate latitudinal climates for matching photoperiodism of crops.

B. Thermal zones that indicate the mean monthly and mean annual temperature for matching temperature requirements.

C. Length of temperature growing periods presenting the periods during which average daily temperatures exceed specified minimum levels tht are useful to detect for instance frost risk.

D. Temperature sums that give an indication of the total heat available for crop development.

E. Temperature profiles that provide a quantification of temperature seasonality.

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Thermal Regimes

A. Thermal climates

Latitudinal thermal climates provide a classification that is used in **Module II** for the assessment of potential crop-LUT **presence** in each grid cell.

The classification approximate temperature seasonality and ranges of prevailing **day-lengths**, which is used as a proxy for matching actual conditions with crop requirements for:

- **short-day crops** (cotton, rice, soybean);
- **day-neutral crops** (tomatoes) and
- **long-day crops**(lettuce, wheat).

The delineation of thermal climates is based on:

- **The mean monthly temperature at sea level and the mean actual monthly temperature**
- **Proportions of respectively summer and winter rainfall, and**
- **The temperature amplitude as a measure of continentality (i.e., difference between temperatures of warmest and coldest month) in zones that lie outside the tropics and subtropics.**

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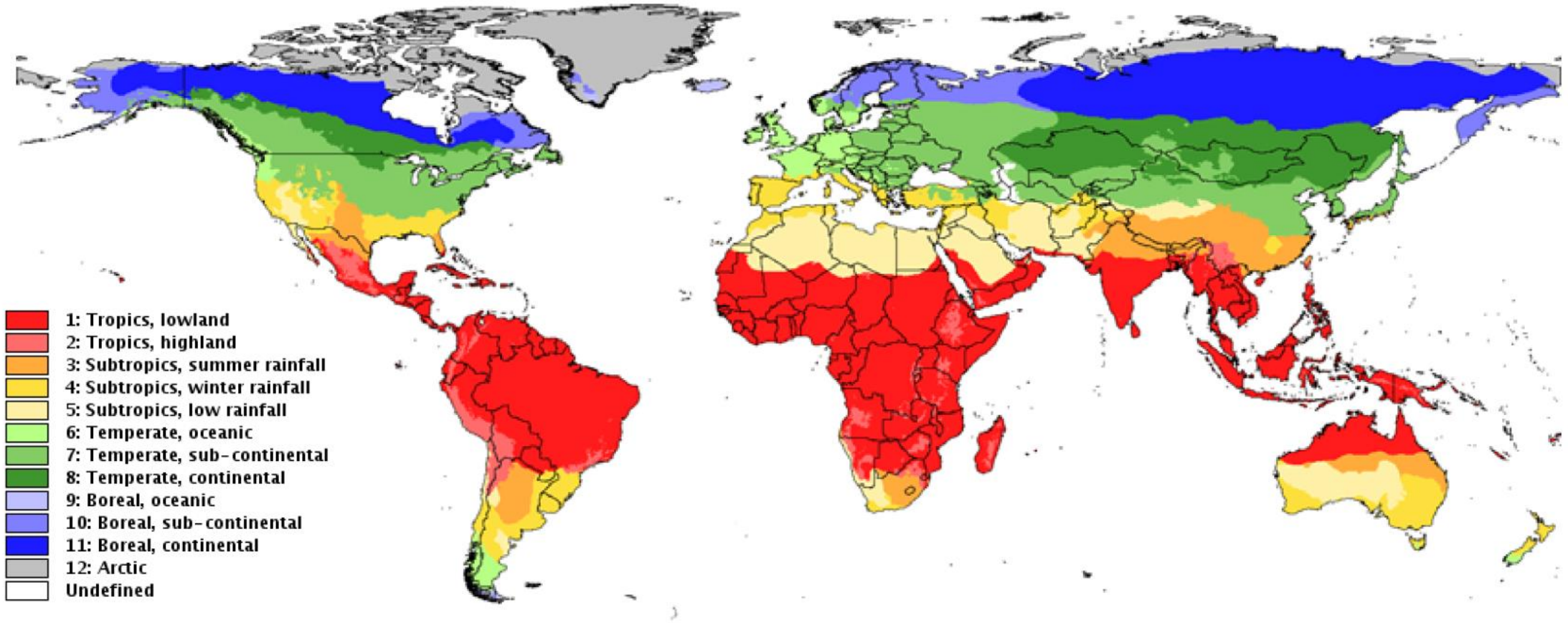
Thermal Regimes

