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Urban tree ecosystem revitalization in the face of climate change

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The functioning and vitality of organisms

- **The functioning of organisms refers to the life of organisms.**

It represents the occurrence of all functions and processes within the organisms themselves or in the environment in which they live.

From this concept, the production function of forests and the general beneficial functions of forests have been derived in forestry, and more recently, ecosystem services in the field of environmental protection

- **The functioning of all organisms on Earth, including urban trees, occurs within ecosystems.**

Organisms never live or function alone, but are always connected to their living and non-living environment.

- **The best indicator of the functioning of organisms in ecosystems is the vitality of organisms.**

Vitality comes from the Latin word "vitae," which means life, or from the English word "vitality," which means to be strong and active. The vitality of organisms refers to their liveliness, life force, life ability, vigor, and resilience.

The functioning of urban tree ecosystems

- **The functioning of urban trees refers to the life of those trees.**

It represents the performance of all functions and processes within the organisms themselves or in the environment in which they live. From this concept, the production function of forests and the general beneficial functions of forests have been derived in forestry, and more recently ecosystem services in the field of environmental protection.

- **The functioning of urban trees takes place within the ecosystems of urban trees.**

Organisms never live or function alone, but are always connected to their living and non-living environment.

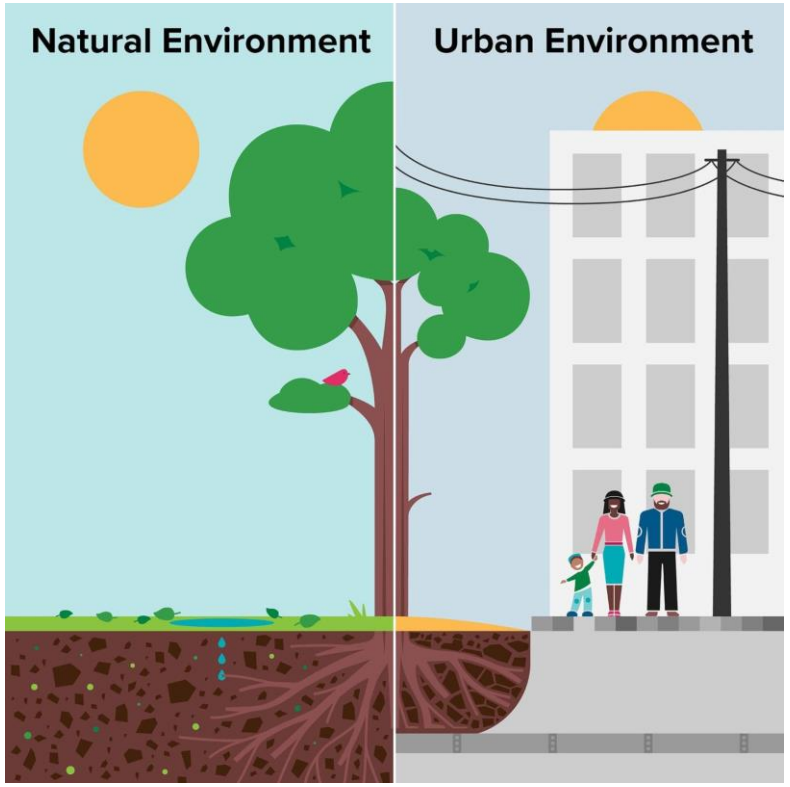
- **The vitality of forest trees is the ability to live in certain living conditions.**

The ability to perform their life functions such as reproduction, growth (height, diameter, volume), development (aboveground and underground organs), physiological processes, and reproduction, resistance to unfavorable biotic and abiotic factors, and the ability to adapt to changes in living conditions.

- **The vitality of urban trees encompasses the ability to thrive, perform all life functions in urban areas, withstand unfavorable living conditions, and adapt to changing circumstances.**

Urban trees problems

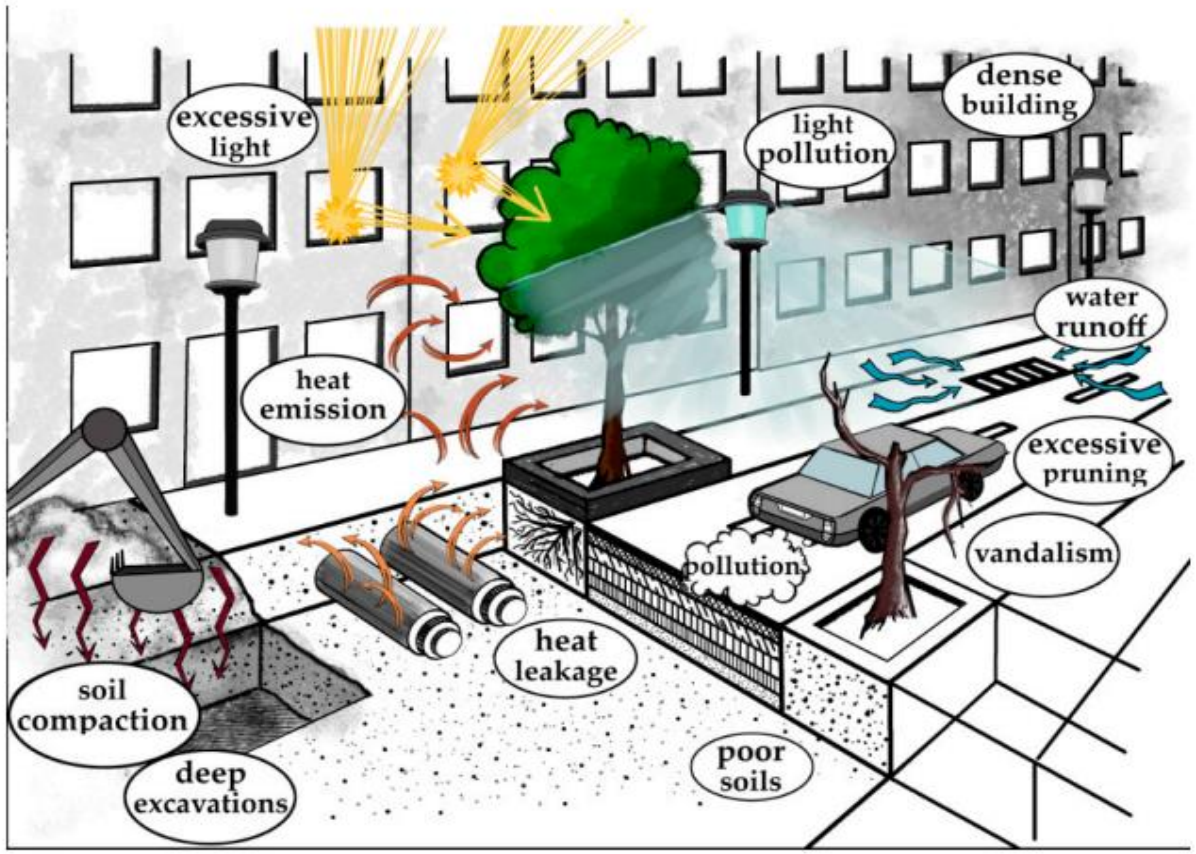
- **Urban trees can be found in various types of green infrastructure**, such as urban forests, park forests, tree-lined streets, or individual trees.
- They often **develop in unfavorable living conditions**, which negatively impacts their vitality, growth, development, and ability to provide general ecosystem functions and services.
- **The main problems faced by urban trees are the lack of space for growth and soil compaction**. All of this reduces their ability to absorb water and nutrients and hampers the life processes in the soil around the roots of urban trees.
- Another problem for urban trees is the **disruption of the formation of the humus organic horizon of the soil,** which is important for the development of micro and meso-fauna in the soil and microorganisms that provide nutrients for urban trees. This problem arises due to grass mowing and removal, as well as the removal of leaf litter under the canopy of urban trees for aesthetic reasons.
- **The development of urban trees is also hindered by planting them in infertile soils** along roads and parking lots, as well as planting them in small planting pits with little soil and nutrients.



https://cities4forests.com/

Urban trees development issues

- **The space for aboveground and underground growth** of urban trees is often limited by urban infrastructure.
- **The space for normal root system development is often insufficient**, making it difficult for trees to access the necessary nutrients and water from the soil.
- **Mechanical damage to the trunk** and other aboveground, as well as underground parts of the tree, is often present.
- **Increasing air temperatures, pollution of rainfall, and insufficient rainfall** in summer months cause stress in urban trees, leading to growth stagnation, canopy damage, and dieback.
- **Large amounts of salt, contaminated water, and other harmful substances reach the soil**, resulting in numerous problems for the root system, and therefore, the tree itself.
- Any unfavorable change in one of the **habitat factors** leads to greater or lesser stress in trees.
- **As a result, the vitality of urban trees decreases**, and pests and fungi develop on them.
- **The most common morphological indicators of reduced tree vitality are**: branch damage and dieback, canopy dieback, thinning of the entire canopy or top parts of the canopy, and leaf and needle drop.

