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Intelligent Survey Technologies and Applications for Urban Forests in Taiwan

By Jan-Chang Chen, Chun-Hung Wei, Yi-Ta Hsieh, Shang-Chuan Huang, and Ping-Hsun Peng

Abstract. Background: Roadside trees play an important role in urban landscaping. They are not only related to urban scenes, traffic safety, quality of life, and health, but also closely related to ecology and cultural development. Thus, effective, intelligent management of an area of urban roadside trees will become an important topic. Methods: This paper evaluates survey technologies and management techniques utilized in many cities of Taiwan, including surveys of roadside trees, risk assessment, and precious protected trees. A roadside tree management database was built using a geographic information system (GIS). Results: The number of urban forest trees exceeded 100,000 in our surveys, and many types of intelligent survey instruments were used to survey the trees, including real-time kinematic (RTK) and non-destructive detection instruments, radio frequency identification (RFID), in-vehicle light detection and ranging (LiDAR), and panoramic streetscape systems. A tree management system can be constructed by introducing the digitized information, which is based on a basic survey of trees. The survey stage primarily relies on manual surveys, in-vehicle LiDAR, and RFID, and then a visualized database retrieval system will be proposed using GIS. This system can be utilized for the health and foundation management of trees and the whole spatial planning of urban forests, among others. Conclusion: This research attempts to summarize the trends in intelligent management of urban forests using our practical experiences with the goal that it will be a reference for the future intelligent construction of urban forests.

Keywords. Geographic Information System (GIS); In-Vehicle Light Detection and Ranging (LiDAR); Non-Destructive Detection Instruments; Urban Forest; Urban Scenes.

CONTENTS AND METHODS OF THE URBAN FOREST SURVEY

Urban forests contain many types of trees that surround a city. These trees have many ecological survey functions, including modulation of the climate, conservation of energy, reduction in emissions, purification of the air, and beautification of the environment, among others. These trees can improve the surrounding environment of a city and the health of its residents, and serve as a crucial green infrastructure of a city. In addition, the ability of urban forests to improve the ecology of the environment, particularly by plantings and the growth of an environment, among others, can provide a good environment for urban trees. The following monitoring and maintenance will ensure the healthy condition of urban trees and enable them to act as optimized ecosystem services (Blum 2016).

When investigating urban forests, the tools to detect tree decay can only function effectively in detecting risks that are hidden inside or outside of the tree if the instrument function matches the expected results. In this study, considering various technical and instrumentation constraints, e.g., the cost of time and the accuracy of detection, a tree detection framework was planned to detect tree decay, and the tool to detect the decay of trees can be used in sequence based on its measurement speed, resolution, and accuracy.

1. Vehicle-mounted LiDAR for the comprehensive acquisition of urban forest data
2. Rapid screening with a visual appearance assessment to distinguish high-risk trees from low-risk ones
3. High-precision assessment with a digital diagnostic tool to assess the decay of trees

Integration of Real-Time Kinematic (RTK) and Geographic Information System (GIS)

In forestry, precise location information in the permanent sample zones or forests is required to facilitate the future reexamination of the trees owing to the sampling method (Zengin and Yesil 2004). The performance of a Global Positioning System (GPS) can be improved by its integration with real-time kinematic (RTK), which provides much more precise location information (Pirti 2007).

Countries from all over the world have different measures for the management of their urban forests. The Town of Wake Forest (2013) and the City of Kirkland (2013), the Climate Action Reserve of urban forests (2019), and the American Public Works Association (APWA [date unknown]) have all developed related plans for urban forests.

After the Act on the Protection of Protected Trees and Roadside Trees in Forests was established, all of the urban forests must be refined and surveyed to ensure the correctness and integrity of the forest database. The related contents will then be integrated to adapt to projects in Taiwan. Professionals will investigate the project, take the latest photos, and record the growth situations of trees and environment conditions to evaluate the health of trees. The reports will provide the situations of the growth of urban forests to aid in their management. These management techniques can provide better plans to tend trees, control pests, and maintain urban forests. The expected effect is that every urban forest can be maintained appropriately.

