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Tree Measurements in the Urban Environment: Insights from Traditional and Digital Field Instruments to Smartphone Applications

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Abstract. Urban forests can provide essential environmental and social functions if properly planned and managed. Tree inventories and measurements are a critical part of assessing and monitoring the size, growth, and health condition of urban trees. In this context, the parameters usually collected are diameter at breast height (DBH) and total height, but additional data about crown dimensions (width, length, and crown projection) are required for a comprehensive tree assessment. These data are generally collected by urban foresters through field surveys using tree calipers or diameter tape for DBH and the electronic ipsometer/clinometer to measure tree height and crown size. Greater detail could be achieved using a digital instrument such as Field-Map, a portable computer station, to quickly realize dimensional and topographic surveys of trees and forest stands. Additionally, the incorporation of a LIDAR scanner into a smartphone such as the iPhone 12 Pro has made this device able to measure tree attributes as well as additional spatial data in the field. In this study, we tested these 3 different measurement systems in a field sampling of an urban forest and compared them in terms of measurable parameters, accuracy, cost, and time efficiency. Furthermore, we discussed the pros and cons of each measurement approach and how the resulted data can be used to evaluate ecosystem services of trees and provide guidance on tree management in order to reduce potential risks or disservices.

Keywords. Digital Technologies; Field-Map; LIDAR Scanner; Smartphone; Tree Measurements.

INTRODUCTION

The urban forest includes all trees in the city and surrounding area (small and fragmented woodlands, street trees, trees in parks and gardens, and isolated trees) which represent essential green infrastructure within the wider urban ecosystem (Konijnendijk et al. 2006). Urban and peri-urban green spaces provide multiple benefits for people and the environment that are closely related to the degree of structural complexity of vegetation (Carrus et al. 2015; Tomao et al. 2018) and their accessibility and usability (Quatrini et al. 2019). Urban forest management is thus crucial to ensure a steady supply of ecosystem services over time (Miller et al. 2015).

The maintenance of trees in the city needs careful planning that considers their value as a public interest (Doick et al. 2018), the costs of management (planting, treatment, pruning, and removal)(Vogt et al. 2015), and, in general, a broader and more comprehensive assessment of urban trees (Roman et al. 2021).

Therefore, urban tree inventory is a required task for maintaining green spaces and assessing ecosystem services (Salbitano et al. 2016). Data usually collected are species, position, diameter at breast height (DBH), and tree height, which allow to assess tree growth and biomass (Ma et al. 2021). Additional information about crown dimension (length and diameter) is relevant to evaluate the effects of severe pruning on crown architecture (Tomao et al. 2015) and can be sampled to estimate leaf area (Nowak 1996). Measuring the size of trees allows to evaluate possible risk conditions and adopt appropriate technical management (Pretzsch et al. 2021). In this way, it is possible to implement climate and pollution adaptation strategies (Pataki et al. 2021), aiming to effectively provide ecosystem services for environment and people (Ferrini et al. 2017).

In fact, the multiple benefits trees provide to citizens and environment, such as pollution removal, carbon storage and sequestration, and rainfall interception, are strongly related to plant characteristics, such as leaf area, biomass, and basal area (Nowak et al. 2008a). This information can be used as input for specific models, such as i-Tree Eco, to estimate the ecosystem services provided by trees in cities (Pace et al. 2018; Lin et al. 2020).

Furthermore, urban forests are valuable recreational spaces for citizens, and tree safety is an important issue to address in city planning (Konijnendijk et al. 2005). Thus, in the urban context, it is required to act often with pruning for canopy maintenance (Fini et al. 2015). A tree risk assessment is generally performed through a visual investigation of tree health and condition (Mattheck and Breloer 1994), possibly using tools, such as tomography, to evaluate the internal structure of the stem (Karlinasari et al. 2018). To this purpose, additional information about the condition and health of the crown is needed to assess and apply appropriate management and avoid undesirable disservices (Roy et al. 2012).

