PyAEZ: Crop Simulation

PyAEZ MODULE II

Asian Institute of Technology

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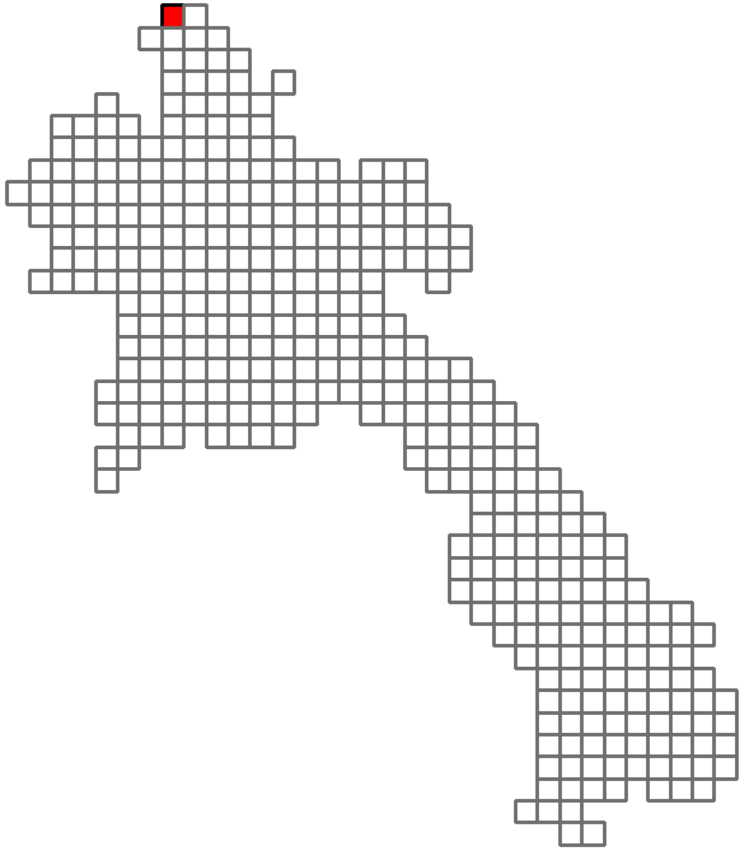
2. How to perform Crop Simulations in PyAEZ

1. Introduction to Crop Simulations

Introduction to Crop Simulations

- This is the main module in PyAEZ that preform most sophisticated calculations.
- In the pervious session, we summarizes climate in the region in to by various parameters such as,
  - Thermal Climate and Thermal Zone
  - Thermal LGP
  - Temperature Sum
  - Temperature Profile
  - Length of Growing Periods (LGPs)
  - Multi Cropping Zone
- In this section, we will simulate crop cycles with couple of mathematical models to find out best cycle that produces highest yield.

How it works



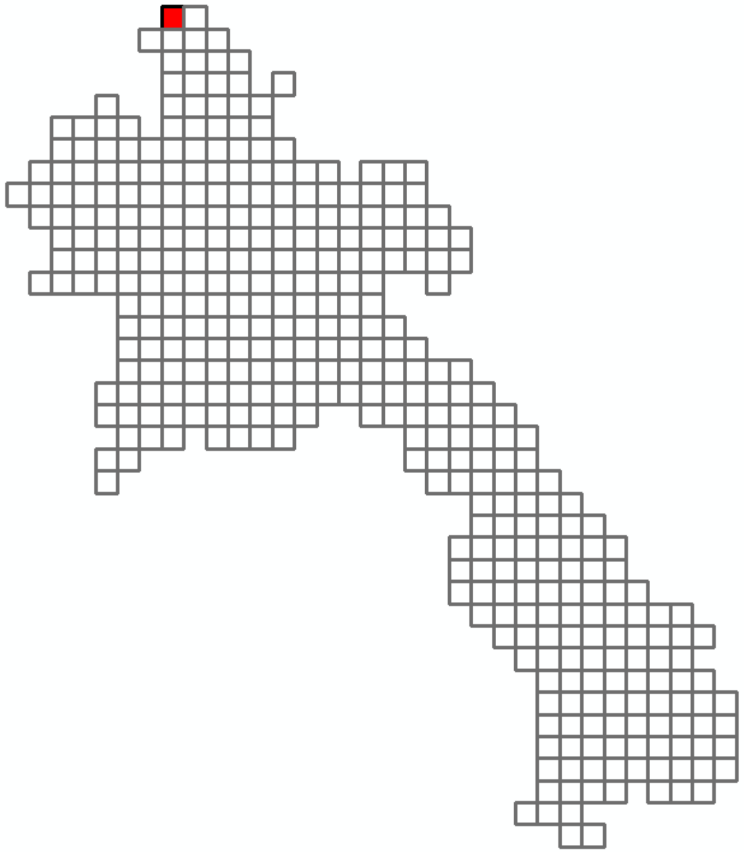
Select Particular Location (Grid)