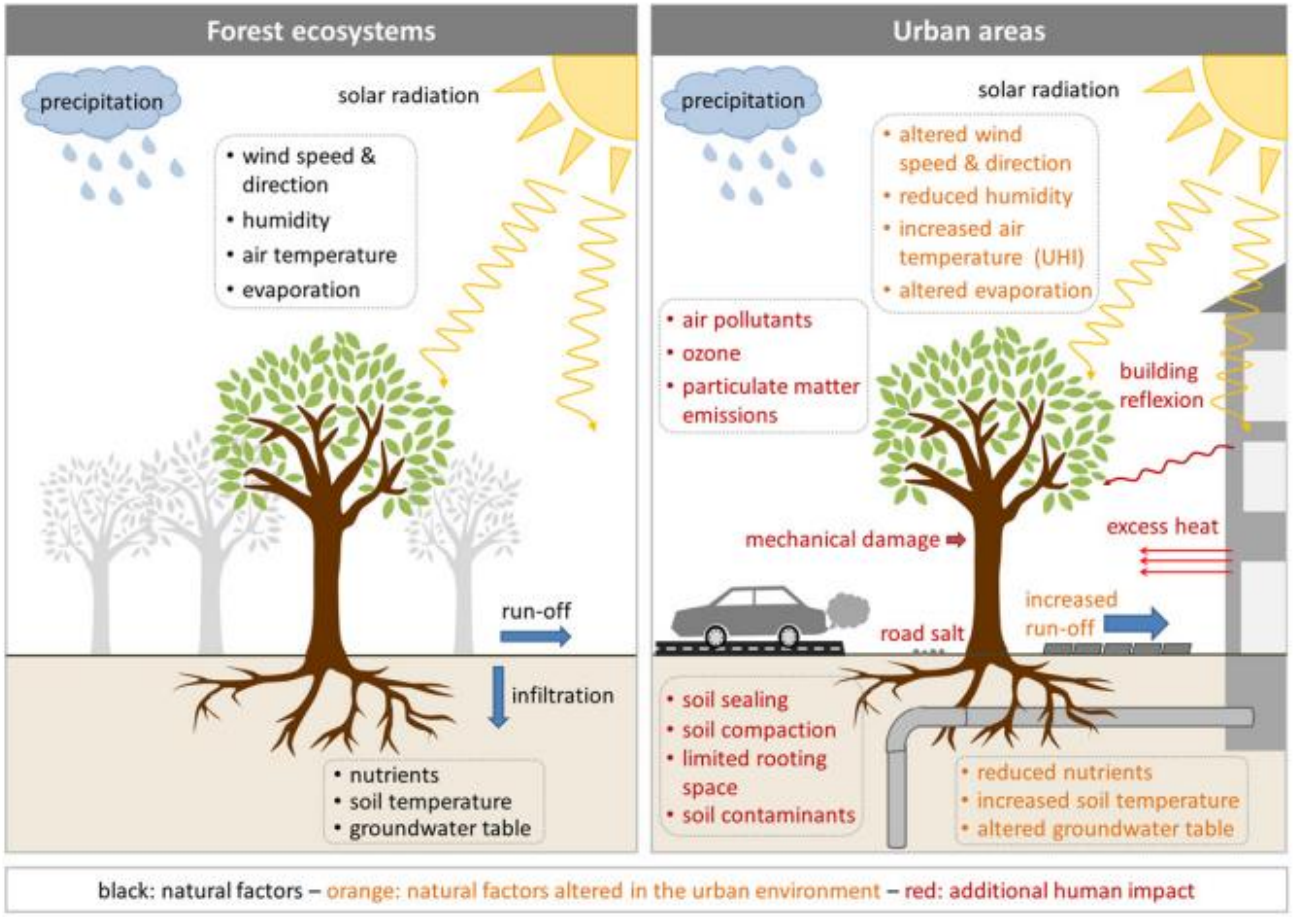


Source: Czaja, M., et al., 2020. The Complex Issue of Urban Trees-Stress Factor Accumulation and Ecological Service Possibilities. Forests, 11, 932.

Enhancing the vitality of urban trees through the revitalization of urban tree ecosystems

Urban tree ecosystem revitalization through biological and ecological renaturalization of ecosystems involves:

1. **Restoring the natural composition of dead organic** matter in the soil
2. **Adding nutrients** to the soil
3. **Improving** the physical, chemical, and biological **properties of the soil**
4. **Ecological irrigation** of urban trees
5. **Creating a favorable microclimate** around urban trees
6. **Protecting the optimal space for urban trees**.



Source: Brune, M., 2016. Urban trees under Climate change. Potential impacts of dry spells and heat waves in three german regions in the 2050's. Report 24, Climate Service Center Germany, Hamburg.

Eco-friendly irrigation for urban trees

The principles of ecological irrigation of urban trees are as follows:

1. **Irrigation is carried out in the ecosystem of urban trees** during periods of insufficient rainfall.

2. **The irrigation is done on the soil surface** beneath which the rhizosphere of urban trees is located.

3. The amount of water for irrigation **is equal to the natural amount of rainfall** per unit area over a long-term period.

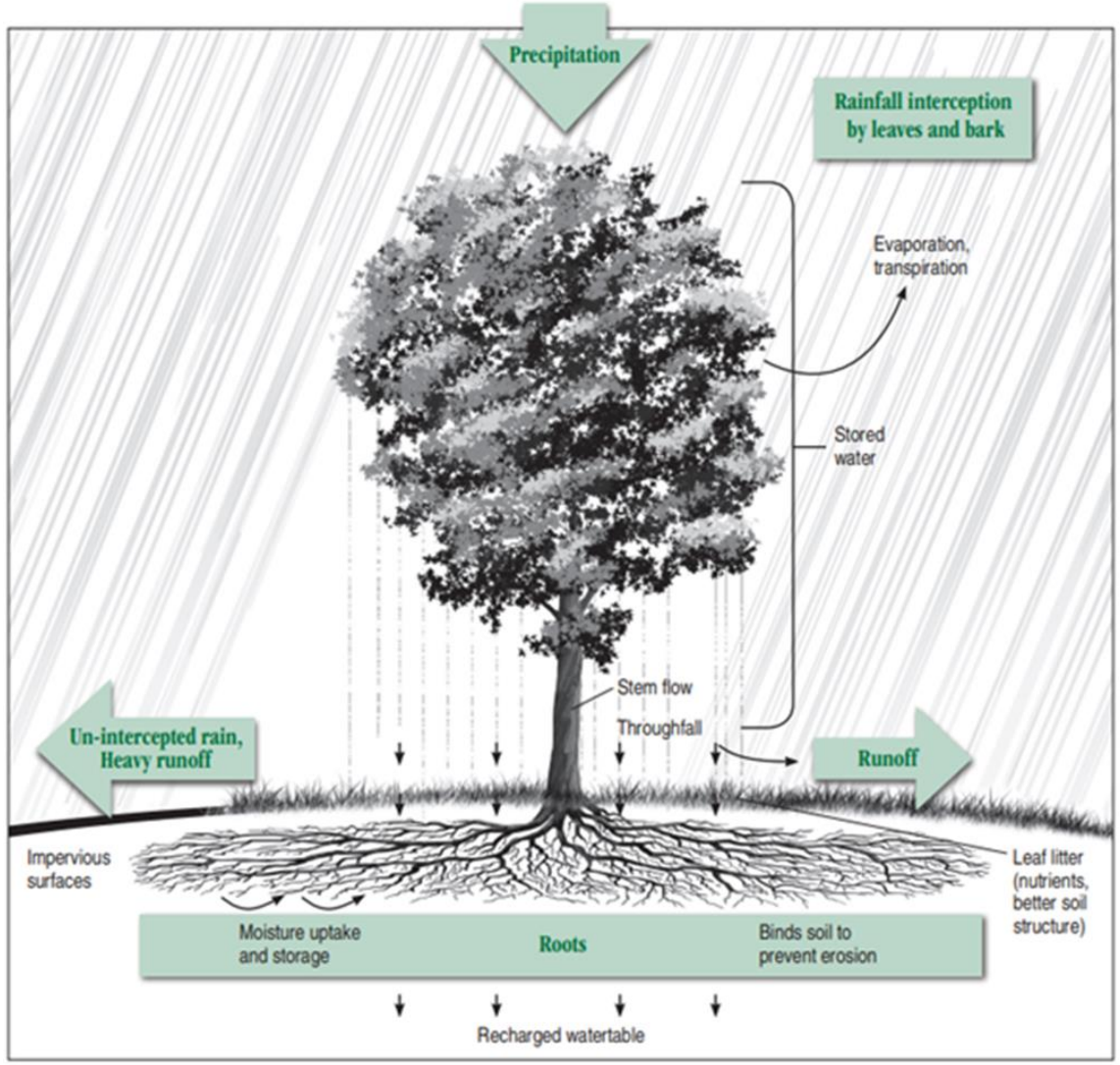
4. The soil is **irrigated to the depth of optimal root development**.