Tree measurements are an essential part of urban foresters' work to manage city trees (Östberg 2013). However, they are very time-consuming and also demand well-trained people (Nowak et al. 2008b). Different inventory methods can be used to obtain tree data, from field surveys to remote-sensing applications. The latter, through the combination of different sensors and analysis methodologies, are able to detect urban trees and their attributes (Shojanoori and Shafri 2016), but a degree of uncertainty remains in the species differentiation (Fassnacht et al. 2016) or accurate assessment of uncommon trees (Alonzo et al. 2014; Alonzo et al. 2016).

Compared to remote-sensing assessments, field surveys allow to get comprehensive information on species and tree size, which may vary by individual tree based on competition and canopy architecture (Nielsen et al. 2014). In fact, accurate estimation of parameters such as total leaf area and biomass depends not only on tree size, but also on features such as crown architecture before and after planting, branches in competition for the light, and branches missing or damaged (Östberg et al. 2013).

The traditional tools used to derive tree measures are caliper or diameter tape for DBH, the ipsometer/clinometer for tree and crown height, and metric tape for crown width. Digital technologies, such as Field-Map, a portable computer station designed to quickly perform topographic and dimensional surveys of tree vegetation within forest inventories, have gradually

Table 1. Tree dendrometric data measured in plots with smartphone (DBH, height, crown base height, crown width), diameter caliper (DBH), ipsometer (height), and Field-Map (crown projection).

Plot	N° trees	Area (m^2)	Species	DBH *iPhone* (cm)	Height *iPhone* (m)	Crown base height *iPhone* (m)	Crown width *iPhone* (m)	DBH *caliper* (cm)	Height *ipsometer* (m)	Crown projection *Field-Map* (m^2)
A	44	220	*Cupressus sempervirens*	20.7 ± 6.1	12.2 ± 2.8	1.8 ± 0.7	1.7 ± 0.8	20 ± 6.1	13.2 ± 1.7	4.4 ± 1.2
B	19	150	*Quercus ilex*	52.5 ± 13.6	23.9 ± 3.4	5.1 ± 0.5	9 ± 4.7	53.6 ± 12.8	26.2 ± 0.7	80.9 ± 36.9
C	15	170	*Pinus pinea*	60.4 ± 16.4	27.5 ± 3.8	14.4 ± 3.1	13.9 ± 5.5	62.1 ± 16.6	27.8 ± 1.7	85.5 ± 47.3
D	2	126	*Abies alba*	43 ± 4.2	20.7 ± 3.8	4.8 ± 0.9	13.5 ± 2.8	43.3 ± 5.3		76.3 ± 28.4
	5		*Cedrus libani*	56.8 ± 10.3	22.7 ± 3.2	6.1 ± 0.5	6.7 ± 0.2	58.4 ± 11.4		53.5
	3		*Chamaecyparis lawsoniana*	36.7 ± 1.5	15.1 ± 0.7	0.8 ± 0.6	3.6 ± 0.1	28.3 ± 14.2		
	2		*Pinus pinea*	59.5 ± 3.5	24 ± 1.4	12 ± 1.4	10.5 ± 1.4	60 ± 7.1	23.6 ± 5.1	61.7
E	2	150	*Abies alba*	8 ± 1.4	5.1 ± 2.2	1.9 ± 0.2	2.9 ± 0.2	8 ± 2.8		8.1
	1		*Cedrus libani*	44	22	6	7	47.5	20	
	3		*Cupressus sempervirens*	70.7 ± 6.1	23.3 ± 0.1	3.2 ± 0.3	7.9 ± 0.3	71.8 ± 5.8	25	
	19		*Pinus nigra*	36.8 ± 3.8	18.8 ± 1.8	11.5 ± 2	5.1 ± 0.9	37.3 ± 3.9	20.5 ± 0.7	24.1 ± 2.1
F	4	80	*Prunus avium*	32.8 ± 8.8	7.6 ± 0.8	2.1 ± 0.2	4 ± 1.3	33.5 ± 9.3	8.5 ± 0.7	19.8 ± 4.5
	4		*Prunus cerasifera*	39.3 ± 9.6	7.7 ± 1.7	1.9 ± 0.3	4.5 ± 1.3	40 ± 9.5		14.8 ± 6.8

Table 2. Comparison of tree measurement methods in terms of instruments, measurable parameters, operators required, application type, approximate costs, and estimated time per plot (8 to 44 trees).

