(Projects funded under the Call 2014 onwards must use this format)

LIFE Project Number

LIFE17 CCA/IT/000079

Final Report

Covering the project activities from 01/07/2018[1] to 31/12/2021

Reporting Date[2]

31/03/2022

LIFE PROJECT NAME or Acronym

LIFE URBANGREEN

Data Project

Project location:	Italy
Project start date:	01/07/2018
Project end date:	30/06/2021 **Extension date:** 31/12/2021
Total budget:	€ 2,513,784
EU contribution:	€ 1,310,335
(%) of eligible costs:	60%

Data Beneficiary

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[1] Project start date

[2] Include the reporting date as foreseen in part C2 of Annex II of the Grant Agreement

This table comprises an essential part of the report and should be filled in before submission

Please note that the evaluation of your report may only commence if the package complies with all the elements in this receivability check. The evaluation will be stopped if any obligatory elements are missing.

Package completeness and correctness check	
Obligatory elements	**✓ or N/A**
Technical report	
The correct latest template for the type of project (e.g. traditional) has been followed and all sections have been filled in, in English *In electronic version only*	✓
Index of deliverables with short description annexed, in English *In electronic version only*	✓
Mid-term report: Deliverables due in the reporting period (from project start) annexed Final report: Deliverables not already submitted with the MTR annexed including the Layman's report and after-LIFE plan Deliverables in language(s) other than English include a summary in English *In electronic version only*	✓
Financial report	
The reporting period in the financial report (consolidated financial statement **and** financial statement of each Individual Beneficiary) is the same as in the technical report with the exception of any terminated beneficiary for which the end period should be the date of the termination.	✓
Consolidated Financial Statement with all 5 forms duly filled in and signed and dated *Electronically Q-signed or if paper submission signed and dated originals* and in electronic version (pdfs of signed sheets + full Excel file)*	✓
Financial Statement(s) of the Coordinating Beneficiary, of each Associated Beneficiary and of each affiliate (if involved), with all forms duly filled in (signed and dated). The Financial Statement(s) of Beneficiaries with affiliate(s) include the total cost of each affiliate in 1 line per cost category. *In electronic version (pdfs of signed sheets + full Excel files) + in the case of the Final report the overall summary forms of each beneficiary electronically Q-signed or if paper submission, signed and dated originals**	✓
Amounts, names and other data (e.g. bank account) are correct and consistent with the Grant Agreement / across the different forms (e.g. figures from the individual statements are the same as those reported in the consolidated statement)	✓
Mid-term report (for all projects except IPs): the threshold for the second pre-financing payment has been reached	N/A
Beneficiary's certificate for Durable Goods included (if required, i.e. beneficiaries claiming 100% cost for durable goods) *Electronically Q-signed or if paper submission signed and dated originals* and in electronic version (pdfs of signed sheets)*	N/A
Certificate on financial statements (if required, i.e. for beneficiaries with EU contribution ≥750,000 € in the budget) *Electronically Q-signed or if paper submission signed original and in electronic version (pdf)*	N/A
Other checks	
Additional information / clarifications and supporting documents requested in previous letters from the Agency (unless already submitted or not yet due) *In electronic version only*	✓
This table, page 2 of the Final report, is completed - each tick box is filled in *In electronic version only*	✓

**signature by a legal or statutory representative of the beneficiary / affiliate concerned*

Instructions:

Please refer to the General Conditions annexed to your grant agreement for the contractual requirements concerning a Mid-term/Final Report.

Both Mid-term and Final Technical Reports shall report on progress from the project start-date. The Final Report must be submitted to the Agency no later than 3 months after the project end date.

Please follow the reporting instructions concerning your technical report, deliverables and financial report that are described in the document Guidance on how to report on your LIFE 2014-2020 project, available on the LIFE website. Please check if you have the latest version of the guidance as it is regularly updated. Additional guidance concerning deliverables, including the layman's report and after-LIFE plan, are given at the end of this reporting template.

Regarding the length of your report, try to adhere to the suggested number of pages while providing all the required information as described in the guidance per section within this template.

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2. List of key-words and abbreviations

Key-words: climate change adaptation, urban green areas management, trees ecosystem services

Abbreviations:

DB	Database
GIS	Geographic Information System
ET_0	Potential evapotranspiration
KPI	Key Performance Indicators
IoT	Internet of Things
LCA	Life Cycle Assessment
LiDAR	Light Detection And Ranging
PLN	Polish Złoty
RS	Remote sensing
TLS	Terrestrial Laser Scanner
TT	TreeTalker
VI	Vegetation Index

3. Executive Summary

This document outlines activities carried out and results achieved in the LIFE URBANGREEN project which ended on the 31st of December 2021. The main result of LIFE URBANGREEN is a smart and integrated management system, which monitors and governs all activities related to urban green area management, maximising ecological benefits. In the project the existing management platform R3 TREES was upgraded to the new GreenSpaces platform and integrated with innovative management components, aimed at:

- optimising water consumption, providing water only when and where needed
- reducing the carbon footprint of maintenance activities through a more efficient job planning
- quantifying ecosystem services provided by green areas
- monitoring health conditions of trees using remote sensing data
- increasing citizen participation in urban green management.

The improved management platform was tested in two European cities: Kraków (in Poland) and Rimini (in Italy). Moreover, the networking activity with professor Yuei-An Liou of the National Central University, Taoyuan, Taiwan, allowed to share the results of the project with the city of Taipei (Taiwan).

The project activities included:

- a research part focused on ecosystem services provided by trees, carried out by the University of Milan
- the study of different techniques to derive trees information from remote sensing data (pointclouds, satellite images)
- the analysis and use of weather data as input information of the new modules related to trees irrigation and ecosystem services.
- measurement campaigns in Rimini and Kraków to define the ecosystem services provided by trees;
- LiDAR scanning of trees and green areas to derive the inventory of green areas managed as well as biometric information on trees;
- maintenance of project areas according to traditional and innovative management practices, in order to evaluate how ecosystem services of trees improve thanks to an innovative maintenance regime;
- development of new software modules
- testing of the new modules developed and finetuning them based on the feedback in the field.

The main result of the project are the new software tools developed:

- METEO: use of meteorological data and forecasts to improve green area management. The module includes a data service with hourly updates of 9 weather parameters and 72 hours of forecasts on the same parameters, which are used to calculate ecological benefits and water needs of trees. In addition, the module includes extreme weather warnings.
- BENEFITS: quantifying ecosystem services provided by green infrastructure on the basis of the algorithms developed within the project, the tree census data and the meteorological data.

- WATER: optimising water consumption, providing water only when and where needed. The water needs are calculated based on meteorological data, precipitation forecasts and the same algorithms used in the BENEFITS module.
- WORKS: reducing the carbon footprint of maintenance activities by organizing a more efficient working plan. The module includes many functions to manage complex work programs: the possibility to have different price lists for different companies, a calendar to schedule day by day and user by user activities, the possibility to register resources for each job, a check to see if planned jobs are compatible with weather forecasts and a check to make sure you do not plan jobs for the same person too far apart.
- CITIZEN: Increasing citizen participation in urban green management. The public portal highlights in real-time the main benefits of urban trees: the amount of particulate matter that trees in a park remove yearly from the atmosphere, the CO2 stocked and absorbed and the energy saved thanks to the cooling effect of trees on hot summer days. This and other information can be displayed for a park or an individual tree. Descriptions of the most common tree species and their environmental benefits complete the portal.

Another important result concerns the evidence that environmental benefits provided by trees are higher in plots treated according to innovative (pilot) practices versus plots where traditional (control) practices were applied. This confirms that the use of the platform and pilot treatments increase the environmental benefits provided by trees.

The dissemination activities allowed to inform many cities in Europe on the results of the project and on the methodologies applied. This raised the interest of some of these cities to extend the research activities in order to study the ecosystem benefits of additional tree species or in other climatic conditions. At the same time, it helped to market the results of the platform GreenSpaces and the tools developed in the project.

According to the original project proposal, the first half of the project included the development of the new software tools, and the research needed to develop the algorithms for ecosystem services calculation. The second half of the project, starting from fall 2019, was dedicated to the testing of the new tools in the two pilot cities. However, the software developments and the baseline definition were completed with a different schedule. This led to the decision, discussed with the E.C. Monitor during the second monitor visit in Kraków, to request for an extension of the project up to December 2021. This request was officially accepted by EASME with the Letter Amendment Nr. 1 to Grant Agreement LIFE17 CCA/IT/000079 - LIFE URBANGREEN - Ref. Ares(2021)1654279 - 05/03/2021. Thanks to this extension all activities could be successfully completed.

4. Introduction

Nearly 4 out of 5 European citizens live in cities and their quality of life depends largely on the quality of the urban environment, yet urban areas in Europe have to deal with a large number of environmental issues. Although the scale and intensity of the problems vary from city to city, a common set of emergencies can be identified, including poor air quality, high levels of ambient noise, climate change and the related need for adaptation, lack of sports and play areas, low quality of green areas. All these issues constitute real environmental challenges and result in significant impacts on the quality of life and economic performance of cities. In this scenario, urban green areas cannot be considered only as aesthetic and ecological elements anymore, but as a real service to the citizen and allies for urban climate regulation and climate change mitigation.

Open space in urban environments provides many advantages: formal and informal sport and recreation, preservation of natural environments, provision of green space, temperature regulation, carbon sequestration, noise limitation, dust and gas pollutant reduction, stormwater mitigation and many more. Thus, the management of green spaces must be a key consideration in urban management to maximise health and environmental benefits. Local governments are investing considerable resources to create and maintain public green areas, whose costs arise primarily from maintenance and operation (lawn mowing, pruning, maintenance of infrastructures, etc.), and by the strong use of water. In addition, local governments have to ensure the safety of citizens in public areas, by monitoring trees and playgrounds. Although some tools are available to support good management and increase resource efficiency, the need for smart and integrated systems considering also environmental benefits is strongly felt. Geographic Information Systems (GIS) provide a good basis for integrating all assets, maintenance operations, environmental indicators and inputs from the citizen to ensure safe and efficient maintenance of public green areas and an enhancement of the environmental benefits arising from them.

In this context, the main objective of LIFE URBANGREEN is to optimize and demonstrate in real-life an innovative technological platform to improve the management of green areas in 2 European cities. To this purpose, in the LIFE URBANGREEN project, the existing basic management tool named R3 TREES has been upgraded to the new GreenSpaces platform and integrated with innovative management components that were tested in real-life conditions within the two project cities of Rimini and Kraków. The strategy of the project was to identify project areas in the two partner cities, where the most common trees of the two cities are represented in different sites, sizes and situations. In these areas carry out detailed measurements of the trees and their physiology. In particular, LiDAR scans of trees were carried out in order to calculate the tree biomass and leaf area. In the same areas, measurements were carried out on selected individuals to assess the transpiration and the deposition of particulate throughout the vegetative season. Also, meteorological data and 72 hours forecasts were collected on an hourly basis. These studies were carried out throughout the duration of the project, from July 2018 to the end of 2021. With all these data algorithms were developed, which can now be applied to all trees of the same or similar species, and which can estimate the CO_2 assimilation, CO_2 sequestration, particulate deposit on leaves, water transpired and cooling of the environment thanks to transpiration.

The software platform R3 TREES, which was in use in both cities at the beginning of the project, was developed with a new architecture and new tools, in order to assist the green area maintenance stakeholders with additional information to better estimate the benefits of urban trees, to address the effects of climate change like heat islands in summer and prolonged

drought periods and to inform and engage the citizen. The renewed platform was also renamed GreenSpaces.