Jan 1	Jan 2	Jan 3	Jan 4	Jan 5	…….
Jan 1	Jan 2	Jan 3	Jan 4	Jan 5	…….
Jan 1	Jan 2	Jan 3	Jan 4	Jan 5	…….
…….	Dec 28	Dec 29	Dec 30	Dec 31	…….
…….	Dec 28	Dec 29	Dec 30	Dec 31	…….
…….	Dec 28	Dec 29	Dec 30	Dec 31	…….

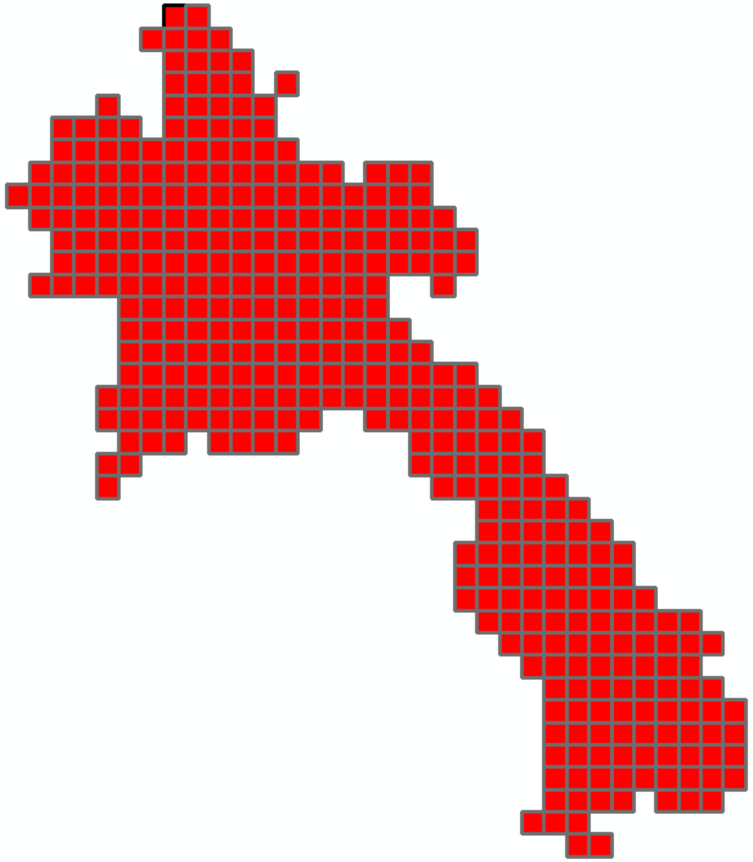
Simulate Crop Cycles starting from every day of year

Select Max yield from all cycles

How it works



Select Particular Location (Grid)