5. **The volume of soil is irrigated to the depth of optimal root development.**

6. The irrigation of the soil is done **with a specific dynamic** that corresponds to the optimal water-air conditions in the soil.

7. Irrigation is done with **rainwater.**

8. Irrigation is done by **spraying the entire tree.**



Trees help reduce stormwater runoff in several ways. One is to intercept falling rain and hold a portion of it on the leaves and bark. Part of this intercepted water will evaporate and part will be gradually released into the soil below. At the surface of the soil, fallen tree leaves help form a spongy layer that moderates soil temperature, helps retain soil moisture, and harbors organisms that break down organic matter and recycle elements for use in plant growth. This important layer also allows rain water to percolate into the soil rather than rushing off carrying with it oil, metal particles and other pollutants. Below ground, roots hold the soil in place and absorb water that will eventually be released into the atmosphere by transpiration.

Source: How Trees Can Retain Stormwater Runoff. Tree City USA Bulletin, No. 55, 2010, Arbor Day Foundation

Urban tree revitalization pilot project using Herbafertil® and eco-friendly irrigation techniques

- **Tree revitalization is one of the professional measures in urban forestry that can improve the disturbed vitality of trees**.
- By properly caring for trees and improving habitat conditions, the unfavorable **vitality of urban trees can be greatly enhanced**, increasing their aesthetic, ecological, and social value.
- **Revitalizing trees through habitat improvement is the most effective and favorable measure** that enables the survival of trees of all ages, prolongs their lifespan, reduces the costs of care, removal, preparation for planting, and planting new trees, as well as accelerates the restoration of functions and benefits.
- While we may not be able to influence some habitat factors of urban trees, **we can control the amount of water and nutrients** they receive.

Hypothesis: Trees can be revitalized through proper irrigation based on ecological principles and the application of suitable nutrients.

Pilot project

In this project, the revitalization of three urban trees in Zagreb was carried out. **Two lime trees** near the Faculty of Agriculture of the University of Zagreb and **one catalpa tree** near the Faculty of Forestry and Wood Technology of the University of Zagreb were revitalized. The aim of the project was to improve the current vitality of the trees using **the soil enhancer Herbafertil®**, along with the application of ecological irrigation, in order to increase the availability of nutrients and water and enhance the overall vitality of the trees.

Urban tree revitalization of low vitality

- **Trees with low vitality were selected for tree revitalization** based on morphological indicators.
- **The vitality of the trees was compromised by dry branches** without foliage and several mistletoe in the tree canopy. Other factors that could negatively affect the tree's condition, such as the proximity of a concrete path, compacted soil due to pedestrians, and poor canopy condition, were also observed.
- **The condition of the trees before and during the implementation of revitalization measures was documented through photographs** to compare the indicators of tree condition and determine the effectiveness of the revitalization measures.
- The project commenced in April 2022 when the trees were fully leafed out, **numerous dry branches were observed, and these trees did not appear to be vital individuals**.

Eco-friendly irrigation in a pilot project for the revitalization of urban trees using Herbafertil® and ecological irrigation

- Calculation of water quantity for eco-friendly irrigation
- Sampler for volume measuring of water

Water replenishment occurs on a weekly basis, following the principles of ecological irrigation.

Adding nutrients in the pilot project for revitalizing urban trees using Herbafertil® and ecological irrigation

- Nutrient addition to the soil was achieved through an innovative technique of incorporating **the soil enhancer Herbafertil®** beneath the tree canopies.
- **8 bags of Herbaferti®l were placed around each tree, within the root system in the canopy projection area**, taking care not to harm roots thicker than 2 cm. The spots where the soil enhancer was integrated are indicated by flags.

Soil enhancer HERBAFERTIL®

- **Herbafertil® is a patented soil enhancer** that has been developed and refined through years of planting practice and successful horticultural care of trees and shrubs.
- **It is obtained by mixing different nutrient organo-mineral components**. This is a blend of natural humus-peat-mineral components that act quickly and effectively to increase the vitality of urban trees.
- **The positive results** obtained through its application have surpassed all previous commercial planting substrates.

REPUBLIKA HRVATSKA
DRŽAVNI ZAVOD ZA INTELEKTUALNO VLASNIŠTVO

SEKTOR ZA PATENTE

KLASA: UP/I-381-03/14-010/0358
URBROJ: 559-03/2-17-026/SŠ
Broj konsenzualnog patenta: PK20140358

Zagreb, 18. siječnja 2017.

Državni zavod za intelektualno vlasništvo na temelju članka 15. stavka 1. Zakona o patentu ("Narodne novine", broj 173/03., 87/05., 76/07., 30/09., 128/10., 49/11. i 76/13.), povodom prijave patenta podnositelja: HERBAFARM-MAGNOLIJA d.o.o., Trnsko 23, 10000 Zagreb, radi priznanja konsenzualnog patenta, donosi

R J E Š E N J E

1. Usvaja se zahtjev za priznanje konsenzualnog patenta po prijavi broj P20140358A, podnesenoj dana 16. travnja 2014. godine, za izum pod nazivom: MJEŠAVINA ZA KOMBINIRANU ORGANSKU-ANORGANSKU PRIHRANU I BIOLOŠKU SANACIJU STABLAŠICA, GRMOVA I PENJAČICA I POSTUPAK KORIŠTENJA MJEŠAVINE, prema opisu, crtežima i patentnim zahtjevima navedenim u spisu konsenzualnog patenta broj PK20140358.

Priznato pravo upisuje se u Registar patenata Državnog zavoda za intelektualno vlasništvo pod brojem

PK20140358

nositelj konsenzualnog patenta: **HERBAFARM-MAGNOLIJA d.o.o.,** Trnsko 23, 10000 Zagreb, HR

s oznakom MKP: ***C05G 3/04*** (2006.01)
C05G 3/06 (2006.01)
A01C 21/00 (2006.01)

izumitelji naznačeni u prijavi: **Darija Breitenberger,** Knežija 9, 10000 Zagreb, HR;
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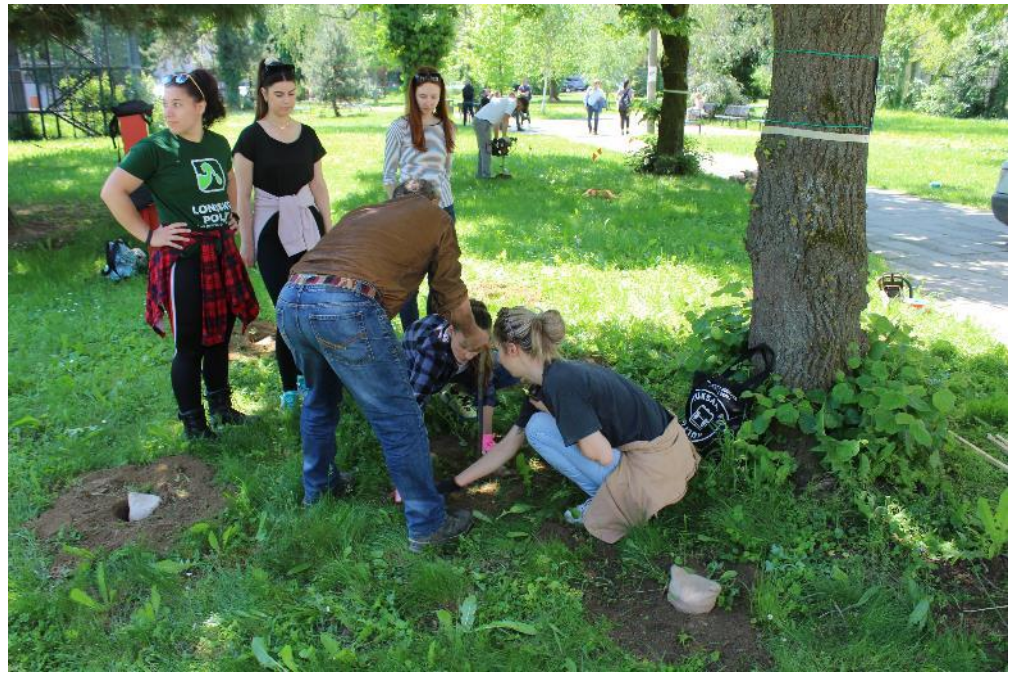
The irrigation system in the pilot project for the revitalization of urban trees using Herbafertil® and eco-friendly irrigation

- **A system of ecological micro-irrigation has been implemented for each bag of soil enhancer Herbafertil®**
- Water is delivered to each bag through tubes from 57-liter watering bags placed on the trees. Irrigation is carried out on a weekly basis.



The “Mouth of the tree”® as a result of HERBAFERTIL® implementation

1 Herbafertil® bag, when implemented, yields 6-7 kg of young roots that stimulate the healthy growth of the tree

“MOUTH OF THE TREE”

Example of successful application of Herbafertil® in Ljubljana, Slovenia in 2014.

