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Urban Vegetation Leveraging Actions

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Abstract: Sustainable Development Goals (SDGs) include a subset of targets that can be advanced through standard urban management activities. In particular, routine urban vegetation management comprises a number of activities with potential impact on Goal #4 (quality education), #11 (sustainable cities and communities), #13 (protect the planet), #15 (life on land), and, perhaps less obviously, but equally important, on Goal #8 (good jobs and economic growth). This paper discusses how urban vegetation management can help achieve the SDGs at a local level. Drawing on a case study (Talavera de la Reina, Spain), it is shown that an intelligent approach to urban vegetation management can leverage resources towards the SDGs at little or no cost to municipalities. Minor modifications and conceptual changes in how standard practices are carried out can make a difference. Including this dimension can even result in a positive balance for the municipal budget. Our analyses and proposals are of broad and direct applicability for urban areas worldwide and can help city authorities and officials to align their cities with the SDGs simply by making minor adjustments to how they currently deal with urban vegetation.

Keywords: urban trees; sustainable cities; SDGs; local policies; municipal works

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1. Introduction

Urban vegetation has traditionally fulfilled a number of functions. These include sensory enjoyment, control of the environment (shade, temperature, noise, humidity, dust, wind, pollution and runoff) and enhancing the economic and environmental value of spaces [1–6]. The different responses to these functions have shaped the current green fabric of cities across the world, with historical evolution going hand in hand with emerging societal issues. Thus, the first modern public park (Birkenhead Park, England, 1847) was intended to fulfil the function of providing leisure activities and recreation for a growing working-class population. The ruling classes soon realized the virtues of ample green spaces for the well-being of urban, alienated factory workers and their families.

The evolution of society, technology, welfare state, and the emergence of early sustainability concerns led to this approach being reoriented and refined, with the emergence of new uses and complementary values for urban vegetation [7]. Thus, other benefits of vegetation include food production. The "edible cities" concept nicely encapsulates the idea [8–12]. An example would be the *Tilia cordata*: its flowers are used to make tea in some parts of Europe (lime tea). Biomass production is also a potential use, while in some areas, trees have been used to improve water quality (through sewage treatment, storm water catchment areas, and percolation of water into the ground). In recent times, the use of green spaces for health and well-being has developed into an active and important research topic [13–17], as epitomized in the Shanghai, highly urbanized case study [15,16]. Research linking health, well-being and green space shows that urban green spaces, as part of the wider environmental context, promote health and well-being throughout the course of life [13].

Today, ensuring that vegetation serves to add value to the entire urban space is a priority if we are to avoid economic and social imbalances within a framework of sustainability and equity. In the field of sustainability, conserving and improving urban woodland and trees is of great interest to municipalities, especially in a context of climatic emergency and in arid, semi-arid or transition areas [7,18].

Another key idea is that trees could be used to leverage advanced productive activities that can offer new economic resources for an area. New social functions can be added to traditional functions of green cover at little or no cost, with intelligent planning that takes into account the most important details of the multiple dimensions of the subject. Thus, for instance, publicizing the scientific activity carried out in a city in this field on an international scale can, in fact, facilitate obtaining additional resources that multiply local efforts, notably improving the international positioning of the city in the economic, tourism and commercial realms [19].

'Democratizing trees' is also a priority of social action to bring cohesion to the urban fabric, i.e., to the physical form of the city, and to expand the heritage value of the central historical areas for the entire city. Indeed, centrality traditionally means more resources, and mature trees are associated with higher income [20,21]. Extending the benefits of green cover to neighborhoods would result not only in a more inclusive, egalitarian and fair society, but also more resilient cities capable of coping with emerging threats, such as the climate emergency.

The Sustainable Development Goals (SDGs) are well known. They consist of a collection of 17 interlinked goals designed to be a "blueprint to achieve a better and more sustainable future for all" (UN, 2017). They are part of the UN Resolution popularly known as "Agenda 2030". Research directions on this topic include responses to climate change [22–25], social equity, education and health [26–31], urban sustainability [32–35], sustainable business [36–40] and policy design, implementation and evaluation [41–45]. It is widely understood that the SDGs are closely interdependent and that their successful pursuit requires integration across most policy areas.

In this paper, the Talavera case is used to exemplify the sorts of actions that can be implemented at local level to leverage urban vegetation management works. These actions need to be tailored to climate, society and local regulations. However, one of the lessons learnt in the Talavera case was that there are commonalities, with many actions being applicable in other cities. The case presented here is intended to be general, and the paper provides a framework for translating the substance of this idea to other cities. Indeed, linking the green infrastructure of a place to the SDGs is a timely and relevant topic as is the need to adapt the type of trees to mitigate for future challenges.

2. Data, Materials and Methods

A description of the city is required to gauge specificities conditioning the choices made, and what should be adapted if these ideas are applied to other geographical spaces. In 2019, the population of Talavera was 83,417 (density of 448.28 inh/km^2). The city existed before the Romans made it a municipality in 182 BC. Settlements in the area can be traced back to the Paleolithic period. Such a long history means the city is home to important cultural, heritage and historical resources. Pre-Roman, Roman, Visigoth, Moorish and Christian cultures have left their footprint on the urban layout since the Roman conquest of Iberian Peninsula about 2200 years ago. A historical landmark, the remains of the silk factory (established 1746) recall the connection of the city with silk weaving and mulberries. As described below, this tree can be used to make a strong vegetation-culture connection and serve as an educational resource.

The lowest part of the city is the Tajo (Tagus) River at 373 m above sea level. The climate of the area was characterized using data from the Climate Research Unit (CRU), University of East Anglia, UK [46]. Figure 1 shows the time series of temperature and precipitation for the period 1900–2000. Mean rainfall is about 350 mm/year, with great interannual variability. Mean temperature is about 15 °C. Applying Köppen's climate

classification (Figure 2) results in a BSk, which is a steppe climate. Other classifications, such as the extended Köppen and Holdridge's method, confirm this.

