LIFE19 ENV/FR/00086

AIRFRESH

Air pollution removal by urban forests for a better human well-being

P. Sicard, ARGANS

F. Coulibaly, J. Lebreton (ARGANS, France)
A. Nicault, S. Bergé (Air Climat, France)
E. Paoletti, Y. Hoshika, J. Manzini (IRET-CNR, Italy)
A. De Marco, G. Pallante (ENEA, Italy)

XIII Workshop of the SILVA MEDITERRANEA
Working Group on Urban and Peri-urban forestry - 28 April 2021

ARGANS

air

CNR IRET

ENEA
Italian national agency for new technologies, energy and sustainable economic development

Project information

LIFE19 ENV/FR/00086

Partners: ARGANS (FR), AIR-Climat (FR), ENEA (IT), IRET-CNR (IT)
Coordinator: Pierre Sicard, ARGANS
Technical support: cities of Aix-en-Provence & Florence (+ conurbations)

Expected start date: September 1st, 2020
Expected end date: 1st March 2025

Total budget: €1.22 million

Website: www.life-airfresh.eu

Facebook: life.airfresh

Twitter: @airfresh19

Italian national agency for new technologies, energy and sustainable economic development

Project maturity: Starting, Developing & Maturing

AIRFRESH

LIFE19 ENV/FR/00086

2013

Reduction of NO_x emissions in Europe (e.g., road traffic) => **O_3 levels increase in cities** & decrease in rural areas.

2016

Ozone is becoming a major **health issue** in cities at European & global scale.

2018

Urban trees – Effective solution to reduce rising ozone levels.

2019

Summer: heat waves & air pollution peaks in EU => **planting strategies**: Milan, Region Sud…

11/2019

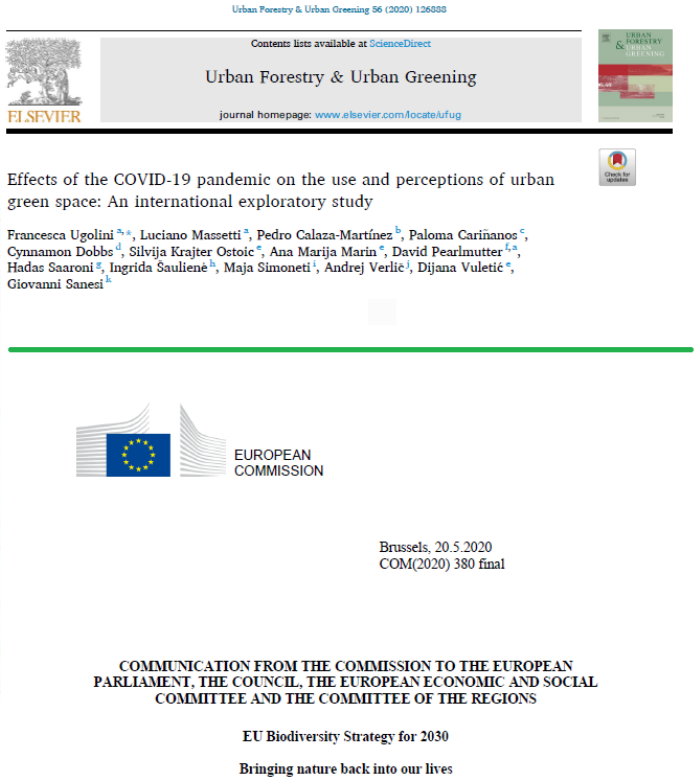
UNECE Clean Air in Cities: few municipalities planted any tree species anywhere => air quality degraded => city planners **urgently need** a suitable selection of tree species.

2020

AIRFRESH funded: a demonstrative & timely project

05/2020

EU Biodiversity Strategy 2030 & COVID-19 => Urban Greening Plans & 3 billion trees by 2030 in EU.



Urban Forestry & Urban Greening 56 (2020) 126888

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

ELSEVIER

Effects of the COVID-19 pandemic on the use and perceptions of urban green space: An international exploratory study

Francesca Ugolini [a,*], Luciano Massetti [a], Pedro Calaza-Martínez [b], Paloma Cariñanos [c], Cynnamon Dobbs [d], Silvija Krajter Ostoic [e], Ana Marija Marin [e], David Pearlmutter [f,a], Hadas Saaroni [g], Ingrida Šauliene [h], Maja Simoneti [i], Andrej Verlič [j], Dijana Vuletić [e], Giovanni Sanesi [k]

EUROPEAN COMMISSION

Brussels, 20.5.2020
COM(2020) 380 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS

EU Biodiversity Strategy for 2030

Bringing nature back into our lives

Main challenges – Greener cities

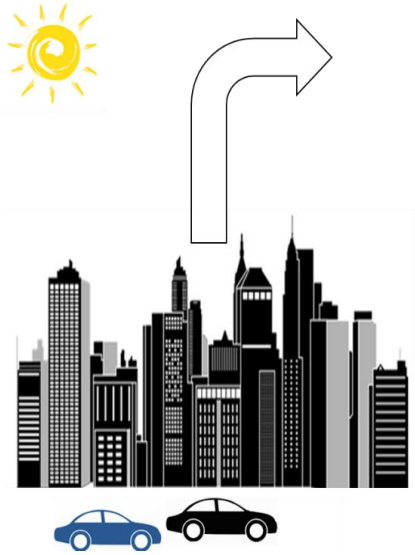
LIFE19 ENV/FR/00086

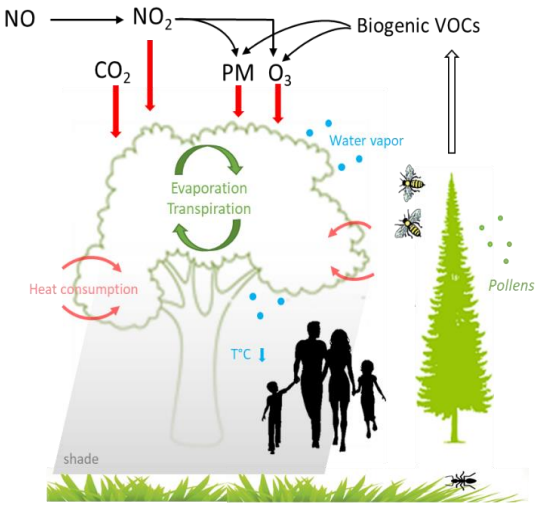
Air pollution & urban heat island: **2 major issues** of public health affecting cities, with > **500,000 premature deaths** in EU.