Simulate for all grids and find max yield for all grids

How it works

- During each simulations,

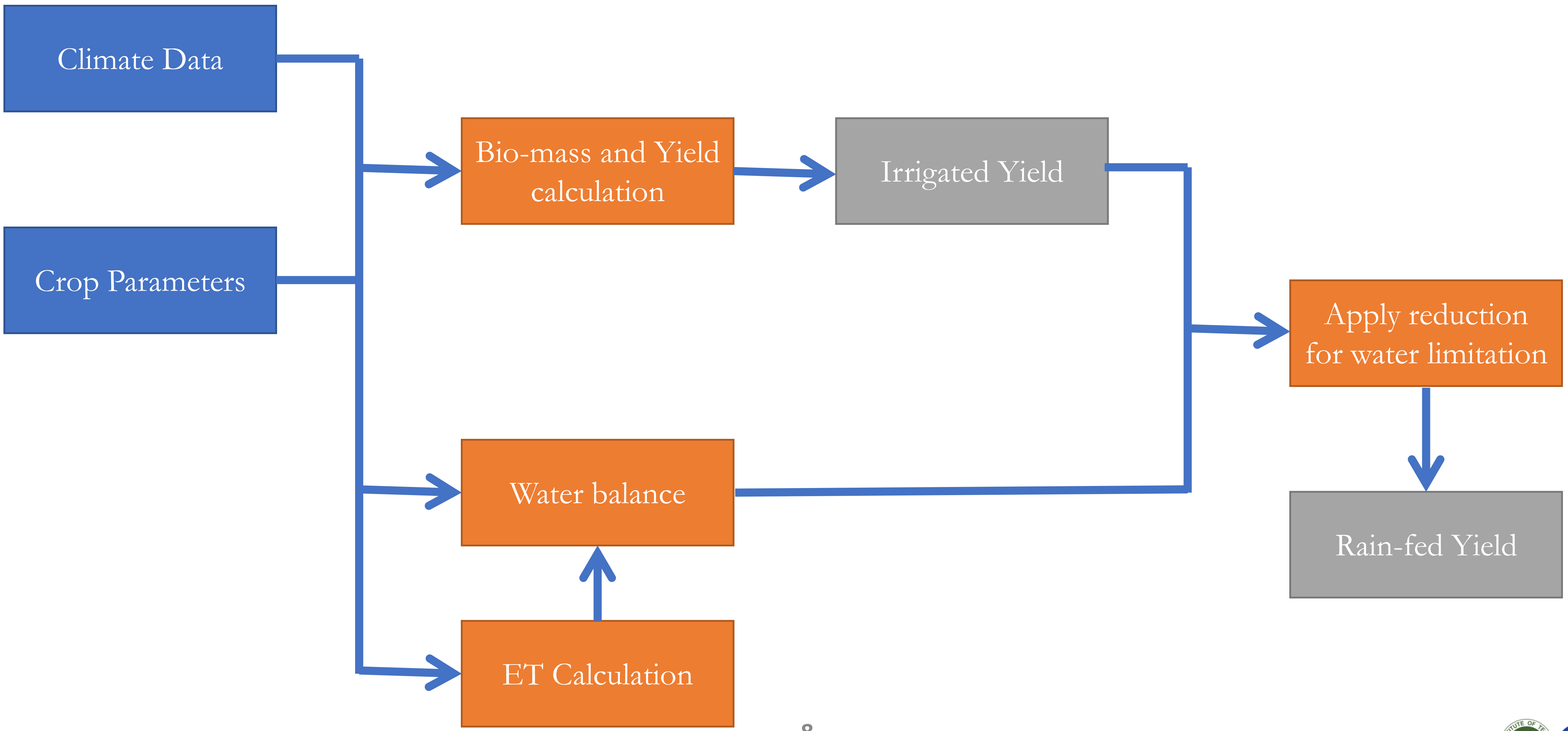
1. Calculate total biomass

2. Calculate crop yield (irrigated yield)

3. Calculate effects of water limitations on rice yield with CROPWAT model (rain-fed yield)

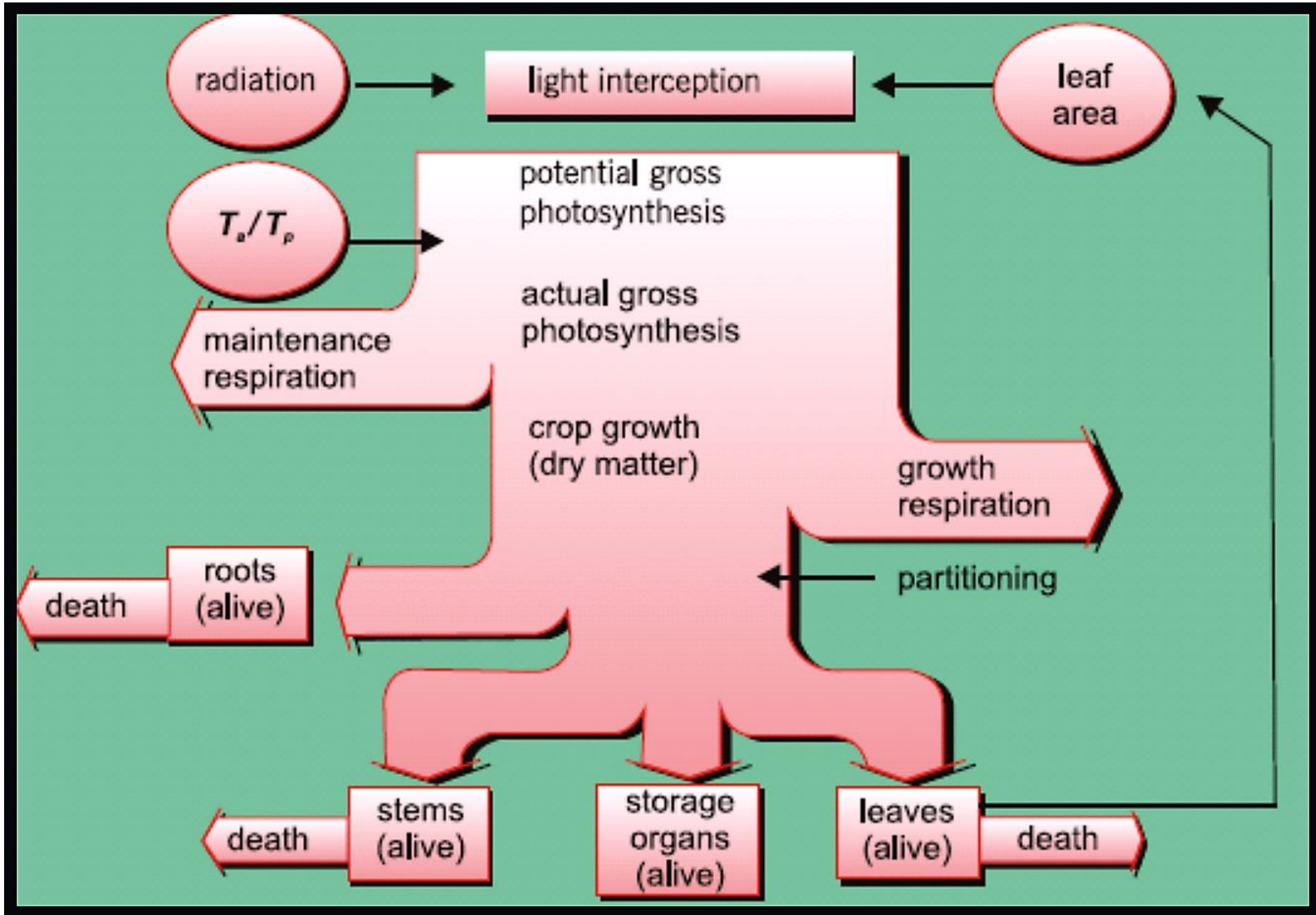
4. Get rid of area / crop cycles which are not suitable based on temperature and LGP

How it works


Climate Data
Crop Parameters
Bio-mass and Yield calculation
Irrigated Yield
Water balance
ET Calculation
Apply reduction for water limitation
Rain-fed Yield

1. Calculate total biomass

- Ecophysiological model developed by A.H. Kassam (1977)
- It models Photosynthesis relation to calculate total biomass produces in a growing period