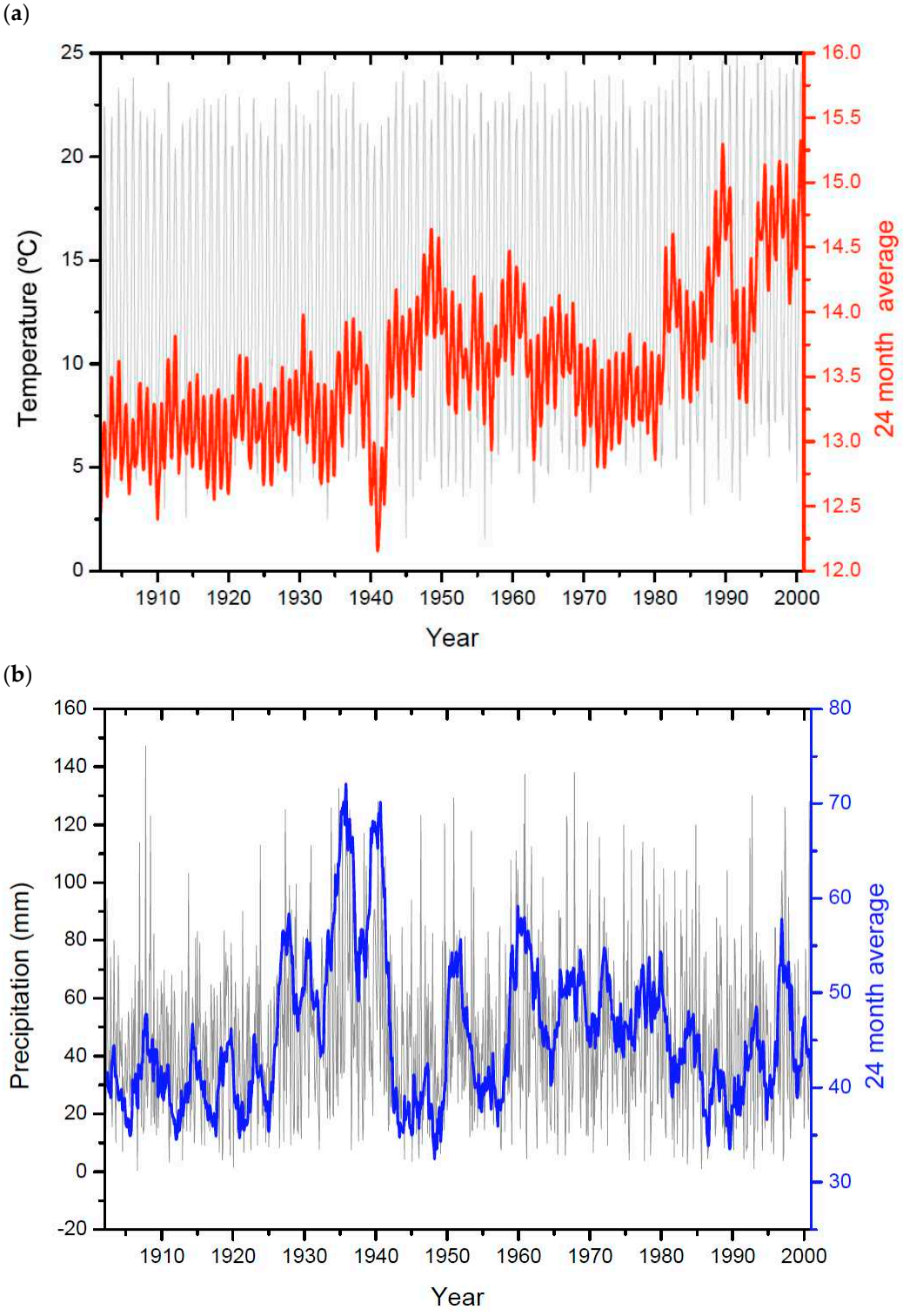

Figure 1. Extended and filtered series (1900–2000) of: (**a**) Temperature (**b**) Precipitation in Talavera de la Reina, including a 24-month moving average. Data from the Climate Research Unit (CRU), University of East Anglia, UK.

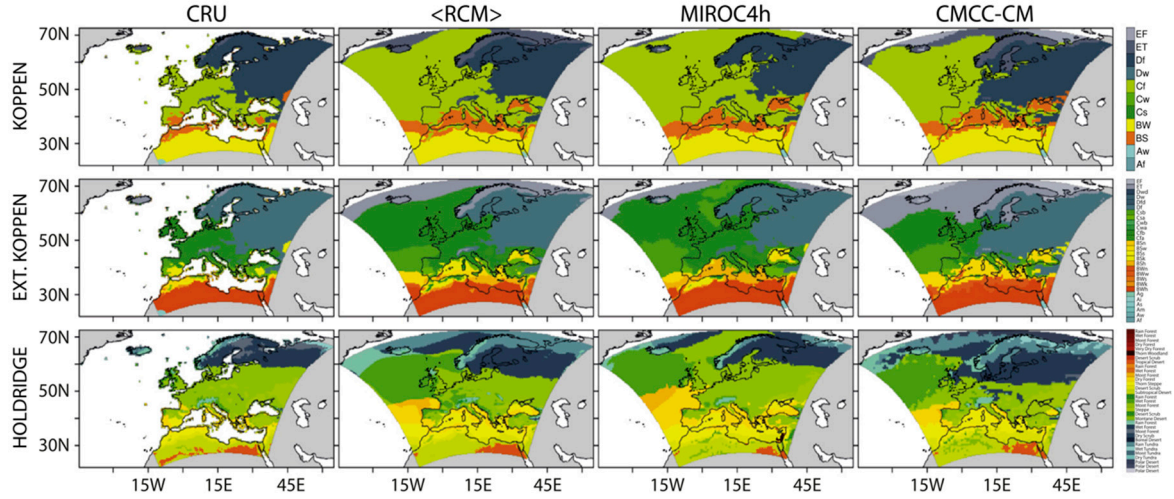

Figure 2. Three classifications (Köppen's, extended Köppen's and Holdridge's) of present climate in Europe as derived from observations (CRU), a Regional Climate Model (RCM) ensemble <RCM> and two Earth System Models (ESMs) (from Tapiador et al. [47]). Individual, high resolution maps are provided as additional information.

Global climate change may generate major impacts in the climate of Talavera, affecting vegetation and thus public works. Figure 3 summarizes the expected changes in the climate, according to standard Representative Concentration Pathways (RCPs) and for Köppen, extended Köppen and Holdridge classifications. Within an overall agreement, it can be seen that the expected changes are not highly dependent on the model used, with global and regional models providing a similar account. The three classification methods are also consistent in that climate shifts are expected for the area, with deeper effects in RCP 8.5 than in the others. Greater aridity and a rise in the mean temperature, together with increased climate variability are key factors for selecting new species and managing urban vegetation. Shade is an important asset in Talavera's climate, and it is known that the urban cover can not only provide relief in the hot summer days but help to mitigate the urban heat-island effect [17].