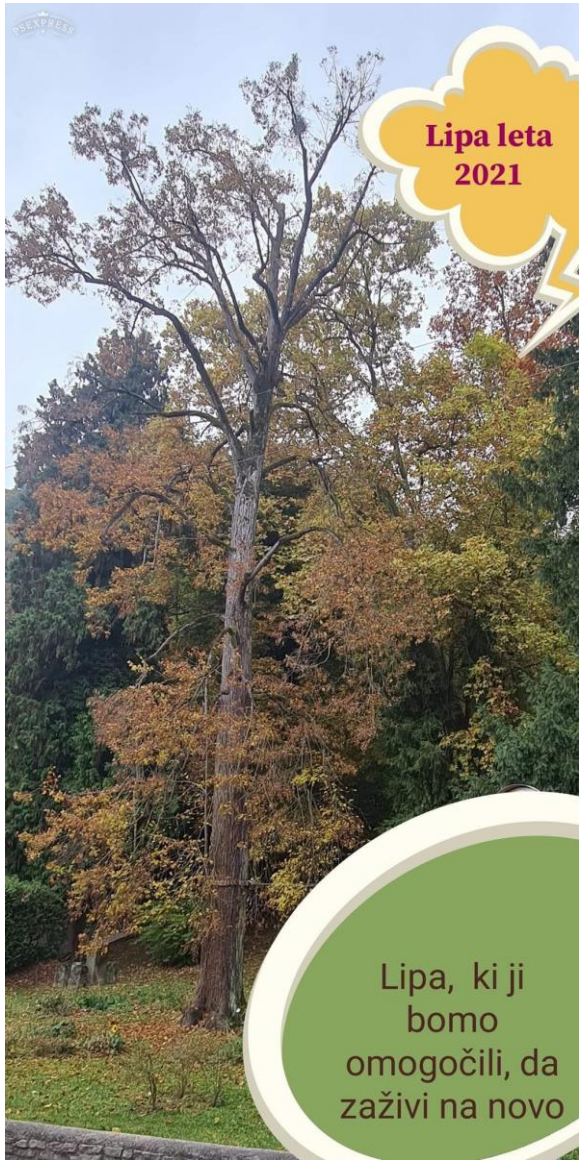
The impact of Herbafertil® on improving the quality of habitat conditions in the soil and enhancing soil microbiome was evident in the increased thickness growth over the years.

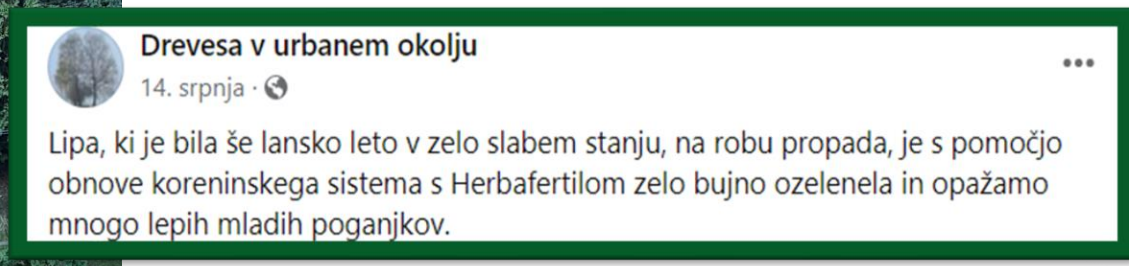
- Slovenia, Ljubljana, Barjanska Road
- **39 trees treated in 2014, while 42 were "as control trees"**
- One side of the tree-lined avenue planted at the same time with equal seedlings was treated
- Measurement carried out by the municipal company VOKA-Snaga
- The measurement is recorded in the Ljubljana tree cadastre (2014 and 2021)
- The circumference was measured in cm.

Average increase in the circumference of treated trees in the observed period from 2014-2021 was **12.84 cm**, and of the untreated trees was 9.52 cm

The difference in the increase in circumference is **3.32 cm, or 34.87%**

Example of successful application of Herbafertil® in Krško, Slovenia in 2021/2022.





The protective fence in the pilot project for the revitalization of urban trees using Herbafertil® and ecological irrigation

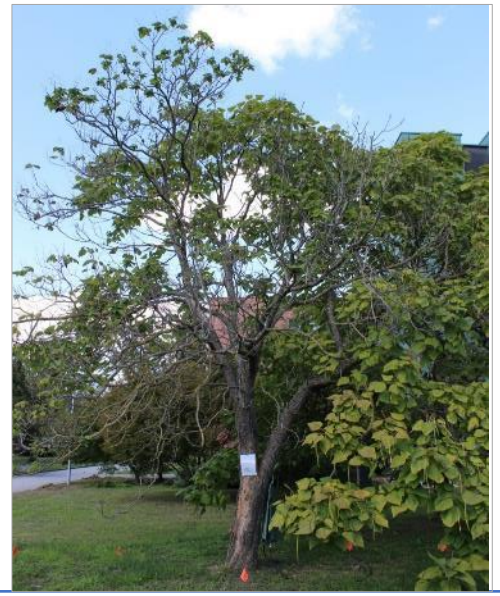
- **A protective fence has been placed around the base of the trees** in the canopy projection zone to prevent walking and mowing under the trees.
- By not mowing, soil compaction and water evaporation from the upper soil layers have been reduced, the temperature of the surface soil has decreased, and the renewal of the organic surface soil horizon has been enabled.
- **The assessment of tree vitality was conducted using a hierarchical method of assessing tree vitality based on morphological indicators of canopy condition**.

The initial outcomes of the pilot project for the revitalization of catalpa and linden trees using Herbafertil® and eco-friendly irrigation

The revitalization of the CATALPA tree canopy in front of the Faculty of Forestry and Wood Technology at the University of Zagreb will take place on the southern side from July 19, 2022, to August 29, 2023.

19. 07. 2022.

01. 09. 2022.



23. 09. 2022.

11. 10. 2022.

14. 06. 2023.

30. 06. 2023.

14. 07. 2023.

29. 08. 2023.

The revitalization of the CATALPA tree canopy in front of the Faculty of Forestry and Wood Technology at the University of Zagreb from the west side will take place from July 19, 2022, to August 29, 2023.

19. 07. 2022.

01. 09. 2022.

23. 09. 2022.

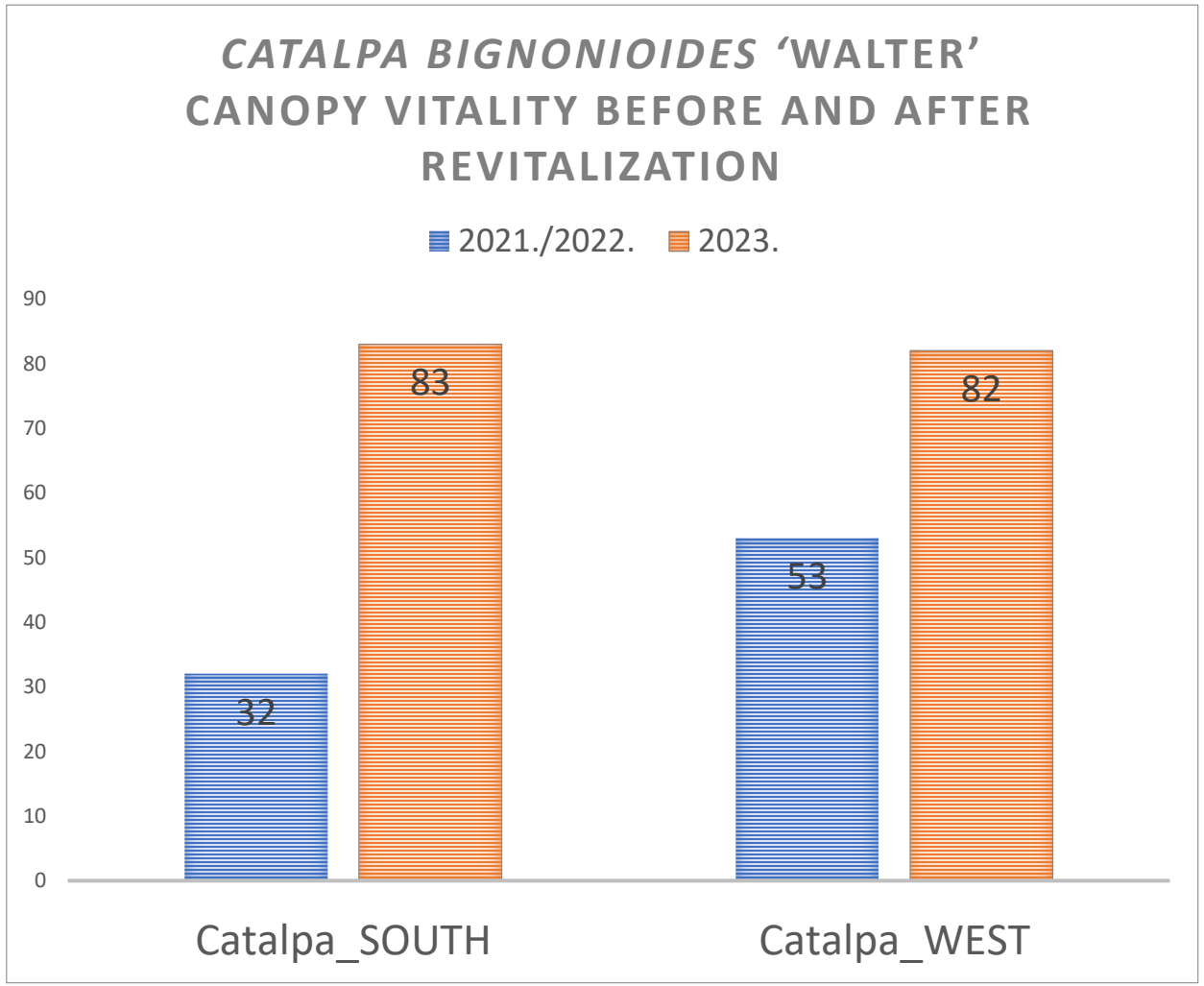
11. 10. 2022.