Urban reforestation & peri-urban reforestation => **meet clean air standards** in cities.

Win-win solutions for citizens: reduction of air pollution, carbon sequestration, air temperature regulation, noise reduction, social and aesthetic benefits…

Example of “Greening cities” (Green path in Nice, France)





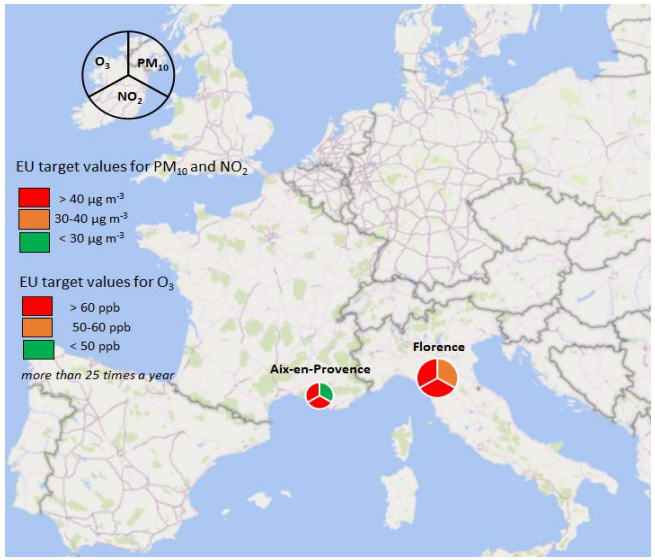
Two front runner cities

LIFE19 ENV/FR/00086

Aix-en-Provence (143,000 people) **& Florence** (380,000 people): human exposure regularly exceeds the WHO protection limits (PM_{10}, NO_2, O_3) & affected by climate change.

- **Ozone**: + 0,24 ppb $year^{-1}$ over the time period 2009-2018.
- **Air temperature**: + 1,9-4,6 °C by 2100.
- Heat wave 2019: **+ 3,5 °C** in Aix compared to peri-urban area.

In 2019, **73 & 167 premature deaths** and **309 and 700 hospital admissions** for cardiovascular & respiratory diseases due to AP in Aix & Florence.



Environmental Science and Pollution Research
https://doi.org/10.1007/s11356-019-06445-8

SHORT RESEARCH AND DISCUSSION ARTICLE

Check for updates

Effect of O_3, PM_{10} and $PM_{2.5}$ on cardiovascular and respiratory diseases in cities of France, Iran and Italy

Pierre Sicard [1] · Yusef Omidi Khaniabadi [2] · Sandra Perez [3] · Maurizio Gualtieri [4] · Alessandra De Marco [4]

Received: 26 June 2019 / Accepted: 5 September 2019

AIRFRESH

Project Objectives

LIFE19 ENV/FR/00086

To efficiently reduce AP in cities, municipalities & city planners need a **quantitative & concrete** assessment of the role of urban trees in affecting air quality and a **suitable selection** of tree species.

For the first time, AIRFRESH aims to:

- Quantify* the **air pollution removal by urban forests** in both cities/conurbations.

** based on in-situ data*

- Quantify* the **environmental & health benefits** provided by a new reforested test area.

** based on in-situ data*

- Propose **recommendations for reforestation policies** (e.g., number and type of tree species to be planted) for attainment of the air quality standards.

Key actions

LIFE19 ENV/FR/00086

Tree level

New Urban Forest Areas: tree species selection, planting, maintenance and data collection.

City level

Estimation & mapping of ES at city scale: AP deposition will be simulated by present forests and test areas.

Conurbation level

Scaling-up & replication: approach scaled-up at conurbation level. Transfer/replication of solutions in **follower cities**.

Assessment of benefits & Knowledge transfer to city planners.

New Forest Areas

Planting, maintenance & data collection

LIFE19 ENV/FR/00086

Proper tree selection: which plant species are more suitable to use, and which one should be avoided ?

3 co-design workshops were organized in Aix-en-Provence & Florence with representatives from both municipalities.

=> list of parameters and characteristics to be included for tree selection.

New Forest Areas

Planting, maintenance & data collection

LIFE19 ENV/FR/00086

Suitable selection of plant species = Services vs. Disservices

1) **environmental** (e.g., effectiveness in removing air pollutants; CO_2 sequestration, release of biogenic VOCs leading to O_3 formation);

2) **social** (e.g., allergenic pollen);

3) **financial** (e.g., pruning).

This list will be discussed & released to the municipality in **June 2021**.

Genus	Species	Net O3 (g/tree/day)	NO2 (g/tree/day)	PM10 (g/tree/day)	CO2 (t/year)
Abies	*alba*	0,794	3,651	8,353	0,1095
Abutilon	*spp.*	na	0,021	0,000	0,0033
Acacia	*dealbata*	1,514	1,570	0,851	0,004
Acacia	*sp.*				
Acer	*campestre*	4,212	4,016	0,326	0,0282
Acer	*japonicum*	na	0,560	0,035	0,001
Acer	*monspessulanum*	na	2,040	0,147	0,0003
Acer	*negundo*	9,232	9,274	0,884	0,0871
Acer	*platanoides*	26,040	24,355	2,580	0,0805
Acer	*pseudoplatanus*	26,124	24,355	2,580	0,0935
Acer	*rubrum*				
Actinidia	*spp.*	na	0,381	0,017	0,0033
Aesculus	*hippocastanum*	26,899	22,474	0,914	0,1223
Ailanthus	*altissima*	8,652	8,614	0,380	0,019

Genus	Species	Carbon stored	Pollen allergenicity	Ozone sensitivity	Drought tolerance	P&D tolerance
Abies	*alba*	1	2	3	3	3
Abutilon	*spp.*					
Acacia	*dealbata*	0				
Acacia	*sp.*	0	2	3	3	2
Acer	*campestre*		1	3	3	2
Acer	*japonicum*					
Acer	*monspessulanum*					
Acer	*negundo*	1	1	2	3	1
Acer	*platanoides*	4	2	2	2	3
Acer	*pseudoplatanus*	3	2	2	2	1
Acer	*rubrum*		1	1	2	3
Actinidia	*spp.*					
Aesculus	*hippocastanum*		2	1	2	1
Ailanthus	*altissima*	1	2	1	3	3
Albizia	*julibrissin*	1	3			
Alnus	*cordata*	3	1	2	2	3
Alnus	*glutinosa*	3	1	3	2	3