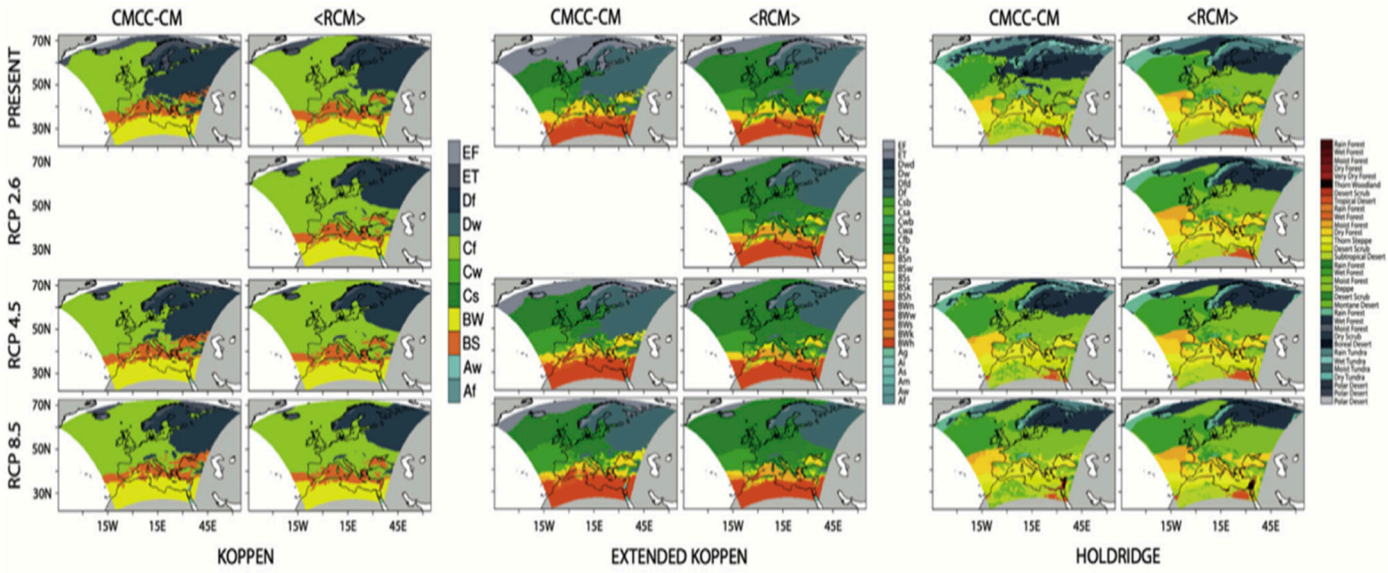

Figure 3. Expected changes in the European climate classifications under RCP 2.6, RCP 4.5 and RCP 8.5 storylines (from Tapiador et al. [47]). Individual, high resolution maps are provided as additional information.

In order to provide a detailed picture of the current green layout of the city, a Geographical Inventory of Vegetation (GIV) was carried out between June and September 2020.

A GIV differs from inventories drawn up by botanists and other specialists by explicitly accounting for not only the natural, but also the anthropic, dimension of vegetation. The spatial component is also a major difference. Thus, instead of focusing on the botanical characteristics of the trees, the GIV is more interested in how people use vegetation, how location affects the choice of species, what kind of green services vegetation provides the community with and the complex interplay between social needs in advanced societies, biota and the climate emergency.

Satellite data allow methodologies to be developed with a high degree of automation, objectivity, possibility of direct comparison and capacity for quick updating [48]. Remote Sensing imagery was used to gauge the scope and the extension of the fieldwork. LIDAR data from the *Instituto Geográfico Nacional* (IGN) were used to differentiate buildings from trees (Figure 4). While the spatial resolution of the satellite image does not always allow individual trees to be distinguished, it suffices to calculate the vegetated area and thus the budget and person-power needed for the field work.

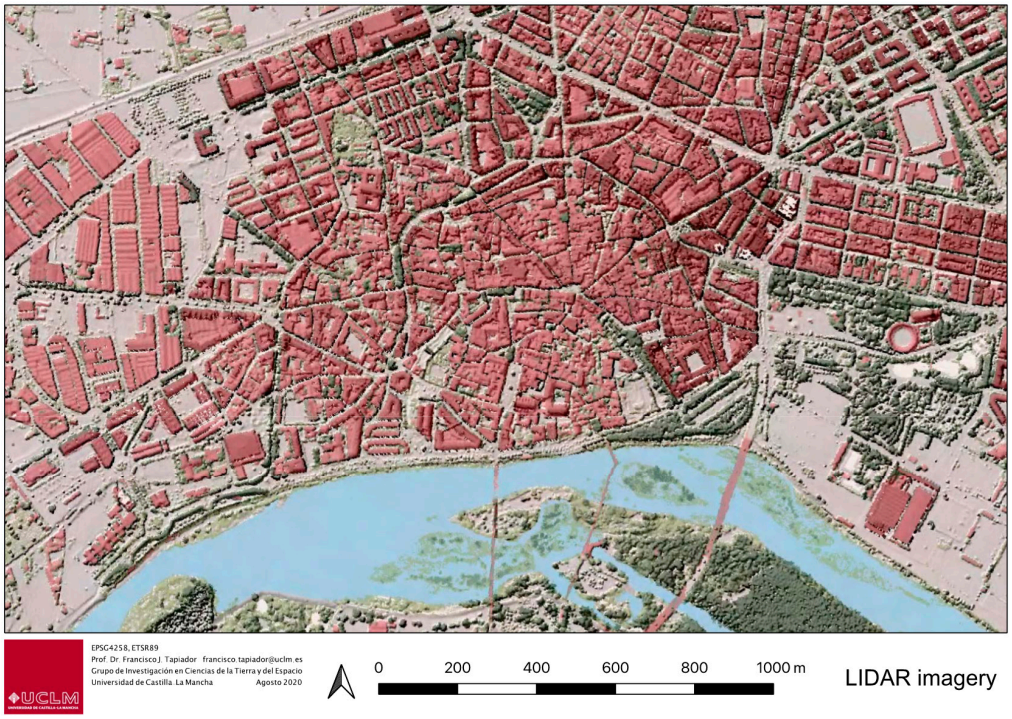

Figure 4. LIDAR image of the historical center of Talavera de la Reina, featuring the buildings in red, vegetation in green and the Tajo River in blue.

In order to organize the fieldwork, a 200 × 200 grid covering the areas of interest of the entire urban layout was defined. An overlap of 10 m between the 172 cells was allowed in order to help technicians in the fieldwork. Figure 5 shows the final scope and extent of the endeavor. The Tajo River runs south of the city from East to West, with three bridges connecting the city with the rural areas southward. The grid was used as the key and reference for the individual maps in the GIV atlas. Unnumbered squares indicate no vegetation of interest.

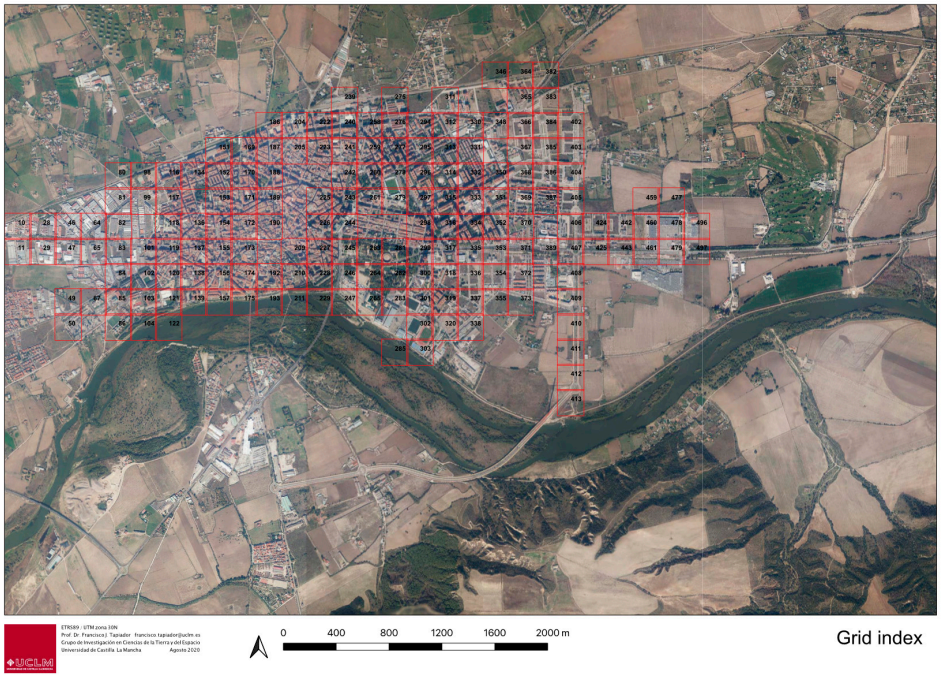

Figure 5. General layout of the GIV in Talavera de la Reina, featuring the grid index used for the field work and the Atlas.

