9th Protocol: Evapotranspiration

Cheyenne Rueda and Simone Massaro

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Contents

1 Motivation

In this chapter we will focus on evapotranspiration. This term is well known in many environmental study fields, but, what is the most precise definition given to this term?

Evapotranspiration is referred according to the relationship of two other factors, such as the soil water evaporation and plant transpiration. The actual evapotranspiration is the one that is measured from these two factors mentioned before, considering changes and not ideal conditions in the meteorological conditions and the type of soil (Labedzki, 2011). In contrast, potential evapotranspiration is that one that occurs with ideal conditions such as abundance of water storage and meteorological conditions. Some differences between potential and actual evapotranspiration are the infiltration capacity of soil, possible diseases, pH of soil and its fertility.

Labedzki, L. (Ed.). (2011). Evapotranspiration. BoD–Books on Demand.

2 Background

3 Sensors and measuring principle

There are many different ways to measure evapotranspiration,some are more accessible than others and depending the scenario some of them might be more suitable than others. The measurement of evapotranspiration claims quantitative data, and this data can be measure by water evaporation and the energy flux between soil and atmosphere.Rana and Kater (2000), describes the different ways to measure evapotranspiration based on hydrological, micrometeorological, plant physiology and analytical approaches. The first one includes: soil water balance and weighing lysimeters, the second one, energy balance and Bowen ration, aerodynamic method and eddy covariance. Plant physiology approach is based on sap flow method or chambers system. Last one, analytical approach are based on Penman-Montheith model. After this one, empirical approach can also be taken into account, such as process based on crop coefficient approach and soil water balance modeling [@articlenoauthor_rana_nodate].

Some of the most frequently measurements applied to evapotranspiration and that we have seeing in class are:

Evaporation pan: a circle panel where precipitation is accumulated and then, with the help of a measuring bucket and based on a scale, water los can be measured by the difference between the potential evapotranspiration of 2 days. Some of the erros are the expansion of water, wrong reading, limited recording for a volume of water and the possibility of the oasis effect to occur.

Piché evaporimeter

Weighing lysimeter

Bowen ratio energy balance method

4 Analysis

```
library(tidyverse)
```

```
## Warning: package 'tidyverse' was built under R version 4.0.5
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.1 --
```

```
## v ggplot2 3.3.4     v purrr   0.3.4
## v tibble  3.1.2     v dplyr   1.0.7
## v tidyr   1.1.3     v stringr 1.4.0
## v readr   1.4.0     v forcats 0.5.1
```

```
## Warning: package 'ggplot2' was built under R version 4.0.5
```

```
## Warning: package 'tibble' was built under R version 4.0.5
```

```
## Warning: package 'tidyr' was built under R version 4.0.5
```

```
## Warning: package 'forcats' was built under R version 4.0.5
```

```
## -- Conflicts ------------------------------------------ tidyverse_conflicts() --
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()    masks stats::lag()
```

```
library(lubridate)
```

```
## Warning: package 'lubridate' was built under R version 4.0.5
```

```
##
## Attaching package: 'lubridate'
```

```
## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union
```

```
et <- read_csv("../Data_lectures/09_Turbulent_fluxes_I_ET/ET_data_forst_botanical_garden.csv" , locale =
  rename(loc_id = replicates)
```

```
##
## -- Column specification --------------------------------------------------------
## cols(
##   date = col_date(format = ""),
##   spot = col_character(),
##   replicates = col_double(),
##   pich_height_cm = col_double(),
##   Tdry_C = col_double(),
##   Twet_C = col_double(),
##   pan_height_mm = col_double(),
##   Tmin_C = col_double(),
##   Tmax_C = col_double()
## )
```

```
meteo <- read_csv("../Data_lectures/09_Turbulent_fluxes_I_ET/MeteoData_BotanicalGarden.csv")
```

```
##
## -- Column specification --------------------------------------------------------
## cols(
##   Date = col_datetime(format = ""),
##   Pressure_hPa = col_double(),
##   `NetRadiation_Wm-2` = col_double(),
##   RH_Perc = col_double(),
##   TA_degC = col_double(),
##   `GroundHeatflux_Wm-2` = col_double(),
##   P1_mm = col_double(),
##   P2_mm = col_double()
## )
```

```
et
```

```
## # A tibble: 32 x 9
##    date       spot    loc_id pich_height_cm Tdry_C Twet_C pan_height_mm Tmin_C
##    <date>     <chr>    <dbl>          <dbl>  <dbl>  <dbl>         <dbl>  <dbl>
##  1 2021-06-25 A-fir        1           13.1   22.2   16              64     16
##  2 2021-06-25 A-fir        2            1.8   22.2   16              64     16
##  3 2021-06-25 B-pole       3            2     22.2   16.2            64     16
##  4 2021-06-25 B-pole       4            2.3   22.2   16.2            64     16
##  5 2021-06-25 C-tower      5            2.6   22.4   16              64     16
##  6 2021-06-25 C-tower      6            3.8   22.4   16              64     16
##  7 2021-06-25 D-acer       7            3.7   22     15.4            64     16
##  8 2021-06-25 D-acer       8            6.1   22     15.4            64     16
##  9 2021-06-26 A-fir        1           17.5   22.6   16.6            60     12
## 10 2021-06-26 A-fir        2            5.2   22.6   16.6            60     12
## # ... with 22 more rows, and 1 more variable: Tmax_C <dbl>
```

```r
meteo
```