During the second part of the project, the developed tools were tested in the pilot plots of the two cities in order to assess their applicability and efficiency. Also, in pilot plots, best practices in management were applied, like soil decompaction, mowing without removing the cut grass, target pruning, mulching and irrigation of trees as suggested by the Water module of the GreenSpaces platform. Control plots were treated in the same way as they have always been treated in the two cities, without applying the best practices. Pilot and control plots were then analysed in order to assess the change in environmental benefits and compare it to the carbon footprint of the pilot and control management regimes. Despite the short period of observation, the results were clearly visible, with higher benefits in the pilot plots.

LIFE URBANGREEN addresses the request to contribute to the development and implementation of Union policy on climate change adaptation, in particular by providing an integrated platform for urban green management as an effective tool for climate change adaptation. It promotes the development and implementation of an integrated approach at local, regional or national level, prioritising ecosystem-based approaches. It improves the knowledge base for effective climate change adaptation actions and measures, based on the monitoring and results from the integration of ecosystem services. Besides promoting urban green management as a tool for adaptation, the LIFE URBANGREEN platform will increase resource and water management efficiency, and finally lower the related costs. Only the right type and amount of maintenance and water, and at the right timing, will be delivered to the plants, trees and grass. Furthermore, healthy urban green areas help combat the urban heat island effect through transpiration and shading, providing cool and ventilated areas, as demonstrated in several publications about the positive effect of green areas on the urban microclimate.

Dissemination and business planning activities were fundamental to ensure full exploitation of the LIFE URBANGREEN results and replication of the URBANGREEN model in other geographic contexts. According to the results of the testing phase carried out during the second half of the project, the following modules resulted to be mature enough to be proposed to existing and new customers using the GreenSpaces platform and included in the commercialization plan:

- the advanced job planning module, named “WORKS” module
- the public portal and app for citizens, named “GREEN CITY” module
- the weather dashboard, weather data and severe weather warnings menus, named “METEO” module
- the ecosystem services module, named “BENEFITS” module
- the smart irrigation system, named “WATER” module

The tool is commercialised as a Software as a Service for customers who are using already GreenSpaces or new customers. According to the realistic scenario of the commercialization plan, we expect to sell the service to 7 cities during the first year after the end of the project; by the third year after the end of the project, we expect 26 cities to use the URBANGREEN modules; by the fifth year of commercialization, the URBANGREEN tools will be used in a total of 58 new cities worldwide.

5. Administrative part

According to the project proposal, the general project coordination and management was carried out by R3GIS in coordination with project managers of all project partners. The management structure encompasses

- A steering committee, led by the overall project coordinator Paolo Viskanic (R3GIS), composed of one representative of each associated beneficiary and three key stakeholder representatives;
- A project management board, led by the Project Manager Alice Pasquinelli (R3GIS) and composed by the project managers of associated beneficiaries;
- A dissemination board, led by Marco Cicala (R3GIS) and composed by one representative from each associated beneficiary.

R3GIS referred to other project partners for specific expertise involved in the project:

- Università degli Studi di Milano for what concerns the scientific supervision of the project, particularly on the topic of ecosystem services provided by trees, green elements in urban context, water needs of plants for the smart irrigation module and best practices in tree management;
- ProGea 4D for activities and issues related to remote sensing, particularly for what concerns green area inventories, LiDAR survey and satellite data handling and interpretation;
- Anthea and ZZM as expert in green area management and final user of the URBANGREEN platform

Communications between R3GIS and the partner consortium continued seamlessly throughout the whole duration of the project. R3GIS compiled a joint technical report and sent it to the EC Monitor on a monthly basis, after the collection of contributions provided by project partners. A copy of the monthly report was also sent to the steering committee members and to professor Yuei-An (from the National Central University of Taiwan) as an external partner of the project. Each project meeting is documented in a minute and attached to the joint technical report sent to the EC Monitor. All project documents were drafted by R3GIS, amended and approved by partners and made available within the project shared folder system.

As highlighted in the mid-term report, the name of the legal representative of Università degli Studi di Milano has changed and from 5/10/2018 Elio Franzini has become the new rector of this university. In addition, on the basis of a power of attorney of the mayor, Łukasz Pawlik, Deputy Director of ZZM, can sign the individual cost statement of this partner. Consequently, the legal representatives signing the individual cost statement of these two beneficiaries differ from the ones who signed the grant agreement.

In March 2020, in conjunction with the delivery of the mid-term report, R3GIS sent an amendment request to EASME in order to change the legal address of the coordinating beneficiary after the transfer of the R3GIS headquarters from Merano to Bolzano. Also, in November 2020 R3GIS sent another request in order to obtain a 6 months extension of the project. Both the requests were officially accepted by EASME with the Letter Amendment Nr. 1 to Grant Agreement LIFE17 CCA/IT/000079 - LIFE URBANGREEN - Ref. Ares(2021)1654279 - 05/03/2021.

6. Technical part (maximum 25 pages)

6.1. Technical progress, per Action

ACTION A.1 | Pilot areas characterization

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 31 December 2018	**Actual end date**: 30 September 2019

Activities undertaken and outputs achieved

Within action A.1 several activities were carried out to identify those specific trees and areas to be used as testbed to demonstrate project effects. Particularly, the following activities were implemented:

- The urban greenery was classified in two strata: parks and paved areas;
- 10 tree species which are typical and well represented were identified for both cities, Rimini and Kraków, and individual trees in different strata, with different age and size for each species were identified for the measurement of ecosystem services provided by urban trees. The preliminary selection of the species was carried out by UniMI starting from existing inventory provided by Anthea and ZZM: this was discussed with the partners during the kick-off meeting of July 2018 and amended during dedicated meetings and field work;
- Taking into consideration the city strata and the tree species identified, specific urban green areas and trees were selected by UniMI to be included in the project: for each species in the two strata, trees having different age were taken into consideration. On a total of 427 trees, measurements were carried out to determine the performance in terms of ecosystem services provided by tree species in parks and paved areas (see action C.3) at different age;
- Selected areas and trees were surveyed using LiDAR technology, allowing to derive biometric data and to generate a georeferenced inventory of project areas which was uploaded in the management platform (see action C.3);
- In Kraków, the full inventory of Park Lotnikow (one of the selected project areas) was carried out by ProGea 4D. Particularly, ProGea 4D acquired LiDAR data of the whole park through a Mobile and Terrestrial Laser Scanning: this survey took place at the beginning of September 2018. In addition, ProGea 4D carried out the dendrological inventory of trees and shrubs in this park, in order to have complete information on plants included in project activities.
- In Rimini, the dendrological inventory was already complete for all selected trees, while a full inventory of project areas was missing. This inventory was compiled by ProGea 4D extracting data from point clouds acquired through terrestrial LiDAR survey (see action C.4)
- Project areas and trees were divided into pilot and control plots, where different management regimes were applied starting from Autumn 2019 (see action C.6): The selection and mapping of pilot and control trees and plots was carried out by Anthea and ZZM with the support of R3GIS and the supervision of UniMI;
- The best practices to be applied by Anthea and ZZM in pilot plots were suggested by UniMI and included target pruning, trees mulching, lawn mowing with no grass collection, smart irrigation and soil decompaction .
- In control plots, maintenance jobs were carried out according to the traditional practices.

Comparison between planned outputs and time schedule

According to the project proposal, the conclusion of activities of action A.1 was expected by December 2018, but the selection of trees and areas to be studied in the project required more time, since the actual conditions encountered in the field turned out to be more challenging than expected. In fact, it was not easy to obtain an equal distribution of trees of different species and age in parks and paved areas. Considering the need to go to the field for measurements on tree leaves using

sophisticated equipment and particular vehicles (e.g. infrared gas analyser, basket elevator), this selection was further complicated by the need to have areas and trees near to each other, in order to reduce movement time. Moreover, in August 2018 it was discovered that one of the parks of the city of Rimini selected as a project area was subject to major excavation works that would affect the area for the whole duration of the project. In addition, the selection of pilot trees in Planty area in Kraków needed to be validated and confirmed by local conservator in charge of Planty Krakowskie. All these issues delayed the selection of project areas and trees. It is due to highlight that deliverable *D.1_Final definition and characterization of pilot areas*, was drafted by September 2018 (in line with the expected schedule) and updated in autumn 2019, when the selection of project areas and trees was completed and officially approved by partners. Considering the complexity of this task two dedicated meetings were organized in Rimini (September 14th 2018) and Kraków (September 11th 2018) in order to discuss problems encountered, with the possibility to visit selected areas. Since this selection took more time than expected, also the LiDAR survey of selected project areas and trees and the generation of the inventory of project areas based on laser scanning was delayed (see action C.3 for details). Consequently, in October 2018 it was requested to postpone the deadline of two deliverables (D.3_*Inventory of pilot areas based on mobile laser scanning* and D.4_*Report of data acquisition of pilot areas*) to September 2019. Despite these modifications, the action was completed and had no implications on overall the results of the project.

Modifications and correspondence with EASME/CINEA acknowledging changes

Changes to the deadline of Action A.1 were communicated through the monthly report delivered on October 2018 and highlighted during the first Monitor Visit held at the end of January 2019.

ACTION C.1 | Smart irrigation system

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 30 June 2019	**Actual end date**: 31 December 2020

Activities undertaken and outputs achieved

Within this action, activities carried out refer to the development of a new module to enable a smart management of irrigation, based on tree species, weather conditions and water provision. Preliminary activities included:

- The definition of species coefficients, based on field measurements carried out by UniMI, to be applied for the calculation of trees water needs.
- The definition of the algorithm to calculate water needs, as reported in deliverable *D.2_ Report with algorithm for water requirement* written by R3GIS and UniMI (modifications applied over time are reported in the revised versions of this document).
- The definition of appropriate terms of reference for the selection of a provider of meteo data to be used in the management platform. From the offers collected UBIMET resulted the best in terms of data provided and costs.
- The subscription of the meteo service by the two cities according to the terms of references and internal procurement rules.

Once these preparatory activities were completed, R3GIS drafted a functional description of the features to be implemented in the management platform for this action (reported in deliverable *D.5_ TOR for tool to be implemented completed and approved by partners).*

Preliminary software developments focused on the release of several functions dealing with weather data, as described in action C.4. That's because the integration of weather data in the management platform was a prerequisite for the development of a smart irrigation system based on past and future weather conditions. However, the main objective reached in this action is the development of a smart irrigation module aimed to highlight those trees that need to be irrigated, when they need to

be irrigated and to calculate the quantity of water to be provided. In addition, a function to record the quantity of water provided to trees during irrigation jobs was developed (see action C.2). This information is used to correctly feed the algorithm that calculates tree water needs considering also water provided through irrigation. A description of this module named WATER is provided in the deliverable *D.10_Release of the water requirement forecast module in URBANGREEN*. The algorithm and functions developed have been fine-tuned and integrated thanks to the feedback received by partners. Modifications applied after the testing phase are described in deliverable *D.29_Release of improvements to URBANGREEN modules based on test data*.

Comparison between planned outputs and time schedule

Since meteo data is quite complex to handle and requires specific expertise, R3GIS decided to hire an expert to work on the interpretation and calculation of meteo data. The budget for this expert comes from savings on other budgeted activities (the hiring of an external auditor), not required anymore according to new accounting rules. A market investigation with multiple offers led to the choice of CISMA, an engineering company with consolidated experience in the field. CISMA was also involved in developing the algorithms for the calculation of tree benefits (Action C3) which are also based on meteorological data. The contract was initially limited to meteorological data, but due to the extended scope of activities and continuous fine-tuning of algorithms was renewed in August 2020 until the end of the project.

As mentioned in the mid-term report, the release of the User Interface of the module to be developed in this action, expected to be completed by June 2019, was postponed. Delays were due to the time required to adapt the original management platform and to the workload related to the development of the advanced job planning module (action C.2), activities that resulted to be more time consuming than expected. The meteo dashboard was released in early January 2020 while the first version of the smart irrigation module was released in September 2020 and finalized by December 2020. However, thanks to the project extension agreed by EASME, it was possible for ZZM and Anthea to test the features developed during the whole vegetative season of 2021. According to the feedback received by partners, R3GIS applied improvements to the features developed under action C6.