A note on the institutional framework is also pertinent to understand the context in which the urban vegetation leveraging actions emerged. The local government of Talavera was committed to "mainstreaming sustainability", i.e., reorganizing, improving, developing and assessing all municipal activities to promote their sustainability [49–51]. Tools included joining the 'Cities for Climate' and the 'Trees for Europe' initiatives, integration in an EU Life project for climate change adaptation, fostering the idea of urban forests as carbon sinks, and establishing the 'Talavera Covenant for Sustainable Development'. All these actions show the public administration's commitment to advancing the SDGs. This is relevant as the whole concept of leveraging hinges on both such political involvement and unequivocal leadership to infuse all the municipal activities with a sustainability component.

While SDG plans are usually led by the administration, any successful initiative requires the active involvement of the society as a whole. Seven dimensions of societal interest were defined in the commission to outline feasible actions and maximize their impact on the community. Questions and topics include:

1. Singular tree awareness: Do you have a favorite tree? Which tree do you think is the most valuable in Talavera? And in your neighborhood?
2. Vegetation attachment: Are you particularly attached to a specific park or green space in the city? Do you have any childhood memories relating to trees or vegetation in Talavera?
3. Public use of vegetation: How often do you go to the park? Which one/s? How long do you stay in the park/s? How do you feel about planting more trees or vegetation near your home?
4. Tree appreciation items: What is a nice tree for you? What criteria do you use to decide whether a particular tree is nice? How important is your personal history in this choice?
5. Heritage dimension: Do you consider old trees an important part of the city? What about new trees? Do you think parks are important for urban life?
6. Green culture: Do you take part in any vegetation-related activity? Do you think trees improve your health and/or your quality of life?
7. Beyond enjoyment: Are you interested in learning about trees and vegetation?

From the beginning, public participation was considered an important part of the process of endowing vegetation management with a sustainability perspective, but a

comprehensive survey was beyond the scope of the commission. As a viable, within-budget alternative, social networks were used to take the pulse of the local relationship with vegetation. A twitter account was set up for the project (Figure 6). A first pilot experience of interacting with the local population by this means was carried out from September to December 2020. The account attracted 117 followers, but only a few provided actual feedback. An important aspect of this survey is the use of a self-selected sample. This introduces a bias in the replies since only people that are truly interested in trees interact with the community managers of the social network. Social network populations are also known to be immensely skewed towards younger generations so data should be taken with caution. In particular, it should not be assumed that people are not interested because our simple and frugal social network approach did not reach a sufficient number of people. Further but more expensive research, using random sampling surveys, would be needed to assess the true interest of the population in trees and vegetation.

Figure 6. Twitter account for @arbolesTalavera (Talavera's trees), a tool for public participation, information, and outreach.

Quantitative, statistical analyses are not appropriate here and the few comments received are merely illustrative of a wide range of opinions (or lack of them on several topics), but are nonetheless informative of the central themes, and for that reason are included here.

3. Results and Discussion

3.1. The Geographical Inventory of Vegetation (GIV)

Figure 7 depicts the location of all the trees that were individually analyzed to build the first Geographical Inventory of Vegetation (GIV) of the city. A total of 10,262 trees were directly inspected by qualified engineers hired for the project, using standard methodologies for tree risk evaluation [52–56]. The information was recorded through a Geographical Information System (Quantum GIS [57], https://www.qgis.org/, accessed on 30 July 2020, cf. Appendix A) and then integrated into the municipal systems to assist in the public works.

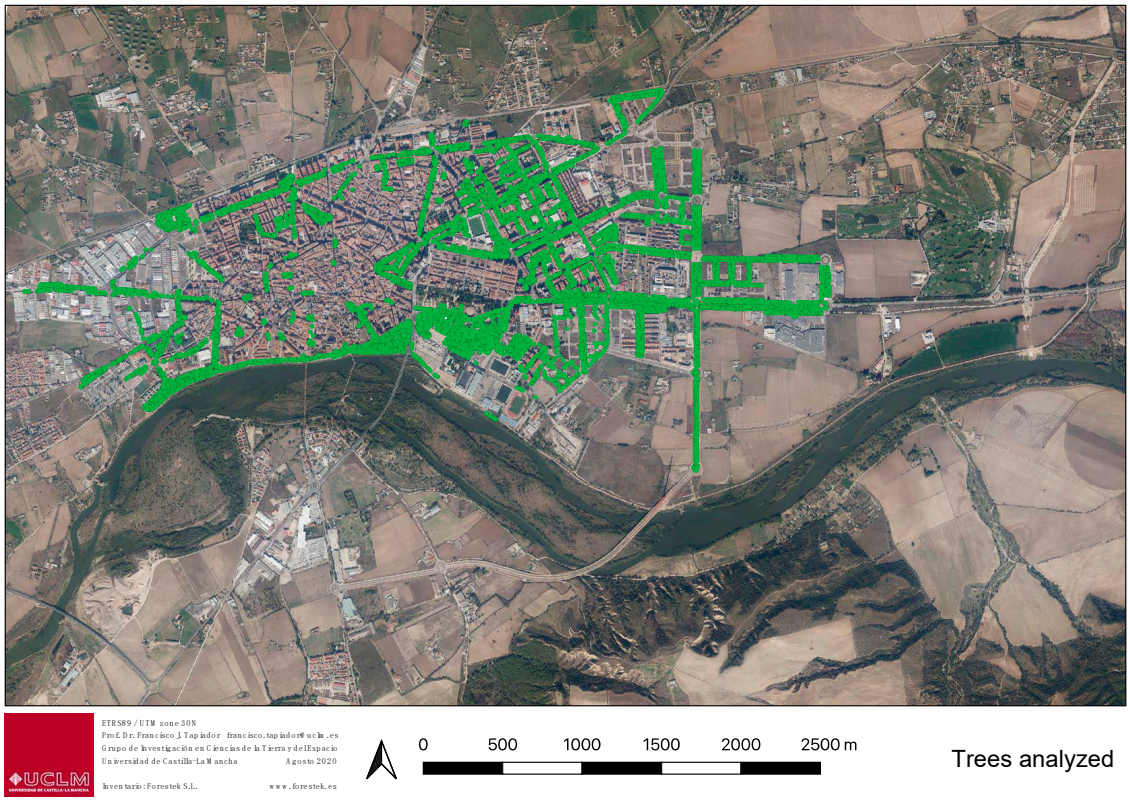

Figure 7. Location of the 10,262 trees analyzed in the GIV for Talavera de la Reina.

The GIV is key to outlining sustainability actions since these depend on the actual green layout and on climate. The sorts of actions that can impact on humid climates, where trees are the norm and grow with little need for extra care, are quite different from those where trees need frequent irrigation. How singular the green cover is also has relevance, as larger biodiversity provides more opportunities for a green edge to urban life (taking advantage of singular vegetation in urban activities) and for attracting advanced economic activities. The number of tree species also affects the value of the urban green cover, and the expected management activities in the near future, including replacing trees no longer suitable for forthcoming harsher climate conditions.