1 Tilia cordata
2 Tilia platyphyllos
3 Aesculus hippoc.
4 Tilia x europaea
5 Quercus cerris
6 Cedrus libani
7 Carpinus betulus
8 Sophora japonica
9 Cedrus atlantica
10 Celtis australis

AIRFRESH

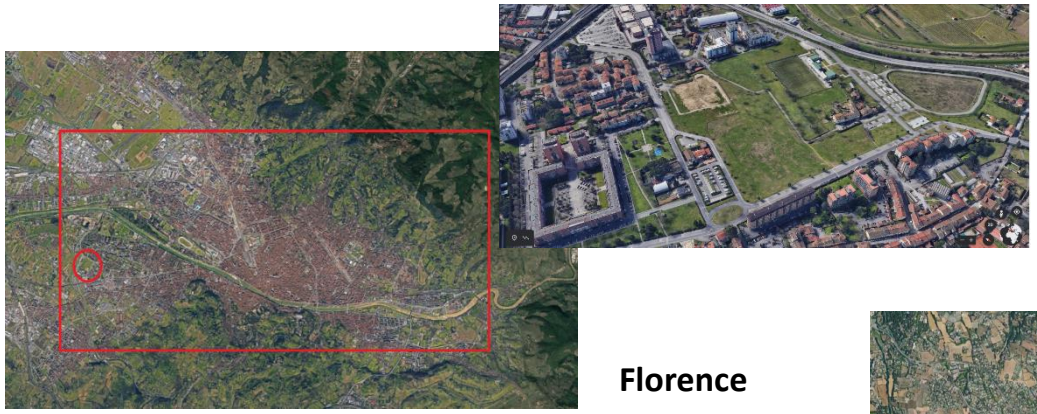
New Forest Areas

Planting, maintenance & data collection

LIFE19 ENV/FR/00086

Planting & maintenance (January - March 2022)

Based on the suitable tree species, at least **400 fast-growing trees** (mixed species, > 2 m tall) will be planted in both areas (spacing 5x5m, i.e., 1-ha).



Florence

Aix

New Forest Areas

Planting, maintenance & data collection

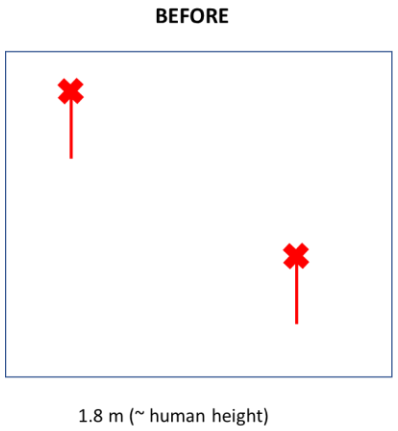
LIFE19 ENV/FR/00086

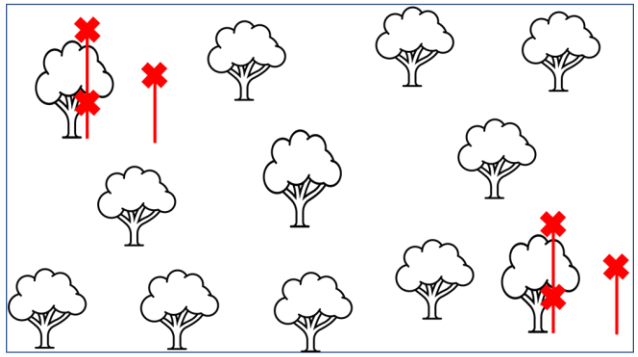
Field campaigns to estimate the benefits

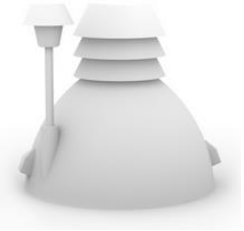
Direct contribution of both test areas in AP abatement ($PM_{2.5}$, PM_{10}, NO_2, O_3, & CO_2) will be evaluated by 4 x **10-day measurement campaigns** in & around the area, above & below the canopy, **before & after tree planting**.

Air temperature & relative humidity will be measured by sensors.

Biodiversity in soil environments - Environmental DNA - Micro- (bacteria, fungi) and macro-organisms (e.g., invertebrates, plants).







AIRQINO air aware

Estimation and Mapping of ES at city scale

LIFE19 ENV/FR/00086

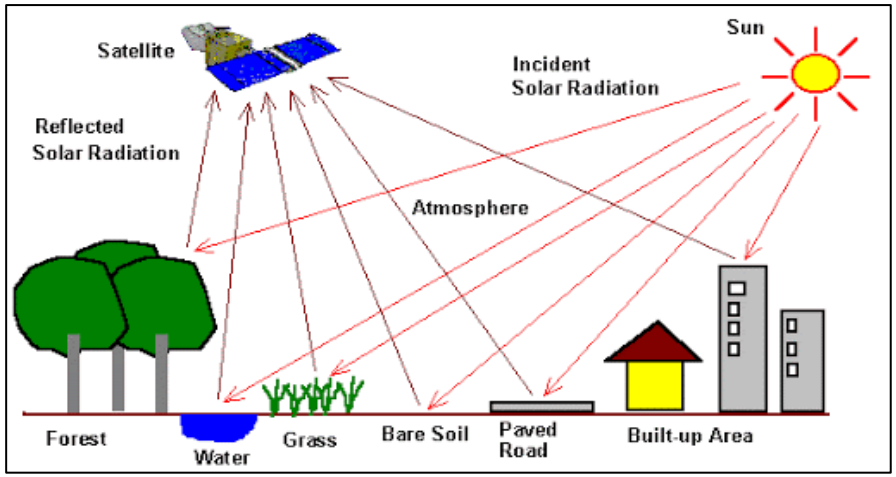
Urban tree distribution & classification

Realistic & proper quantification = **consistent tree inventory** at city scale is needed.

Tree inventories of both cities = “public” trees i.e., 15-20% of the total number.