Method	Instruments	Measurable parameters	Number of operators	Application type	Estimated time	Approximate costs
Traditional	Diameter caliper, Ipsometer, Metric tape, GPS	DBH, tree height, crown height, crown width, stem inclination, tree position	1 (2)	Tree inventory	30 min – 60 min	1,600€ – 2,000€ 80€ – 150€ 20€ – 50€ 300€ – 400€
Spatial	Fied-Map station (Antelope model)	Georeferenced tree and crown position	2	Tree and canopy spatialization	20 min – 40 min	9,000€
Smartphone	iPhone 12 Pro, Apps	DBH, tree height, crown height, crown width, tree position, stem volume, surface and inclination, photos	1	Tree inventory, LAI, 3D model	30 min – 60 min	From 1,189€ + app cost

simplified measurements. Recently, smartphones incorporated advanced technologies such as the LIDAR scanner inside the camera, which allowed the development of applications to perform spatial measurements and tree surveys. These tools could be very supportive for urban foresters' practice to inventory and monitor trees; however, their accuracy is uncertain and thus their use may generate inaccurate data.

In this explorative study, we investigated and tested the potential of digital field instruments (Field-Map and iPhone 12 Pro) compared to traditional tools (tree caliper, ipsometer/clinometer), highlighting what information can be derived, their accuracy and time-cost efficiency, and the potential for research and practice in urban forestry.

MATERIALS AND METHODS

The study area is the 17th century Villa Paolina, located in the village of Porano (province of Terni) in central Italy (42.68° N 12.09° E). The villa's park consists of several orthogonal tree rows that cross the whole area and includes an Italian-style garden and some wooded areas along with a large meadow. The dominant tree species are century-old cypresses, cedars, pines, horse chestnuts, and holm oaks that reach considerable dimensions.

In this study, we measured 6 plots (5 inside the villa: A–E, and 1 outside: F)(Figure 1). The sample plots are *Cupressus sempervirens* L. tree rows (A), a *Quercus ilex* L. tree-lined pathway (B), a tree-lined street of *Pinus pinea* L. (C), a mixed conifer area (D), a more recent plantation of *Pinus nigra* Arnold (E), and a broadleaf urban park (F)(Figure 2). Tree dendrometric data measured in the plots are described in Table 1.

Diameter at breast height of trees was measured with tree caliper, and the height of representative trees was measured with the electronic ipsometer (Vertex IV, Haglöf Sweden, Långsele, Sweden)(Traditional method in Table 2). The portable computer station Field-Map (Antelope model, Institute of Forest Ecosystem Research, Ltd., Jílové u Prahy, Czech Republic) was used to acquire a very accurate georeferenced position of the tree and crown area, as well as record several dendrometric and structural data of the stand (Spatial method in Table 2). The tool equipment consists of a laser distance meter, an electronic compass, a GPS, and a tripod. It is directly connected with the GIS software of the computer station, providing in real time a georeferenced 2D visualization of the single tree or a forest area (Mattioli et al. 2009; Tomao et al. 2012).

Tree biometric data were also collected by the smartphone iPhone 12 Pro (Apple Inc., Los Altos, California, USA) which incorporates a LIDAR scanner inside the camera and allows it to measure objects and create a depth map of space (Smartphone method in Table 2). The application Arboreal Tree Height (Arboreal AB, Umea, Sweden) was used to measure tree height, crown base height, and crown width, and the default "Metric" app was used for DBH. In

Figure 1. Sample plots in Villa Paolina (A–F) with tree position and canopy area recorded by Field-Map.

Figure 2. Representative pictures of measured plots in the study area.

Table 3. Comparison of measured shading factors with reference values from Nowak 1996.