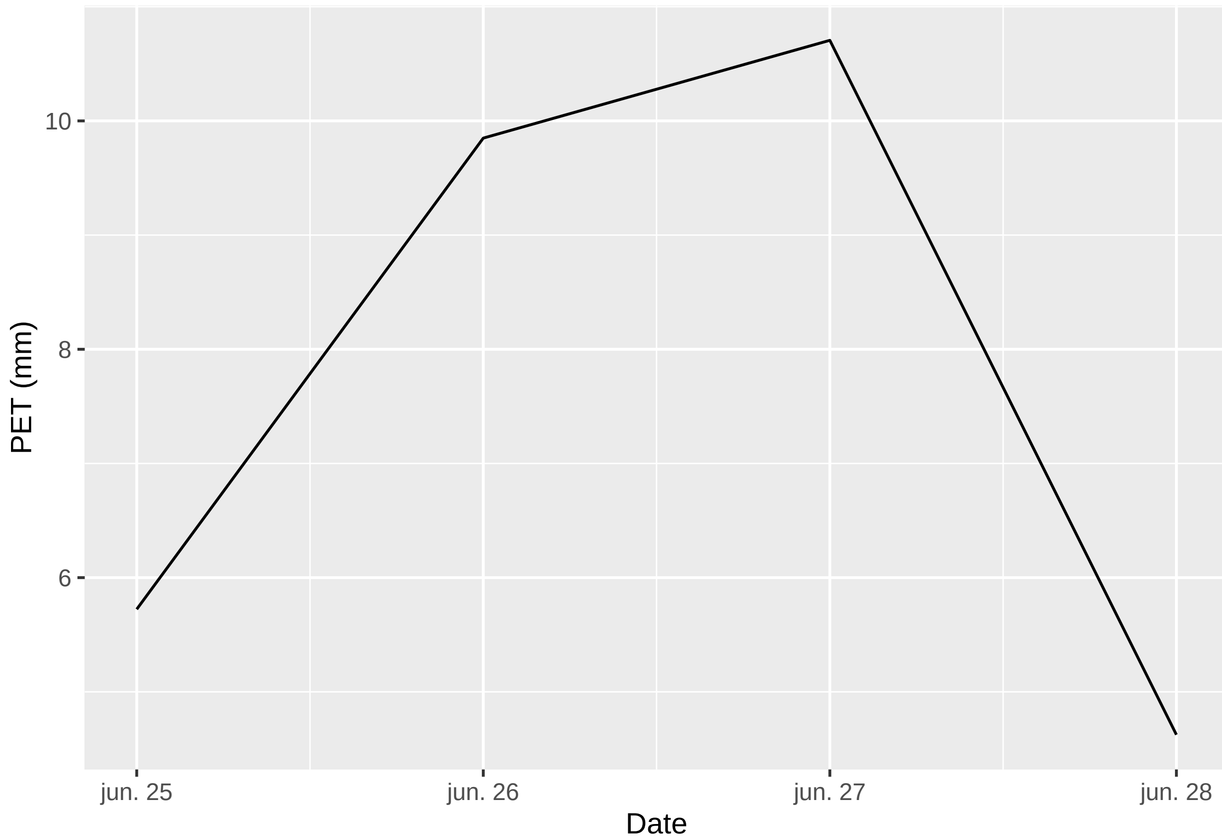
```
## # A tibble: 573 x 8
##    Date                Pressure_hPa `NetRadiation_Wm-2` RH_Perc TA_degC
##    <dttm>                     <dbl>               <dbl>   <dbl>   <dbl>
##  1 2021-06-25 00:00:00         990.               -13.8    99.9    15.5
##  2 2021-06-25 00:10:00         990.               -14.4    99.8    15.4
##  3 2021-06-25 00:20:00         990.               -13.8   100.     15.3
##  4 2021-06-25 00:30:00         990.               -13.9   100.     15.3
##  5 2021-06-25 00:40:00         990.               -15.6   100.     15.2
##  6 2021-06-25 00:50:00         990.               -14.4   100.     15.3
##  7 2021-06-25 01:00:00         990.               -14.5   100      15.3
##  8 2021-06-25 01:10:00         990.               -15.7   100      15.2
##  9 2021-06-25 01:20:00         990.               -14.8   100      15.2
## 10 2021-06-25 01:30:00         990.               -14.5   100      15.1
## # ... with 563 more rows, and 3 more variables: GroundHeatflux_Wm-2 <dbl>,
## #   P1_mm <dbl>, P2_mm <dbl>
```