Modifications and correspondence with EASME/CINEA acknowledging changes

As described in the mid-term report, two minor budget shifts were discussed with the EC Monitor during the first Monitor visit:

- R3GIS proposed to reallocate the costs budgeted for the audit report to contract an external assistance on meteo data;
- ZZM proposed to move costs foreseen for the construction of the pond from action C.1 to action C.6.

Both proposed budget shifts were found reasonable by the EC Monitor.

Beside previous communication through monthly technical reports (September 2019 and December 2019) the final postponement of the deadline related to the release of the Smart irrigation module was made official with the amendment request submitted to EASME on November 2020: in this request, the new deadline for the deliverable "*Release of the water requirement forecast module in URBANGREEN"* was officially postponed to 31/12/2020.

ACTION C.2 | Efficient programming of jobs and control activities

Foreseen start date: 1 January 2019	**Actual start date**: 1 January 2019
Foreseen end date: 31 December 2019	**Actual end date**: 31 December 2020
Activities undertaken and outputs achieved	

Activities included in action C.2 are aimed at improving the current workforce planning module in R3 TREES enriching it with new advanced functions. In order to define the modifications and integrations to be implemented to this module, R3GIS carried out an internal review of the functions in R3 TREES, discussing current shortcomings and possible enhancements to the current job planning module. In parallel, R3GIS had meetings with Anthea and ZZM as end-users and testers of the new platform, with the scope of understanding workflows adopted by green area managers in job programming and planning, discussing needs and wishes that new functions of GreenSpaces should address. The meetings were held in Rimini on February 14th 2019 and in Kraków on March 14th 2019. The outputs of such activities were reported in the deliverable *D.8_Analysis of the needs and criteria for workforce planning and proposed management platform*, drafted by R3GIS, shared, amended and approved by Anthea and ZZM.

Modifications and integration to the workforce planning module were discussed with the development team in R3GIS. A first version of the efficient programming of jobs module was released at the end of February 2020 including most of the features (improved visualisation of job planned, job scheduling function and calendar, flexible association between companies and sites). The module was finalized by December 2020, including the possibility to report materials and equipment used in order to calculate the costs incurred for each job carried out: this function allows also to collect data on the irrigation provided to trees, feeding the algorithm developed in action C.1. The final results of these developments are described in the deliverable *D13_Release of the advanced job planning module_v1.1*. In addition, during the testing phase of the project in 2021, two functions were developed to improve the efficiency of day to day management: one is related to the interaction between job scheduled and weather forecasts; the other verifies that two or more jobs planned on the same day are not too far away from each other. Through these functions, planning and monitoring of maintenance activities is more efficient and has a lower carbon footprint. These developments that led to the creation of the WORKS module are described in the deliverable *D.29_Release of improvements to URBANGREEN modules based on test data.*

Comparison between planned outputs and time schedule

The implementation of this part of the software was originally planned to be completed by end of September 2019, but the changes to the architecture of R3 TREES to allow for new modules to be developed took longer than expected and the original deadline was moved to January 2020. However, also the implementation of some of the features resulted to be longer and more complicated than expected. Nevertheless, a first version of the efficient programming of jobs module has been released at the end of February 2020, including a major part of the features foreseen. As soon as the missing features were developed, they were progressively activated on the GreenSpaces platform of Rimini and Kraków and the action was declared concluded in December 2020, in time for the test run 2021.

Modifications and correspondence with EASME/CINEA acknowledging changes

A first shift of the deadline of action C.2 was communicated through the October 2019 technical report. A Second postponement to January 2020 was discussed during the second monitor visit and reported in the December 2019 technical report. The first version of the module was released in February 2020: the related deliverable "*D.13_Release of the advanced job planning module_v.1*" was annexed to the March 2020 technical report. The final version of this document was updated in December 2020, when developments related to this action were finally concluded. The final postponement of the deadline related to the release of the Advanced job planning module was made official with the amendment request submitted to EASME in November 2020: in this request, the deadline for the deliverable *D13_Release of the advanced job planning module* was officially postponed to 31/12/2020.

ACTION C.3 | Integration of ecosystem services

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 30 June 2019	**Actual end date**: 31 December 2020

Activities undertaken and outputs achieved

The main aim of action C.3, was to define algorithms for the estimation of ecosystem services provided by urban trees and collecting all the necessary data to feed such algorithms, like species parameters related to trees physiological functions, trees biometrics and meteorological data affecting the provision of ecosystem services.

In order to determine the ecosystem services provided by the different species, from July 2018 to September 2019 extensive leaf gas exchange measurement campaigns were carried out by UniMI with the support of ZZM and Anthea in the cities of Kraków and Rimini. Net CO2 assimilation, latent heat dissipation by transpiration and air quality amelioration were measured on about 12 replicas of 10 species per city. Under this action, 315 trees were measured in Kraków and 225 trees were measured in Rimini. Also, individual leaf samples were collected and analysed in the laboratory for particulate matter (PM2,5 and PM10) of pollutants deposited on leaf surface. Statistics on data collected were primarily targeted to identify significant differences in growth and physiology among the different species growing in unpaved and paved areas. Tested models for the calculation of ecosystems services (namely "Big leaf" and "Multi-layer" model) included the effects of species, leaf position, strata, season and their interactions. The 'Big Leaf' model fits with measurements obtained on leaves exposed to full sunlight, while the 'Multi-layer' model fits with measurements conducted on both full sun and shaded leaves and with the repartition of the canopy between sun and shade.

To derive biometric data on trees (such as total leaf area, leaf area exposed to the sun with a different degree, size and mass of trunk and branches, etcetera), LiDAR survey of trees measured by UniMI were carried out in Kraków by ProGea 4D on 60 trees and in Rimini by an external provider (Cartorender) on 112 trees. Also, ProGea 4D hired Mobile Laser Scanning equipment to scan Park Lotnikow. Starting from available point clouds, ProGea 4D generated the full inventory of Park Lotnikow in Kraków and all project areas in Rimini by September 2019 (see action A.1). From October 2019 to December 2020 ProGea 4D dedicated a lot of effort testing existing procedures and methods to derive tree leaf area and woody biomass from point clouds, and trying to validate the results obtained through direct measurements on felled trees and leaves (see action D.1).

Statistical analysis of the collected data was carried by UniMi out using both the Big leaf model and Multi-layer model. The description of the algorithms defined to calculate ecosystem services of trees to be implemented in the management platform is reported in the deliverable *D.9_Analysis and provisional Algorithms to calculate the CO2 sequestration, pollutants reduction and microclimate influence*, finalised by June 2019 (version 1) and updated and integrated in February 2020 (and version 1.1) and finally revised in February 2022 (version 1.2). Outputs related to the analysis of tree growth, CO_2 assimilation and storage, water transpiration and pollutants adsorption expressed per unit leaf area are fully described in deliverables *D15_growth curves*, *D20_Report of CO2 assimilation and storage", "D21_Report of microclimate effects of trees in the pilot areas"* and *"D22_Report on pollution sequestration by different tree species in the pilot areas",* which were progressively updated as new results from the measurement campaigns were available. Results from this activity were used to select representative trees for monitoring action D.1. Data collected and outputs obtained were already presented in several conferences at national and international level (see action E.1).

The algorithms and the species coefficients provided by UniMI were finally implemented in GreenSpaces in the BENEFITS Module. Using the tree position (paved or unpaved area) the species and the size or age and the current meteorological data (potential evapotranspiration and solar radiation) the CO_2 stocked and assimilated, the water traspired, the energy saved thanks to cooling

through the tree and the particular matter sequestrated are calculated on a daily and yearly basis. The final results of this activity are described in the deliverable *D19_Release of the ecosystem services module in URBANGREEN.* Trees ecosystem services are also displayed on the public portals developed within action C.5.

Comparison between planned outputs and time schedule

Tree point clouds were expected to be fully acquired by autumn 2018. Because of the delay in the selection of pilot and control areas, laser scanning campaigns were actually completed in October 2019 in Kraków and in January 2020 in Rimini. Consequently, the extraction of biometric parameters of trees derived from TLS was delayed. In addition, difficulties encountered in finding the correct procedure to extract those parameters required ProGea 4D to work on this activity for the whole duration of the action and under action D.1.

Moreover, the staff of UniMI requested an extension of action C.3 during the second monitor visit, because of the workload related to the laboratory analysis of leaf samples collected and because of the time-consuming processing of the acquired data. Finally, the deadline of the deliverables responsibility of UniMI for action C.3 was postponed to March 2020, as well as the calculation of baseline values of ecosystem services (action D.1): deliverables reporting algorithms and coefficients to be applied were annexed to the March 2020 technical report.

After this delivery by UniMI, R3GIS had all the information to start, in February 2020, the development of the Ecosystem services module, that was activated in September 2020 on the GreenSpaces installation of Rimini and Kraków: minor integrations have been carried out until December 2020, when the action was declared concluded.

Modifications and correspondence with EASME/CINEA acknowledging changes

Issues related to the LiDAR survey in Rimini were reported to the EC Monitor in the September 2018 technical report and the shift of the deadline concerning the completion of LiDAR survey were communicated through the October 2018 monthly report: this issue was also discussed during the first and second Monitor Visit. The updated deadlines for pending deliverables were communicated through the November 2019 technical report and reported during the second Monitor Visit. The final postponement of the deadline related to the release of the Ecosystem services module was made official with the amendment request submitted to EASME on November 2020: in this request, the new deadline for the deliverable *D19_Release of the ecosystem services module in URBANGREEN* was officially postponed to 30/09/2020.

ACTION C.4 | Integration of monitoring through IoT, meteo and RS data

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 30 June 2021	**Actual end date**: 31 December 2021

Activities undertaken and outputs achieved

This action encompassed activities related to three different topics as follows.

IoT sensors

In the project proposal, the creation of an IoT sensor network to monitor the quality of green areas was expected by March 2019. However, several issues required this deadline to be shifted and the original selection of IoT sensors to be modified. Details about all these matters are reported in annex 2. Once the new shortlist of sensors was defined, Anthea and ZZM proceeded with the acquisition of materials according to their internal procedures and with the installation in the field. A 2 days'

workshop dedicated to the mounting and installation of IoT sensors was held in Rimini in June 2019 by Stefano Manini (R3GIS consultant) with the participation of Anthea personnel in charge of the installation of sensors. Finally, on September 24th and 25th 2019, a workshop held by Nature4 staff was organised in Rimini concerning the installation of TreeTalker (TT) sensors: ZZM also attended this meeting. During the whole duration of the project, Anthea and ZZM changed the batteries and checked the conditions of the sensors. IoT sensors were configured, installed and maintained from June 2019 throughout the whole duration of the project.

Remote sensing data acquisition and analysis

Anthea and ZZM acquired satellite images for the duration of the project, according to their internal purchasing procedures. The definition of a workflow to monitor trees health from Planet satellite images was implemented by ProGea 4D. The tree monitoring procedure foresees the download of images on a periodical basis: at the end of the project, 131 Planet images resulting to be suitable for processing were downloaded for the city of Rimini and 88 for the city of Kraków. In addition, ProGea 4D also tested the use of Sentinel data, freely available but at a lower resolution. One of the difficulties encountered was the different sensors and different acquisition angle of Planet images downloaded in different moments. This resulted in the need to calibrate images with different methodologies. In Kraków additional images were acquired with a Micasense multispectral camera mounted on a drone in the same days as the satellite images were acquired, in order to calibrate the satellite images and test different vegetation indexes. In addition, R3GIS encountered several problems due to the continuous change of the API specifications to download the images. ProGea 4D also worked on the automatic extraction of cities global cover from WorldView II images, using GEOBIA methodology, in order to derive a land cover map for the city of Rimini and Kraków: this map is a reference data for the calculation of the total green areas existing in the two cities, encompassing both public and private greenery. This analysis was carried out using images acquired at the beginning and at the end of the project, allowing to detect modifications occured between 2018 and 2021.