2. Calculate crop yield

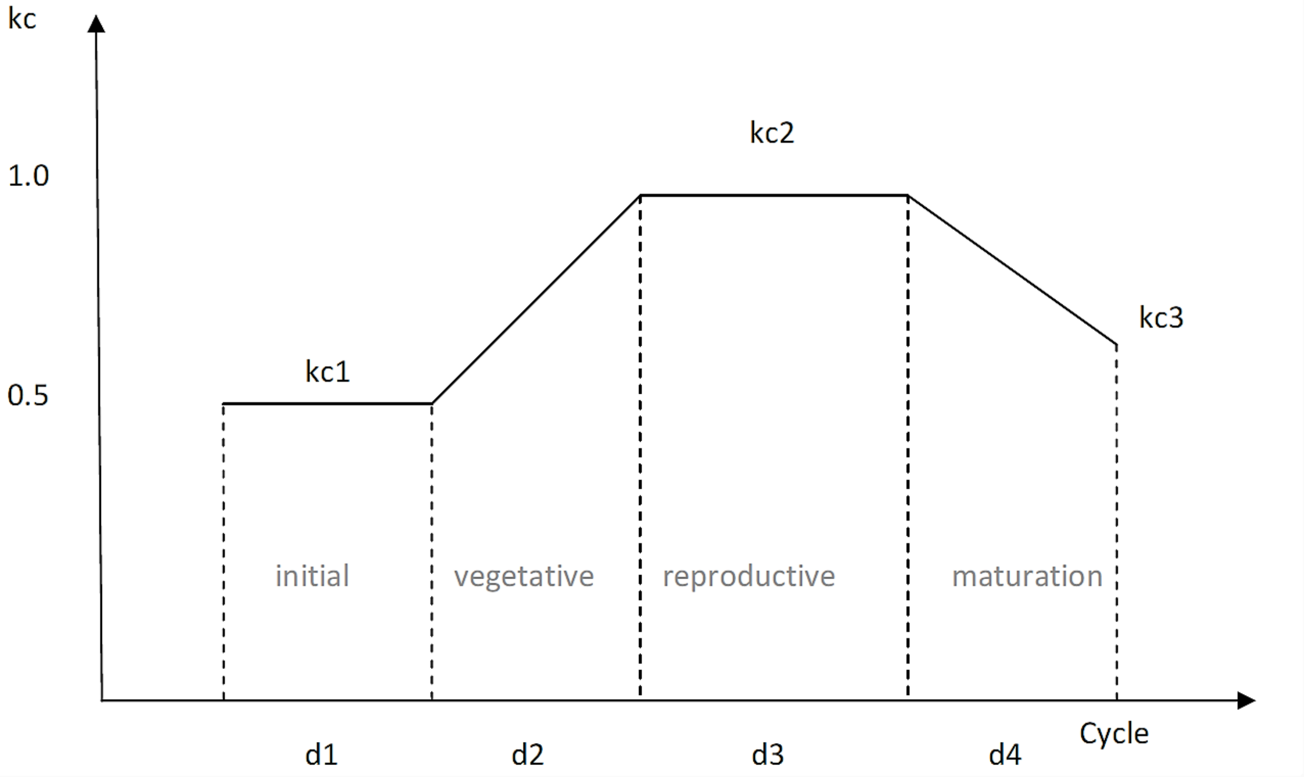
$$Y = HI \times B$$

- Y = Crop Yield (Unit: Tons per Hectare)
- HI = Harvest Index, i.e., proportion of the net biomass of a crop that is economically useful.
- B = Biomass calculated from Kassam (1977) model

3. Calculate effects of water limitations on rice yield

- Water requirement of plants are different in 4 stages of growth.

- And daily water balances calculation is calculated to obtain available water. And if water is deficient, reduction factors on yield will be applied (CROPWAT)