=> avoid a **large underestimation** of the AP removal capacity.

Since 2000, the new generation of satellites at **very high resolution** (e.g., WorldView-2, Pléiades) allows identifying individual tree crowns at fine scale.



AIRFRESH

Individual Urban Trees
from Very High-Resolution Satellite Images

LIFE19 ENV/FR/00086

Geo-located UF characteristics from **Pleiades (50cm) & Worldview (30cm) images** by spectral & textural classification & tri-stereo.

Step 1 Detection, location & tree species.

Step 2 Structure variables: tree height, LAI, DBH, crown diameter.

Step 3 Field campaigns vs. Remote Sensing (validation).

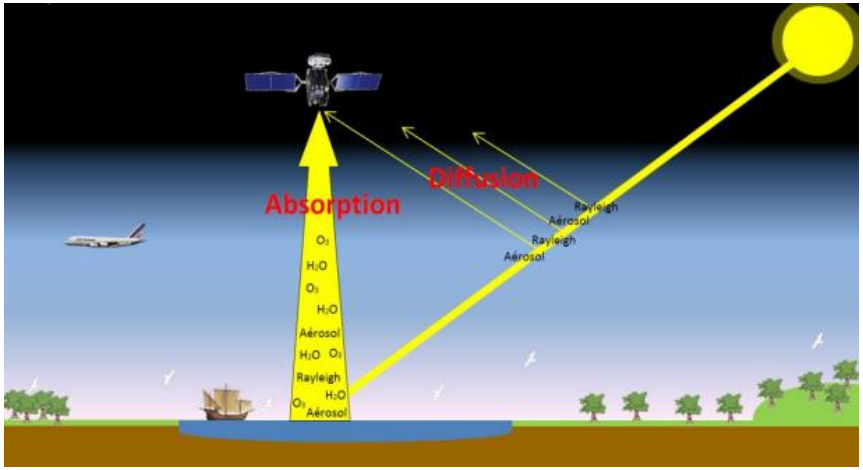
Step 4 Quantification of AP removal capacity.

Mapping of tree species in Florence (28 tree species)

Mapping of canopy cover in Aix-en-Provence

Detection & species classification

Bottom-of-atmosphere



Atmospheric correction

Tree species classification

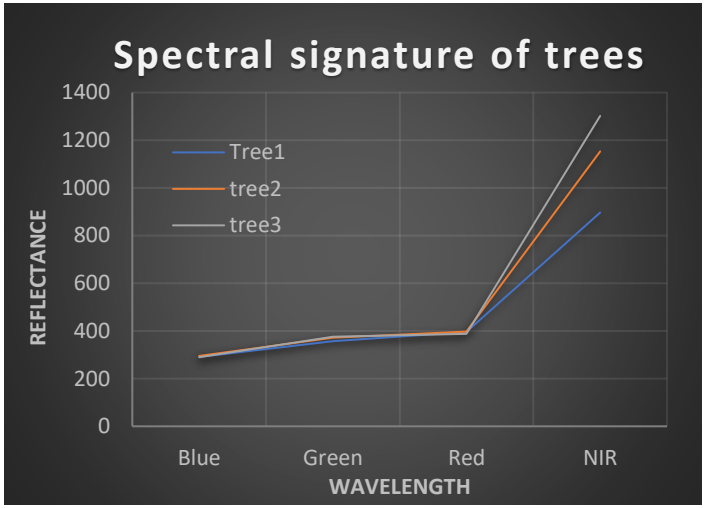
AIRFRESH

LIFE19 ENV/FR/00086

- Winter vs Summer or deciduous vs Evergreen

Summer

Winter



$$NDVI = \frac{NIR-R}{NIR+R}$$

Outputs of NDVI classification (area in ha)

Methodology	Study area	Summer	Winter	Broadleaves
Classification with NDVI	7,200	3,511	2,949	562
Bottalico et al. (2017)	10,200	1,064		700

Tree species classification

LIFE19 ENV/FR/00086

Species	Acer campestre	Celtis	Platanus	Prunus Dome
Genus	acer	celtis	platanus	prunusDo
Leaves (yes=1, no=0)	1	1	1	1
Latitude X_c	677278,9	677914,6	679753,8	677041,9
Longitude Y_c	4850918,2	4850305,2	4848830,6	4849551,9
Mean	442,4615	415,9213	540,7962	705,9059
Standard deviation	117,64817	61,0721	140,2895	115,8303
Dissimilarity	29,2504	19,7239	40,6051	31,9250
Corrélation	0,933599	0,913626	0,926803	0,931319
Energy	1789,4726	653,4891	2866,3472	1813,7250
Contraste	0,045305	0,051043	0,030626	0,046020
Homogeneity	0,028516	0,035455	0,031962	0,040805
Second Order Moment	0,000813	0,001257	0,001021	0,001665
NDVI	0,726791	0,727576	0,562106	0,319009

AIRFRESH

Tree species classification

LIFE19 ENV/FR/00086

Mapping of main tree species in Florence (x 28 tree species)

Tree species classification

AIRFRESH

LIFE19 ENV/FR/00086

✓ Textural classification provides more information

Methodology	Textural (this study)	Spectral (this study)	Bottalico *et al.* (2017)	Public tree inventory
Area of study (ha)	7200	7200	10200	-
Area of forest cover (ha)	1080	1080		236,5
Number of trees	345 312		-	75 672
Deciduous	651,65	562	580,0	133,2
Evergreen	199,55		24,9	41,3
Coniferous	229,33		54,3	49,9
Mixed Forests			404,7	-