As an illustration of these considerations, Table 1 shows the most frequent tree species and their share of the total number of trees analyzed for the GIV of Talavera. The total number of species was 82, but some only accounted for a few, or even a single, specimen. The dominance of the *Platanus hispanica* is of concern, as hairs and seeds from this species affect the

eyes and nose and it is not particularly well suited to the future climate of the area. Regarding opportunities, the current state of many of these trees calls for prompt replacement.

Table 1. Major tree species in number and % of the total that were individually analyzed for the Geographical Inventory of Vegetation (GIV).

Species	Number	% Over Total
Platanus hispanica	3948	38.47
Celtis australis	755	7.36
Tilia cordata	496	4.83
Magnolia grandiflora	493	4.80
Pinus pinea	404	3.94
Liquidambar styraciflua	329	3.21
Fraxinus angustifolia	316	3.08
Prunus pissardii	303	2.95
Ulmus pumila	285	2.78
Acer negundo	261	2.54
Aesculum hippocastanum	257	2.50
Populus bolleana	252	2.46
Quercus palustris	235	2.29
Trachycarpus fortune	208	2.03

The analysts presented a plan to adapt the vegetation to new conditions, increasing biodiversity and enhancing the public space, and suggested new species to replace the *Platanus hispanica*. Additional actions included sensitivity to historical and cultural aspects (promoting species from Asia in areas of the city historically related to the silk trade, or trees accounting for the Islamic heritage of the city around the Muslim castle), but the analysis evolved a step further, suggesting a new way to deal with vegetation in local administrations.

Before going into detail, it is worth explicitly detailing the process for which the conclusions are drawn, and their actual connection to the GIV and the public participation exercise. The idea of leveraging urban works emerged in response to the requirement of the commission to provide added value to the classic tree inventory that is required for municipal works and planning [58]. Thus, the GIV was intended as an opportunity to rethink the potential of public works in the context of sustainability, endowing the standard cataloguing exercise with a broad perspective. Once the GIV identified the scope (more than 10,000 trees of interest), the weaknesses (too many *Platanus hispanica*, little citizen engagement), the challenges (ongoing climate emergency), and the experts had made their proposals (e.g., replacing the *Platanus hispanica* with more suitable species), came the realization that involving the population in the process could greatly help advance the SDGs at a local scale.

The climate emergency will call for the substitution of a substantial number of trees, as they belong to species ill-adapted to new conditions, and the city cannot afford to lose such a large share of its green cover. The scope of work required would certainly make an impact on the citizens and attract their attention. Indeed, a great deal of public communication will be required to show the need for the work and the associated benefits. This can be integrated with wider processes of environmental education at all levels [59–66]. Knowledge of specific, valuable and scarce trees is almost absent among the population. The overall unawareness of the actual services that trees can offer urban life is another area that requires prompt action. The goal of encouraging an appreciation in their trees is valuable in itself, and so herein naturally emerges the key insight of using urban vegetation

management tasks as a lever, transcending the traditional approach of public works as activities seamlessly done by technicians and workers without any public engagement.

Thus, studying the current status of the urban vegetation as derived from the GIV, analytical work by the research teams and inspection of the expected changes in the climate of the region developed into a series of proposals connecting the SDGs with urban vegetation management activities. Aligning these two ideas: routine works in vegetation that must be carried out as part of standard maintenance, and topical sustainability actions, actually release resources for other sustainability programs that require an extra budget [49–51]. In fact, leveraging a few sustainability actions through urban vegetation management unleashes a whole set of such actions, as it increases the critical mass at no extra cost, and reinforces ongoing actions. Once the population is made aware of sustainability considerations through the trees, it is easier to convey more complex, less immediate but equally important matters to the public. The benefits of awakening this new sensibility permeate the whole endeavor and can help achieve the SDGs.

Indeed, the SDGs include a number of targets that can easily be related to standard urban management activities. Routine vegetation management in particular was determined to include a number of actions with potential impact on Goals #4 (quality education), #11 (sustainable cities and communities), #13 (climate action), #15 (life on land), and, perhaps less obvious in terms of vegetation but equally important, on Goal #8 (decent work and economic growth).

3.2. The Urban Vegetation Leveraging Actions (UVLAs)

The following paragraphs discuss how urban vegetation management works can be endowed with a sustainability perspective to help achieve the SDGs at local level. The concept of leveraging urban vegetation works is central but requires a precise conceptualization that can help further development of the actions. Urban Vegetation Leveraging Actions (UVLAs) can be defined as *a set of minor adjustments and re-focusing of existing urban vegetation management activities that can be used to advance SDGs*. The idea is aligned with the philosophy of endowing all economic actions with a sustainability component instead of specifically devoting additional resources to advance the goals ('mainstreaming sustainability'). UVLAs can be easily transferred to other municipal departments, such as tourism and utilities. In addition, the actions are not exclusive to cities: they can also be applied to rural towns and villages as a tool for integrated rural management [58].

In the case of the city of Talavera, the UVLAs arise from the GIV and further analysis of the climate and environmental constraints. They also account for the social structure and social mores of the population. They are:

- **UVLA 1: Endowing urban vegetation works with a social dimension ('the social tree').** Planting, pruning, grafting and tree care are opportunities to bring people together and engage the population in the sustainability discourse. This is especially important for the older population, who often have a great deal of spare time, as these activities can provide them with an additional chance to meet and socialize with younger generations [59–61]. While it cannot be automatically assumed that all the older population have relevant knowledge and skills, the mere socialization process is a valuable asset. The idea of public works as a family activity can be realized through specific sessions such as 'pruning day'. Showing people how a tree is evaluated is also an enjoyable activity for all, which can be guided by environmental educators, and only minor adjustments are required in the work schedule: all that is needed is to announce the activity, direct the municipal educators to this task and brief the workers to ensure the smooth running of the activities.
- **UVLA 2: Providing specific information on urban trees in K-12 education ('trees for kids', T4KZ)**. Local schools can use vegetation works as outdoor activities to illustrate specific topics in biology, botany, ecology, geography, zoology and engineering. Public works can be integrated into the 'open lecture room' concept to illustrate actual work on nature as a live experience. This can also be used to foster vocations and guide

young people to develop their skills in the realm of natural sciences 63–65]. Few adjustments are required to make vegetation-related activities in the municipality public and accessible and to brief workers and teachers. Other initiatives, such as a tree campus K-12 program and community gardening are interesting activities to stimulate collaboration between schools and local communities [65]. Many schools in the area already run garden learning programs, so synergisms are clear.