14. 06. 2023.

30. 06. 2023.

14. 07. 2023.

29. 08. 2023.


CATALPA BIGNONIOIDES 'WALTER'
CANOPY VITALITY BEFORE AND AFTER REVITALIZATION
2021./2022.
2023.
90
80
70
60
50
40
30
20
10
0
83
82
53
32
Catalpa_SOUTH
Catalpa_WEST

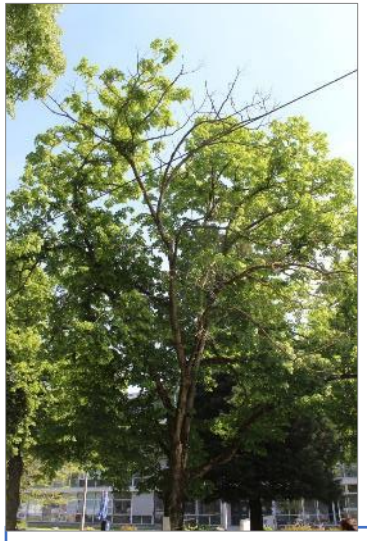
The revitalization of the lime tree canopy (1) in front of the Faculty of Agriculture at the University of Zagreb on the western side will take place from October 20, 2021, to September 1, 2023.

20. 10. 2021.

13. 07. 2022.

06. 09. 2022.

23. 09. 2022.



05. 05. 2023.

14. 06. 2023.

30. 06. 2023.

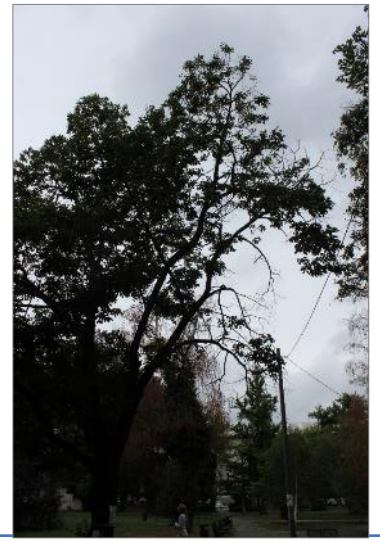
14. 07. 2023.

01. 09. 2023.

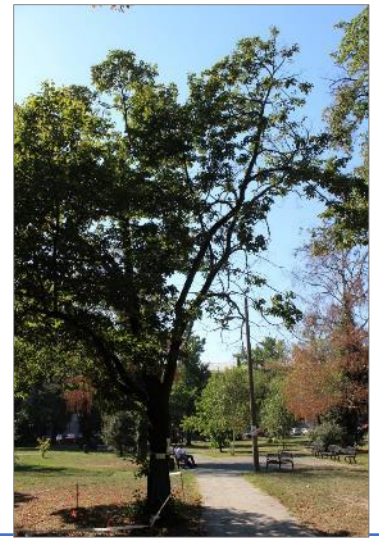
The revitalization of the lime tree canopy (1) in front of the Faculty of Agriculture at the University of Zagreb, on the north side, will take place from October 20, 2021, to September 1, 2023.

20. 10. 2021.

13. 07. 2022.

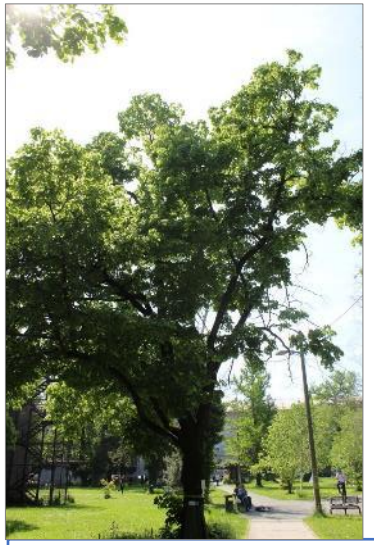


01. 09. 2022.



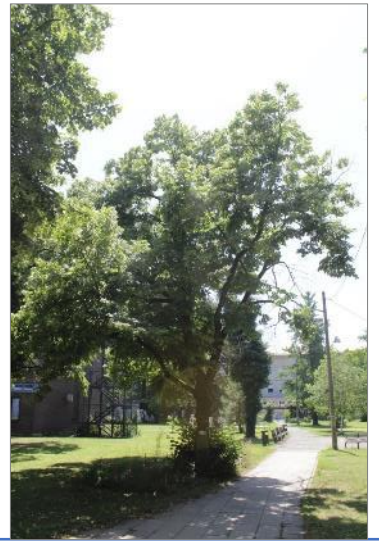
06. 09. 2022.

23. 09. 2022.



05. 05. 2023.

14. 06. 2023.



30. 06. 2023.

14. 07. 2023.

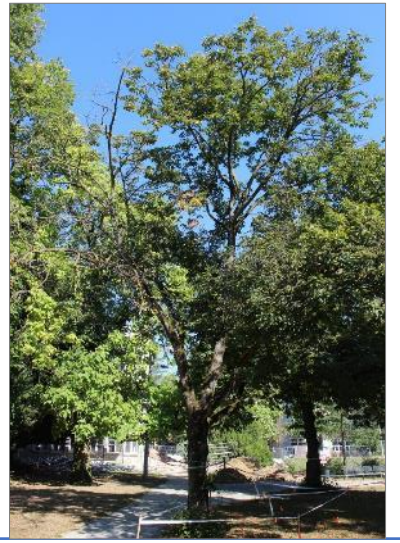
01. 09. 2023.

The revitalization of the linden tree canopy in front of the Faculty of Agriculture at the University of Zagreb on the southern side will take place from October 20, 2021, to September 1, 2023.

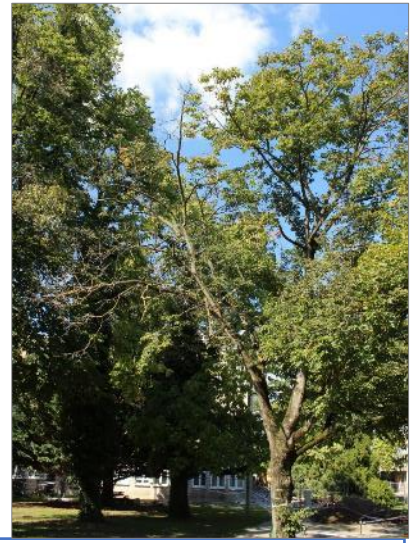
20. 10. 2021.

13. 07. 2022.

01. 09. 2022.



06. 09. 2022.



23. 09. 2022.