```r
#' Potential evapotranspiration using Priestley-Taylor equation
calc_pet <- function(T_air, Rn, G){
  g <- 0.067 # kPa K -1
  s <- ( 4098 * (0.6108 * exp((17.27 * T_air ) / (T_air +237.3) ) ) ) / ( T_air + 237.3 )^2
  pet <- 1.26 * s * (Rn - G)/ (s + g)
}
```

```r
#adding R_n and G to the
(meteo_d <- meteo %>%
  group_by(Date = floor_date(Date, "day")) %>%
  # Need to convert from W (J/s) to MJ/d, using a factor 0.0864
  summarise(R_n_d = mean(`NetRadiation_Wm-2`) * 0.0864, G_d = mean(`GroundHeatflux_Wm-2`) * 0.0864, T_a
  mutate(
    PET = calc_pet(T_air, R_n_d, G_d)
  ))
```

```
## # A tibble: 4 x 5
##   Date                R_n_d   G_d T_air   PET
##   <dttm>              <dbl> <dbl> <dbl> <dbl>
## 1 2021-06-25 00:00:00  7.47 0.463  17.1  5.72
## 2 2021-06-26 00:00:00 12.5  0.561  17.6  9.85
## 3 2021-06-27 00:00:00 13.3  0.804  19.7 10.7
## 4 2021-06-28 00:00:00  5.67 0.405  21.1  4.62
```