A. Thermal climates



Thermal Climates of the world

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Thermal Regimes

B. Thermal zone

Thermal zones reflect the prevailing temperature regimes of major thermal climates.
The are determined by the mean monthly and mean annual temperatures and are used to screen thermal suitability of crops to be included in the analysis.

- **WARM:** in the **tropics** indicates a mean annual Temperature > 20˚C**.** (all lowland Tropics are warm by definition)

In the **highland tropics** and in the **subtropics** the following thermal zones may occur:

- **MODERATELY COOL** refers to actual temperature conditions characterized by one or more months with monthly average temperatures below 18˚C but all above 5˚C and 8-12 months above 10˚C;
- **COOL** refers to conditions with at least one month with monthly mean temperatures below 5˚C and four or more months above 10˚C;
- **COLD** refers to conditions with at least one month with monthly mean temperatures below 5˚C and 1-3 months above 10˚C
- **VERY COLD** refers to conditions with monthly mean temperatures of all months below 10˚C

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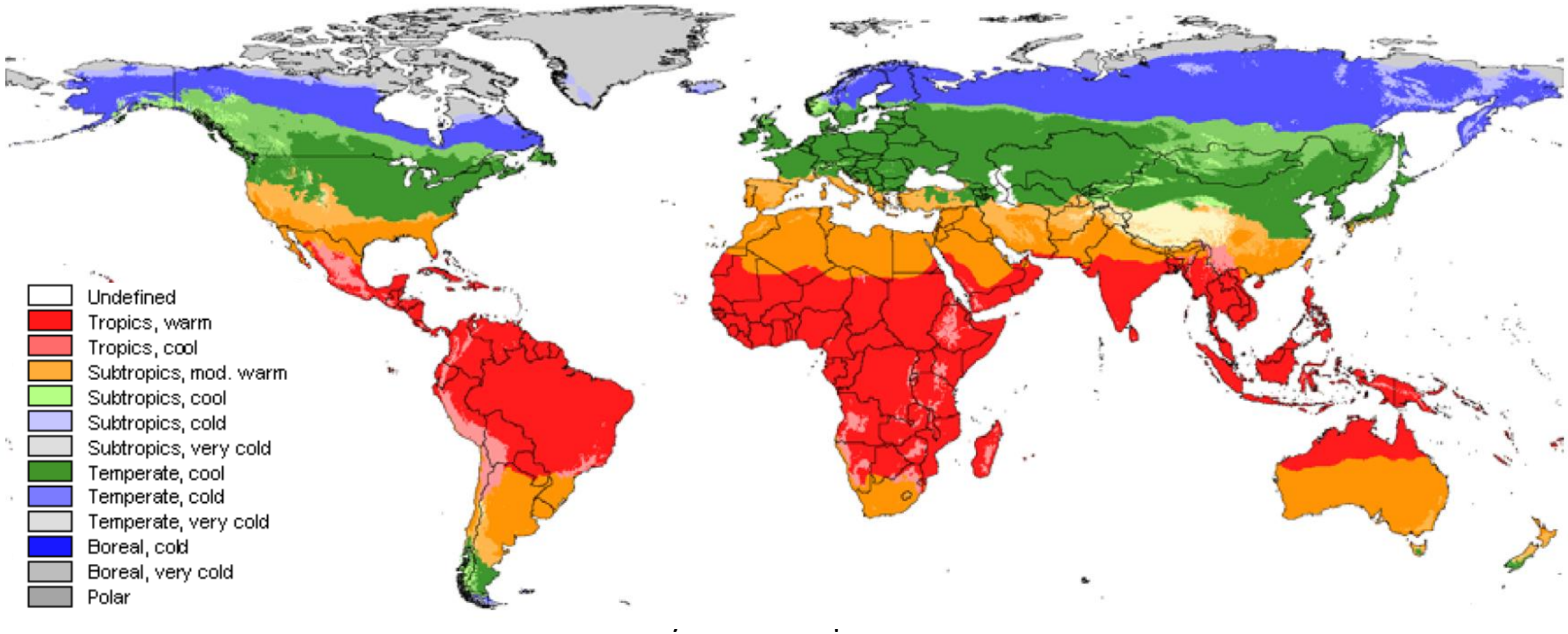
Thermal Regimes