Acquisition and storage of meteo data

As mentioned in Action C.1, an external consultant (CISMA) was hired to assist the project in converting the acquired meteo data and calculating reference values. CISMA supported R3GIS in the definition of a data structure related to meteorological information and in the creation of a dedicated DB, with data at different time resolutions (hourly, every six hours, daily). Also, the calculation of ET_0 and net radiation was implemented based on the parameters provided by UBIMET. Data computed and stored in the meteo database is used to feed the different algorithms developed in the GreenSpaces platform, as listed in the following paragraph.

Integration of monitoring data in the management platform

The main output of this action was the integration of different types of data inside the GreenSpaces software. In order to achieve this output, R3GIS and ProGea 4D analysed IoT, satellite and weather data and defined how to integrate and use them into the management platform, as described in deliverable *D.7_Analysis of the integration of Remote Sensing, Meteo and IoT data in urban green area management.* Data coming from the different type of sensors are now downloaded continuously and made visible in form of tables, graphs and cockpits in GreenSpaces.

The data of the sensors was made visible in GreenSpaces through specific tools:

- TreeTalker data is downloaded from the cloud each hour and converted into the units of the different measurements: Temperature and Humidity, Sap flow, radial tree growth, wood humidity, light passing through the crown (visible and near infrared) and position of the tree. In addition also the information from TTCloud routers is downloaded and displayed in GreenSpaces
- Lansitech sensors in Kraków measure air temperature and humidity every 20 minutes

- Enless sensors measure temperature in Rimini every 20 minutes
- Airly sensors measure particulate matter, temperature and humidity.

R3GIS developed a tool in GreenSpaces to compare vegetation indexes calculated on the tree crown of a specific tree based on the periodic satellite images and comparing them to the average indexes for all trees of the same species. The results were interesting, but not conclusive enough to finalize a tool with this methodology. Further research needs to be done to understand if this methodology can be of interest to help cities monitor their trees. From mid-February 2022, Planet images calibrated with Sentinel data are available. This should produce better results than the 4-channel, non calibrated images available in previous years.

For what concerns meteo data, beside the developments described in action C.1 and C.2, weather data in the GreenSpaces platform were integrated as:

- a dashboard and a map tool to visualize weather data and forecasts at city scale;
- a menu for the query, visualisation and export of weather values (raw hourly data of each Point of Interest in the city, average hourly data at city scale, data aggregated at 6-hours interval at city scale);
- a menu to visualise and export severe weather alerts.

The modules released inside this action are described in the deliverable *D.18_Release of IOT data, RS data and meteo data modules in URBANGREEN.*

Comparison between planned outputs and time schedule

The deadline for the creation of an IoT network in Rimini and Kraków was postponed. Due to technological changes the list of sensors and the budget was revised, as reported in the March 2019 technical report. The actual procurement of sensors was completed in September 2019. In addition, different technical, organisational and political matters affected the timing of installation of the devices, as described in annex 2 of this report.

As already mentioned, the integration of Planet images resulted to be more complex than expected because of calibration and download problems. This slowed the work carried out by ProGea 4D and R3GIS that led to the creation of a tree monitoring of trees through RS data, as described in the annex 2 of the mid-term report.

As discussed during the second monitor visit (and reported in the November 2019 technical report) the complete set of developments foreseen in action C.4 by December 2019 was split into 3 parts to be released according to the following deadlines:

- Meteo dashboard: December 2019
- Trees monitoring through RS data: January 2020
- Integration of IoT sensors: March 2020

Of these three, only the deadline related to the monitoring of trees through RS data was furtherly postponed because of issues with the download of Planet images. Despite these shifts, the activities of this action were concluded with no negative impacts on the project.

Modifications and correspondence with EASME/CINEA acknowledging changes

The delay for the installation of IoT sensors was discussed with the EC Monitor during the first Monitor visit. The revised list of sensors to be purchased by Anthea and ZZM was included in the March 2019 technical report. The progressive configuration, installation and substitution of sensors was reported in monthly reports from June 2019.

Issues related to Planet data (and consequent delay in the implementation of the monitoring system through satellite data) were reported in several monthly reports between February 2019 and October 2020 and discussed during the third and fourth monitor visits.

The shift in the releases of the software components foreseen in this action were agreed during the second Monitor Visit. In the amendment request submitted to EASME in November 2020 the new deadline for the deliverable *D.18_Release of IOT data, RS data and meteo data modules in URBANGREEN* was officially postponed to 31/12/2020.

ACTION C.5 | URBANGREEN portal and app

Foreseen start date: 1 January 2019	**Actual start date**: 1 January 2019
Foreseen end date: 30 June 2020	**Actual end date**: 31 July 2021

Activities undertaken and outputs achieved

The scope of the LIFE URBANGREEN portal and app targeted at citizens was to provide information to citizens about urban green areas and their benefits and to engage them in the management process. R3GIS analysed existing portals and apps on green areas, targeted at citizens in order to understand the current state-of-the-art. This analysis is included in the deliverable *D.11_Report on needs assessment of public portal and app for Rimini and Kraków*, which was reviewed and integrated with feedback provided by project partners.

Starting from this analysis, taking into consideration feedback from partners, R3GIS developed the public portal for citizens of Kraków (https://krakow.lifeurbangreen.eu/pl/) and Rimini (https://rimini.lifeurbangreen.eu/). In these portals, ecosystem services of trees (calculated with algorithms developed in action C.3 and meteo data provided in action C4) are displayed at trees, park and city scale. Since the project focused on the 10 most common species of these cities, ecosystem services are available only for these species and assimilated species and varieties, covering about 50% of the trees of the two cities. The portals contain also a page explaining the LIFE URBANGREEN project and another section aimed at describing the benefits of trees, with a specific focus on the species studied in the project.

The public portals were developed as responsive web applications optimized for mobile devices without the need to download and install a dedicated app. Each portal is available in English and in the native language of each city (Italian for Rimini and Polish for Kraków). The result of the developments done in this action are described in the deliverable *D.17_ Public portal and app developed.*

Anthea and ZZM enriched the contents reported in the GreenSpaces platform including pictures and descriptions of urban parks: these contents are now visible by the citizens of Rimini and Kraków through the public portals. UniMI provided a description of the 10 most common species in the two cities to be published on the citizen portal.

Comparison between planned outputs and time schedule

The release of the public portal and app, originally foreseen for December 2019, was postponed to June 2020. However, delays incurred for the development of other modules determined a further delay of the activities related to action C.5 and software developments started in August 2020. In fact, priority was given to the developments foreseen in action C.1-C.4 since the functions included in these modules had to be properly tested by Anthea and ZZM in their daily activity and provided the data on benefits to be published on the portal.

Despite this shift, the activities of this action were concluded with no negative impacts on the project: the public portal of Kraków was released in March 2021 and the one of Rimini in June

2021. The releases happened with a little delay compared to the final expected deadline defined for February 2021. The two cities had enough time to publicise their portals.
Modifications and correspondence with EASME/CINEA acknowledging changes The first postponement of the release of the public portal and app was communicated through the June 2019 monthly report. The final postponement of the deadline related to the release of the modules foreseen in this action was made official with the amendment request submitted to EASME on November 2020: in this request, the new deadline for the deliverable *D.17_ Public portal and app developed* was officially postponed to 28/02/2021.

ACTION C.6 | Testing and demonstration of LIFE URBANGREEN in pilot areas

Foreseen start date: 1 October 2019	**Actual start date**: 1 January 2019
Foreseen end date: 30 June 2021	**Actual end date**: 31 December 2021

Activities undertaken and outputs achieved

Activities encompassed in this action are aimed at testing the GreenSpaces platform in the field, applying different management regimes to pilot and control plots. Since autumn 2019, in pilot plots, Anthea and ZZM started to carry out management activities according to best practices while in control plots, traditional practices were followed. Preparatory activities were required in order to be ready to carry out field work as soon as action C.6 started, especially considering the timing of tender procedures required by ZZM. For this reason, since January 2019, ZZM started to work on the tender related to the purchase of a water tank, waterbags and a soil aeration kit. All the mentioned equipment were delivered in November 2019. Also the tender for the construction of a water retention pond in Park Lotnikow started to be prepared in the same period. The tender was published on May 2019 and on August 14th ZZM signed the contract for the construction.

In order to ensure the correct application of the two maintenance regimes, UniMI provided training to the operators of ZZM (November 2019) and Anthea (January 2020) involved in the project, about treatments to be carried out in pilot and control areas. The best practices to be applied in pilot areas consisted in soil decompaction, mowing without removing the cut grass, target pruning, mulching and irrigation of trees as suggested by the Water module of the GreenSpaces platform. Control areas were treated in the same way as they have always been treated in the two cities, without applying the best practices. Anthea and ZZM drafted their management plan including activities to be carried on project areas in 2020, as described in the deliverable *D.12_Management plan of project areas*. From autumn 2019 to autumn 2021 Anthea and ZZM carried out maintenance jobs in pilot and control plots according to the instruction received by UniMI. The detailed list of maintenance jobs carried out in pilot and control plots was provided to R3GIS in autumn 2021 and was used to calculate the balance between environmental costs and benefits related to trees maintenance, as described in the deliverable D30_*Report of costs (including CO2 emissions) for the URBANGREEN pilot and control areas.*

Since the beginning of 2020 R3GIS activated the new GreenSpaces platform in Rimini and Kraków in parallel to the existing R3 TREES Platform. Finally, in January 2021 R3GIS migrated the data of the old R3 TREES platform to the new GreenSpaces installation of ZZM. Training on the use of the software was provided through online sessions: however, the complexity of the green area management in Kraków required one person from R3GIS to travel to Kraków and carry out one week of training and tutoring of the ZZM staff. In Rimini, the migration from R3 TREES to GreenSpaces occurred at the end of February: in this case, the training took place online. Thanks to the project extension agreed by EASME Anthea and ZZM had the possibility to test the new software and the new URBANGREEN modules until December 2021 and R3GIS could apply modification and carry out bug fixing on the basis of feedback received. Improvements and

modifications are reported in the deliverable *D.29_Release of improvements to URBANGREEN modules based on test data.*

Comparison between planned outputs and time schedule

The project team highlighted a mistake in the deadline of the deliverable of action C.6 *D.12_Management plan according to URBANGREEN platform indication* expected by September 2019: since the release of the job planning and scheduling module was expected by September 2019, in the April 2019 Technical report a shift of the deadline of the above-mentioned deliverable was proposed to December 2019. This management plan was described and reported in the deliverable *D.12_Management plan of project areas"* (slightly renamed compared to the original title) by the end of 2019.

Some issues affected the application of treatments to the selected trees in Rimini and Kraków: in some cases, trees were felled for safety reasons. In addition, due to organisational problems, the mulching of pilot trees in Rimini was applied later than expected. In order to preserve the successful outcome of the analysis of the impacts of the treatments, UniMI proposed to extend the duration of action D.1 and to focus the monitoring of impacts on 7 species out of the 10 originally selected (see action D.1). It is due to highlight that UniMI was afraid that in Rimini the pilot and control pruning had been carried out in a similar way, as it was visually difficult to distinguish the pruned trees in pilot and control areas. However the values resulting from the analysis of the data measured by uniMI are different between pilot and control, confirming that the pruning was carried out correctly.

The construction of the water pond was expected to be finished by early 2020, but because of delays, the pond could be declared completed only in July 2021. Since then, this infrastructure is now able to provide water for the irrigation of trees as well as enjoyable and social spaces thanks to the recreational areas built in its surroundings. However, the construction contract could not be fully settled before the end of the project: for this reason, the eligible costs of this infrastructure was not charged to the project.