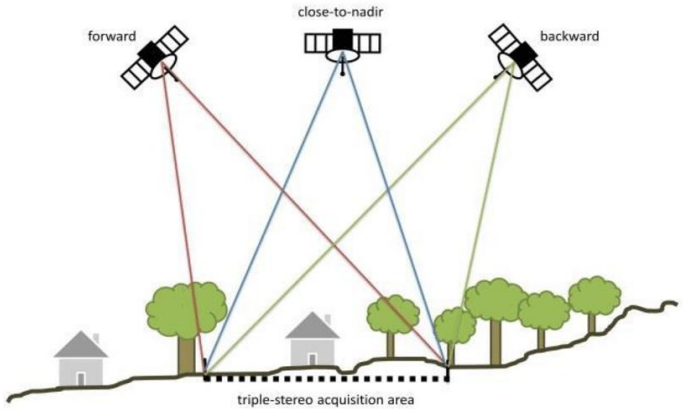
Species	Area covered (ha)
Acer	75,0
Aesculus	27,5
Cedrus	63,0
Celtis	42,9
Cupressus	37,2
Ligustrum	147,7
Magnolia	20,2
Olea	23,0
Pinus halepensis	50,4
Pinus pinea	178,9
Platanus	197,1
Populus	19,1
Prunus sp	17,4
Prunus dome	1,4
Quercus	32,6
Robinia	55,1
Tamarix	3,8
Thuja	6,1
Tilia	11,9
Ulmus	64,4
Zelkova	5,6
TOTAL	1080,5

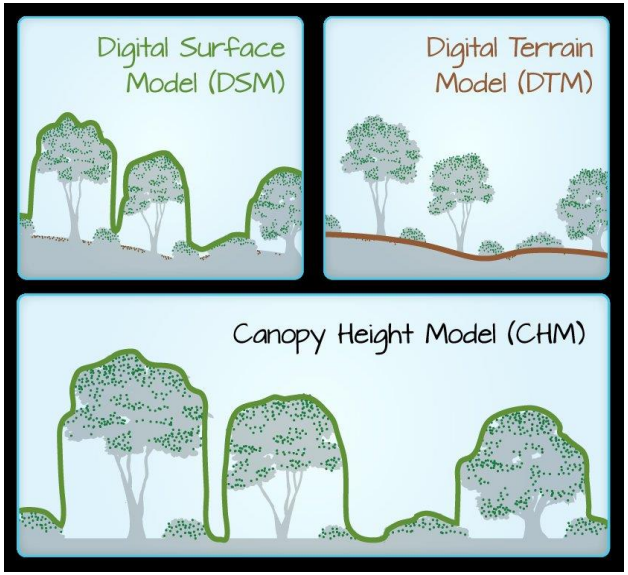
Canopy Height Model

AIRFRESH

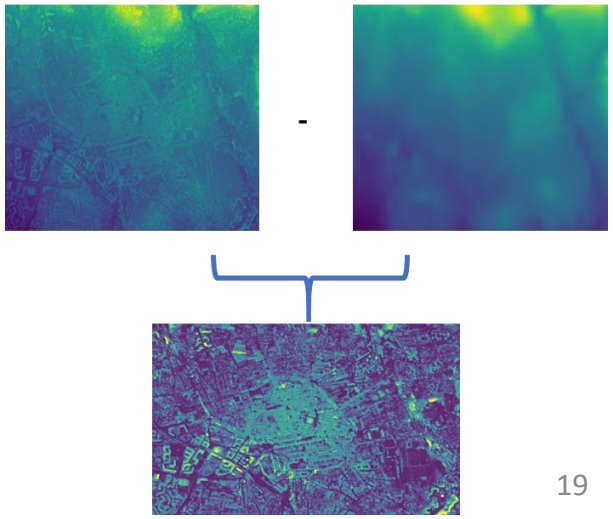
LIFE19 ENV/FR/00086

- 3 angles of view -> **Tri-stereo images**





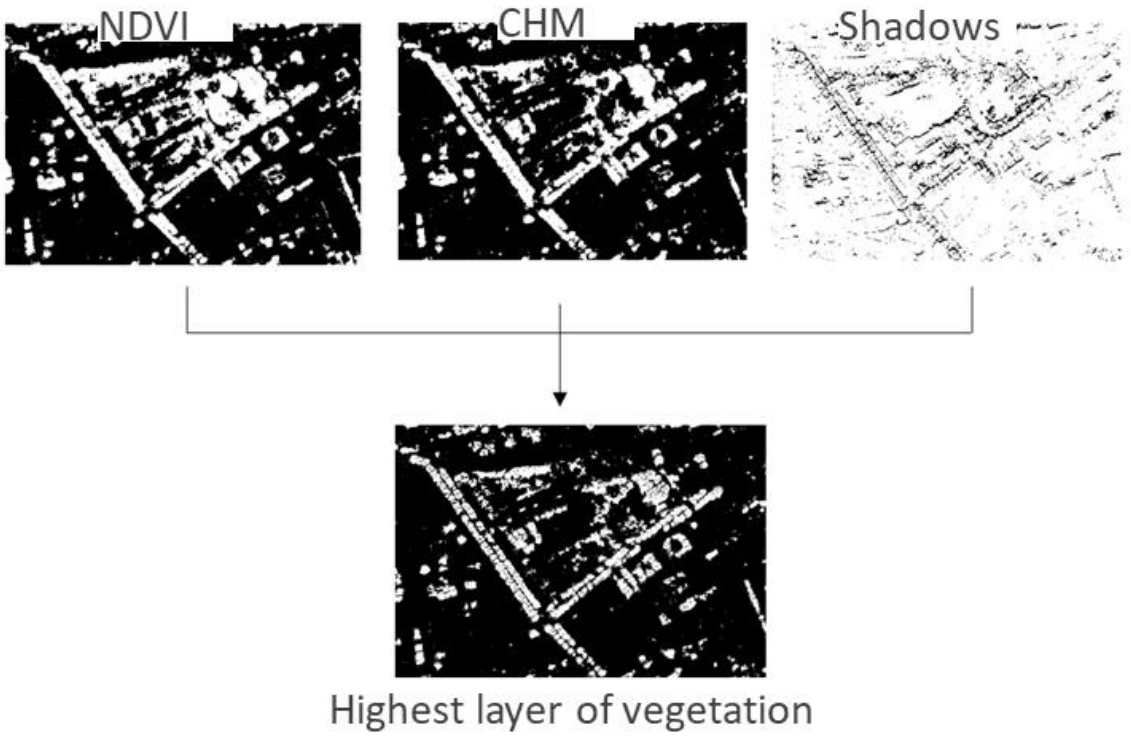
DSM - **DTM** = CHM



Canopy Height Model

LIFE19 ENV/FR/00086

Extraction of the highest layer of vegetation



Classification by threshold

- NDVI mask
- CHM mask
- Shadows mask

Tree height estimation

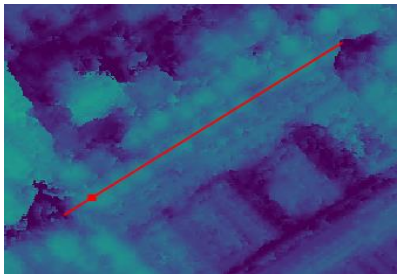
AIRFRESH

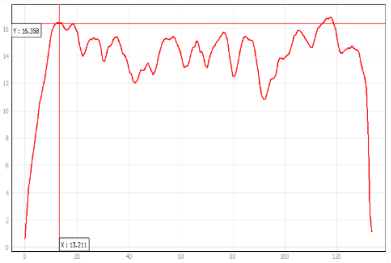
LIFE19 ENV/FR/00086

Peaks detection by **local maxima filter** = > Each peak is associated to the height of the tree.