B. Thermal zone



Thermal Zones of the World

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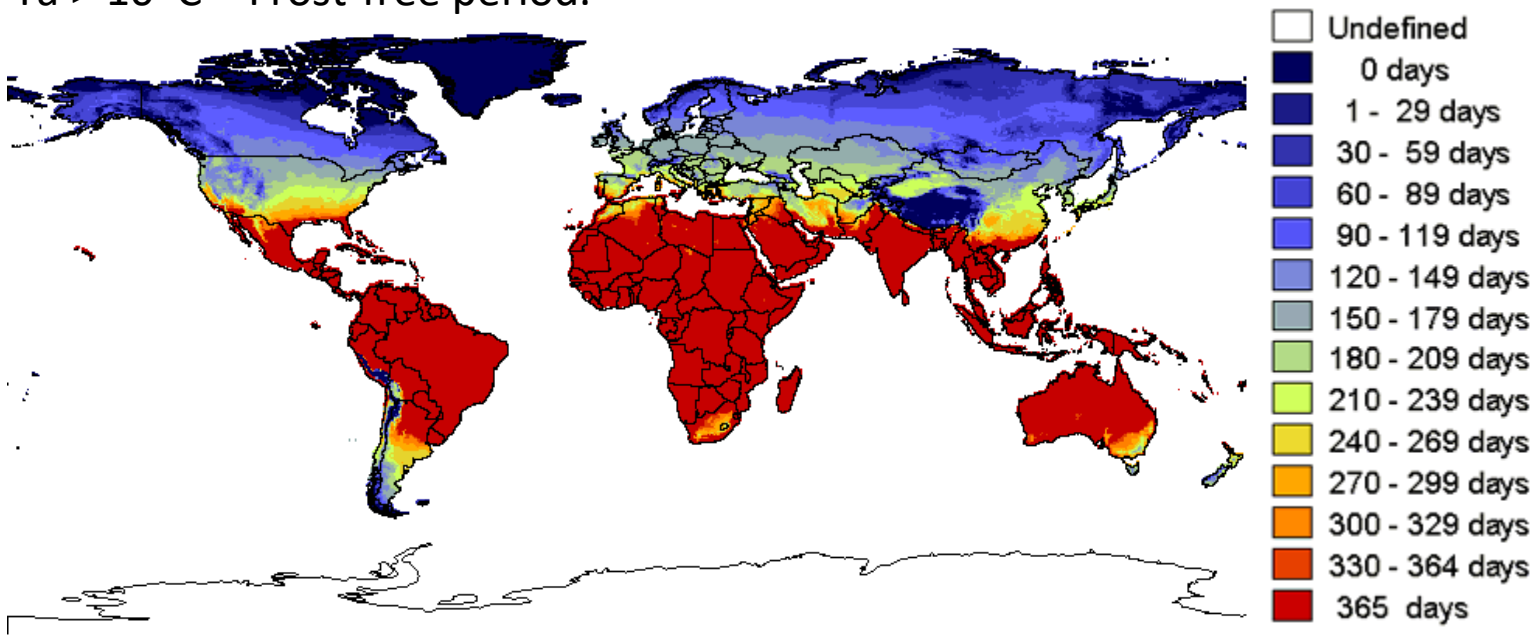
Thermal Regimes

C. Temperature growing periods (LGPt)

The length of the ‘temperature growing period’ (LGPt) is calculated as the number of days in the year when average daily temperature (Ta) is above a temperature threshold “t”.