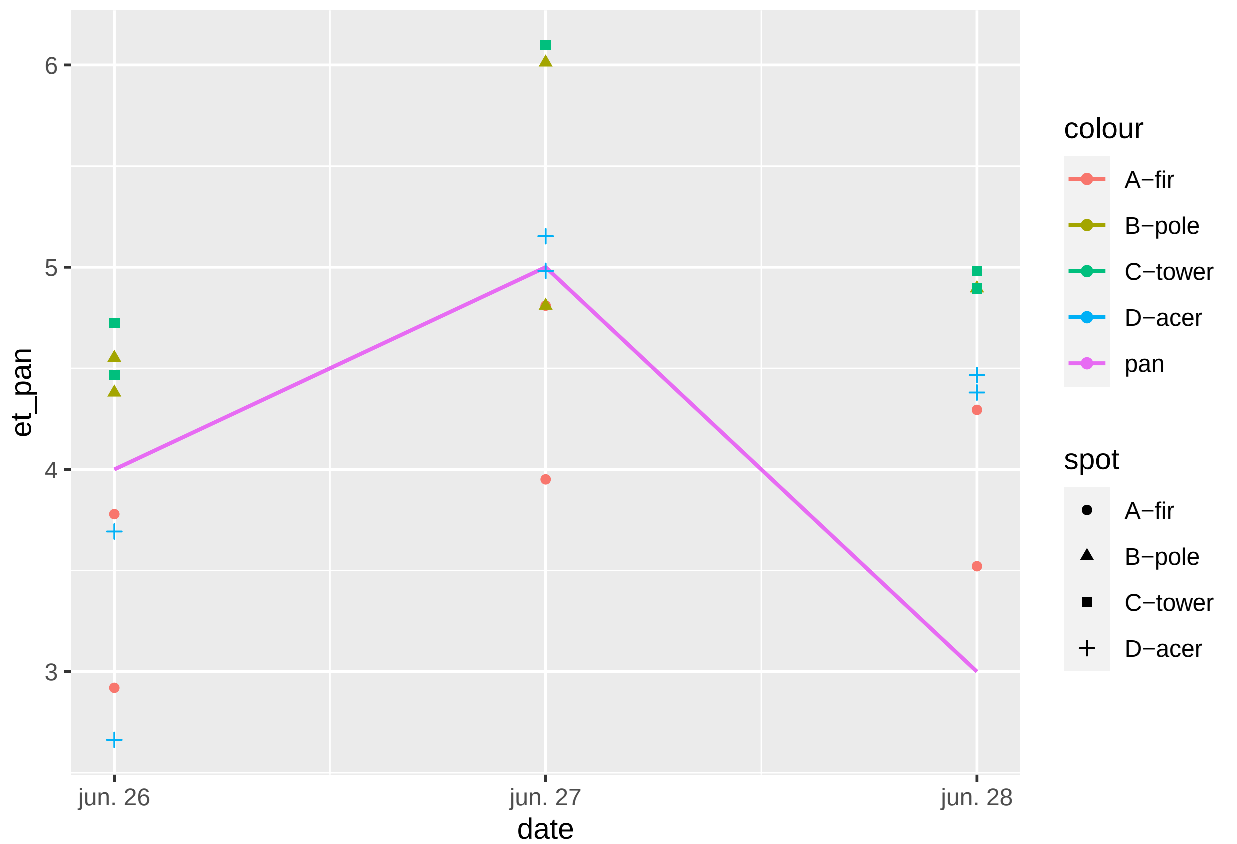
```r
ggplot(meteo_d, aes(Date, PET)) +
  geom_line() +
  labs(y="PET (mm)")
```




```r
pich_d <- 3 #cm
pich_inn_d <- 0.9 # cm
# calc area exposed to air:
#2 times the area of the pare dish (two sides) - the area of glass
pich_dish_area <- 2 * (pi / 4 * pich_d ^ 2) - (pi / 4 * pich_inn_d ^ 2) # cm^2
pich_int_area <- (pi/4 * pich_inn_d ^2 ) # cm^2
```