Species	Measured shading factors	Reference shading factors (Nowak 1996)
Magnolia grandiflora L.	0.75	0.83
Cedrus libani A. Rich.	0.73	0.91
Tilia cordata Mill.	0.95	0.88
Pinus pinea L.	0.56	0.83
Aesculus hippocastanum L.	0.91	0.88

addition, under-canopy photos of trees were acquired to evaluate the shading factors (S) of several tree species (Table 3) with the software GIMP (version 2.10.24) using the following equation:

$$S = 1 - \frac{1}{(\text{Total pixels} - \text{Wood pixels})} \times \text{Light pixels}$$

The 3D model of stems in the study area based on smartphone LIDAR data was obtained using the Polycam application (Polycam Inc., https://poly.cam). We tested the volume and area calculation of 3D model stems using the software Agisoft Metashape (version 1.7.3, Agisoft LLC, St. Petersburg, Russia).

Pearson's test was used to evaluate the statistical correlation between tree parameters measured by different instruments.

RESULTS AND DISCUSSION

Different types of tree stands were evaluated in our study area: tree-lined avenues with different species and densities (A, B, and C), a mixed forest (D), a quite dense plantation (E), and an urban park with isolated trees (F)(Table 1; Figure 2). Tree-lined streets with *Cupressus sempervirens* L., *Quercus ilex* L., or *Pinus pinea* L. are frequent in the landscape of Italian cities (Caneva et al. 2020) and can reach even monumental sizes, such as trees in our plots B and C with diameters greater than 50 cm and heights up to 30 m for pine. This results in a large leaf area, as shown by canopy diameter and projection. Plot D includes different

