# Life CLIVUT
# Climate Value of Urban Trees

**LIFE18 GIC/IT/001217**

## ACTION A4

**Models available in the Life Clivut TreeDb platform for estimating environmental/climatic services and their value**

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In the Urban Green Asset Management System (www..lifeclivut.treedb.eu) the functions already available to assess and optimize of the ecosystemic value of urban trees through good management practices are the following:

## 1. CO2 Storage

For each tree, on the basis of the species and the DBH value collected by the census and registered in the lifeclivut.treedb.eu, the height and age are estimated and the value of stored $CO_2$ is calculated. The emission sequestration is estimated by the system on the base of biomass of the tree using volumetric equations, calculating green volume and converting it to dry-weight biomass and then in carbon (C) and stored carbon dioxide equivalents ($CO_2$).

**Equations**

The equations estimate volume (m3/tree) from diameter at breast height (DBH in centimeters) and height (ht in meters) measurements.
Dry-weight (DW) biomass and carbon stored were calculated by applying DW biomass density factors (reported in scientific literature) and incorporating belowground biomass by multiplying the DW biomass by 1.28 (Sinacore et al., 2017; Tritton, and Hornbeck, 1982). DW biomass was converted into kilograms of carbon (C) by multiplying by the constant 0.50 (Lamlom and Savidge, 2003), while stored carbon was converted into stored carbon dioxide ($CO_2$ in metric tons) by multiplying by the constant 3.67 (molecular weight of $CO_2$).
Allometric equations were selected for evaluating tree volume were chosen among different sources to better adapt the modeling of the trees in the different areas analyzed (Zianis et al., 2005; McPherson et al., 2016; GlobalAllomeTree)
Carbon sequestration and storage are calculated at different age, estimating the crown dimensions, growing speed, pruning technics. Starting from the known or estimated age of the tree at the moment of its introduction in the lifeclivut.treedb.eu the value of stored $CO_2$ is calculated over years (every 5 years from 5 to 70).

## 2. PM10

The potential tree absorption of particulate (PM10), depends by several morphological, physical characteristics of tree and from the environment variables.
The PM absorption calculation is done considering the pollutant concentrations recorded during the previous year.
The UFORE formula was adopted to estimate the yearly total PM10 absorption modified as following

$$PMa = \sum_{1}^{12} Vd * C * 3600 * 24 * Ti * (LAIt)$$

where LAIt is the leaf area of each tree expressed in square meters (instead of the LAI of canopy as in the original formula). This to consider the discontinuity of tree presence in urban areas. Leaf area was obtained utilizing the allometric equations to estimate tree component dimensions. Urban tree growth equations allowed to predict tree height, crown height, crown diameter, and leaf area using d.b.h. (McPherson et al. 2016)
The other parameters utilized for PM absorption estimation are:
$Vd$: Deposition velocity that is set differently according to the leaf structure, it depends on the leaf conformation and the presence of trichomes.
*C*: is the monthly PM10 concentration (μg/m3).
*Ti*: is the number of days per month when the leaves are present (the time period April-October was considered for deciduous broadleaved).
In the UFORE formula the resuspension rate coefficient equal to 0,5 is present (Zinke, 1967) but we preferred not to consider the resuspension rate due to its uncertain evaluation.
Moreover, the results expressed as yearly grams of PM10 absorbed per plant is calculated per tree crown area projected on the soil to obtain the total yearly (μg of PM10 absorbed per square centimeter of arboreal surface.
To calculate the PM10 absorbed by trees, the system uses the daily environmental data collected by the environmental stations relating to PM10, wind and rain (loaded into the system from regional sources). For each single tree, the data collected from the station closest to the tree is used.
For each tree is determined the value of pm10 absorbed from the environment, on the basis of species, dbh value, crown size and, if available, crown density, and of environmental data available. These values are returned, tree by tree, both as an annual summary and as a monthly summary.