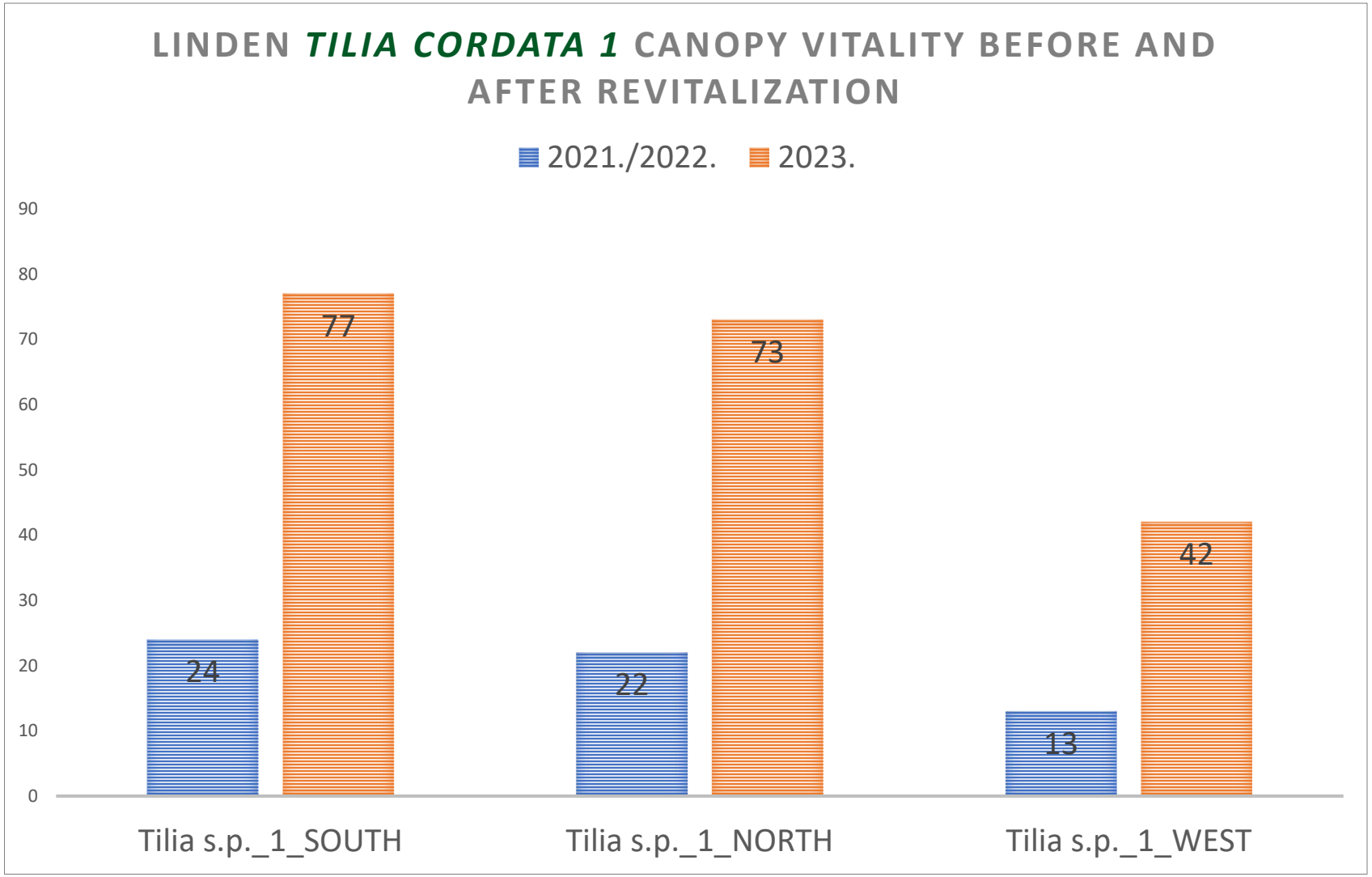
05. 05. 2023.

14. 06. 2023.

30. 06. 2023.

14. 07. 2023.

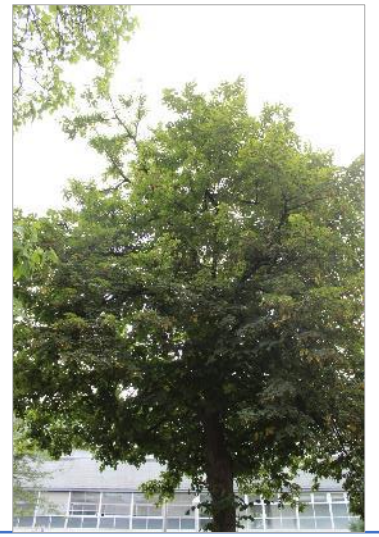
01. 09. 2023.


LINDEN TILIA CORDATA 1 CANOPY VITALITY BEFORE AND AFTER REVITALIZATION
2021./2022.
2023.
90
80
70
60
50
40
30
20
10
0
24
77
22
73
13
42
Tilia s.p._1_SOUTH
Tilia s.p._1_NORTH
Tilia s.p._1_WEST

The revitalization of the linden tree canopy (2) in front of the Faculty of Agriculture of the University of Zagreb on the western side will take place from October 20, 2021, to September 1, 2023.

20. 10. 2021.

13. 07. 2022.



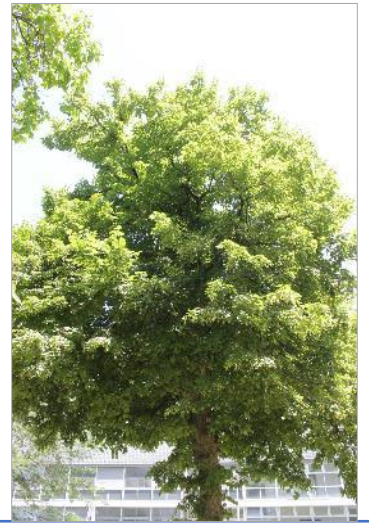
01. 09. 2022.

23. 09. 2022.

05. 05. 2023.

14. 06. 2023.

30. 06. 2023.



14. 07. 2023.

01. 09. 2023.

The revitalization of the lime tree canopy (2) in front of the Faculty of Agriculture at the University of Zagreb, on the north side, will take place from October 20, 2021, to September 1, 2023.

20. 10. 2021.

24. 06. 2022.

13. 07. 2022.

01. 09. 2022.

23. 09. 2022.

05. 05. 2023.

14. 06. 2023.

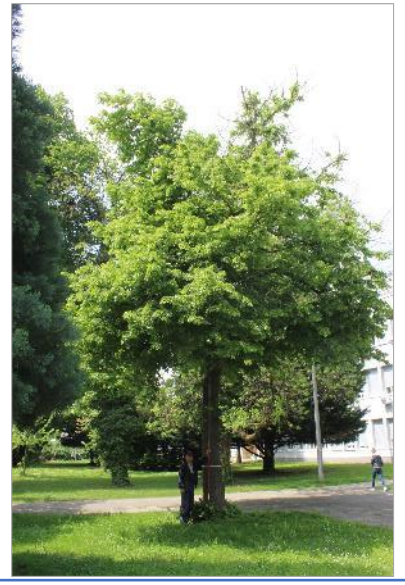
30. 06. 2023.

14. 07. 2023.

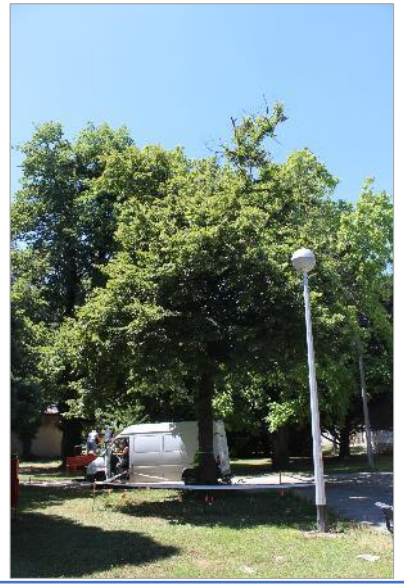
01. 09. 2023.

The revitalization of the lime tree canopy (2) in front of the Faculty of Agriculture at the University of Zagreb, on the eastern side, will take place from October 20, 2021, to September 1, 2023.

20. 10. 2021.



10. 05. 2022.



13. 07. 2022.

01. 09. 2022.

23. 09. 2022.