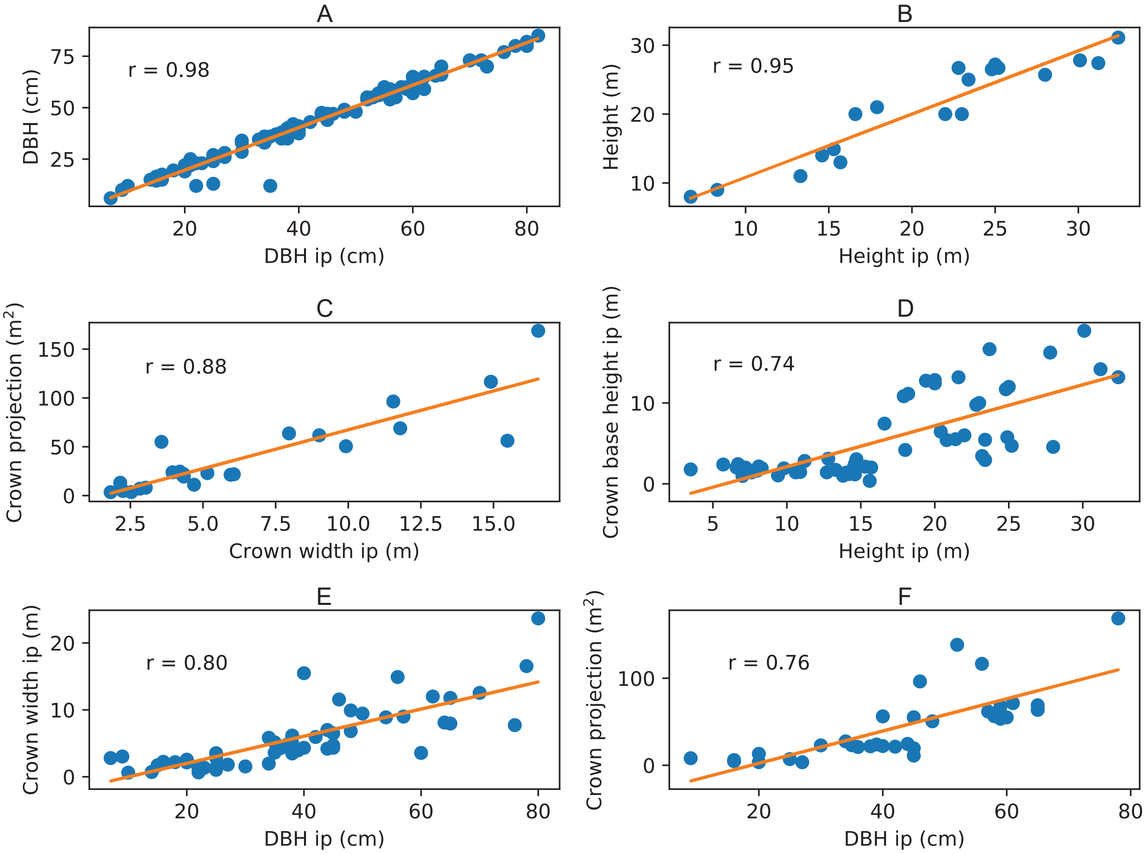

Figure 3. Correlation of tree parameters measured by smartphone and other tools (*r*-values are significant with $P < 0.001$). (A): DBH measured by smartphone (DBH ip) vs. tree caliper (DBH); (B): tree height measured by smartphone (Height ip) and electronic ipsometer (Height); (C): crown width measured by smartphone (Crown width ip) vs. crown projection assessed by Field-Map (Crown projection); (D): relationship between Height ip and crown base height measured by smartphone (Crown base height ip); (E): relationship between DBH ip and Crown width ip; (F): relationship between DBH ip and Crown projection.

conifer species with large dimensions, while the dominant species in Plot E is *Pinus nigra* Arnold, along with other conifers. *Cupressus sempervirens* L. and *Chamaecyparis lawsoniana* Murray trees in plots A and D showed lower values of crown base height and limited crown width, due to their characteristic canopy shape. The broadleaved trees in plot F, despite limited height, present a well-developed canopy due to both the absence of competition for light (Bechtold 2003) and the effects of pruning (Drenou 2000; Dujesiefken et al. 2005), assuming a common canopy shape for trees in the city.

The comparison between the DBH and tree height measurements of the smartphone with those carried out with the tree caliper and the electronic ipsometer showed a strong correlation (*r*-values of 0.98 and 0.95, respectively)(Figure 3). A good relationship (*r*-value of 0.88) was also found between the crown width measured with the smartphone and the crown projection assessed with the Field-Map tool. Tree size in diameter and height are generally correlated with canopy size, but species characteristics and management can influence these measurements. This is shown by the less evident (*r*-value of 0.74) relationship between crown base height and total height, both measured by the smartphone. In fact, crown base height is affected by canopy shape, which is a species-specific characteristic (e.g., cypress crown), and it proves the importance of including this information in field measurements to correctly estimate crown length and thus leaf area and biomass of trees (Nowak 1996). Tree diameter is also positively correlated with crown width (*r*-value of 0.8) and crown projection (*r*-value of 0.76), although canopy size, and thus space requirements for open-grown trees, vary according to species (Pretzsch et al. 2015). Therefore, it is necessary to assess the crown size for tree management based on site requirements, such as an appropriate distance from buildings in the urban area.