Based on average daily temperatures (Ta). There are 3 kinds calculated:

- **LGPt0** : period of the year when Ta > 0˚C = No Permafrost
- **LGPt5** : period of the year when Ta > 5˚C = Conductive for plant growth.
- **LGPt10**: period of the year when Ta > 10˚C = Frost-free period.



Frost free period in number of days during the year (LGPt10)

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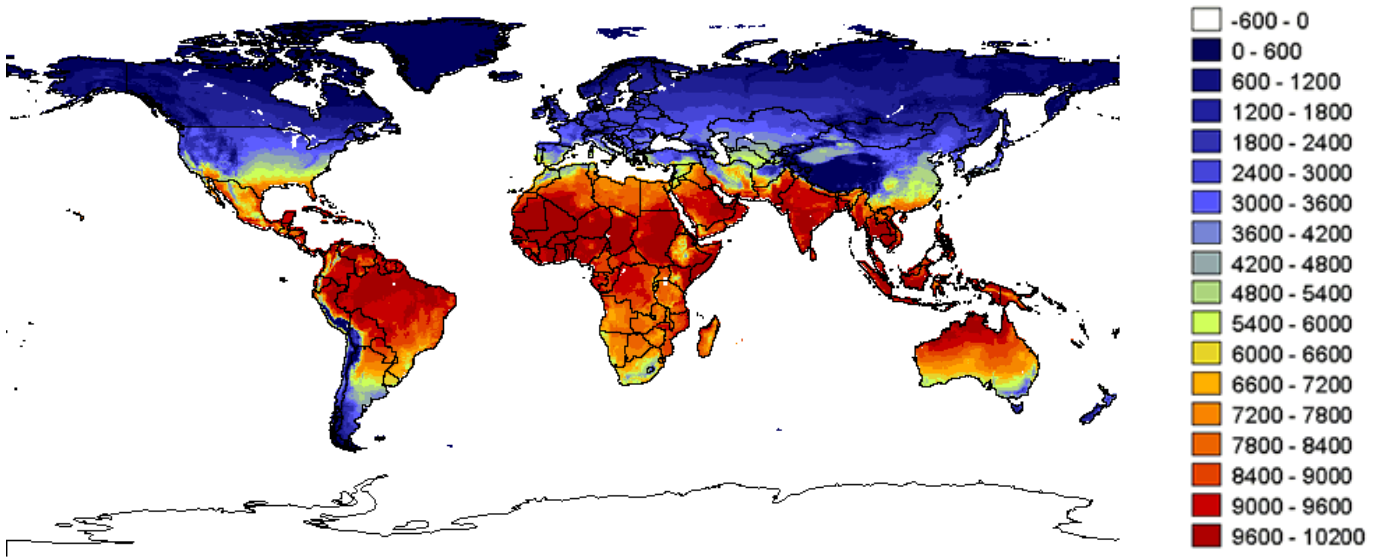
Thermal Regimes

D. Temperature Sums

Temperature sums (Tsum) refer to the sum of temperatures above a threshold temperature. **Heat requirements of crops** are expressed in accumulated temperatures. Reference temperature sums (Tsum) are calculated for each grid-cell by accumulating daily average temperatures (Ta) for days when Ta is above the respective threshold temperatures "t" as follows:

(i) 0˚C (**Tsum0**) is the summation of all daily temperatures above 0˚C
(ii) 5˚C (**Tsum5**) is the summation of all daily temperatures above 5˚C
(iii) 10˚C (**Tsum10**) summation of all daily temperatures over 10˚C



Summation of all daily average temperatures above 10˚C (Tsum 10)

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Thermal Regimes

E. Temperature profiles

Temperature profiles are defined in terms of 9 classes of "**temperature ranges**" for days with Ta <-5˚C to >30˚C (at 5˚C intervals) in combination with distinguishing increasing and decreasing temperature trends within the year.