- **UVLA 3: Fostering vegetation-related hobbies such as gardening ('green hobbies').** Conveying technical information from workers and specialists to the general public can help extend the concept of sustainable urban vegetation to the public. The concept of 'democratizing trees' also includes people using their private homes to complement rather than to compete with vegetation in public parks and avenues. Minor changes in the way municipalities carry out their activities would include the work of professionals in the civic structure of the city through conferences, public displays, courses and workshops on gardening. Future programs could include using city land to promote community gardens and nurseries for plants that could later be used in the green areas of the city or in private spaces.
- **UVLA 4: Highlighting the roles and services of urban vegetation ('tree services').** A key aspect to develop a mindset of care for the planet is to show how vegetation contributes to the wellbeing of the population, highlighting its role not only for sensory enjoyment but also for the control of the environment (shade, temperature, noise, humidity, pollution, wind, dust, runoff) [67], and to create urban microclimates. This UVLA is mainly oriented towards actions for the professional world (architects, developers, builders) but also applies to individuals, with a focus on construction. Climate change topics are ideally suited to be conveyed through this UVLA at little cost and through extremely powerful and visual examples in semi-arid climates. Raising the population's awareness would facilitate further adaptation of public buildings using nature-based solutions, such as increasing the surface of green roofs or walls, or using sensible tree planting to provide shade in school or nursing home courtyards, which would greatly increase wellbeing in arid and hot areas such as Talavera. It would also be an opportunity to reduce air-conditioning costs and increases the livability of a city due to a reduction in the heat-island effect. Water management issues can also be conveyed through this action. Science, technology, engineering and mathematics (STEM) projects could be developed in coordination with city officials to increase the awareness of how engineering or natural resources impact a city. We acknowledge that these projects can be difficult to implement, but the use of, for example, LIDAR imagery in Spain is free, and they can foster state-of-the-art projects from even high school students. Specific focus can be put on the vulnerable and on taking a gender perspective, including promoting the access of women to science.
- **UVLA 5: Education in tree appreciation ('tree appreciation')**. Sharing specific botany and landscape-planning skills can help people better appreciate the role of the scientific method in knowledge-building. The only adjustment required to standard works is to make the effort to communicate what is being done on trees. While this is not practical for the everyday operations of the plants and gardens department, specific sessions on tree appreciation can be set up in advance. Specific focus can be put on the vulnerable. Virtual Reality (VR) and Enhanced Reality (ER) technology can be used to educate everyone about vegetation, landscaping and tree appreciation [68]. Trees are also powerful tools for developing advanced observational skills (aesthetics, harmony, biological processes) and to educate sensibility (poetry, painting, sculpture, etc.). Educating people to differentiate species (botany), appreciating what is and what is not a healthy tree, and conveying the cultural aspects related to each species (biogeography, anthropology, history) also contribute towards some SDGs.
- **UVLA 6**: **Recognizing trees as social, economic and wellbeing assets ('treellbeing').** For a long time, urban trees in southern Spain have been appreciated mainly for shade. Trees, however, enhance the urban fabric and are valuable assets for communities and

private housing and are a source of personal wellbeing ('treellbeing'). Indeed, trees and vegetation have a demonstrable effect on people recovering from illness [2]. In a different direction, making the added value of trees in urban areas explicit can help re-evaluate green spaces within the city for traditional businesses, entrepreneurs and professionals, thus facilitating obtaining additional resources that can multiply local efforts and improve the international positioning of the city in the economic, tourism and commercial domain. Disseminating bibliography and multimedia resources is actually inexpensive for the municipality, and creating new content is value for money in terms of societal returns. Documenting (photographs, video) public works is also not costly and builds materials for the municipal archive. Making Talavera a green oasis amid the semiarid countryside in the South can help increase the overall attraction of the city. The 'tree traction' idea should not be underestimated in climate scenarios with increased aridity in Southern Europe as the 'luxury of vegetation' [11] is more evident in dry areas.

Biomass, 'edible cities' [8–12], flood mitigation and water treatment all have an impact on the UVLAS and will generate cost reductions/added income to municipalities and utilities. Specifically, then, how do these UVLAs contribute to fulfilling the SDGs? All the actions for Talavera directly contribute to *Goal 11: Make cities inclusive, safe, resilient and sustainable*, notably to its Target 11.7, 'universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities'. But, more broadly, the UVLAs are of interest to several other SDGs, as described below. While targets here have been tailored to the case of Talavera, i.e., a city in a developed country, they are in fact quite general. Note it is no accident that several, if not all the UVLAs, can be applied to almost any given goal, as they have been specifically designed to be multipurpose and of broad applicability in order to make efficient use of typically scarce resources.

Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

The goal of providing quality education by 2030 is actioned through several targets. Indeed, urban vegetation plays a central role to boosting; for instance, Target 4.3, which aims for equal access to affordable technical, vocational and higher education. Nonetheless, there are others targets of interest:

- *Ensuring that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and Goal-4 effective learning outcomes.* **UVLA 2 'trees for kids'** is clearly central and directly targeted to achieving such a goal, but **UVLA 1 ('the social tree'), UVLA 4 'tree services'** are also applicable. **UVLA 1** activities and actions to realize this goal include participating in family activities: visits to ongoing works such as planting or pruning, sharing time with older relatives (the population of Talavera has a Mediterranean familiar structure with close ties between generations, often living under the same roof). For **UVLA 4**, activities can be devised to promote girls' interest in traditionally male jobs like timberline pruning or woodcut, and to encourage both boys and girls to seek out STEM subjects, including remote sensing (tree identification through satellites, woodland management), robotics (drones, monitoring bird nests using Arduino or Raspberry micros, etc.) or engineering (exemplifying the physics of statics, stability or elasticity, the complex dynamics of water movement in the trunk, or the quantum mechanics of photosynthesis).
- *Ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university.* **UVLA 5 'tree appreciation'** is pivotal to help both women and men gain access to vocational training in botany, irrespective of gender. Some skills are transferable to other sciences. **UVLA 3 'green hobbies'** is also applicable to gardening skills: these are a classic example of quality technical education and students can make the transition to university after a few years. **UVLA 4 'tree services'** provides a new dimension to the public by showing how city planning, architecture, and the environment are interlaced and how gender issues arise in the

planning of itineraries and urban equipment. Quality education in climate change and its effects, including adaptation and mitigation strategies can be easily conveyed using this UVLA. **UVLA 6 'treellbeing'** is also applicable. Activities in this direction include new opportunities for training in tree appreciation and links with artistic activities and social assistance for older adults: teaching people to host and manage tree appreciation workshops increases the tools available to workers in an advanced welfare state.

- *Substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.* While higher education has been covered above, actual tree management in the field has a direct bearing on technical education. Ensuring that the professionals of the future have been in contact with a number of interesting, sustainability-related trades is one of the best ways to encourage them away from dropping out of education. Witnessing experts expressing simple but rewarding skills in their daily routines (pruning, grafting) is a powerful stimulus for children to emulate them. (**UVLA 1 'the social tree', UVLA 2 'trees for kids', UVLA 4 'tree services', UVLA 5 'tree appreciation', UVLA 6 'treellbeing'**)
- *Eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities and children in vulnerable situations.* Trees provide multisensory experiences: sight (colors, shades, trembling leaves), smell (leaves, fruits, soil, branches), touch (trunk texture, waxy leaves, flexible branches, etc.), hearing (the sound of the canopy in the wind) and taste (fruits and berries, obviously, but also edible leaves and infusions). Directing the attention towards these elements not only provides new sensations and opens a new world for all but can especially help people with disabilities and children in need of mind and body healing (**UVLA 5 'tree appreciation'**).
- *Ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles and culture's contribution to sustainable development.* **All the UVLAs** can help achieve this target. Sustainable development is a multifaceted field. Creating a new generation of concerned citizens requires putting dissimilar skills together and pooling abilities. Trees play a dominant role in nature, so it is only natural to thematically focus on them. The UVLAs delve into sustainable development from a variety of directions, from the analysis of the abiotic/biotic/anthropic cross-relationships in **UVLA 2 'trees for kids'** and **UVLA 4 'tree services'**, to the cross-generational approach in **UVLA 1 'the social tree'**. **UVLA 5 'tree appreciation'** has a special focus on the cultural aspects of vegetation (Islamic, Roman and Asian heritage in the case of Talavera).

Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all. Here, UVLAs are relevant for the following targets:

- *Sustain per capita economic growth in accordance with national circumstances.* Economic growth in Talavera is hampered by a series of complex factors beyond environmental constraints. UVLAs can only make a moderate impact on the target. Actions include developing vegetation-related spin offs on sustainable architecture (through **UVLA 4 'tree services'**), setting up consulting firms or enhancing the activity of garden centers and plant suppliers for **UVLA 3 'green hobbies'**, or adding tree appreciation as part of other leisure-oriented business (**UVLA 6 'treellbeing'**).
- *Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high-value added and labor-intensive sectors.* Automating menial tasks is clearly a short-term goal of any technological innovation program. In the field of urban vegetation management, new tools and methods have greatly reduced the workload. Further developments, including drones, robots and automatisms require new levels of professional competence that should complement those acquired through **UVLAs 4** and **5. UVLA 6 'treellbeing'** can help disseminate

new inventions and innovations in this field and strengthen the position of the city in the landscape of international innovation.

- *Promote development-oriented policies that support productive activities, decent job creation, entrepreneurship, creativity and innovation, and encourage the formalization and growth of micro-, small- and medium-sized enterprises.* Companies of any size could benefit from new policies aligned with tree care and consideration (**UVLA 3 'green hobbies', UVLA4**). Corporate strategies can capitalize on a green-driven municipal policy to showcase their own engagement in providing sustainable products (**UVLA 6 'treellbeing'**).
- *Promote youth employment, education and training.* Vegetation-related business cannot be central to a fully-fledged employment strategy in Talavera, but complementary job opportunities can be envisioned though **UVLA 1 'the social tree'** (environmental educators), **UVLA 2 'trees for kids'** (teaching assistants, science communicators), **UVLA 3 'green hobbies'** (sustainable gardening trainers), **UVLA 4 'tree services'** (architects, decorators), **UVLA 5 'tree appreciation'** (botanists, biologists), and **UVLA 6 'treellbeing'** (mindfulness or yoga instructors, psychologists, etc. that utilize trees in their services).
- *Promote beneficial and sustainable tourism.* Activities in **UVLAs 1 'the social tree', 3, 5** and **6** can be powerfully attractive for sustainable tourism, as they provide a culturally-rich, environmentally-friendly approach to the idea of travel, thus transcending the sun-and-beach tourism that has dominated the economy of Spain over recent decades. Indeed, employment possibilities can go beyond tourism in the context of a green city that also provides educational services.
- *Increase aid for trade support.* Talavera can help in the demand-side of aid for trade support by actively supporting production more efficiently produced elsewhere, and focusing on areas in which the city has a comparative advantage. Technology for **UVLA 5 'tree appreciation'** (VR and ER tools) falls into the former category, while exporting local knowledge on pioneering approaches to leveraging urban vegetation may be included in the latter. Vegetation near the old silk factory (present and past: mulberries) can be used to convey to the general public relatively complex ideas on trade (the Silk Road), the effects of the industrial revolution (decay of the factories, ecological transition), and new uses of abandoned landmarks of the industrial architecture. The experience of the older population (**UVLA 1 'the social tree'**) can help add a historical perspective to economic cycles. All these ideas can contribute to understanding why focusing on the local is not always a good idea.
- *Develop a global youth employment strategy.* Unemployment is a major concern for the city, with the current rate being 30%. A joint effort to integrate job opportunities under the target "Promote youth employment, education and training" into a sustainability-based, green-jobs strategy could emerge from the sub-area of green space management as a way to illustrate the potential of leveraging actions and mainstreaming sustainability. A strategy through **UVLAs 5** and **6** for volunteer work and internships in the parks and gardens department linked to community colleges and vocational training institutions in the city could help achieve the target.

Goal 11: Sustainable cities and communities

UVLAs are relevant for the following targets:

- *Inclusive and sustainable urbanization.* Sustainable urbanization is in line with the concept of 'democratizing trees' in two directions: making lush vegetation not just a privilege of central areas (**UVLA 4 'tree services'**) and the public sector's promoting the possibility of individuals reconnecting with trees in their homes (**UVLA 5 'tree appreciation'**). Conveying the new sensitivity (**UVLA 6 'treellbeing'**) through social, cross-age contact (**UVLA 1 'the social tree'**), early education (**UVLA 2 'trees for kids'**), leisure activities (**UVLA 3 'green hobbies'**) and tree services awareness (**UVLA 5 'tree appreciation'**).
- *Protect the world's cultural and natural heritage.* Vegetation can be used to enhance cultural heritage (such as the Silk Factory in Talavera) by selecting appropriate species. Highlighting the cultural links is an aspect of **UVLA 5 'tree appreciation'**, and **UVLA**

6 'treellbeing' dissemination resources can also be used to advance towards this target. Urban forests can also be considered natural heritage and therefore integrated into a new sensibility towards trees.

- *Reduce the adverse effects of natural disasters.* Trees have been used in Spain to mitigate the effects of floods. Ordinances forbidding deforestation to avoid the consequences of natural disasters date back to the Middle Ages. Willows (Salix, sp.) have historically been essential in protecting riverbanks from flooding. Today, trees are still planted to avoid runoff and for flood mitigation in the semiarid parts of the country. Cities in these areas should bear this goal in mind when managing the tree cover within the municipality. Highlighting such urban vegetation services is part of **UVLA 4 'tree services'**. Since flood management requires attention to upstream riverbank dynamics, coordination with peri-urban and hinterland authorities is required. Such involvement represents an additional opportunity to convey to the population complex ideas on the feedbacks in the Earth system, and specifically in the role of vegetation for our safety.
- *Reduce the environmental impacts of cities.* The city of Talavera has established a 'Covenant for Sustainable Development' joined to the 'Cities for Climate' and the 'Trees for Europe' initiatives, and integrating the municipality into an EU Life project for climate change adaptation. Actions in **UVLA 4 'tree services'** devoted to sustainable and nature-based solutions for buildings can help to reduce the environmental impact of urban life. Additional focus can be put in the responsible use of biomass, in mitigating the effects of the urban heat-island on the city and the hinterland, and in using trees to control the built environment (shade, temperature, noise, humidity, dust, wind, pollution and runoff).
- *Provide access to safe and inclusive green and public spaces.* **UVLA 1 'the social tree'** can help make green spaces more inclusive by first occupying degraded or unused spaces and then reclaiming their full use for the population. Safety from numbers, public vigilance and monitoring, and extensive and continuous use for **UVLAs 3, 4, 5** and **6** can contribute to restoring leftover and abandoned spaces and help regain and reposition large portions of the urban fabric to societal use. Planners, engineers and the general public should also be aware of the ideas under the 'edible city' concept [8–12] to ensure the full range of tree benefits are understood and utilized.
- *Strong national and regional development planning.* **UVLA 4 'tree services'** and **UVLA 6 'treellbeing'** are particularly suited to being integrated into planning strategies at local and regional level and can be included in most programs at the three different levels of regional law: guidelines, plans and projects. Multi-level coordination meetings between the different levels of the administration (urban, rural, regional, national) are also a chance to underline the additional benefits of trees for the population and for utility providers (water/energy).