## 3. Cooling

The cooling effect of trees is determined the system using the evapotranspiration and the shading effect

**Evapotranspiration**
For the estimation of evapotranspiration the system use the following formula ETA= ƒ ETO where ƒ is a coefficient of evapotranspiration calculate for different trees typology and land coverage (Larondellea N., D.Haase 2013) , and ETO is the potential evapotranspiration calculated with the Hargreaves and Samani mode. (Hargreaves G, Z.A.Samani 1985)

$$R_s = a.R_a\left(T_{\max} - T_{\min}\right)^{0.5}$$

Where Rs is in $MJ.m^{-2}. d^{-1}$; Tmax and Tmin are daily maximum and minimum air temperature, in °C, respectively, Ra is extraterrestrial radiation, in $MJ.m^{-2}. d^{-1}$ which is a function of latitude and day of the year; and a is an empirical coefficient, the value of a to be 0.16 for interior regions and 0.19 for coastal regions.
The value of Ra is given by

$$R_a = (1440/\pi).SC.DF.(\cos\phi.\cos\delta.\sin W_s + W_s.\sin\phi.\sin\delta)$$

where SC is solar constant (1367 $W/m^2$ or 0.082 $MJ.m^{-2}. min^{-1}$), DF is eccentricity correction factor of the earth's orbit, f is the latitude of site, and d is solar declination while Ws is mean sunrise hour angle. The value of Ra depends on Julian day, and the value of Rs is proportional to the difference between maximum and minimum air temperature.

Solar radiation allows the evaluation of Evapotranspiration through which Heat reduction potential is calculated as W/m2 per tree (considering all the tree crown surface). Successively energy loss (W/m2) per projected tree crown is calculated for each monitored tree. In this manner we were able to obtain an estimation of the percentage of heat loss on tree projected canopy compared to total daily radiation (per m2).

The system uses environmental data collected by the environmental stations relating to daily temperatures (loaded into the system from regional sources). For each single tree, the data collected from the station closest to the tree is used.

The value of daily solar radiation at the latitude of the city is also calculated.

**Tree crown shadow effect**. T

Tree crown shadow effect mitigating "urban heat island" phenomenon.is estimated by the system. A morpho-geographical survey were realized through the green census activities and dendrometric parameters related to tree crown shape were elaborated to simulate shaded areas provided by the trees in the park.

The free software ShadeMotion 4.0 was utilized to simulate shaded areas related to the different tree classes taken in consideration by census protocol adopted by the Project. From a database of 2057 plants, those with the same crown shape (Conical, Irregular, Oval_columnar, Spherical, Spreading) were extracted and each crown-shape group was divided in 4 percentiles (P25, P50, P75, P100) considering the crown height parameter. So, each crown-shape percentile group was represented by a various number of plants with similar shape and size and for each group mean values of crown height, crown width and crown density were calculated to obtain mean parameters for estimating shaded areas through the cited software.

The cooling parameters are computed on the basis of species, height, trunk height, crown size, crown shape, and, if available, crown density of the plant.

## 4. Growth

Starting from tree census parameters (species), the system determines the values that the plant will assume over the years (from 5 to 70 years step 5) relating to:

- DBH
- plant height
- diameter of the crown
- plant area
- leaf area
- leaf area weighted in the year (evergreen, deciduous)
- $CO_2$ stored.

## 5. City Green regulation

The system determines the classification of the tree, on the basis of relevant data as dbh and species, for the purposes of applying the Green Regulation adopted by the City.

## 6. Economic Value of trees.

The system calculates the economic value of tree linked to it landscape contribution and CO2 storage. According to the international Literature and Municipality regulations, for the first value 5 parameters are considered: the cost of the tree at the nursery (DBH 15-16 in average), the size of the tree measured as DBH size at 1,30 m from the soil, the location of the tree within the City (center, periphery etc.), the health and esthetic value.
For the assessment of the value in terms of CO2 storage we consider the average price of the year for one ton of CO2 in the International Carbon Market.

## 7. Biodiversity

A model for the Biodiversity evaluation is applied utilizing Shannon-Wiener index. This is one of the most commonly used measures of species diversity, it accounts the relative abundance and evenness of a species in the community. The measure is based on two information: the number of species (i.e. richness) and the number of individuals in each species. H increases with the number of species (i.e. richness) in the community. However, increasing the number of species in a community will not necessarily increase diversity. Moreover, evenness measure represents the equitability of species in a community and a measure of evenness is supportive for the diversity index.

## 8. Management parameters

The state of health of the tree and the recent pruning interventions are recorded in the database when the plant is inserted together with a photographic documentation of any damaged parts or the presence of pathologies. These data, which are part of the context analysis of the Strategy, are relevant for the planning of interventions and the monitoring of the city's arboreal heritage.
In addition, the system records the year of planting, starting from 2019 and estimates the age of the plant on the basis of the growth curves.