In **Module II** of GAEZ, these temperature profiles are **matched** with crop-specific temperature profile **requirements** providing either optimum match, sub-optimum match or rendering a crop not suitable for the respective location.

Average temperature (Ta, ˚C)	Temperature trend	
	Increasing	Decreasing
> 30	A1	B1
25-30	A2	B2
20-25	A3	B3
15-20	A4	B4
10-15	A5	B5
5-10	A6	B6
0-5	A7	B7
-5-0	A8	B8
< -5	A9	B9

Temperature intervals		Temperature Periods (days)					
		Bangkok	Harbin	Manaus	Marseilles	Nairobi	Vienna
A9	< -5°C	0	56	0	0	0	0
A8	-5 - 0°C	0	14	0	0	0	23
A7	0 - 5°C	0	13	0	0	0	36
A6	5 - 10°C	0	17	0	79	0	32
A5	10 - 15°C	0	22	0	43	0	33
A4	15 - 20°C	0	27	0	40	227	74
A3	20 - 25°C	0	38	0	33	9	0
A2	25 - 30°C	95	0	258	0	0	0
A1	> 30°C	21	0	0	0	0	0
B1	> 30°C	25	0	0	0	0	0
B2	30 - 25°C	224	0	107	0	0	0
B3	25 - 20°C	0	32	0	43	8	0
B4	20 - 15°C	0	20	0	38	121	49
B5	15 - 10°C	0	19	0	29	0	29
B6	10-5°C	0	17	0	60	0	26
B7	5-0°C	0	14	0	0	0	39
B8	0- -5°C	0	13	0	0	0	24
B9	< -5°C	0	63	0	0	0	0

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Length of Growing Periods (LGPS)

The agro-climatic **potential productivity** of land depends largely on the number of days during the year when **temperature regime and moisture supply** are conducive to crop growth and development.

This period is termed the **length of the growing period (LGP).**

When the LGP is determined based on prevailing temperatures and the daily water balance for a **reference crop** and a **reference soil** it is named the **Reference LGP.**

The reference LGP refers to the number of days when average daily temperature is above **5˚C** (i.e. falls within LGPt5) and when **ETa ≥ 0.5 ETo.**

It is assumed that Sa = 100mm/m and D= 1m and kc = 1.0 and p is set at 0.5

The growing period ends when ETa<0.5 ETo and all readily available soil moisture has been consumed.

In some areas of Southeast Asia **Discontinuous Growing periods** may occur (two rainy seasons or a cold spell)

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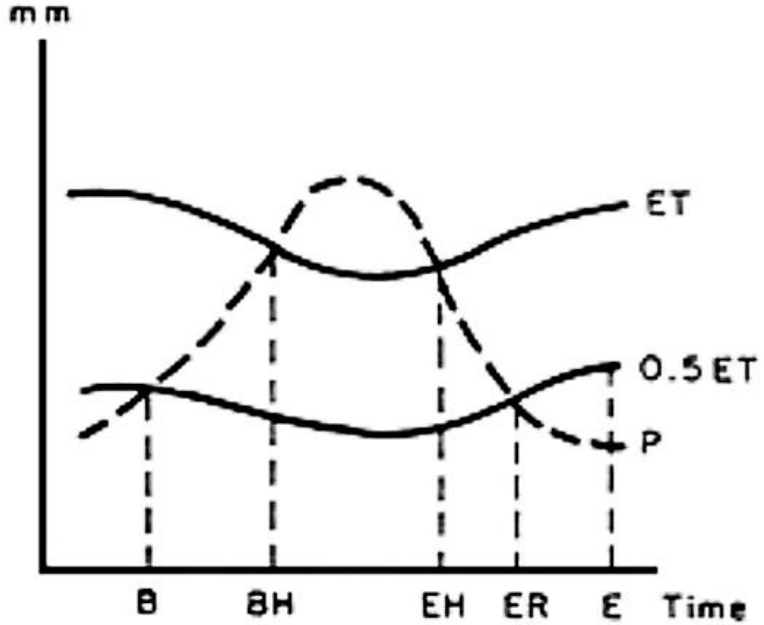
Length of Growing Periods (LGPS)