Goal 13: Climate action

The relevance of the UVLAs to the targets of this goal are highly dependent on the evolution the of the region's climate. As described in Section 2 above, global climate change may result in major changes in the climate of Talavera, affecting vegetation and thus the administration's response to urban vegetation management. The recent evolution of the temperature (Figure 1a) and the increasingly irregular distribution in time of precipitation (Figure 1b) indicate that even in the historical era, the effects of ongoing warming are apparent. For future climates, the simulations from global, comprehensive Earth System Models (Figures 2 and 3) indicate a worrying trend towards harsher climates for current vegetation (Semi-Arid climate in Köppen's classifications), a tendency that features in the RCP 45 and RCP 85 storylines. Drawing on this information, the links for Talavera between the GIV, the UVLAs and the targets of Goal 13 are as follows:

- *Strengthen resilience and adaptive capacity to climate-related disasters.* Weaknesses and threats can be identified in the GIV and in the species catalog (Table 1). Some of the trees in the city may not be suitable for future climate conditions, so action is required. Beyond direct measures (tree replacement program, selective substitution, etc.) the essence of

UVLA 4 'tree services' is to address emergent issues through a policy of making the population aware of the value of trees and their relationship with the local microclimate.

- *Integrate climate change measures into policy and planning.* It is important to realize that the implementation of climate change measurements requires public engagement. Illustrating the benefits of trees (**UVLA 4 'tree services'**) and vegetation can help the public understand their contribution in modulating the effects of climate change. A grassroots dedication to sustainability can be carefully built from **UVLAS 1 'the social tree'** and **2 'trees for kids'**, culminating in a fully-fledged sensitivity towards trees and, by extension, to the natural world.
- *Build knowledge and capacity to meet climate change.* All UVLAs contribute to this topic. **UVLA 1 'the social tree'** increases the engagement of the population, with a special focus on older generations, who are often less aware of the dangers of the climate emergency; **UVLA 2 'trees for kids'** educates the next generation in environmental issues; **UVLA 3 'green hobbies'** advances in creating climate knowledge and in taking climate effects to the backyard where issues and problems may be more apparent; **UVLA 4 'tree services'** increases the capacity of the city to respond to the climate emergency; **UVLA 5 'tree appreciation'** and its focus on the vulnerable can help galvanize the efforts of the whole community and integrate everyone in the endeavor; and actions in **UVLA 6 'treellbeing'** go in the direction of enhancing the population's awareness of environmental issues, which is a must for successful implementation of climate mitigation and adaptation policies.

Goal 15: Life on land

UVLAs are relevant for the following targets:

- *End desertification and restore degraded land.* The **UVLA 1 'the social tree'** can help create a critical mass favoring the extension of the green cover to the south of the city, providing topological continuity to the green, and increasing the surface with new trees. The same applies to **UVLA 2 'trees for kids'**, this time from the base of the demographical pyramid. **UVLA 3 'green hobbies'** can be instrumental in regaining waste land and dump sites for tress and orchards. Awareness of the environmental services provided by the trees through **UVLA 4 'tree services'** and **5** would also contribute to the push towards sustainable development policies in the vegetation realm.
- *Protect biodiversity and natural habitats.* Moving from urban parks to urban forests is a natural development to respond to the demands of a new society. As mentioned in the introduction, spaces such as Birkenhead Park were created to meet the particular demands of the XIX century Zeitgeist, namely the leisure of the emerging working class in the industrial revolution. Now, sustainability awareness and new sensitivities demand using the urban layout to increase urban biodiversity and protect the few natural habitats in and around the city. **UVLA 2 'trees for kids', 3 'green hobbies', 4 'tree services', 5 'tree appreciation'** and **6 'treellbeing'** all contribute to this idea.
- *Prevent invasive alien species on land and in water ecosystems.* The urban space can host invasive species, such as parrots. Avoiding trees these species favor can contribute to a healthier environment. Protecting valuable trees and species that are not well represented in the city is necessary, but not always well understood by the general population. **UVLA 3 'green hobbies'** can be key to predispose the population to often controversial conservational choices, and **UVLA 2 'trees for kids'** is an absolute must to avoid building a misguided, sentimental and naïve approach to the natural world in the next generation.
- *Integrate ecosystem and biodiversity in governmental planning.* Urban biodiversity overflows the actual limits of the city and extents to the hinterland. In the Talavera case, integrating the natural values of the Chamelo river island with the urban continuous through **UVLA 4 'tree services'** and **UVLA 5 'tree appreciation'** can benefit the urban population and help boost biodiversity around the river. Riparian vegetation is a valuable asset to advance towards goal 15. 'Edible city' actions can also be included under this idea.

4. Conclusions

The local government of the city of Talavera de la Reina in the Autonomous Community of Castilla-La Mancha, Spain, commissioned, in 2020, a geographical analysis of the vegetation. The overarching goal of integrating SDGs in all the municipal activities evolved and developed into how to redefine public works for a sustainable future. Budget is always a serious constraint in any public endeavor, and thus the challenge was how to advance towards fulfilling sustainability goals without incurring additional costs and remaining within a tight budget. This work presents a novel use of a Geographical Inventory of Vegetation (GIV) in the context of sustainable development. A GIV is indeed a powerful tool to assist traditional urban vegetation management but its use can transcend traditional urban management tasks.

We have shown that a GIV can be used to start aligning routine operations with the Sustainable Development Goals (SDGs). Drawing on the case study it has been shown that an intelligent approach to urban vegetation management can leverage resources towards the SDGs at little or no cost for municipalities, while engaging people in the process. Minor modifications and conceptual changes in how standard practices are carried out can make all the difference. Adding this dimension can even result in a positive balance in the municipal budget. We have coined the term 'Urban Vegetation Leverage Actions' (UVLAs) to refer to such initiatives.

UVLAs include but are not limited to: (1) Endowing urban vegetation works with a social dimension; (2) Providing specific information on urban trees in K-12 education; (3) Fostering vegetation-related hobbies, such as gardening; (4) Highlighting the roles and services of urban vegetation; (5) Education in tree appreciation; and (6) Recognizing trees as social, economic and well-being assets. Transmitting these concepts to the general public as slogans and in the form of named campaigns can help with dissemination. Thus, we have initiatives with the names 'the social tree', 'trees for kids', 'green hobbies', 'tree services', 'tree appreciation' and 'treellbeing' address, respectively, the six UVLAs in a format suitable for public use.

Both the conclusions of this study and the UVLAs we have defined are of wide and direct applicability for urban areas worldwide and can help city authorities and urban managers to align their cities with SDGs with just a small change to the focus on how to deal with urban vegetation.

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Appendix A

Talavera's Geographical Inventory of Vegetation (GIV) is organized in a set of thematic maps such the one in Figure A1. Requests for the data and maps should be directed to parquesyjardines@talavera.es.

Figure A1. A sample of one of the sheets of the GIV Atlas, illustrating the identification of individual trees at a scale suitable for routine management operations on urban vegetation.

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