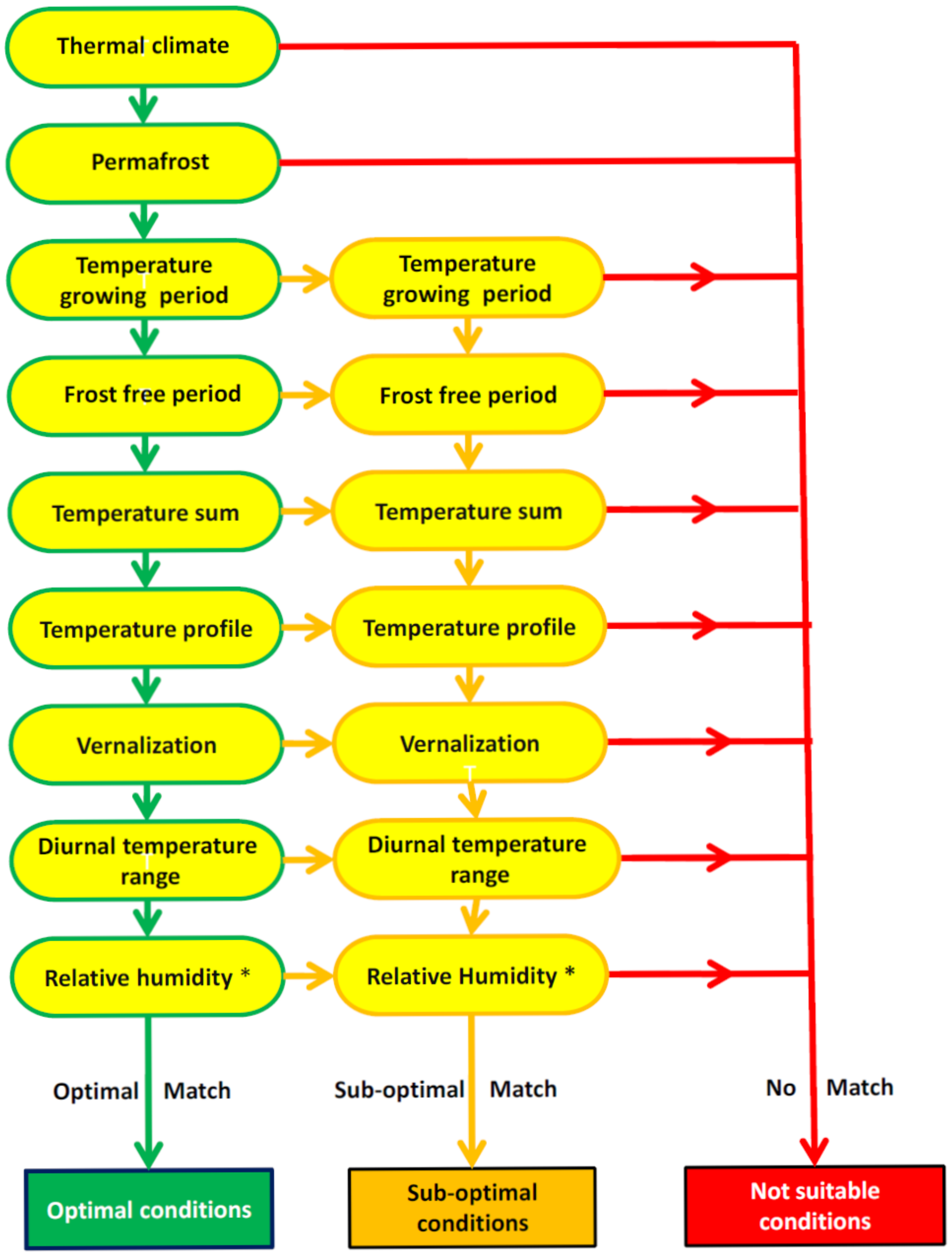
3. Calculate effects of water limitations on rice yield

- Simple idea here is, simple water balances calculation considering water intake (precipitation), water in the soil and how much water is consumed by crop (evapotranspiration).

- Reduction factors are applies based on this water balance.

- Evapotranspiration is based on FAO recommended Penman-Monteith method.

4. Get rid of area / crop cycles which are not suitable based on temperature and LGP



2. How to perform Crop Simulations in PyAEZ

Reading Data

- Here we will read following data which is required for crop simulation
    - Climate Data
        - Minimum temperature (Celcius)
        - Maximum temperature (Celcius)
        - Precipitation (mm / day)
        - Shortwave radiation (W/m^2)
        - Wind Speed (m/s)
        - Relative humidity (Fraction)
    - Other Data
        - Admin Mask
        - Elevation (m)

Handing Data

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

min_temp = np.load('./sample_data/input/climate/min_temp.npy') # Celcius
max_temp = np.load('./sample_data/input/climate/max_temp.npy') # Celcius
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') # Fraction
```

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

admin_mask = imageio.imread('./sample_data/input/LAO_Admin.tif')
srtm_elevation = imageio.imread('./sample_data/input/SRTM_Elevation.tif') # m
```

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Handing Data

- Now, we have read data into computer memory and now, let's pass this data into our Crop Simulation model

```
'''setting input data'''

aez.setMonthlyClimateData(min_temp, max_temp, precipitation, short_rad, wind_speed, rel_humidity)
aez.setLocationTerrainData(lat_min=13.90, lat_max=22.51, elevation=srtm_elevation)
aez.setStudyAreaMask(admin_mask=admin_mask, no_data_value=0)
```