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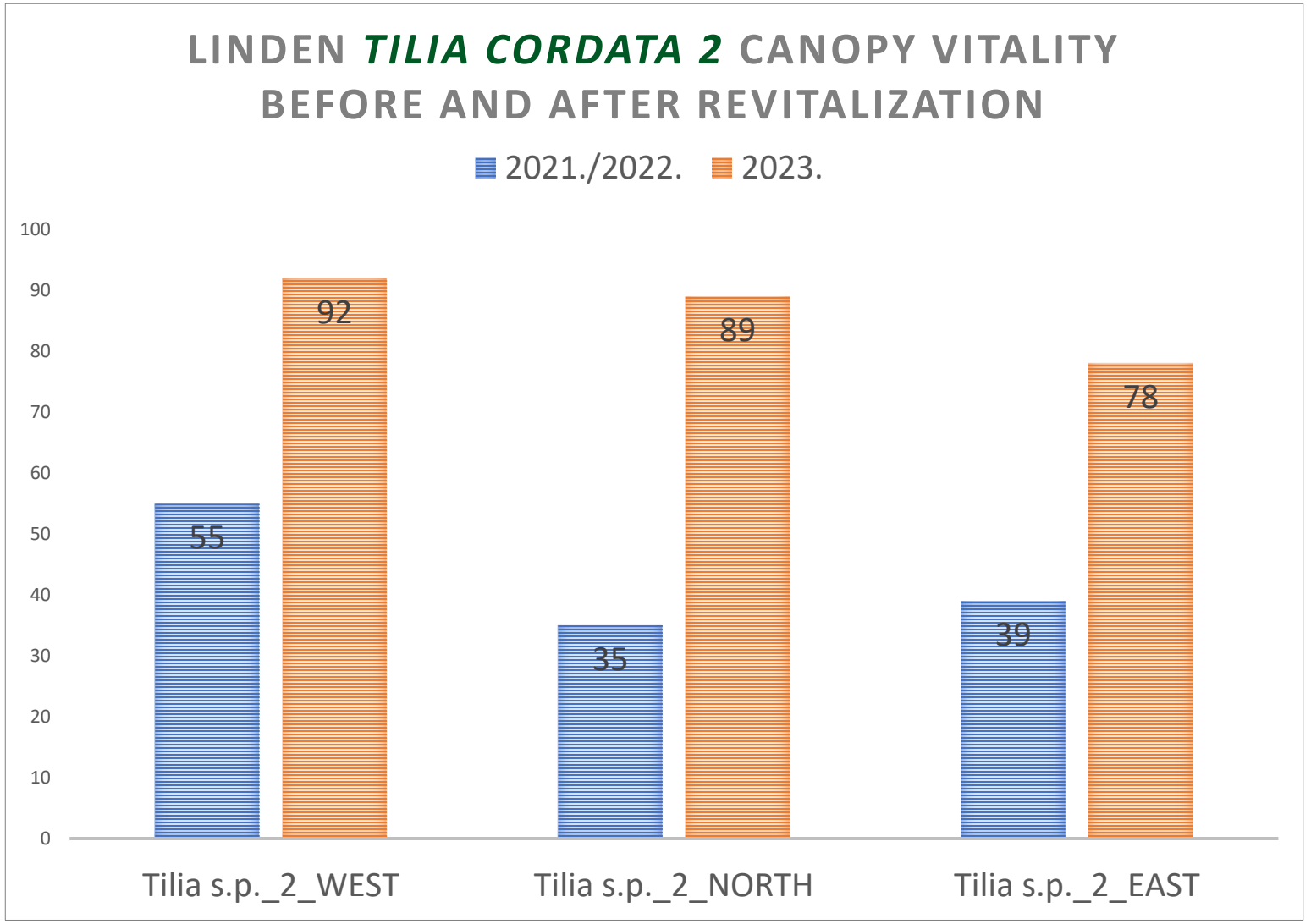
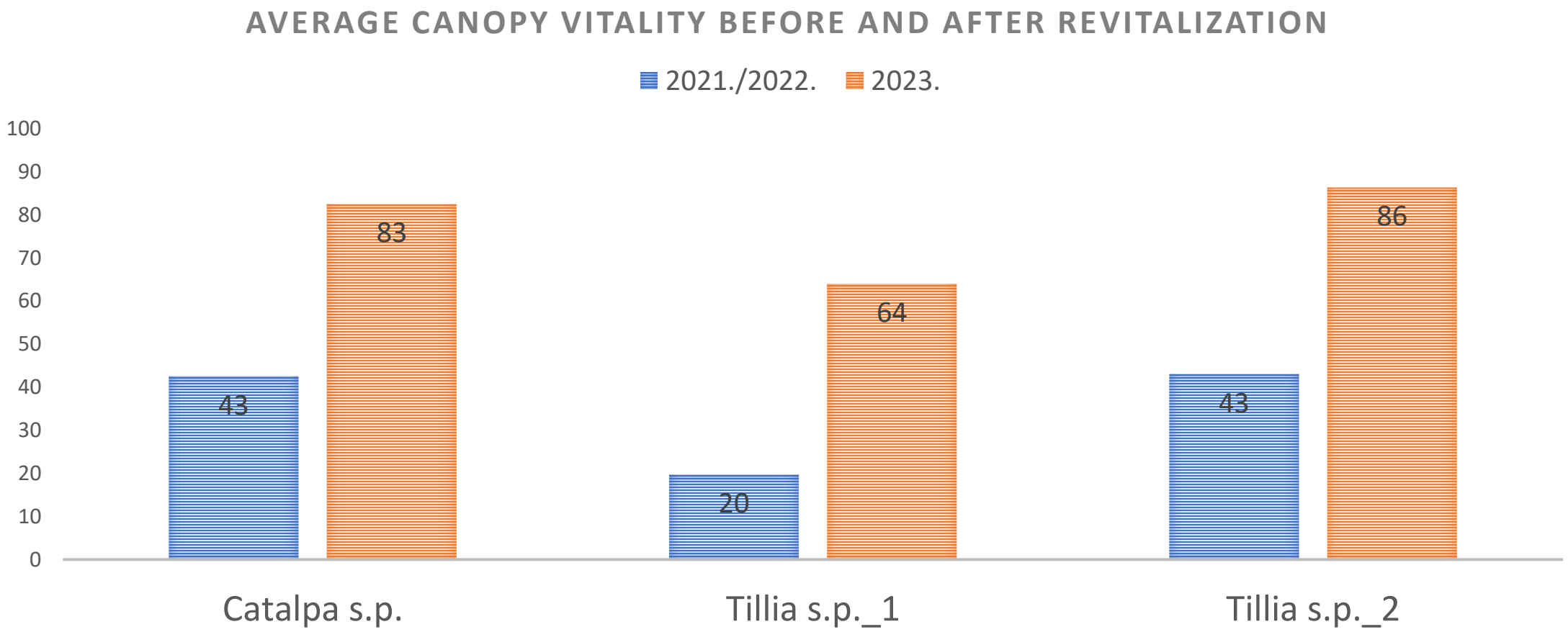
14. 07. 2023.

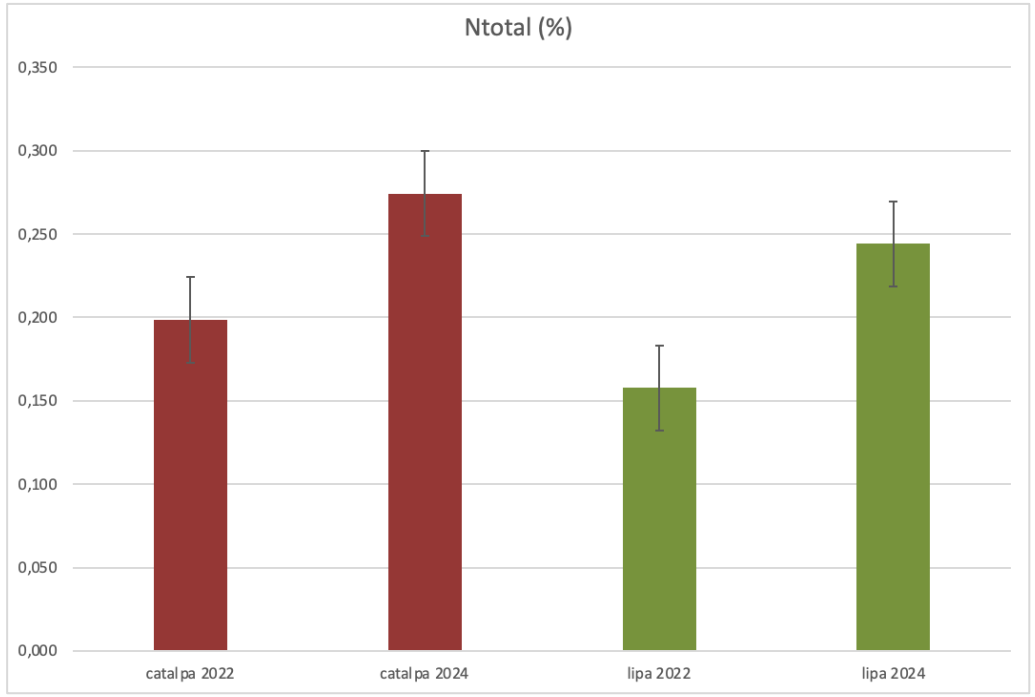
01. 09. 2023.


LINDEN TILIA CORDATA 2 CANOPY VITALITY
BEFORE AND AFTER REVITALIZATION
2021./2022.
2023.
100
90
80
70
60
50
40
30
20
10
0
92
89
78
55
35
39
Tilia s.p._2_WEST
Tilia s.p._2_NORTH
Tilia s.p._2_EAST