1. Daily rainfall is higher than crop water requirements (P>ETm) and stored soil moisture is less than field capacity (Wb<Sfc). Excess rainfall now adds to replenish the soil moisture storage.(Begin Humid period)

2. Daily rainfall is higher than crop water requirements, P>ETm, and soil moisture is at field capacity (Wb=Sfc). In this case excess precipitation is lost to surface runoff and/or deep percolation. (During Humid period)

3. Days when rainfall falls short of crop water requirements (P<ETm) but easily available soil moisture exceeds crop water requirements (Wb>(ETm-P)+Wr). In this case ETa equals ETm and the soil moisture content in the soil profile is decreasing. (During Rainy Period)

Growing period days with water stress (ETa<ETm): ETa falls short of ETm. The crop experiences water stress as not enough readily available water can be obtained from rainfall or moisture stored in the soil profile. crop growth and yield formation are reduced.



B: Begin growing period: P > 0.5 ETo
BH:Begin Humid Period: P > ETo
EH: End Humid Period: P < ETm
ER: End rainy period P < 0.5 ETm
E: End growing period when all soil moisture storage (< 100 mm) has been consumed

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Multiple Cropping Zones

- In areas where the **growing periods** are sufficiently **long** to allow more than one crop to be grown in the same year or season, single crop yields do not reflect the full potential for rain-fed production.

- Depending on the crop, the LGP, the LGPt and the TS (Heat Units) different multiple cropping zones can be recognized (Table next slide)

- Delineation of multiple cropping zones for rain-fed conditions is solely based on agro-climatic attributes calculated during AEZ analysis.

The following attributes were used in the definition of cropping zones:

1. **LGP** length of growing period, i.e., number of days when temperature and soil moisture permit crop growth.
2. **LGPt=5** number of days with mean daily temperatures above 5 ^{o}C.
3. **LGPt=10** number of days with mean daily temperatures above 10 ^{o}C.
4. **TSt=0** accumulated temperature (degree-days) on days when mean daily temperature ≥ 0 ^{o}C.
5. **TSt=10** accumulated temperature (degree-days) on days when mean daily temperature ≥ 10 ^{o}C.
6. **TS-Gt=5** accumulated temperature during growing period when mean daily temperature ≥ 5 ^{o}C.
7. **TS-Gt=10** accumulated temperature during growing period

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Multiple Cropping Zones

Zone	LGP	$LGP_{t=5}$	$LGP_{t=10}$	$TS_{t=0}$	$TS_{t=10}$	$TS\text{-}G_{t=5}$	$TS\text{-}G_{t=10}$
A[19]	-	-	-	-	-	-	-
B[20]	≥ 45	≥120	≥90	≥1600	≥1000	-	-
C[21]	≥220	≥220	≥	≥5500		≥	≥
	≥200	≥200	≥120	≥6400	n.a.	≥3200	≥2700
	≥180	≥200	≥	≥7200		≥	≥
D[22]	≥270	≥270	≥	≥5500		≥	≥
	≥240	≥240	≥165	≥6400	n.a.	≥4000	≥3200
	≥210	≥240	≥	≥7200		≥	≥
E	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
F	≥300	≥300	≥240	≥7200	≥7000	≥5100	≥4800
G	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
H	**≥360**	**≥360**	**≥360**	**≥7200**	**≥7000**	**-**	**-**