Setting Crop Parameters

- Here we have to set following crop parameters (these crop parameters)
    - Main Crop Parameters
        - LAI – Leaf Area Index = 4
        - HI – Harvest Index = 0.4
        - adaptability - Adaptability Class = 2
        - legume – Legume or not =0
        - cycle_len – Crop Cycle Length in Days = 105
        - D1 – rooting depth at the earth stage (m) = 0.75
        - D2 – rooting depth at the matured stage (m) = 0.75
    - Crop Cycle Parameters
        - stage_per – Percentage of each growing stage = [10,30,30,30]
        - kc – Kc factors to calculate crop-specific ET for each stage as a list = [1.1,1.2,1]
        - kc_all – Kc factors to calculate crop-specific ET for entire season = 1.1
        - yloss_f – yield loss factors for each stage as a list = [1,2,2.5,1]
        - yloss_f_all– yield loss factors for entire season = 2
    - Soil-Water Related Paramers
        - Sa – soil moisture holding capacity (mm/m) = 100
        - pc – soil water depletion fraction = 0.5
- Setting crop parameters and simulation will be done separately for each crop-input level combinations.

Setting Crop Parameters

- Now let's setup crop parameters which are specific for the crop-input level combination that we are simulating

```
aez.setCropParameters(LAI=4, HI=0.4, legume=0, adaptability=2, cycle_len=105, D1=0.75, D2=0.75)
aez.setCropCycleParameters(stage_per=[10, 30, 30, 30], kc=[1.1, 1.2, 1], kc_all=1.1,
            yloss_f=[1, 2, 2.5, 1], yloss_f_all=2)
aez.setSoilWaterParameters(Sa=100*np.ones((admin_mask.shape)), pc=0.5)
```

Thermal Screening (Optional)

- This is an optional step that we can apply further restrictions of climate parameters.

```
'''setting climate screening (optional)'''

aez.setLGPTScreening([75,75,75],[105,105,105])
aez.setTSumScreening([2000,2000,2000],[3000,3000,3000])
```

Perform Simulations

- We have already passed all input data, and crop parameters. Now, we can perform crop simulations with following code.

```
'''run simulations'''

aez.simulateCropCycle() # results are in kg / hectare
```

Extracting Outputs and Visualization

- Crop simulations perform all complex calculations under the hood and provide following outputs
  - Maximum attainable yield under Irrigated condition
  - Maximum attainable yield under Rain-fed condition
  - Optimum crop cycle starting date

Extracting Outputs and Visualization

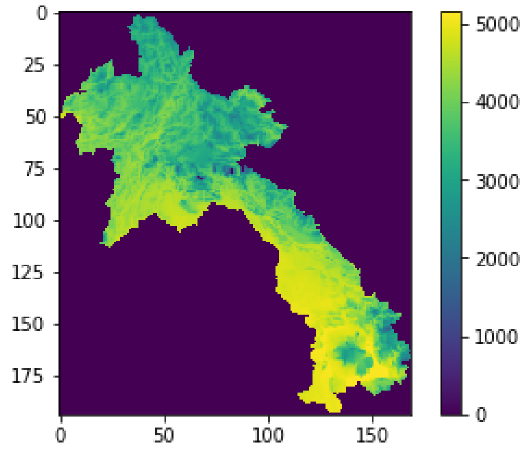
- We can use following code to extract outputs

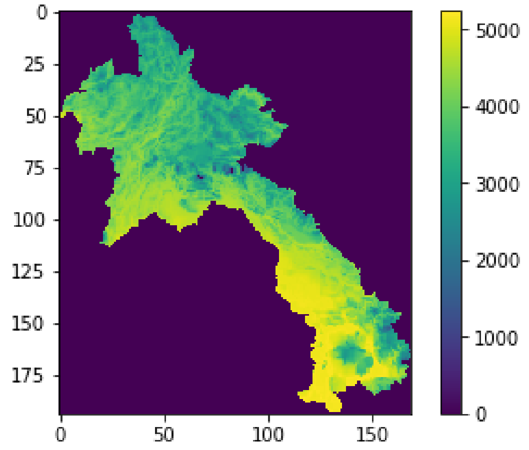
```
'''get result'''

yield_map_rain = aez.getEstimatedYieldRainfed()
yield_map_irr = aez.getEstimatedYieldIrrigated()

starting_date = aez.getOptimumCycleStartDate()
```