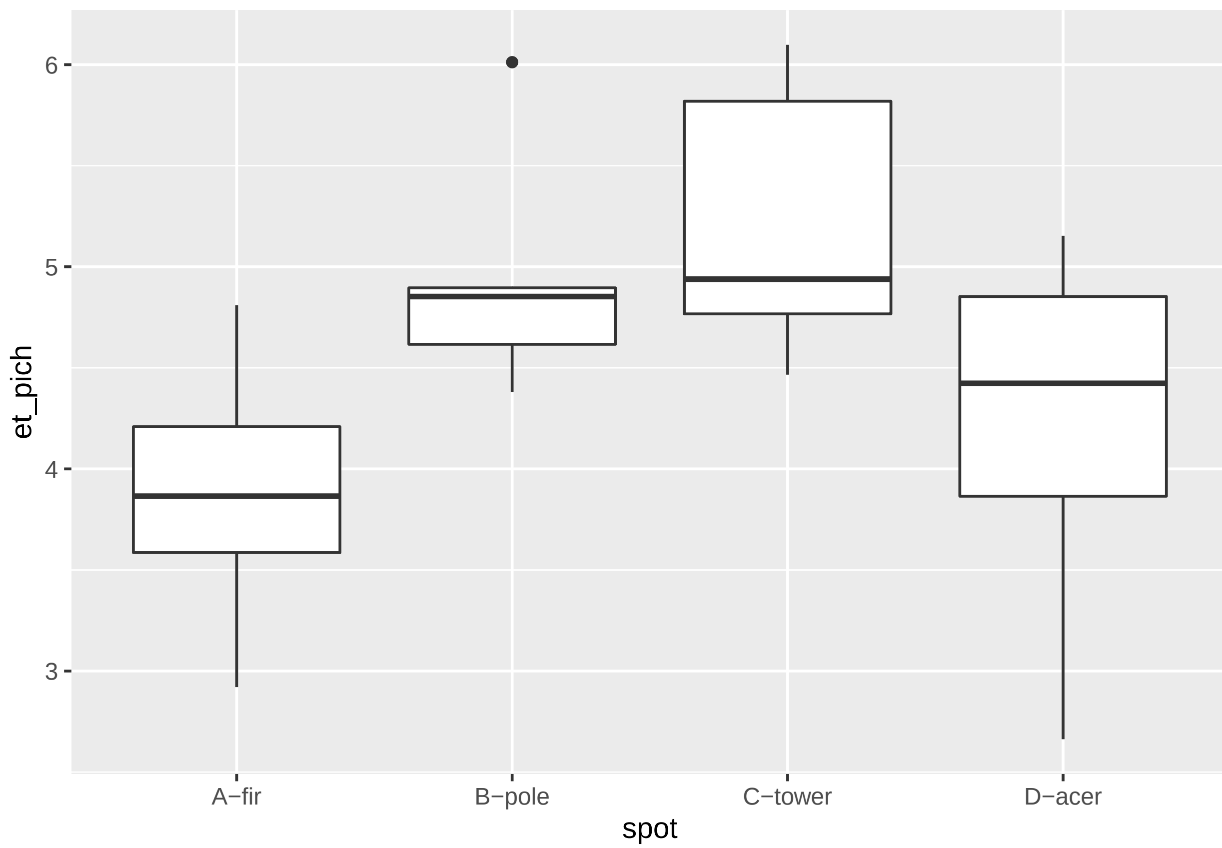
```r
et <- et %>%
  group_by(loc_id) %>%
  mutate(
    # here the scale is the opposite, the lower the number the more the water
    diff_pich = pich_height_cm - lag(pich_height_cm),
    et_pan = lag(pan_height_mm) - pan_height_mm,
    # need to convert to right unit
    et_pich = diff_pich * pich_dish_area * pich_int_area / 10
  )
```

```r
et %>%
  drop_na() %>% #removing first empty day
ggplot(aes(date)) +
  geom_line(aes(y=et_pan, col="pan"), size=.7) +
  geom_point(aes(y = et_pich, col=spot, shape=spot))
```