Multiple Cropping Zones

A: Zone of NO Cropping (too dry or too cold for cropping)
B: Zone of Single Cropping
C: Zone of limited Double Cropping (relay cropping / Single Rice crop may be possible)
D:Zone of Double Cropping (Sequential cropping but two wetland Rice crops NOT possible)
F: Zone of limited triple cropping (partly relay cropping no third crop possible if two rice crops are grown.)
H:Zone of triple cropping (sequential cropping of three rice crops possible)

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2. Generate the Agro-climatic indicators by PyAEZ

PyAEZ Module I: Climate Regime

```
'''connecting to google drive'''

from google.colab import drive
drive.mount('/content/drive')
```

```
'''setting working directory'''

import os
os.chdir("drive/My Drive/your/directory")
```

```
'''import supporting libraries'''

import numpy as np
import matplotlib.pyplot as plt
```

PyAEZ Module I: Climate Regime

Setting-up Input

```
'''reading climate data'''

min_temp = np.load('./sample_data/input/climate/min_temp.npy') # Celsius
max_temp = np.load('./sample_data/input/climate/max_temp.npy') # Celsius
precipitation = np.load('./sample_data/input/climate/precipitation.npy') # mm/day
short_rad = np.load('./sample_data/input/climate/short_rad.npy') # W/m^2
wind_speed = np.load('./sample_data/input/climate/wind_speed.npy') # m/s
rel_humidity = np.load('./sample_data/input/climate/relative_humidity.npy') #
```

```
'''reading study area and elevation data'''

admin_mask = np.load('./sample_data/input/LAO_Admin.npy');
srtm_elevation = np.load('./sample_data/input/SRTM_Elevation.npy'); # m
```