The migration of the old R3 TREES platform to the new GreenSpaces platform resulted to be more complex than expected because of both technical and organisational reasons as explained in February 2020 monthly report: for this reason, R3 TREES and Green Spaces coexisted in the two organisations, giving time to Anthea and ZZM to get used to the new platform and to R3GIS to solve the technical issues encountered. Considering delays in the development of the smart irrigation module and the need to apply irrigation to pilot trees during the vegetative season of 2020, UniMI provided instructions to ZZM and Anthea on the frequency and quantity of water to be provided to pilot trees from May to September 2020: these instructions substituted the indications that should have been provided by the smart irrigation module. In 2021 the indications from the smart irrigation module were followed. From a budget point of view, 3 points are worth to be mentioned:

1. Anthea used budget remainings related to the hiring of the external auditor to enrol some of its operators to a course to obtain a European Tree Worker certification;
2. R3GIS sent one member of its staff to Kraków for a 1-week training in person: the costs incurred for this travel could be covered with saving from other travels;
3. finally, depreciation costs related to the construction of the pond were not charged to the project as originally planned, because of administrative issues.

Modifications and correspondence with EASME/CINEA acknowledging changes

The movement of costs budgeted for the construction of a water retention pond in Kraków from action C.1 to action C.6 was discussed during the first Monitor visit. Delays related to the construction of the pond were communicated through monthly reports. The consequent issue related to the late inclusion of the pond in the inventory of ZZM (pre-condition needed to start its depreciation) was communicated to the Monitor during the fourth monitor visit. The wrong deadline of deliverable *D.12_Management plan according to URBANGREEN platform indication* was

communicated through the April 2019 monthly report to the EC Monitor. The intention of Anthea to use budget remainings to cover an European Tree Worker (ETW) training course was communicated during the second monitor visit. The unforeseen travel to Kraków for training purposes was communicated through the March 2021 monthly report.

The duration of this action and the deadline of deliverable D30_*Report of costs (including CO2 emissions) for the URBANGREEN pilot and control areas* was postponed to December 2021 as reported in the amendment request submitted to EASME in November 2020.

ACTION C.7 | Business plan, replicability and project continuation

Foreseen start date: 1 July 2018	**Actual start date**: 1 October 2018
Foreseen end date: 30 June 2021	**Actual end date**: 31 December 2021

Activities undertaken and outputs achieved

Since October 2018, R3GIS started to work on the user manual of the future GreenSpaces platform including both web and mobile functions. Even if this is not a strict marketing-related operation, the availability of such a technical document is essential to support users to take the most out of the management platform, easing the transferability and use of this technology in new contexts at international level. In November 2018 data specification for the inventory of urban green areas was presented to the Italian Ministry of the Environment. The specifications were discussed and approved by the scientific committee working on the definition of environmental rules to be applied to public tenders related to urban green area maintenance in Italy. This aspect represents a competitive advantage for the diffusion of the URBANGREEN platform in Italy, since the data model approved by the Ministry is already implemented in the software. As an integrative part of the R3 TREES user manual, data specifications for the inventory of green areas were also updated: this document was defined with the scientific support of Politecnico di Milano in 2009 and guides users in the classification and inventory of green infrastructure.

R3GIS was invited by EASME to participate in a close-to-market initiative: after completing the checklist sent by Neemo, R3GIS participated in a webinar on this initiative. During the mid-term meeting in Kraków R3GIS met the consultant David Zlamal from Ernst and Young, who explained the support to be provided to the LIFE URBANGREEN project. After this meeting R3GIS started to work on the business plan, making research on marketing and pricing strategies, urban and environmental trends connected to WebGIS applications, comparable WebGIS solutions and competing products, projects similar to LIFE URBANGREEN, academic research on WebGIS Applications. The final draft of the deliverable *D25_Preliminary plan on Market scenario and business plan* was finalized by October 2020. Based on the feedback from E&Y in March 2021, R3GIS reviewed the business plan and enriched it with specific sections on the selling strategy of the GreenSpaces platform and URBANGREEN modules. The revised version of the plan was submitted again in August 2021 to E&Y for further evaluations. A dedicated call with E&Y and the project monitor was held on September 13th 2021 to revise the latest contents and collect input and guidance for the conclusion of the last chapters (sales and financial forecast). In December 2021 the deliverables *D26_Commercialization Plan* and *D27_Final report on Market scenario and Business plan* were finalised.

Since there is great interest from many cities on the results of the LIFE URBANGREEN Project, and since the project itself is able to measure ecosystem services only on a limited number of tree species and only in two climatic conditions, R3GIS is working with the partners on project extension packets, which could be offered to interested cities and which have a double benefit: on one side they help to market the URBANGREEN platform to new cities worldwide, on the other side they extend the scientific database of ecosystem services and help to market also related services. An example of such a packages could include the use of the URBANGREEN Platform, the

measurement of ecosystem services, services by our partners for the inventory of the green areas and the interpretation of LiDAR and remote sensing data, the extended Works module, the smart irrigation module and the public portal for citizens.

Comparison between planned outputs and time schedule

Deliverable *D25_Preliminary plan on Market scenario and business plan*, expected by June 2020, was concluded in October 2020. This was due to the willingness to include customer feedbacks: to this purpose, R3GIS created a dedicated form, but the collection of answers from a significant number of customers required time and several reminders. Despite this shift, the activities of this action were concluded with no negative impacts on the project.

Modifications and correspondence with EASME/CINEA acknowledging changes

The duration of this action and the deadline of the related deliverables was postponed as reported in the amendment request submitted to EASME in November 2020. Deliverables *D26_Commercialization Plan* and *D27_Final report on Market scenario and Business plan* were postponed to December 2021 and deliverable *D34_After file plan* was moved to 31/03/2022.

ACTION D.1 | Baseline definition and monitoring of parameters and impact indicators

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 30 June 2021	**Actual end date**: 31 December 2021

Activities undertaken and outputs achieved

Baseline measurement campaigns in Rimini and Kraków were conducted by UniMI in spring, summer and fall from July 2018 to September 2019 on pilot and control trees using an infra-red gas analyser: under this action, 109 trees were measured in Kraków and 112 trees were measured in Rimini. Measurements were conducted on four leaves per tree. Leaf gas exchange of each individual tree was measured in the morning, at midday and in the afternoon. Dark respiration and night-time transpiration were measured on a subsample of trees per each species. 981 and 1008 leaves samples (about 300 cm^2 of leaf surface for each sample), for Kraków and Rimini respectively, were collected from July 2018 to September 2019 for the quantification of PM removal (laboratory analysis). Similarly to the field operation carried out for action C.3, during D.1 measurement campaigns Anthea and ZZM staff supported UniMI providing a basket elevator and the related operator. Data collected during measurement campaigns and derived from laboratory analysis were used for statistical analysis to calculate the baseline contribution of the different species to carbon assimilation, transpirational cooling and air quality amelioration. Data collected were primarily used to assess if bias exists between the selected control and pilot trees and plots. Results allowed to take into account any pre-existing (not related to management) difference between pilot and control trees in the estimation of the impact. Data was then profitably used to define baseline values for the calculation of tree ecosystem services and the results of this analysis are provided in the deliverable *D14_Baseline performance indicators report*.

From June 2020 to October 2021, in the spring, summer and fall, UniMI (with the support of Anthea and ZZM) carried out monitoring campaigns in Rimini and Kraków following the same methods defined during the baseline campaigns. Trees monitored were the same measured for the baseline, but measurements were only conducted on 7 species per city. Reasons for such subsampling included: 1) focus on management (it was referred to have a higher number of replicates on fewer species than viceversa), 2) events which affected randomization of species and treatments (fallen trees, removed trees, uneven tree distribution, 3) species of little interest for the municipality and species on which management treatments were hardly detectable or inconsistent among years.In total, 84 trees were measured in Kraków and 72 trees were measured in Rimini. As for previous

campaigns, laboratory analyses were carried out on leaf samples and data collected (in the field and in the laboratory) were organised and used for statistical analysis. Finally, baseline values were compared with monitoring values, which were collected during the second half of the project: the outputs in terms of impacts related to the application of different treatments to pilot and control trees are described in the deliverable *D33_Impact of pilot and control management on ecosystem services*. Data collected during the measurement campaigns carried out within this action and related outputs were also used by UiMI to update deliverables of action C.3. R3GIS applied modifications to the algorithm implemented as soon as modifications were released by UniMI.

Within this action, ProGea 4D completed the work started in action C.3 related to the extraction of tree biometric parameters from point clouds in Kraków and Rimini. As stated in action C.3, LiDAR scanning of project trees was carried out later than expected and the extraction of biometric parameters (especially total leaf area and trunk/branches volume) resulted to be a complex activity that required a lot of investigation and testing of the results obtained with the different existing modelling techniques. ProGea 4D provided data on tree crown calculating the LAI of scanned trees, but this parameter was not considered adequate by UniMI to feed the Multi-layer model that requires the segmentation of the leaf areas exposed to the sun with different degrees. However, to compensate for this shortcoming, UniMI found in literature a model which can allow the partitioning of the canopy into sun and shade leaves as a function of leaf area index (LAI) and Solar Zenith Angle. This new model was used to upscale CO_2 assimilation and transpiration measured per unit leaf area to the whole canopy. In addition, in order to validate tree volumes obtained from the modelling of LiDAR data, ProGea 4D and ZZM carried out direct measurements on trees that were expected to be cut down, with the scope to calculate the real biomass of trees growing in Kraków. This activity was originally not foreseen but resulted to be very helpful to validate values obtained from the processing of pointclouds by ProGea 4D. The data provided in May 2021 were considered reliable by ProGea 4D and UniMI used it for calculating carbon storage. Only volume data related to evergreen species were omitted as they seemed to be overestimated.

Comparison between planned outputs and time schedule

In 2019 the staff of UniMI realized that the analysis of data and samples collected was more time consuming than originally foreseen: for each round of measurements (2 weeks of field work), 3 weeks of laboratory analysis and 1 week of data processing were required. This influenced the timing of the deliverable *D14_Baseline performance indicators report*, expected by December 2019. During the second Monitor visit UniMI proposed to extend the deadline of action D.1 in order to include monitoring data from Spring/Summer 2021 and have more robust data to evaluate the effects of treatments applied on trees. In addition, to better evaluate the mulching of pilot trees in Rimini applied later than expected, the autumn monitoring campaign in Rimini was postponed from 2020 to 2021. These issues, and further delays incurred some weeks later because of the spread o Covid-19 pandemic, led the partners to submit an amendment request for project extension in November 2020. The project extension of 6 months up to December 2021 was agreed by EASME and compensated the above mentioned delays. The deliverable *D33_Impact of pilot and control management on ecosystem services* was timely included in the December 2021 monthly report.

In order to improve the algorithms related to the calculation of tree water needs and tree ecosystem services, UniMI collected and analysed soil samples of the green areas of Rimini and Kraków: this allowed them to evaluate the quantity of water available in the soil.

Modifications and correspondence with EASME/CINEA acknowledging changes

Postponement of deliverable "*D14_Baseline performance indicators report"* was discussed with the EC Monitor during the second Monitor Visit. The document was finally provided with the April 2021 monthly report.

The duration of this action and the deadline of the related deliverables were revised as reported in the amendment request submitted to EASME in November 2020. Deliverable *D33_Impact of pilot*

and control management on ecosystem services (originally named *D33_State of art of the ecosystem services (CO2 sequestration and air pollution capture by leaves) in the different pilot and control areas* .) was postponed to December 2021.

ACTION D.2 | Assessment of environmental and socio-economic impacts

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 30 June 2021	**Actual end date**: 31 December 2021

Activities undertaken and outputs achieved

As the developments of the LIFE modules became consolidated, R3GIS decided to work on the definition of a methodology to calculate the carbon footprint of maintenance activities that could be applied to the field of green maintenance in general and thus become replicable for any customer. The main scope was to have by the end of the project all information needed to implement this calculation in the GreenSpaces platform. Specific terms of reference for the selection of a company that could support R3GIS in this task were drafted and four possible suppliers were invited to submit their offer. The TOR also included support for the analysis of the socio-economic impacts related to the LIFE URBANGREEN Project. The contract was awarded to the only participating company (Warrant hub), considered to be highly qualified for the work to be carried out.