Tree peaks in city

Profil of tree heigth along a boulevard

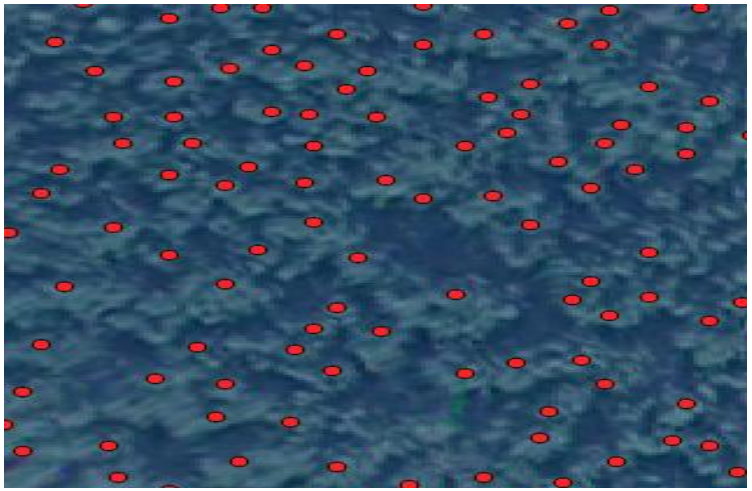




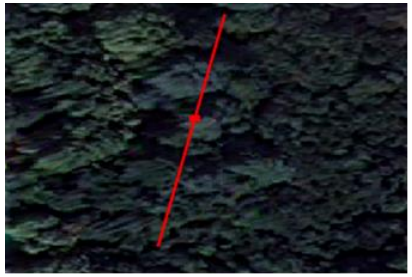
Tree height estimation

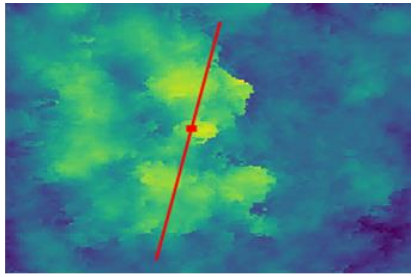
LIFE19 ENV/FR/00086

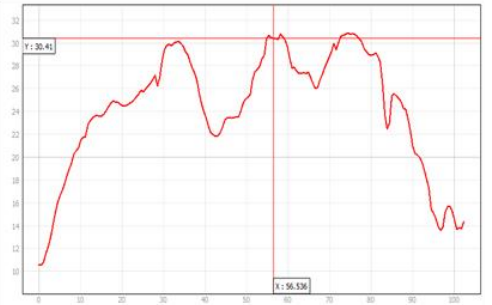
Dense vegetated area: domiant tree height can be identify.



Tree peaks in forest





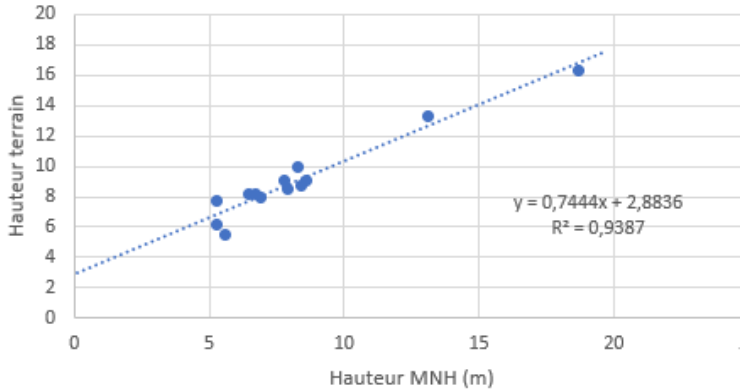


Tree height estimation - Validation

AIRFRESH

LIFE19 ENV/FR/00086

- **Input data:** Field measurements with smartphone application & hypsometer
- **Mean squared error:** 1.0 m
- **Sources of errors :**
  - Accuracy of tree height measurement
  - Accuracy of the DTM (70cm)