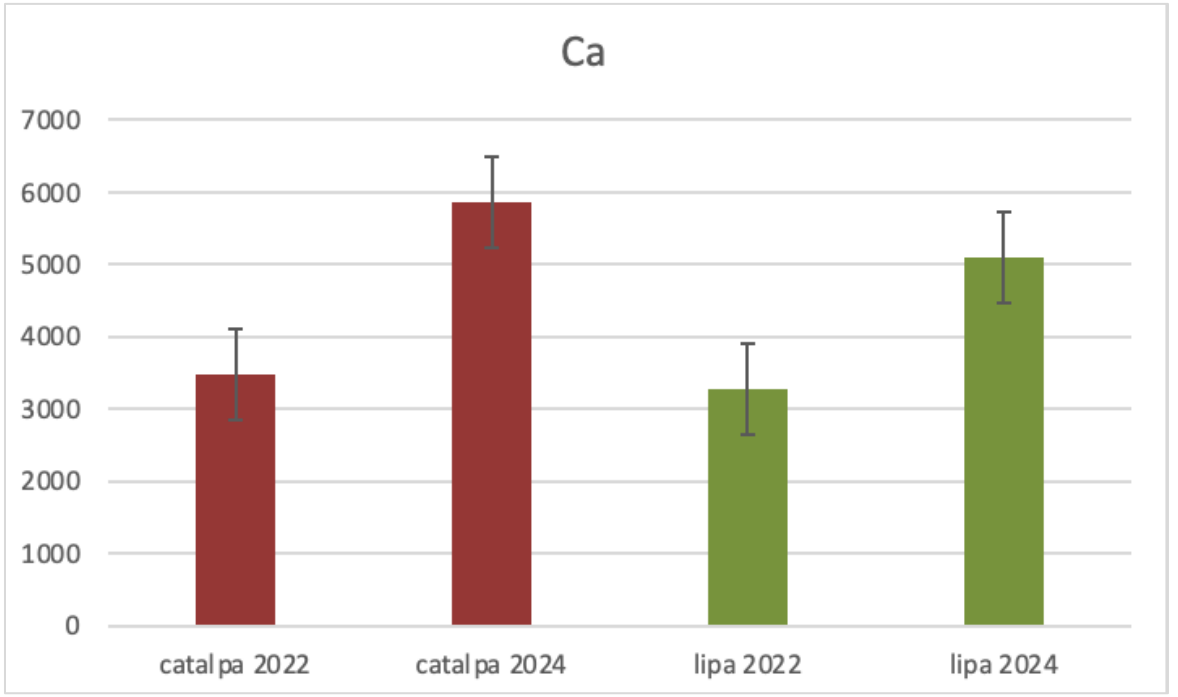

AVERAGE CANOPY VITALITY BEFORE AND AFTER REVITALIZATION
2021./2022.
2023.
100
90
80
70
60
50
40
30
20
10
0
43
83
20
64
43
86
Catalpa s.p.
Tillia s.p._1
Tillia s.p._2

The results of the pedological analysis in the pilot project for the revitalization of catalpa and linden trees

Total nitrogen content in the soil

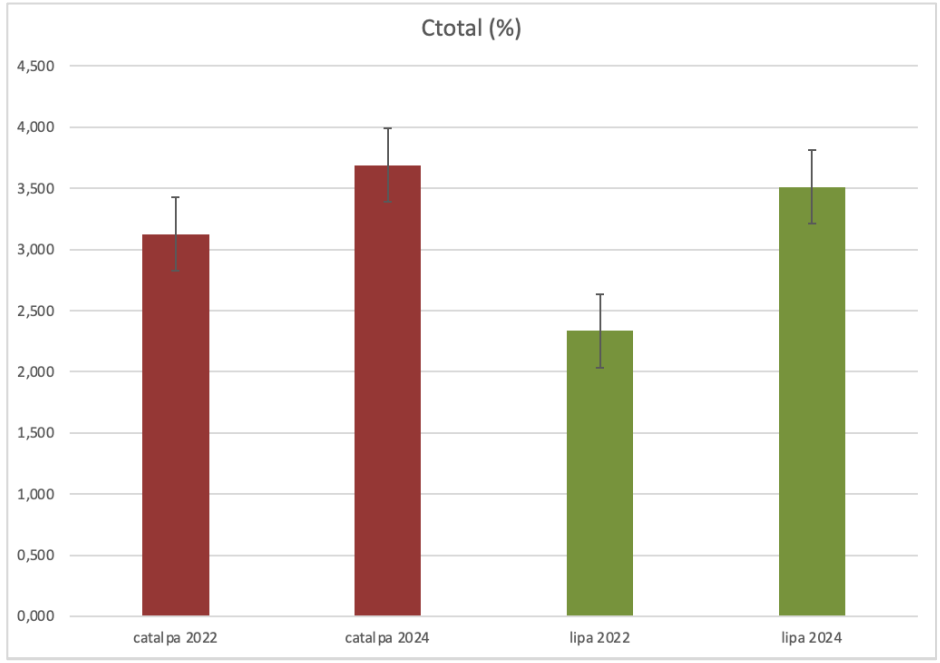


Calcium content in the soil

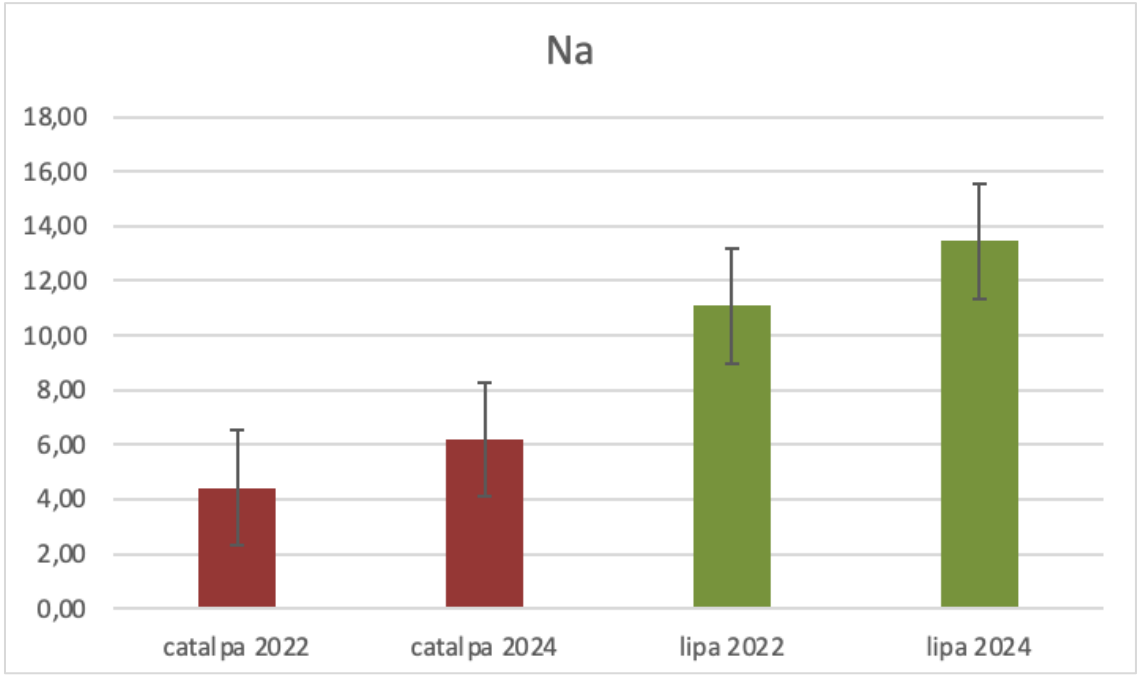


The results of the pedological analysis in the pilot project for the revitalization of catalpa and linden trees

Total carbon content in the soil



Sodium content in the soil



Discussion

- **The pilot project of urban tree revitalization using Herbafertil® and ecological irrigation** has proven that trees with significantly reduced vitality, due to various biotic and abiotic factors such as droughts, high air and soil temperatures, soil compaction from lawn mowing and pedestrian traffic, removal of mowed grass and leaves, water evaporation from the topsoil, **can significantly improve their vitality by introducing nutrients and adding a minimal amount of water to prevent stress and strengthen and develop the root system**, which, with the enhanced action of Herbafertil, regenerates the entire above-ground part of the tree.

- At the location where the soil enhancer Herbafertil is installed, **a new cluster of young roots** weighing 6 to 7 kg is developing, known as the "MOUTH OF THE TREE"®.

- Based on the initial results of the pilot project, it **can be concluded that a weakly vital tree can be significantly revitalized within one vegetation season** using minimal irrigation directly into the newly formed young root system. This means that the newly developed young roots will absorb almost all of the water input, resulting in minimal water wastage.

- Already during June, new leaf buds were noticed in the crown of trees on branches that had not leafed in early spring, and new young leaves appeared on them. The crowns of the trees looked healthy, dark green in color and the leaves did not fall off during the summer due to drought, as was the case on neighboring trees that were not treated with Herbafertil or watered.

The Research Conclusion

- The vitality of the researched Catalpa and Linden trees before the project implementation ranged from low to moderate, between 20 to 43%.
- Just one year after the application of HERBAFERTIL® and ecological irrigation, the vitality of the trees increased in the range of 64 to 86%.
- The research revealed an increase in tree vitality of around 40% during the first year of the urban tree revitalization pilot project.
- This proves that trees in urban areas developing under stress and unfavorable conditions can be helped and their vitality increased, rather than just monitoring their decline.
- Recently, urban trees have been exposed to numerous unfavorable factors and extreme climatic conditions that reduce vitality of soil microbiome that negatively affects vitality of the trees.
- In such conditions, it is necessary to take care of their ecological and biological living conditions. The revitalization measures for urban tree ecosystems showcased in this research pilot project can significantly help in this regard.
- Timely revitalization of urban trees reduces the risk for pedestrians, property, and infrastructure in the immediate vicinity, improves the aesthetic appeal of trees, as well as the functions and services they provide.

Thank you

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