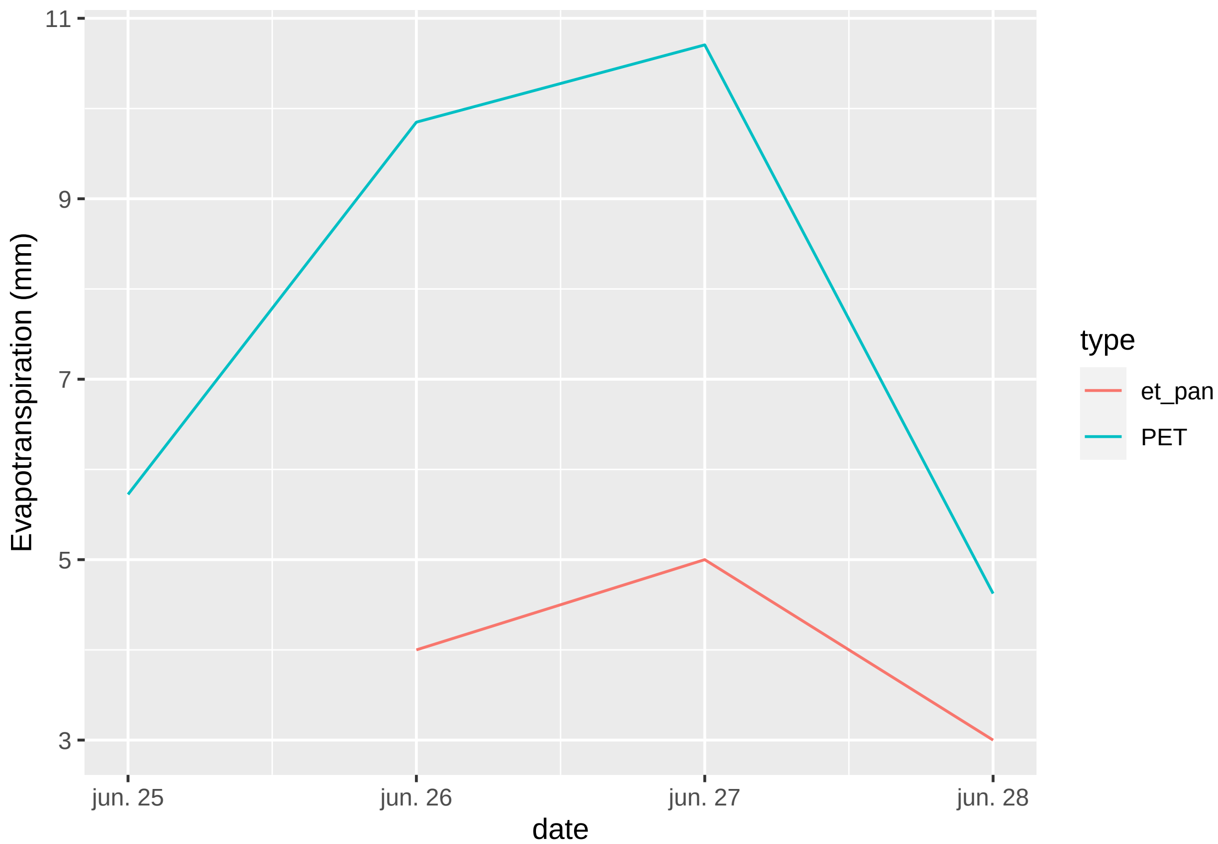

```
ggplot(et, aes(spot, et_pich)) +
  geom_boxplot()
```

```
## Warning: Removed 8 rows containing non-finite values (stat_boxplot).
```




```
et %>%
  left_join(meteo_d, by = c("date"= "Date")) %>%
  gather("type", "et", et_pan, PET) %>%
  ggplot(aes(date, et, col=type)) +
  geom_line() +
  labs(y= "Evapotranspiration (mm)")
```

```
## Warning: Removed 8 row(s) containing missing values (geom_path).
```




```
et
```

```
## # A tibble: 32 x 12
## # Groups:   loc_id [8]
##    date       spot    loc_id pich_height_cm Tdry_C Twet_C pan_height_mm Tmin_C
##    <date>     <chr>    <dbl>          <dbl>  <dbl>  <dbl>         <dbl>  <dbl>
##  1 2021-06-25 A-fir        1           13.1   22.2   16              64     16
##  2 2021-06-25 A-fir        2            1.8   22.2   16              64     16
##  3 2021-06-25 B-pole       3            2     22.2   16.2            64     16
##  4 2021-06-25 B-pole       4            2.3   22.2   16.2            64     16
##  5 2021-06-25 C-tower      5            2.6   22.4   16              64     16
##  6 2021-06-25 C-tower      6            3.8   22.4   16              64     16
##  7 2021-06-25 D-acer       7            3.7   22     15.4            64     16
##  8 2021-06-25 D-acer       8            6.1   22     15.4            64     16
##  9 2021-06-26 A-fir        1           17.5   22.6   16.6            60     12
## 10 2021-06-26 A-fir        2            5.2   22.6   16.6            60     12
## # ... with 22 more rows, and 4 more variables: Tmax_C <dbl>, diff_pich <dbl>,
## #   et_pan <dbl>, et_pich <dbl>
```

5 References