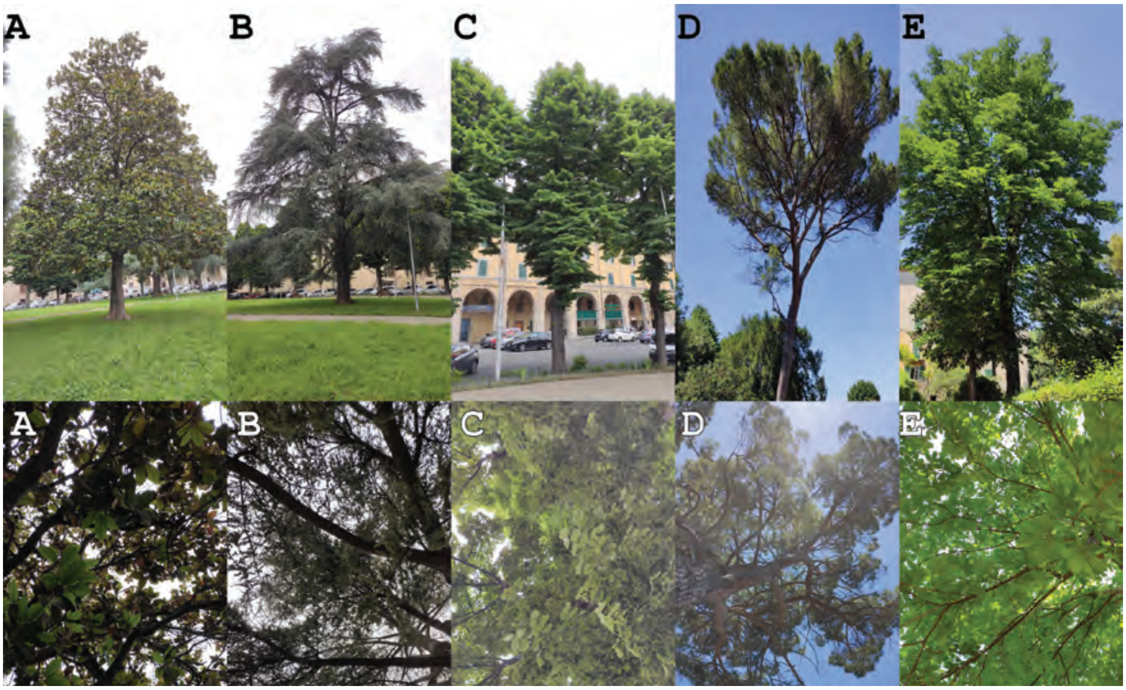

Figure 4. Horizontal and under-canopy photos for the shading factor evaluation (A = *Magnolia grandiflora*, B = *Cedrus libani*, C = *Tilia cordata*, D = *Pinus pinea*, E = *Aesculus hippocastanum*).

The investigated tree measurement methods (Traditional, Spatial, Smartphone) show different characteristics in terms of instruments, measurable parameters, number of operators, estimated time, and approximate costs (Table 2). Regarding the equipment, the use of a smartphone for tree survey is the most practical because a single device can measure many parameters. The Traditional method also allows to assess a complete set of tree information but requires the use of several tools (diameter tape, ispometer, metric tape, GPS). The Field-Map station is a portable instrument that, compared to others, provides very accurate data on the location of trees in the plot and the spatial representation of canopies (Tomao et al. 2015). However, the model used in this study (Antelope) does not allow to measure tree diameter and height but only to record these data in the field, resulting in less measurable parameters.

Furthermore, the Smartphone method requires only one operator to measure all tree parameters. The Traditional method can be carried out by only one operator except for the measurement of the crown width, in which case two are required. The Spatial method with the Field-Map instrument instead requires at least two operators to measure distances with the laser to assess tree position and crown projection.

In terms of time, due to the limited number of plots, we can only indicate an estimated value that varies depending on the size of the analyzed area and the number of trees (Nowak et al. 2008b). The Field-Map tool is faster than others, although less complete as to measurable parameters. The Traditional and Smartphone methods are comparable in terms of time because they are based on a similar single-tree approach to measure several types of tree information.

The costs range from 9000€ for Field-Map, to 2000€ to 2600€ for the traditional instruments, which includes the cost of several tools, to 1189€ for the smartphone plus the app cost. These are approximate costs based on the set used in this study and may vary in the future based on implementation and spread of tools and devices. For instance, the incidence of the cost of the smartphone could be lower in the future considering that this device equipped with a LIDAR sensor will be more and more widespread among people.