Figure 1. Roadside trees position by RTK.

When managing urban forests, processing a spatial analysis and the complete management of the forest is difficult if it only relies on basic surveys that include basic seed information, growth situations, and health situations, among others. Therefore, our survey integrates GPS and RTK to realize the location (Figure 1), and then we will build a database to summarize these survey data. The refinement of these analyses can provide suggestions for the effective management of urban forests.

All of the survey data are acquired by standard operating processes with standard projects and tables, and they meet the requirements of urban forest management. These processes will provide better maintenance for each tree, which should result in more efficient management. The spatial database can be built with a geographic information system (GIS) after data processing. It will aid in future management, and its graphical information can be integrated to improve the application of urban forest survey data.

Health Survey of Forests Using Non-Destructive Detection Instruments

Wood decay is a natural phenomenon that appears after the tree has died. The fungi invade and secrete many types of enzymes to decompose the cytoplasm and cell wall. However, wood decay can happen while the tree is alive owing to external factors such as pest infestations or internal growth features. This phenomenon is called the decay in living trees. If this condition becomes serious enough, it can lead to a decrease in growth and quality, potentially resulting in the appearance of some cavities in a tree or the destruction of the tree's function. As a result, the trees could be knocked over when a strong external force, such as wind, is applied. The decay in living trees can easily remain undiscovered because it does not immediately destroy the appearance or growth trend of a tree (Shortle and Dudzik 2012; von Döhren and Haase 2019). As described by Lilly (2010), tree health and structural stability are independent of each other, but they are closely related. This correlation occurs because the trees with a high risk of structural safety may be healthy and have a dense canopy; however, they may be at risk of collapsing owing to an inadequate structural strength. Conversely, trees in poor health do not necessarily have problems with structural stability. Therefore, if we consider that tree health and structural stability are closely related, this suggests that healthy trees can produce compensatory growth to reduce the damage caused by decay, breakage, and injury. Therefore, in this study, a visual tree assessment (VTA) of the trees was conducted from the following 2 viewpoints, as suggested by Mattheck and Breloer (1996):

1. The biological point of view, including the growth of the tree; the growth of branches and leaves; the presence of pests and diseases; the presence of fungal parasites on branches and roots, decay, and cavities; the presence, size, and location of wounds; or the presence of bulges on the trunk of the tree.
2. The mechanical point of view, including (1) an assessment of the possible breakage of the trunk, such as swelling, tumors, holes, decay, wounds, tilting, and cracks, and the endogenous bark of a certain part of the trunk, and (2) an assessment of whether the tree will fall, such as the condition of the root surroundings, root tension, root injury and decay, and soil conditions. After completing the collection of various visual evidence, the health of the tree was evaluated to determine if further testing was merited.

The assessment of decay usually utilizes instruments owing to the excellent concealment of inner decay. There are 3 conventional instruments that can acquire the situation of inner decay and related information: destructive test (DT), micro-destructive test (MDT), and non-destructive test (NDT)(Goh et al. 2018; Coelho-Duarte et al. 2021). DT can be established using a drilling machine, endoscopy, or monitor drill top. The principle of DT is to drill one or multiple holes to observe the inner decay of a tree, but it will wound the trees. In addition, it can only observe the monitoring points and may ignore other types of decay. This situation restrains the precision of DT, and secondary infections can happen to the objective (Johnstone et al. 2007). MDT is also a type of destructive test, but the hazards are much lower than those of DT owing to its small- or medium-sized probe. NDT utilizes sound, light, electricity, magnetism, or other media, which would not destroy the tree but indirectly detect the inner decay. Although the precision is higher and the range of detection is larger than that of other methods, NDT is more expensive to use than other methods. In recent years, its cost has been decreasing and it has replaced DT for use in detecting the decay in living trees (Ponneth et al. 2014).