The purpose of the study was to define a methodology and parameters which could be applied to the typical maintenance activities managed in GreenSpaces, with different levels of detail. This allowed to calculate the carbon footprint of the activities carried out in Rimini and Kraków in pilot and control areas, in order to evaluate the net difference in ecosystem services provided with the different maintenance regimes. However, the study includes all parameters used and all assumptions made by the consultant so that at a later stage the algorithms can be implemented in GreenSpaces in a flexible way. Details are reported in the deliverable *D24_Goal and Scope and Life Cycle Inventory (LCI)* and *D31_Report on LCA*

In parallel, R3GIS worked with the support of Warrant on the definition of a socio-economic questionnaire, which was submitted to the project partners. The questionnaire evaluated the socio-economic impact of the project and was submitted to the project partners in September 2021. Dedicated interviews were carried out with representatives of project partners in August 2021. In summary, the project contributed to the creation of new job opportunities (8 new employees in total), to the increase of the skills of its participants (167 attendees to training events organized within the project) and to the sharing of knowledge among partners. The results of these surveys are commented in the deliverable *D32_Report on the socioeconomic impacts*.

Comparison between planned outputs and time schedule

The core of the activities related to action D.2, expected to start in 2020, was concentrated during the last year of the project. Despite this shift, the activities of this action were concluded successfully and in time.

The cost of the external service to support R3GIS in this action resulted to be higher than expected, but given the extensive scope of work R3GIS accepted the offer received. The increased cost was covered using savings available from other budget lines

Modifications and correspondence with EASME/CINEA acknowledging changes

The first postponement of the deliverable *D24_Goal and Scope and Life Cycle Inventory (LCI) template for LCA and LCC* was communicated with the June 2020 monthly report. The duration of this action and the deadline of the related deliverables was revised as reported in the amendment

request submitted to EASME in November 2020. In the May 2021 monthly report it was communicated that deliverables D24 and D31, originally expected by 31/12/2020 and 31/12/2021, will be provided in one unique delivery on 31/12/2021.

ACTION D.3 | Reporting of the outputs and impacts from the project

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 30 June 2021	**Actual end date**: 31 December 2021

Activities undertaken and outputs achieved

R3GIS is responsible for reporting of project outputs through the web KPI platform. This included an analysis of the KPIs included in the project proposal (with the support of tutorial videos provided within the EC PM toolkit) in order to fit the platform requirements. R3GIS drafted a new version of project KPIs in an Excel file and discussed it with project partners to understand which data were currently available for the calculation. Several conference calls with project partners were organised for this purpose: during these calls, it was decided which data needed to be collected by project partners and how to report it to R3GIS. A template was created for the reporting of vehicle data by Anthea and ZZM: this template is organised in order to allow the calculation of pollutants related to fuel consumption of each vehicle based on the type of fuel used. The final set of KPIs was reported and discussed in the deliverable *D16_Mid-Term report of the outputs and impacts from the project, included in the Mid-term report*.

During the second half of the project, every 3 months, Anthea and ZZM provided R3GIS with data on km run and fuel consumed by vehicles used by the staff in charge of maintenance of urban green areas. R3GIS processed these data and calculated yearly emission values for vehicles used by Anthea and ZZM for the years 2019, 2020 and 2021. Environmental KPIs were updated by UniMI starting from the data collected under action D.1. Data on dissemination activities were constantly recorded by R3GIS on a monthly basis, starting from the description of activities carried out by partners provided in the monthly reports. In addition, as requested by the EASME officer, R3GIS and UniMI worked on the calculation of two additional indicators that could substitute two KPIs which were included in the project proposal but were not included in the final set of project KPIs, such as water use efficiency and NOx absorption. Water Use Efficiency values were produced for Rimini and Kraków, comparing the values of pilot plants with the respective control plants. For what concerns the absorption of NOx by trees, coefficients obtained from literature were used in the calculation and values related to pilot trees were compared to values related to control trees. Updated KPI values are described in the deliverable *D36_Final report of the outputs and impacts from the project, included in the final report*.

As foreseen in the project proposal, R3GIS contributed to the Climate Adapt Platform: https://climate-adapt.eea.europa.eu/metadata/projects/innovative-technological-platform-to-improve-management-of-green-areas-for-better-climate-adaptation.

Comparison between planned outputs and time schedule

Given to modifications introduced in the KPI reporting platform, some of the KPIs configured by the mid-term report were modified in order to fit the new mandatory requirements of the platform. The current configuration of the KPIs is described in the deliverable *D36_Final report of the outputs and impacts from the project, included in the final report*

Modifications and correspondence with EASME/CINEA acknowledging changes

The duration of this action was revised as reported in the amendment request submitted to EASME in November 2020. Deliverable *D36_Final report of the outputs and impacts from the project, included in the final report* was postponed to March 2022.

ACTION E.1 | Dissemination planning and execution

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 30 June 2021	**Actual end date**: 31 December 2021

Activities undertaken and outputs achieved

All activities carried out within this action are fully described in the deliverable *D28_Final report on dissemination and networking activities*. Since the beginning of the project, the partner consortium worked to produce digital and printed material to disseminate the project. A press release to announce the starting of the project was published after the kick-off meeting in Bolzano and was sent to all major local newspapers in Bolzano, Kraków and Rimini and posted on social networks. The project dissemination board was nominated and included one representative of each partner. By January 2019 a dissemination and communication plan was produced with the contribution of all partners, including the list of events that partners planned to attend or organise, as well as the list of channels and tools to be used to disseminate the project. The dissemination plan was submitted as deliverable *D.6_ Dissemination and Communication plan* in January 2019 and updated for each monitor visit. All activities carried out to implement the dissemination plan were documented in the monthly technical reports to the EC Monitor.

Warrant Hub was selected as an external consultant for the communication and the dissemination of the project by R3GIS and supported the partners in the design of the project coordinated image, including:

- logo
- brochure (11.000 copies printed in English and Polish)
- noticeboard (installed on partners' premises and updated after the acceptance of the amendment request)
- roll-up (also translated in polish)
- graphic design of the project website www.lifeurbangreen.eu (available in in English, Italian and Polish)
- layman's report (3.500 copies available in English, Italian and German, Polish version available in digital format)

Moreover, Anthea designed landmarks in Italian and English to be placed in project areas to raise awareness of the project among citizens and users of urban parks: the digital file was made available to ZZM which translated it into Polish. In total, 150 small landmarks were placed in Kraków project areas while in Rimini 30 big landmarks were installed in project parks and project logos were applied on all project trees. Further printed materials were prepared by Anthea, ZZM and ProGea 4D, such as a brochure to inform the citizens of Rimini about the pruning of trees during the project (10.000 copies) and a booklet for the citizens of Kraków about the trees of the city (1.000 copies). Finally, in October 2021, R3GIS prepared some flyers describing the new modules developed within the project, in order to promote them and facilitate their sale.

Within the website, a form for the subscription to the project newsletter was created: starting from February 2019 to December 2021, 7 project newsletters were sent to subscribers. Project pages were also created on Facebook, Linkedin, Slideshare and Youtube and information on the project is being published regularly. Also, articles on technical magazines were published throughout the project. The list of workshops and conferences that project partners organised (10) or attended (57) to present the project was continuously updated in order to derive data to feed project KPIs on

dissemination (see section 7). The updated list of all the dissemination activities carried out is reported in deliverable *D28_Final report on dissemination and networking activities.*

Some of the networking contacts created through emails and dissemination activities led to more in-depth interaction and exchanges with 9 different projects, as reported in the deliverable *D28_Final report on dissemination and networking activities*. Among the others, Particularly relevant is the collaboration with the INTERREG IT-CH Project "VerdeVale". This project, also coordinated by R3GIS, shares common topics with the LIFE URBANGREEN project and activities are complementary. In fact, while LIFE URBANGREEN focused on the study of ecosystem services provided by trees, VerdeVale focuses on the study of ecosystem services provided by shrubs and hedges. This collaboration allows for a first extension of the list of studied species in the GreenSpaces platform.

As reported in the project proposal the city of Taipei expressed formal interest to implement project activities in Taiwan at their own cost. Several meetings and conference calls were organised with prof. Yuei An Liou (Head of the Hydrology Remote Sensing Laboratory of the National Central University of Taiwan) and his staff in order to define project activities to be replicated and carried out in Taiwan. On January 2019 a delegation of the LIFE URBANGREEN project including Paolo Viskanic (R3GIS project coordinator), Piotr Wezyk (ProGea 4D) and prof. Francesco Ferrini (University of Florence) was invited by prof. Yuei An to present project objectives and activities to the Taiwanese group. Also, in May 2019 prof. Yuei An visited R3GIS and prof. Ferrini at their premises in Bolzano and Florence. A working week in Taiwan was scheduled in February 2020 and postponed to November 2021: however, because of the restrictions introduced by the Taiwanese government to contain the Covid-19 pandemic, this travel could not be carried out and was substituted with an online workshop.

At an initial stage, the City of Moscow also expressed interest in the LIFE URBANGREEN project. Paolo Viskanic and Prof. Francesco Ferrini were invited by the City of Moscow to present the LIFE URBANGREEN project at the 2nd Climate Forum for Russian Cities in Moscow in September 2018. After that event, Paolo Viskanic visited the municipality of Moscow several times during the second half of 2018 and 2019 to present the project and find an agreement on activities to be carried out in Russia. However the City of Moscow did finally not proceed with the project.

Comparison between planned outputs and time schedule

Due to the restrictions introduced to contain the Covid-19 pandemic, the training week in Taiwan could not be finalised. However, contacts with the working group of professor Yuei-Anh were kept for the whole duration of the project and a final, online workshop was held on November 18th 2021. The minute of this meeting is reported in the deliverable D23_*Report on the online workshop with Taiwan* (where the previous title "Report on the training event in Taiwan" was modified in order to better match the contents of the document).

The participation in some international events originally planned was not possible since the events were cancelled due to the pandemic. Therefore R3GIS used part of the money allocated to conferences and fairs to produce and disseminate 5 short videos professionally filmed in Kraków and Rimini to highlight the achievements of the project. The videos were also used during the final event at Ecomondo in Rimini, where also Mr. Salsi of the EU LIFE Programme participated.

Modifications and correspondence with EASME/CINEA acknowledging changes

The duration of this action was revised as reported in the amendment request submitted to EASME in November 2020. Deliverable *D28_Final report on dissemination and networking activities* was postponed to December 2021 and deliverable *D34_After-LIFE plan "submitted as part of the Final report"* was postponed to March 2022.

ACTION F.1| Project management and coordination

Foreseen start date: 1 July 2018	**Actual start date**: 1 July 2018
Foreseen end date: 30 June 2021	**Actual end date**: 31 December 2021

Activities undertaken and outputs achieved

The project management board provided updates to the EC Monitor on a monthly basis through a technical report, written by R3GIS with the contribution of the project partners. The joint report was also sent to the internal and external steering committee members and to prof. Yuei An (project coordinator of activities in Taiwan). All recipients of the technical reports who are not project partners signed the NDA agreement. After each technical or organizational meeting minutes were prepared by R3GIS and shared through the shared folder system created by R3GIS to which also the EC Monitor has access. R3GIS with the support of the partners replied to the technical and financial questions raised by EASME after the yearly meetings with the Monitor and the Mid Term report, and collected the required supporting documentation. The mid-term report was sent to EASME in March 2020. Together with this deliverable, also an amendment request to change the coordinating beneficiary's legal address was enclosed. The progress report was sent to the EASME officer Bernd Decker in early July 2021. An amendment request was sent in November 2020, asking for a 6 months extension (see next section). The following meetings were organised or attended by the project partners:

- Kick-off meeting with all partners held in Bolzano on July 11th and 12th 2018: on this occasion also external steering committee members participated.
- LIFE17 Climate Action Kick Off Meeting held in Brussel on October 2nd and 3rd 2018, attended by R3GIS (Project coordinator and project manager) as coordinating beneficiary of LIFE URBANGREEN.
- First Monitor Visit, held in Bolzano on January 30th and 31st 2019. In that occasion also the meeting related to the selection of project areas was organised on February 1st
- Mid-term meeting and second Monitor Visit, held in Kraków from 26th to 28th November 2019. Also in this case, external steering committee members were invited and two meetings were combined together to save travel money.
- Third Monitor Visit, held online on December 10th to 11th 2020.
- Final meeting and fourth Monitor Visit, held in Rimini from 25th to 26th October 2021. Also in this case, external steering committee members were invited and two meetings were combined together to save travel money.