In situ measurements

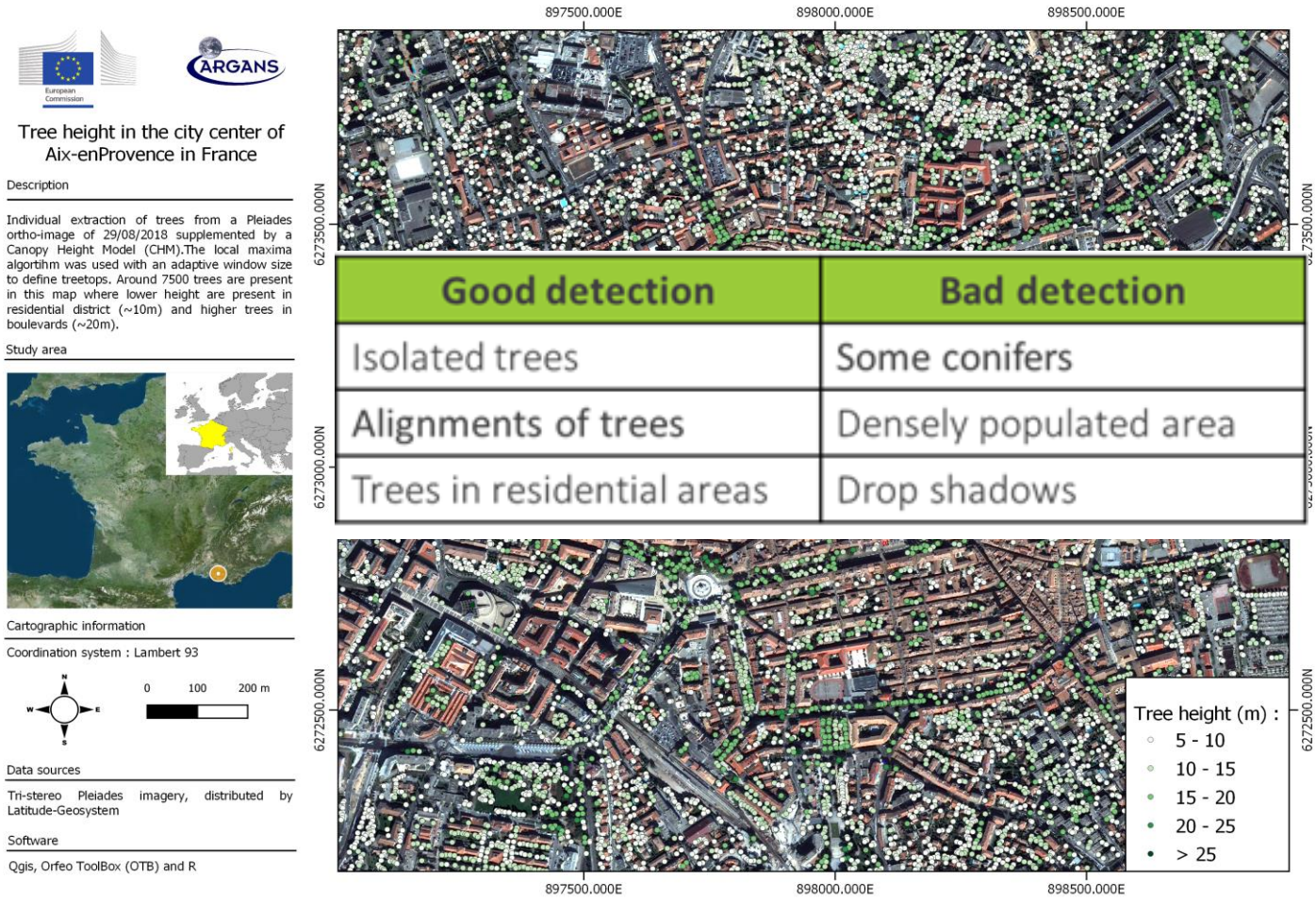
Tree height estimation

AIRFRESH

LIFE19 ENV/FR/00086

Study area : 30 km²

Total : 150,000 dominant trees



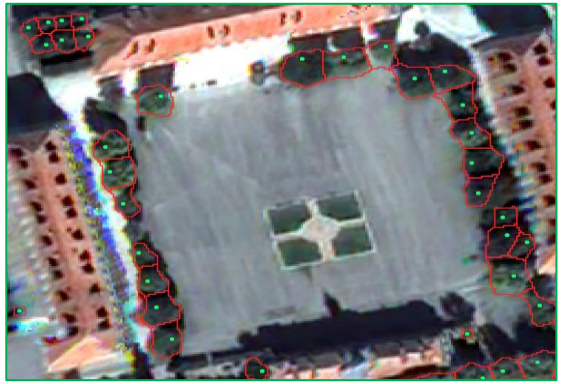
Delineation of individual tree crowns

AIRFRESH

LIFE19 ENV/FR/00086

Segmentation by « Region growing»

Segmentation technique to group pixels or groups of pixels. Starting with some seed pixels, the neighboring pixels are examined 1 by 1 and added to the growth region if their predefined properties are similar to those of the seeds.



Mapping of canopy cover in Aix-en-Provence

Quantification & mapping of benefits

LIFE19 ENV/FR/00086

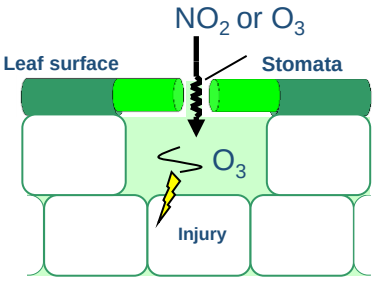
The **annual removal** of $PM_{2.5}$, PM_{10}, NO_2, CO_2 and O_3 by UF and peri-UF will be quantified & mapped at city scale **before** & **after** reforestation.

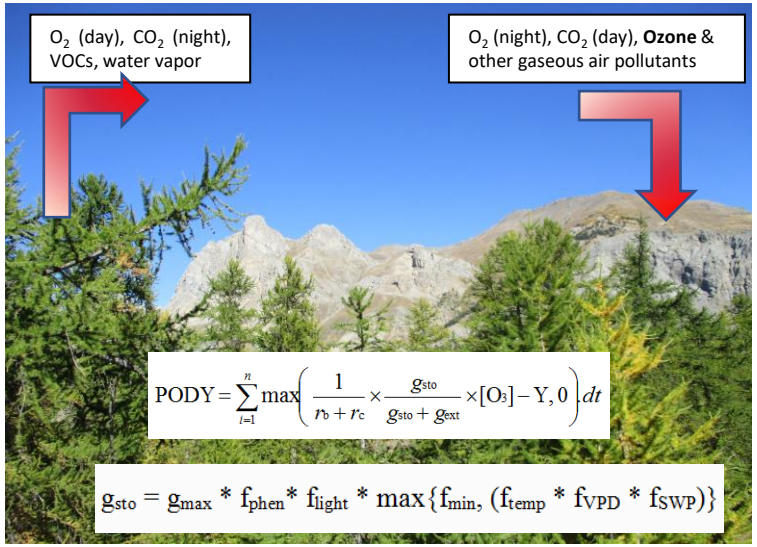
Deposition $Q = V_d \times C \times LAI \times T$

Q = amount removed on 1m² of leaf surface (µg m^{-2}), V_d = deposition velocity, C = concentration (µg m^{-3}), LAI (m^2 m^{-2}) and T (s) = vegetative period.

O_3 & NO_2 absorption - Gaseous pollutants

Stomatal & non-stomatal.





Carbon stock & CO_2 equivalent estimation - Biomass model CO2FIX incl. DBH, tree height and the covered area.

Cooling effect - Based on the Pennman-Monteith evapotranspiration equation.