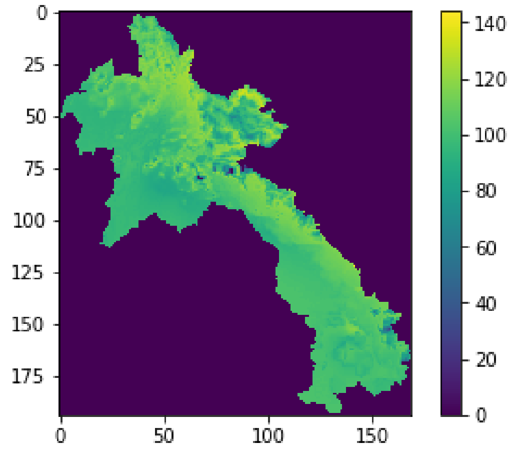
Extracting Outputs and Visualization

- And we can use this code to visualize final outputs

```python
'''visualize result'''

plt.imshow(yield_map_rain)
plt.colorbar()
plt.show()

plt.imshow(yield_map_irr)
plt.colorbar()
plt.show()

plt.imshow(starting_date)
plt.colorbar()
plt.show()
```







Exercise 1

- Let's assume, HI is increased to 0.6
- And rerun the simulations and see the difference in yield.

Exercise 2 – Simulation for Maize - Low Input Simulation

- Use following crop parameters
    - LAI – Leaf Area Index = 2.3
    - HI – Harvest Index = 0.33
    - adaptability - Adaptability Class = 4
    - legume – Legume or not =0
    - cycle_len – Crop Cycle Length in Days = 115
    - D1 – rooting depth at the earth stage (m) = 0.3
    - D2 – rooting depth at the matured stage (m) = 1
  - Crop Cycle Parameters
    - stage_per – Percentage of each growing stage = [16,26,33,25]
    - kc – Kc factors to calculate crop-specific ET for each stage as a list = [0.3,1.2,0.5]
    - kc_all – Kc factors to calculate crop-specific ET for entire season = 0.85
    - yloss_f – yield loss factors for each stage as a list = [0.4,0.4,0.9,0.5]
    - yloss_f_all– yield loss factors for entire season = 1.25
  - Soil-Water Related Parameters
    - Sa – soil moisture holding capacity (mm/m) = 100
    - pc – soil water depletion fraction = 0.5

Exercise 3 – Simulation for Maize – High Input Simulation

- Use following crop parameters (only LAI and HI will be changed from Exercise 2)
    - **LAI – Leaf Area Index = 4**
    - **HI – Harvest Index = 0.49**
    - adaptability - Adaptability Class = 4
    - legume – Legume or not =0
    - cycle_len – Crop Cycle Length in Days = 115
    - D1 – rooting depth at the earth stage (m) = 0.3
    - D2 – rooting depth at the matured stage (m) = 1
  - Crop Cycle Parameters
    - stage_per – Percentage of each growing stage = [16,26,33,25]
    - kc – Kc factors to calculate crop-specific ET for each stage as a list = [0.3,1.2,0.5]
    - kc_all – Kc factors to calculate crop-specific ET for entire season = 0.85
    - yloss_f – yield loss factors for each stage as a list = [0.4,0.4,0.9,0.5]
    - yloss_f_all– yield loss factors for entire season = 1.25
  - Soil-Water Related Parameters
    - Sa – soil moisture holding capacity (mm/m) = 100
    - pc – soil water depletion fraction = 0.5

What's Next

- Now we have found maximum yield that we can obtain under climate conditions in the study area.

- But so far, we have ignored other factors such as soil, slope, other climate related stuff like pest and deceases.

- These factors are hard to model deterministically. To get around this issue, we will apply empirical weights to take into account these factors.

- In next section, we will apply empirical weights top of simulated yield.

Thank you !