Financial and administrative issues related to project reporting were presented to all partners during the kick-off meeting by Warrant Hub (R3GIS consultant) and repeated during all monitor visits. In preparation to each Monitor Visit, a financial revision was carried out by R3GIS with the support of Warrant Hub. Each partner was required to fill an Excel template for financial reporting and provide supporting documentation with costs incurred: problems encountered were notified to each partner. Before each Monitor Visit, R3GIS provided the EC Monitor access to the shared folder system.

Since the beginning of the project, ZZM and ProGea 4D worked to obtain additional funding for the LIFE URBANGREEN project from the National Fund for Environmental Protection and Water Management. An official agreement for the grant amount of 340.266 PLN, not exceeding 30% of the eligible project costs, was signed by ZZM on August 22nd 2018: so far, the additional funds obtained were used to cover expenses related to the purchase of satellite images and meteo data. For what concerns ProGea 4D an official agreement for the grant amount of 94.601 PLN was signed on August 21st 2018: the additional funds obtained were used to cover expenses related to maintenance of eCognition, Terrasolid and ArcGIS software. After the control conducted by National Fund for Environmental Protection and Water Management in March 2021 ZZM and ProGea 4D received a very positive feedback from the controller.

Comparison between planned outputs and time schedule

Technical reports sent on a monthly basis to the EC Monitor are rich in information and details, describing project progresses compared to planned activities: this allowed to avoid the drafting of the semestral interim report (as foreseen by the project proposal).

Due to changes in the financial rules the audit report originally required is not needed anymore, since no partner reaches a grant sum of € 750.000. Therefore the costs budgeted for the audit were available to cover justified extra costs incurred. R3GIS used the amount for expertise on meteo data (see action C.1). Anthea decided to allocate these resources to the professional training of its gardeners, in order to certify their job in line with the best practises proposed by UniMI (see action C.6).

During the first monitor visit in Bolzano the partner consortium agreed to organise the second monitor visit in Kraków (instead of Bolzano) in combination with the mid-term meeting. Also, it was agreed that the monitor visit should occur prior to the deadline of the mid-term report, in order to get feedback from the EC Monitor on the technical and financial documentation.

As stated in action D.1 UniMI proposed to extend the deadline of action D.1 up to September 2021 and this proposal was accepted by project partners. However, the need for a longer extension became clear after the spread of Covid-19 pandemic, which slowed down part of the project activities, as mentioned in the mid-term report. For this reason, in July 2020, the partner consortium decided to ask EASME for a 6 months project extension. The request was submitted in November 2020 and it was officially accepted in March 2021 with the Letter Amendment Nr. 1 to Grant Agreement LIFE17 CCA/IT/000079 - LIFE URBANGREEN - Ref. Ares(2021)1654279 - 05/03/2021. The project extension required the scheduling of an additional monitor visit that took place in Rimini in October 2021 in conjunction with the Final meeting of the consortium. Even if this new deadline implied new further costs (e.g. extension of the subscription of UBIMET and Planet data, an additional monitor visit, etc.), thanks to savings on previous project activities no additional budget was needed.

An unforeseen travel to Kraków was made by the project coordinator Paolo Viskanic and the project manager Alice Pasquinelli in September 2020 in order to overview the progress of activities under the responsibility of ZZM and ProGea 4D and discuss open issues. Costs were covered with other travel budget savings.

Modifications and correspondence with EASME/CINEA acknowledging changes

The organisation of the second Monitor Visit in Kraków instead of Bolzano was reported in the Minute of the first Monitor Visit and in the March 2019 technical report. The shifting of the R3GIS budget foreseen for the external auditor from action F.1 to action C.1 was reported in the technical report of January 2019 and was discussed during the first Monitor Visit in Bolzano. The shifting of the Anthea budget foreseen for the external auditor from action F.1 was discussed during the second Monitor Visit.

The intention to ask for a six-month extension was communicated through the July 2020 technical report. The duration of this action was revised as reported in the amendment request submitted to EASME in November 2020.

6.2. Main deviations, problems and corrective actions implemented

Main problems highlighted in section 6.1 are summarised in the following lines.

Final selection of project areas (action A.1): as described in action A.1, because of problems in finding areas containing a good distribution of trees of the selected tree species, and because of an unexpected excavation site affecting one of the parks chosen in Rimini, the deadline of

this activity was moved from September 2018 to September 2019. This affected the schedule foreseen for the survey of selected trees and areas using laser scanner technology (action C.3 and D.1).

LiDAR scanning of selected trees and areas (action C.3 and D.1): because of the late definition of project areas and trees and because of the flight restrictions over project areas in Rimini (close to airport), this activity could not be concluded in the expected time (spring 2019). The complete survey of trees and areas in Kraków was concluded by August 2019, while the one in Rimini was completed in January. This affected the deadline of the deliverable D.3_*Inventory of pilot areas based on mobile laser scanning* and D.4_*Report of data acquisition of pilot areas* (action A.1) as well as the calculation of tree ecosystem services using the Multilayer model (requiring LiDAR parameters, action C.3 and D.1). In addition, when tree LiDAR data became available, finding the optimal procedure to extract biometric parameters resulted to be more complex than expected and the investigation of existing methodology went on after the end of action C.3 and within action D.1. Not all the parameters obtained resulted to be suitable to be used for the purpose of the project: while data on woody biomass estimated form pointclouds resulted to be reliable, it was not possible to derive data on the quantity of leaf area with different exposure to the sun. However, UniMI found in literature a model which allowed the partitioning of the canopy into sun and shade leaves as a function of leaf area index (LAI) and Solar Zenith Angle. This allowed the calculation of tree ecosystem services using both the "Big leaf" and the "Multilayer" model.

Definition of ecosystem services provided by trees (action C.3): analysis of leave samples and data processing resulted to be very time consuming. Also considering the delay of LiDAR data provision, an extension of the deadline for all deliverables of C.3 expected by December 2019 was discussed during the mid-term meeting. However, algorithms for the calculation of ecosystem services were finally defined by February 2020. This delay did not affect other activities.

Configuration of an IoT sensor network in Rimini and Kraków (action C.4): because of technical issues described in annex 2 the deadline for this activity was moved from March 2019 to June 2019 and was completed in September 2019. However, this shift didn't affect general project results.

Release of the software modules (action C.1, C.2, C.3, C.4, C.5): the development of the new modules was postponed, mainly because preliminary changes to the architecture of the original R3 TREES platform, needed to allow for new modules to be developed, took longer than expected. Also, the developments related to the advanced job planning module resulted to be more complex than planned. Postponements were also due to the delay of other preliminary activities (e.g. the definition of algorithm for calculation of ecosystem service or the selection and installation of IoT sensors). However, new modules and functions were released progressively in 2020 and only minor features and improvements were concluded in 2021 (under action C.6). Thanks to the six-months extension agreed by EASME, Anthea and ZZM could test all modules for the whole vegetative season of 2021.

Issues on the application of treatments (action C.6): some trees originally selected to be studied within the project had to be felled for safety reasons. In addition, due to organisational problem, the mulching of pilot trees in Rimini was applied later than expected. In order to preserve the successful outcome of the analysis of the impacts of the treatments, UniMI proposed to extend the duration of action D.1 and to focus the monitoring of impacts on 7 species out of the 10 originally selected.

Scope of the Life Cicle Assement (action D.2): for what concerns the Life Cicle Assessment, activities described in the project proposal resulted to be very generic and the focus of this analysis was limited to the activities carried out in the project. However, R3GIS decided to go

beyond this limit and to work on the definition of a methodology that could be applied to green maintenance and make it replicable for the main activities in this sector. The final scope of action D.2 became to have by the end of the project all the information needed to implement in the GreenSpaces platform the evaluation of the carbon footprint of maintenance activities planned, seen as an added value for the software. This objective was reached and the description of the methodology to calculate the carbon footprint of green areas maintenance jobs is provided in the deliverable D31_Report on LCA.

Training week in Taiwan (action E.1): due to the restrictions introduced to contain the spread of the Covid-19 pandemic, the training week in Taiwan foreseen in project proposal could not be carried out. However, contacts with the working group of professor Yuei-Anh were kept for the whole duration of the project and a final, online workshop was held on November 18th 2021.

Request of project extension (action F.1): during the mid-term meeting, UniMI proposed to extend the deadline of action D.1 up to September 2021 and this proposal was accepted by project partners. However, the need for a longer extension became clear after the spread of Covid-19 pandemic, which slowed down part of the project activities. For this reason, the partner consortium decided to ask EASME for a 6 months project extension. The request was submitted in November 2020 and it was officially accepted in March 2021 with the Letter Amendment Nr. 1 to Grant Agreement LIFE17 CCA/IT/000079 - LIFE URBANGREEN - Ref. Ares(2021)1654279 - 05/03/2021. No additional budget was needed to extend project activities by 6 months and activities were completed on time by 31/12/2021.

6.3. Evaluation of Project Implementation

Action	Foreseen in the revised proposal	Achieved	Evaluation
A.1	*Objectives:* definition of project areas and trees *Expected results:* * List of tree species to be investigated selected * Trees to be measured for ecosystem services selected * Pilot/control plots defined * Project areas inventoried	* List of tree species to be investigated selected * Trees to be measured for ecosystem services selected *Pilot/control plots defined * Project areas inventoried	Achieved
C.1	*Objectives:* development of a smart irrigation module to calculate trees water needs based on tree species, meteo data and past irrigation *Expected results:* * Algorithm to calculate tree water requirements defined * Use of meteo data to calculate potential evapotranspiration * Determination and update of species coefficient to calculate tree water need * Integration and visualisation of meteo data in URBANGREEN platform	* Algorithm to calculate trees water requirement defined * Use of meteo data to calculate potential evapotranspiration * Determination of species coefficient to calculate tree water need * Integration and visualisation of meteo data in URBANGREEN platform	Achieved

Action	Foreseen in the revised proposal	Achieved	Evaluation
C.2	*Objectives:* development of an advanced job planning module *Expected results:* * Analysis of users needs for workforce planning * definition of functions to be developed * improvement of current job programming module * warning on weather events affecting jobs scheduled * warning on jobs located to far away	* Analysis of users needs for workforce planning * definition of functions to be developed * improvement of current job programming module * warning on weather events affecting jobs scheduled * warning on jobs located to far away	Achieved
C.3	*Objectives:* calculation of ecosystem services provided by trees *Expected results:* * algorithm to calculate trees ecosystem services defined * measurement campaign complete * species coefficients to apply for the calculation of ecosystem services calculated with Big Leaf model * trees biometric data to apply for the calculation of ecosystem services extracted from LiDAR data * calculation of ecosystem service of trees in GreenSpaces platform	* algorithm to calculate trees ecosystem services defined * measurement campaign complete * species coefficients to apply for the calculation of ecosystem services calculated with Big Leaf model * trees biometric data to apply for the calculation of ecosystem services extracted from LiDAR data * calculation of ecosystem service of trees in GreenSpaces platform	Achieved
C.4	*Objectives:* implementation of a system to monitor the quality of green areas based on IoT, meteo and RS *Expected results:* * Opportunity of use of IoT, meteo and RS data in URBANGREEN platform analysed * algorithm to monitor trees health based on satellite images defined * IoT network configured in Rimini and Kraków * monitoring of severe weather events integrated in URBANGREEN platform * development of the trees health monitoring workflow based on satellite images	* Opportunity of use of IoT, meteo and RS data in URBANGREEN platform analysed * algorithm to monitor trees health based on satellite images defined * IoT network configured in Rimini and Kraków * monitoring of severe weather events integrated in URBANGREEN platform * development of trees health monitoring workflow based on satellite images	Achieved
C.5	*Objectives:* development of a public portal and app targeted to citizen *Expected results:* * Requirements of public portal and app for Rimini and Kraków analysed * public portal and app developed	* Requirements of public portal and app for Rimini and Kraków analysed * public portal and app developed	Achieved