Scaling-up & replication

LIFE19 ENV/FR/00086

Estimation & Mapping of ES at conurbation scale

From 2023, the core activities will be upscaled from city to conurbation scale.

The **vegetation** will be detected (delineation), categorized as forest categories from satellites images (Sentinel-2, Sentinel-3).

The annual removal of PM, NO_2, CO_2 and O_3 & carbon stock by each forest category will be quantified and mapped.

Replication activities

Know-how transfer & replication in Zagreb from 1st January 2024.

Follower cities e.g., Bucharest in Romania; Birzai, Kretinga, Kupiškis, Rokiskis, Vilkaviskis & Vilnius in Lithuania.

AIRFRESH

Quantification of benefits

LIFE19 ENV/FR/00086

Baseline conditions (2019, ~~2020~~). Before reforestation & after reforestation, and by 2030.

Air quality & climate benefits - Based on field measurements & modelling at city & conurbation scales. CO_2 & O_3 classified as "*Short-Lived Climate Forcer*"

Ecological benefits - **Singapore Index** on Biodiversity to evaluate the progress of biodiversity: greenness, environmental DNA, pollinators, etc.

Health benefits of cleaner air - AirQ+ model (WHO) to estimate the short–term health effects due to AP exposure: mortality & morbidity.

Economic valuation of cleaner air - Monetary benefits of "avoided" premature deaths and hospital admissions, attributed to the reduction of AP after reforestation. Concept of "value of a statistical life".

Core Components		Indicators	Maximum Score
Native Biodiversity in the City	1.	Proportion of Natural Areas in the City	4 points
	2.	Connectivity Measures	4 points
	3.	Native Biodiversity in Built Up Areas (Bird Species)	4 points
	4.	Change in Number of Vascular Plant Species	4 points
	5.	Change in Number of Bird Species	4 points
	6.	Change in Number of Butterfly Species	4 points
	7.	Change in Number of Species (any other taxonomic group selected by the city)	4 points
	8.	Change in Number of Species (any other taxonomic group selected by the city)	4 points
	9.	Proportion of Protected Natural Areas	4 points
	10.	Proportion of Invasive Alien Species	4 points
Ecosystem Services provided by Biodiversity	11.	Regulation of Quantity of Water	4 points
	12.	Climate Regulation: Carbon Storage and Cooling Effect of Vegetation	4 points
	13.	Recreation and Education: Area of Parks with Natural Areas	4 points
	14.	Recreation and Education: Number of Formal Education Visits per Child Below 16 Years to Parks with Natural Areas per Year	4 points
Governance and Management of Biodiversity	15.	Budget Allocated to Biodiversity	4 points
	16.	Number of Biodiversity Projects Implemented by the City Annually	4 points
	17.	Existence of Local Biodiversity Strategy and Action Plan	4 points
	18.	Institutional Capacity: Number of Biodiversity Related Functions	4 points
	19.	Institutional Capacity: Number of City or Local Government Agencies Involved in Inter-agency Co-operation Pertaining to Biodiversity Matters	4 points
	20.	Participation and Partnership: Existence of Formal or Informal Public Consultation Process	4 points
	21.	Participation and Partnership: Number of Agencies/Private Companies/NGOs/Academic Institutions/International Organisations with which the City is Partnering in Biodiversity Activities, Projects and Programmes	4 points
	22.	Education and Awareness: Is Biodiversity or Nature Awareness Included in the School Curriculum	4 points
	23.	Education and Awareness: Number of Outreach or Public Awareness Events Held in the City per Year	4 points
		Native Biodiversity in the City (Sub-total for indicators 1-10)	**40 points**
		Ecosystem Services provided by Biodiversity (Sub-total for indicators 11-14)	**16 points**
		Governance and Management of Biodiversity (Sub-total for indicators 15-23)	**36 points**
		Maximum Total:	**92 points**

World Health Organization

Main expected results

LIFE19 ENV/FR/00086

Environmental benefits

Each reforested area will remove annually **3.0 tons O_3, 2.5t NO_2, 1.5t PM_{10}, 0.8t $PM_{2.5}$, 10t CO_2,** ambient air **2° C cooler** compared to surrounding area, increase **carbon stocks** (2t per ha).

Socio-economic benefits

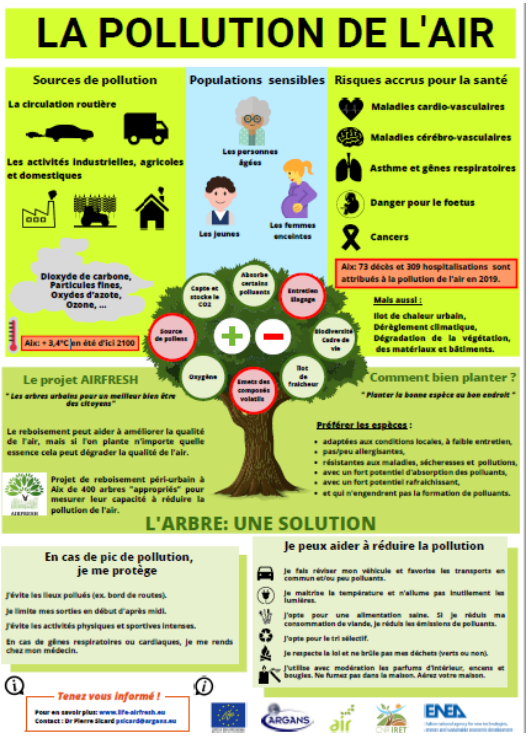
With the above AP reduction, **3 premature deaths & 12 hospital admissions** for respiratory and cardio-vascular diseases will be averted annually, i.e., a minimum benefit for healthcare of **€9.1 million each year** from 2024.

Communication

LIFE19 ENV/FR/00086

Educational activities

Education of citizens about the good practices for a cleaner air in cities & for a better citizens' well-being by displaying A3 boards in doctor's waiting rooms in Aix & Florence. The target is **240,000 people reached**.



Public events

In 2022, we will organize a **Tree Planting ceremony**, and support the **godfathering** of a tree: **100 trees** will be planted by citizens in private gardens.

Air Pollution & Plants Conference

11-15 October 2021, Paphos (Cyprus)

www.cyprus2021.com

Session 2. Urban green: sinks or sources of air pollution and climate change