PyAEZ Module I: Climate Regime

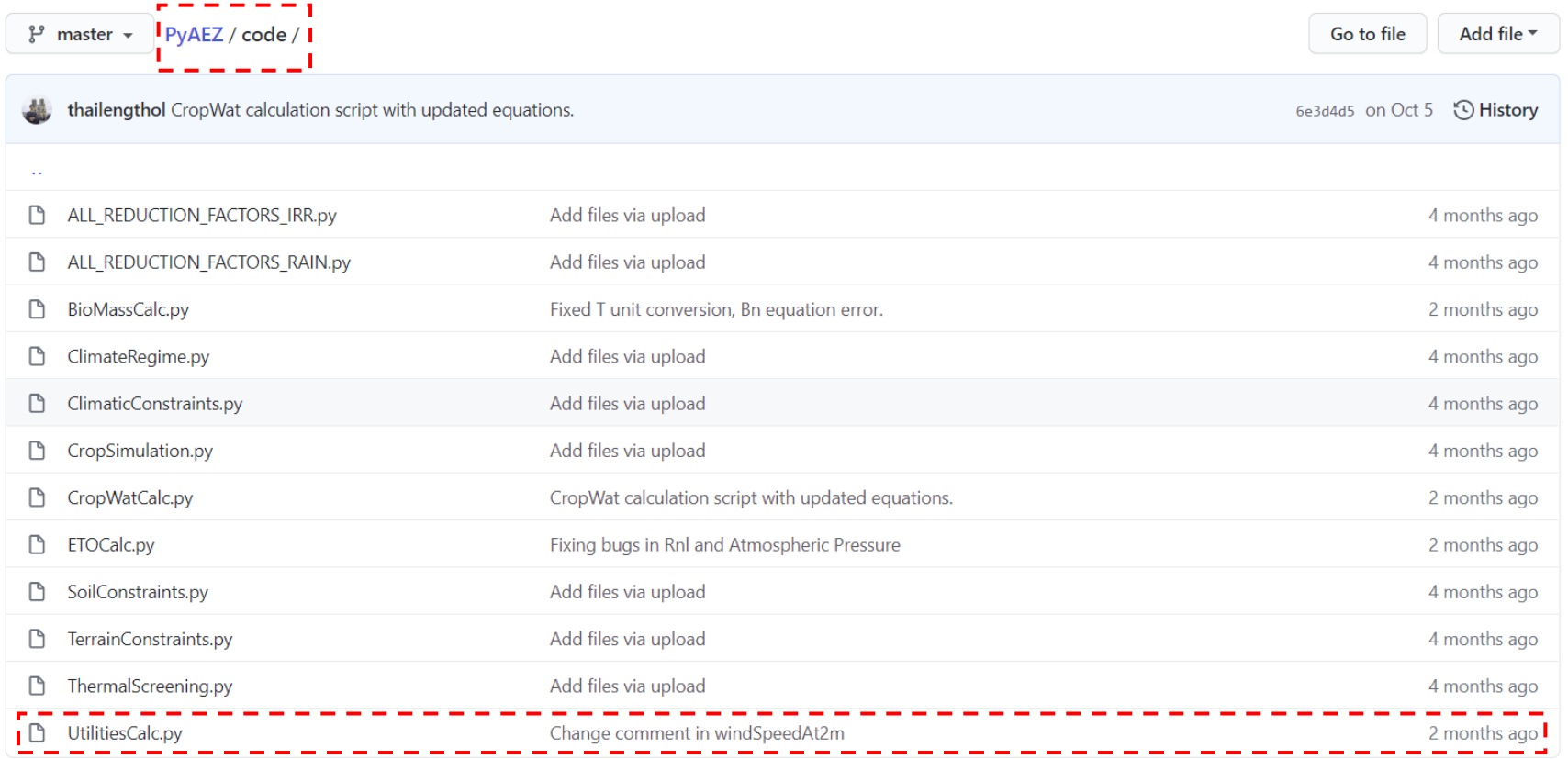
Climate Regime Calculations

```
'''importing of the ClimateRegime library. And passing climate data'''

import ClimateRegime

clim_reg = ClimateRegime.ClimateRegime()

# latitude limits of the study area
lat_min = 13.90
lat_max = 22.51

clim_reg.setStudyAreaMask(admin_mask, 0)
clim_reg.setLocationTerrainData(lat_min, lat_max, srtm_elevation)
clim_reg.setMonthlyClimateData(min_temp, max_temp, precipitation, short_rad, wi
nd_speed, rel_humidity)
```

PyAEZ Module I: Climate Regime

Climate Regime Calculations

```
'''importing of the UtilitiesCalc library for saving results'''

import UtilitiesCalc
obj_utilities = UtilitiesCalc.UtilitiesCalc()
```



PyAEZ Module I: Climate Regime

Climate Regime Calculations

```
## Calculate all agro-climatic indicators

tclimate = clim_reg.getThermalClimate()
tzone = clim_reg.getThermalZone()
lgp0 = clim_reg.getThermalLGP0()
lgp5 = clim_reg.getThermalLGP5()
lgp10 = clim_reg.getThermalLGP10()
tsum0 = clim_reg.getTemperatureSum0()
tsum5 = clim_reg.getTemperatureSum5()
tsum10 = clim_reg.getTemperatureSum10()
tprofile = clim_reg.getTemperatureProfile()
lgp = clim_reg.getLGP()
lgp_class = clim_reg.getLGPClassified(lgp)
lgp_equv = clim_reg.getLGPEquivalent()
multi_c_zone = clim_reg.getMultiCroppingZones(tclimate, lgp, lgp5, lgp10, tsum0, tsum10)
```

Practices Session

- Open Google Colab
- Create New notebook
- Simulate PyAEZ Module I

End