Action	Foreseen in the revised proposal	Achieved	Evaluation
C.6	*Objectives:* testing of URBANGREEN tools in real life *Expected results:* * management plan drafted * pilot and control treatments applied	* management plan drafted platform defined * pilot and control treatments applied	Achieved
C.7	*Objectives:* definition of a business and commercialisation plan to market URBANGREEN platform and transfer project results *Expected results:* * preliminary activities to introduce the platform into the market * business and commercialization plan defined	* preliminary activities to introduce the platform into the market * business and commercialization plan defined	Achieved
D.1	*Objectives:* determination of variation in the performance of ecosystem services provided by trees in pilot and control plots *Expected results:* * baseline of ecosystem services calculated with Big Leaf and Multi layer model * impacts of pilot and control treatments on ecosystem services provided by trees	* baseline of ecosystem services calculated with Big Leaf and Multi layer model * impacts of pilot and control treatments on ecosystem services provided by trees	Achieved
D.2	*Objectives:* assessment of environmental and socio-economic impacts *Expected results:* * preliminary activities for project LCA and cost/benefit analysis	* preliminary activities for project LCA and cost/benefit analysis	Achieved
D.3	*Objectives:* reporting of outputs and impacts from the project *Expected results:* * set of project KPI configured in KPI webtool * Mid-term upload of KPI values * final update of KPI values	* set of project KPI configured in KPI webtool * Mid-term upload of KPI values * final update of KPI values	Achieved
E.1	*Objectives:* dissemination of project activities and results *Expected results:* * website * brochure * noticeboard * rollup * landmarks * attendance to conferences and events	* website in EN, IT and PL * brochure * noticeboard * rollup * landmarks * 67 conferences and events attended * 19 articles published * laymans' report in 4 languages	Achieved

Action	Foreseen in the revised proposal	Achieved	Evaluation
	* publication of articles * laymans' report * final project event	* final project event at Ecomondo (Rimini) on October 27th 2021	
F.1	*Objectives:* financial and technical monitoring of project activities *Expected results:* * monthly technical reports * organisation of meetings * mid-term, progress and final report	* monthly technical reports regularly drafted * Technical meeting * kickoff meeting * first, second third and fourth Monitor Visits * mid-term meeting * final meeting * mid-term, progress and final report delivered	Achieved

6.4. Analysis of benefits

The implementation of the LIFE URBANGREEN project led to different types of benefits.

From an environmental point of view, the project demonstrated that the application of innovative maintenance practices results in healthier trees providing higher benefits for citizens. In Rimini, CO_2 assimilation of pilot trees was 2,4% lower than control trees during the baseline. After the imposition of treatments, CO_2 assimilation of pilot trees was on average 21,9% higher than control trees, resulting in a 24,3% improvement of CO_2 assimilation because of pilot management. In Kraków, CO_2 assimilation of pilot trees was 9,3% lower compared to control trees. After the imposition of treatments, instead, CO_2 assimilation of pilot trees was 6,1% higher compared to control trees, resulting in a 15,4% increase in CO_2 assimilation because of pilot management. At three years after the end of the project, in Rimini CO_2 assimilation is expected to be 28,7% higher if trees are managed according to pilot regimes than if they were managed according to traditional practices. In Kraków, CO_2 assimilation at three years after the end of the project is expected to be 88,32% higher if trees are managed according to pilot regimes than if they were managed according to traditional practices.

Table 1 -Absolute values of CO_2 assimilation per tree and by all trees included in the experimental areas of both cities.

	END OF THE PROJECT	**END OF THE PROJECT**	**3 YEARS AFTER THE END**	**3 YEARS AFTER THE END**
	Total	**Per tree**	**Total**	**Per tree**
Rimini	***44.680 trees***	***1 tree***	***44.680 trees***	***1 tree***
Pilot	7567 t CO_2/year	169 kg CO_2/year	8449 t CO_2/year	189 kg CO_2/year
Control	6170 t CO_2/year	138 kg CO_2/year	6566 t CO_2/year	147 kgCO_2/year
Krakow	***114.935 trees***	***1 tree***	***114.935 trees***	***1 tree***
Pilot	46746 t CO_2/year	407 kg CO_2/year	58000 t CO_2/year	504 kg CO_2/year

Control	34407 t CO_2/year	299 kg CO_2/year	30797 t CO_2/year	268 kg CO_2/year

For what concerns PM removal, in Rimini during the baseline PM_{10-100}, $PM_{2.5-10}$ and $PM_{0.2-2-5}$ removal of pilot trees were, on average, 5,7%, 7,8% and 24,4% lower compared to control trees. After the imposition of treatments, PM_{10-100}, $PM_{2.5-10}$ and $PM_{0.2-2-5}$ of pilot trees became, on average, 14,9%, 23,8% and 9,5% higher compared to control trees, resulting in a 20,5%, 31,6%, and 33,8% improvement in the trapping of PM_{10-100}, $PM_{2.5-10}$ and $PM_{0.2-2-5}$ because of pilot management. In Kraków, during the baseline PM_{10-100}, $PM_{2.5-10}$ and $PM_{0.2-2-5}$ of pilot trees were, on average, 17,8%, 14,4% and 19,3% lower compared to control trees. After the imposition of treatments, PM_{10-100}, $PM_{2.5-10}$ and $PM_{0.2-2-5}$ trapping of pilot trees were, on average, 5,3% and 3,3% lower than control, while PM0.2-2-5 trapping became 0,5% higher compared to control trees. Thus, pilot management improved trapping of PM_{10-100}, $PM_{2.5-10}$ and $PM_{0.2-2-5}$ by 12,5%, 11% and 19,9%. At three years after the end of the project, in Rimini PM_{10} deposition is expected to be 37,4% higher if trees are managed according to pilot regimes than if they were managed according to traditional practices. In Kraków, PM_{10} deposition at three years after the end of the project is expected to be 41,14% higher if trees are managed according to pilot regimes than if they were managed according to traditional practices.

Table 2 - absolute values of PM_{10} removal per tree and by all trees included in the experimental areas of both cities.

	END OF THE PROJECT	**END OF THE PROJECT**	**3 YEARS AFTER THE END**	**3 YEARS AFTER THE END**
	Total	**Per tree**	**Total**	**Per tree**
Rimini	***44.680 trees***	***1 tree***	***44.680 trees***	***1 tree***
Pilot	22.729 kg PM_{10}/year	0,62 kg PM_{10}/year	54.550 kg PM_{10}/yearr	1,22 kg PM10/year
Control	22.375 kg PM_{10}/year	0,61 kg PM_{10}/year	39.701 kg PM_{10}/year	0,89 kg PM10/year
Krakow	***114.935 trees***	***1 tree***	***114.935 trees***	***1 tree***
Pilot	140.626 kg PM_{10}/year	1,22 kg PM_{10}/year	13.6268kg PM_{10}/yearr	1,19 kg PM_{10}/year
Control	113.488 kg PM_{10}/year	0,99 kg PM_{10}/year	96.171 kg PM_{10}/year	0,84 kg PM_{10}/year

In addition, it is due to highlight that healthier trees reduce safety risks in an urban context (e.g. the falling of branches on assets and people) and extend the life of trees, requiring less tree substitutions.

From a scientific perspective, thanks to the field data, laboratory measurements and data analysis carried out by UniMI, the project allowed the creation of a new database related to ecosystem services provided by tree species in two typical European climatic contexts. The results of the analysis carried out on 20 selected species in Rimini and Kraków will be applied in other cities having similar climatic conditions and hosting the same tree species. But this is only a starting point, since the objective of the next years will be to widen the list of studied species. Given the relevance of the study carried out and the quality or results obtained, the partners of the LIFE URBANGREEN project have already been contacted by other municipalities that are keen to apply the innovations introduced by the project and study new species (e.g. the city of Padova in Italy).

From the point of view of the technology that can support the cities in ensuring the best quality in the maintenance of urban green areas, the project allowed to develop innovative modules aimed at providing water to trees when actually needed, calculating ecosystem services provided by trees, managing maintenance activities in the most efficient way, monitoring the quality of trees and green areas, sharing and communicating to the public information about urban green areas and nature benefits provided by trees. These modules are integrated in the GreenSpaces platform and, thanks to the testing carried out, some of them are ready to be marketed right after the end of the project. This means that the results obtained by the project will be transferred to other cities (in Europe and beyond) that are already using or will acquire GreenSpaces.

In addition, with the support of the Close-to-Market team of Earnst & Young, we had the possibility to define a business plan that can help R3GIS in marketing the GreenSpaces platform integrated with the URBANGREEN modules. Considering the company's range of action, the main market opportunities were identified in Italy and in the German-speaking DACH region including Germany, Austria and Switzerland. Thanks to the intense dissemination activities carried out through the project and guided by the business and commercialization plan defined, we expect the technology developed to be transferred to 26 new municipalities in 3 years by the end of the project. However, considering the existing partnerships of R3GIS in many other countries, we expect the results of the project to be transferred even beyond European borders.

From a socio-economic perspective, the LIFE URBANGREEN project contributed to the creation of new job opportunities, to the increase of the skills of its participants and to the sharing of knowledge among partners. For the purpose of the project, 8 new workers were employed among the staff of all project partners, including women and young employees. In total 11 full-time equivalent (FTE) workers were involved in the project.

Trainings organized during the project were focused on the innovative treatments to be applied in urban green areas: in this case, the University of Milan organized two dedicated meetings to address this topic with Anthea and ZZM, including classroom lessons and practical demonstrations. Training sessions were also organized by R3GIS on the use of the GreenSpaces platform and URBANGREEN modules, enabling Anthea and ZZM to make the best use of the technology developed. In total, 167 people participated to training events organized within the project. In addition, some of the workers of Anthea were enrolled in training courses to obtain the European Tree Worker (ETW) certification for professional arborists recognized at European level.

From a policy point of view, activities carried out during the project led to important achievements. In November 2018 the data model for the inventory of urban green areas was presented to the Italian Ministry of the Environment. The model was discussed and approved (April 2020) by the scientific committee working on the definition of environmental rules to be applied to public tenders related to urban green area maintenance in Italy. This aspect represents a competitive advantage for the diffusion of the GreenSpaces platform integrated with the URBANGREEN modules in Italy, since the data model approved by the Ministry is already implemented in the software.

Moreover, the tools developed by LIFE URBANGREEN are recognised and published as best practices in the White book for urban green management in Italy and are included in the database of the Best Practices for local authorities in Italy.

The Italian National Plan for Recovery and Resilience (PNRR) foresees among others actions to improve urban and peri-urban green areas and to plant trees. GreenSpaces and the new modules developed in the LIFE URBANGREEN project could play an important role in the implementation of the plan. With GreenSpaces the projects financed by the PNRR can be implemented in a transparent way and the new tools can assist to take care of the newly planted trees and demonstrate their ecological benefits.