**Appendix E**

This section aims to provide a full description of parameters used for calculating the Reference Evapotranspiration included in the modeling. This study uses the Penman-Monteith formula to determine Cocoa crop evapotranspiration based on a Reference Grass Evapotranspiration. Penman-Monteith formula provides the best accepted way of evapotranspiration calculations worldwide using the following formula:

|  |  |
| --- | --- |
|  | [] |

where, is the reference evapotranspiration [], the air temperature at height , slope vapour pressure curve , is the net radiation at the crop surface , represents the soil heat flux density , the psychrometric constant , the wind speed at height , the saturation vapor pressure , and actual vapor pressure . Below relates the procedures required for determining each related parameter in the calculus.

1. **Temperature () - .** It is the local environmental mean temperature in the air at height.
2. **Slope vapor pressure - .** It is a required parameter that represents the slope of the relationship between saturation vapor pressure and air temperature. It is determined by:

|  |  |
| --- | --- |
|  | [] |

1. **Net Radiation .** It represents a balance between the energy absorbed, reflected and emitted by the earth. It is determined by the following equation:

|  |  |
| --- | --- |
|  | [] |

where is the net shortwave radiation [, and represents the net longwave radiation [. is determined by the following equation:

|  |  |
| --- | --- |
|  | [] |

where is the albedo coefficient (canopy reflection factor), which is for the hypothetical reference grass and is the incoming or all-sky solar radiation [. On the other hand, is obtained through:

|  |  |
| --- | --- |
|  | [] |

where, is the Stefan-Boltzmann constant , represents the maximum temperature in during 24-hours period, the minimum temperature in during 24-hours period, the actual vapor pressure , the all-sky solar radiation [ (which represents around the 75% of ), and the clear-sky solar radiation [. Where represents the actual vapor pressure and it is determined by:

|  |  |
| --- | --- |
|  | [] |

being the saturation vapor pressure regarding the air temperature ( and ) and the mean relative humidity. In the equation [6], the value is determined by the following equation, where represents the respective temperature in :

|  |  |
| --- | --- |
|  | [] |

1. **Soil heat flux density () - .** It represents the amount of energy used in heating the soil. It ranges between positive (the soil is warming) and negative (the soil is cooling) values. Nevertheless, this parameter is very small regarding the daily net radiation, then is normally ignored (Allen et al., 2006).
2. **Psychrometric constant () - .** It relates the partial pressure of water in the air and represents the energy required to increase a unit of air (mass) one degree regarding constant pressure (Allen et al., 2006). It is determined by the following equation:

|  |  |
| --- | --- |
|  | [] |

being is the atmospheric pressure and calculated through:

|  |  |
| --- | --- |
|  | [] |

where represents the altitude above sea level .

1. **Wind speed () - .** It is the wind speed at height.
2. **Saturation vapor pressure () - .** It is the vapor pressure in the air and is determined using the following equation, where and are obtained by equation [7]:

|  |  |
| --- | --- |
|  | [] |

**Water balance estimation parameters**

Table E1: Summary of parameters required for ETo estimation

Summary of parameters required for ETo estimation

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Parameter | Unit | Input Parameters | Independent Parameter | Source |
| Slope vapor pressure () |  | - | The mean temperature - () | Estimated |
| Temperature () |  | - | - | (NASA, n.d.-b) |
| Net Radiation |  | Net shortwave radiation - () | The albedo coefficient - | (Allen et al., 2006) |
|  |  | The net longwave radiation - () | The Stefan-Boltzmann constant - | (Allen et al., 2006) |
|  |  |  | The maximum temperature - () | (NASA, n.d.-b) |
|  |  |  | The minimum temperature - () | (NASA, n.d.-b) |
|  |  |  | The all-sky solar radiation - - ( | (NASA, n.d.-b) |
|  |  |  | The clear-sky solar radiation - ( | (NASA, n.d.-b) |
|  |  |  | The actual vapor pressure () - | Estimated |
|  |  |  | The Relative Humidity - () | (NASA, n.d.-b) |
| Soil heat flux density () |  | - | - | (Allen et al., 2006) |
| Psychrometric constant () |  | The atmospheric pressure - () | Altitude above sea level - | (Allen et al., 2006) |
| Wind speed () |  | - | - | (NASA, n.d.-b) |
| Saturation vapor pressure () |  | Maximum vapor pressure - () | The maximum temperature - () | (NASA, n.d.-b) |
|  |  | Minimum vapor pressure - () | The minimum temperature - () | (NASA, n.d.-b) |