A further advantage of using the smartphone is the ability to take photographs of trees both horizontally to assess the size of the crown and under the canopy to assess the amount of light passing through the canopy (shading factor)(Figure 4) and estimate leaf area index (LAI)(Chianucci et al. 2015). In fact, urban

Area (m²): 5.056

Volume (m³): 0.029512

Figure 5. A 3D visualization of tree stems of plot E and calculation of diameter, height, area, and volume.

trees perform an important function of surface temperature reduction through shading (Massetti et al. 2019) that is strongly related to leaf density in the canopy, expressed through LAI (Rahman et al. 2020; Pace et al. 2021). The calculated shading factor of isolated urban tree species, using under-canopy photographs, are comparable with values in Nowak 1996 (Table 3), which are used in the i-Tree Eco model to calculate leaf area and biomass. *Tilia cordata* Mill. and *Aesculus hippocastanum* L. show higher values than other tree species, not only for foliage properties but also for the effect of management that tends to compress the crown by increasing leaf density (Dujesiefken et al. 2005). The shading factor of *Cedrus libani* A. Rich. is similar to *Magnolia grandiflora* L. but greater than *Pinus pinea* L. In fact, the cedar crown architecture is not comparable to other conifers with greater leaf density, such as firs or cypresses, demanding a specific class. The possibility to measure this parameter in the field could allow a more accurate assessment of LAI and, therefore, also the shading capacity of the species (Speak et al. 2020).

We also explored the potential of the LIDAR scanner integrated in the smartphone camera to create a 3D map of the plot (Figure 5). From a first analysis, we obtained a good representation of the stem to obtain an accurate measure of diameter, height, and especially volume for biomass evaluation. The app requires a close distance between the smartphone and the object to create a 3D image, and for this reason we could not frame the crown through the camera due to the greater height of trees compared to the operator.

The potential of this methodology deserves thorough evaluation in future studies to extract highly detailed information about the structure of urban trees and a comparison with terrestrial laser scanner applications (Hu et al. 2018; Kükenbrink et al. 2021).

Finally, the citizen involvement through smartphone applications could be of considerable support to municipalities for urban forest management and scientific research on urban green area awareness and development. For example, citizens could report the presence of underperforming trees, conflicts with pavements or other structures, spontaneously grown trees in inappropriate areas, and other useful information for management (Cambria et al. 2021). In addition, more widespread data on size and tree species could be used to quantify their ecosystem services using existing models and design effective green infrastructure for cities (Gatto et al. 2021; Pace et al. 2021).

CONCLUSIONS

This study provided a first positive evaluation of the support that digital technologies can give to field surveys and urban tree inventories for quantitative assessment of tree size (DBH, height), crown dimension (length, width, projection), and georeferenced position of trees and canopy. Compared to traditional tools, the use of smartphones for tree measurement is a practical and reliable option because it allows the accurate assessment of several tree parameters with a single device, reducing costs and training time for use. These user-friendly devices can be also a valuable tool to engage citizens in the urban tree assessment to ensure ongoing monitoring of tree conditions and improve the assessment of actual ecosystem services they supply to cities.

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Résumé. Les forêts urbaines peuvent générer des fonctions environnementales et sociales indispensables si elles sont correctement planifiées et gérées. Les inventaires et les mesures des arbres constituent un élément crucial pour l'évaluation et la surveillance de la dimension, de la croissance et de la condition de santé des arbres urbains. Dans ce contexte, les paramètres habituellement relevés sont le diamètre à hauteur de poitrine (DHP) et la hauteur totale, mais des données supplémentaires sur les dimensions du houppier (largeur, longueur et projection de la ramure) sont nécessaires pour une évaluation détaillée de l'arbre. Ces données sont généralement recueillies par les forestiers urbains lors de relevés sur le terrain, à l'aide d'un compas forestier ou d'un ruban circonférentiel pour le DHP et d'un télémètre/clinomètre électronique pour mesurer la hauteur des arbres et la dimension de leur ramure. Un niveau de précision plus élevé pourrait être atteint par l'utilisation d'un instrument numérique tel que Field-Map, une station informatique portable, permettant de réaliser rapidement des relevés dimensionnels et topographiques des arbres et des peuplements forestiers. De plus, l'incorporation d'un dispositif LIDAR dans un téléphone intelligent, tel que l'iPhone 12 Pro, a rendu cet appareil apte à mesurer les attributs des arbres ainsi que diverses données spatiales supplémentaires sur le terrain. Pour cette recherche, nous avons testé ces 3 différents systèmes de mesure lors d'un échantillonnage dans une forêt urbaine et nous les avons comparés en termes de paramètres mesurables, de précision, de coût et d'efficience. De plus, nous avons échangé sur les avantages et les inconvénients de chaque approche de mesure et sur la manière dont les données obtenues peuvent être utilisées pour évaluer les services écosystémiques des arbres et fournir des conseils sur leur gestion afin de réduire les risques ou les dysfonctionnements potentiels.

Zusammenfassung. Städtische Wälder können wesentliche ökologische und soziale Funktionen erfüllen, wenn sie richtig geplant und bewirtschaftet werden. Bauminventuren und -messungen sind ein wichtiger Bestandteil der Bewertung und Überwachung von Größe, Wachstum und Gesundheitszustand von Stadtbäumen. In diesem Zusammenhang werden in der Regel der Brusthöhendurchmesser (DBH) und die Gesamthöhe erfasst. Für eine umfassende Baumbeurteilung sind jedoch zusätzliche Daten über die Kronenabmessungen (Breite, Länge und Kronenüberstand) erforderlich. Diese Daten werden in der Regel von städtischen Förstern im Rahmen von Feldbegehungen erhoben, bei denen Baumzirkel oder Durchmesserbänder für den Brusthöhendurchmesser und elektronische Ipsometer/Klinometer zur Messung der Baumhöhe und Kronengröße verwendet werden. Mit einem digitalen Instrument wie Field-Map, einer tragbaren Computerstation, können schnell dimensionale und topografische Erhebungen von Bäumen und Waldbeständen durchgeführt werden, um mehr Details zu erhalten. Durch den Einbau eines LIDAR-Scanners in ein Smartphone, wie z. B. das iPhone 12 Pro, ist dieses Gerät in der Lage, Baumattribute sowie zusätzliche räumliche Daten im Feld zu messen. In dieser Studie haben wir diese drei verschiedenen Messsysteme bei einer Feldbeprobung in einem städtischen Wald getestet und sie in Bezug auf die messbaren Parameter, die Genauigkeit, die Kosten und die Zeiteffizienz verglichen. Darüber hinaus haben wir die Vor- und Nachteile jedes Messansatzes erörtert und erörtert, wie die gewonnenen Daten zur Bewertung der Ökosystemleistungen von Bäumen und zur Bereitstellung von Leitlinien für die Baumbewirtschaftung verwendet werden können, um potenzielle Risiken oder Nachteile zu verringern.

Resumen. Los bosques urbanos pueden proporcionar funciones ambientales y sociales esenciales si se planifican y gestionan adecuadamente. Los inventarios y mediciones de árboles son una parte crítica de la evaluación y el monitoreo del tamaño, el crecimiento y la condición de salud de los árboles urbanos. En este contexto, los parámetros que generalmente se recopilan son el diámetro a la altura del pecho (DBH) y la altura total, pero se requieren datos adicionales sobre las dimensiones de la corona (ancho, longitud y proyección de la corona) para una evaluación integral del árbol. Estos datos generalmente son recopilados por silvicultores urbanos a través de encuestas de campo utilizando forcípula o cinta de diamétrica para DBH y el ipsómetro / clinómetro electrónico para medir la altura del árbol y el tamaño de la copa. Se podría lograr un mayor detalle utilizando un instrumento digital como mapa de campo, una estación de computadora portátil, para realizar rápidamente levantamientos dimensionales y topográficos de árboles y rodales forestales. Además, la incorporación de un escáner LIDAR en un teléfono inteligente como el iPhone 12 Pro ha hecho que este dispositivo pueda medir atributos de árbol, así como datos espaciales adicionales en el campo. En este estudio, probamos estos 3 sistemas de medición diferentes en un muestreo de campo de un bosque urbano y los comparamos en términos de parámetros medibles, precisión, costo y eficiencia de tiempo. Además, discutimos los pros y los contras de cada enfoque de medición y cómo los datos resultantes se pueden utilizar para evaluar los servicios ecosistémicos de los árboles y proporcionar orientación sobre el manejo de los árboles con el fin de reducir los riesgos o perjuicios potenciales.