Additional ways of inspecting trees, considering the portability of the instrument and operational safety, include acoustic-based stress wave or ultrasonic inspection tools such as the FAKOPP Microsecond Timer, the ArborSonic 3D Acoustic Tomograph, or the CBS-CBT Sylvatest TRIO (ultrasonic timer), which are more commonly used. These tools are used to record the distance and time between the transmittance and receiving ends by actively or passively emitting a specific frequency of sound waves, which are converted into values for the speed of sound, the speed of sound of the decay rate, the chordal to radial speed of sound penetration time, and the radial to chordal speed of sound ratio, among others, to assess whether the cross section of the tree is decayed. There are many NDT instruments and products with different practicability, convenience, safety, and economy, among others. The most commonly used methods to assess wood decay include stress waves and ultrasonic techniques, which have already been accepted by tree health managers and practitioners. The range of use is also very broad (Johnstone et al. 2010; Ponneth et al. 2014).

Stress waves and ultrasonic techniques both use acoustical instruments to measure the velocity of energy in a test wood. The main difference between these methods is that the ultrasonic waves are generated from a known frequency pulse, but the stress waves are not. In theory, the wave velocity in the wood is much faster than it is in the air, and it depends on the type of wave and the elasticity and density of the materials. Thus, the inner decay of a tree will change the velocity in different inner conditions (Wang 2013; Li et al. 2014). We have tested instruments that utilize both methods. In recent years, a diagnostic method and instrument called “PONTA” (Suyama et al. 2010; Suyama et al. 2013) was invented in Japan, which utilizes the stress waves of a knock on the tree. After a crosswise knock, using fast Fourier transform (FFT), the stress waves are recorded and the frequency distribution is analyzed. The highest peak of frequency is analyzed and compared with the diameter of other healthy trees to detect the abnormal phenomena. This NDT can detect the damage to a tree through a simple and time-saving method (Yamada et al. 2019).

The knock method of decay testing is also related to the resonant frequency value (DFr), which will decrease with the inner decay, the cavity, or a reduction in water. Kamaguchi et al. (2001) used a crosswise knock instrument to test the decay of protected trees. Because of the substantial influences of trunk base decay, we knocked the diameter at breast height (DBH)(1.3 m) of a protected tree 3 times crosswise using a 364-g rubber hammer. The stress wave was received by a handheld PDA, and then the DFr and decay proportion in different directions were acquired by analysis. However, the detection of stress waves was still restrained by many limits, such as the types of trees, knock ways, and natural environments, and the precision will differ. We used 2 methods to ensure high precision when the crosswise knock detection was used to identify decay. If the percentage of decay is greater than 30%, a microdigital drilling resistance method (DMP) is used to measure the level and location of decay and provides references for the further maintenance of trees. The probe of microdigital DMP is shaped like a flat spoon and can drill in a tree using its motor. The level of decay and its location can be confirmed using this method. If the probe encounters materials with high density, the rotation time and drilling resistance will increase. If the probe encounters materials with a low density, such as decay, the rotation time and drilling resistance will decrease. The inner materials and drilling resistance of a tree can be tested at different positions. The distribution curve of the drilling resistance can reveal the possible location and size of decay (Figure 2).

Compared with the crosswise knock decay detection, the microdigital DMP can reveal the decay with desirable precision and scope, but it must be used multiple times to detect the whole decay situation, therefore it requires more human power and time, which adds to the expense of its use. As shown in this study, the crosswise knock detection of decay can quickly detect decay, but the precision is influenced by many factors (e.g., bark surface type, environmental noise interference, difference in investigator's percussion force). The microdigital DMP is highly precise, but it is time consuming. Therefore, the advantages of these 2 instruments are integrated to complete the survey of wood decay. This method can judge both the inner and outer decay conditions of a tree, and the reliable data can be referenced for forest management.

Comprehensive Urban Data Sampling by the Integrated In-Vehicle LiDAR and Panoramic Streetscape System

A substantial amount of research on LiDAR shows that the applications of LiDAR, multi-LiDAR, and integrated LiDAR with hyperspectral imaging can all

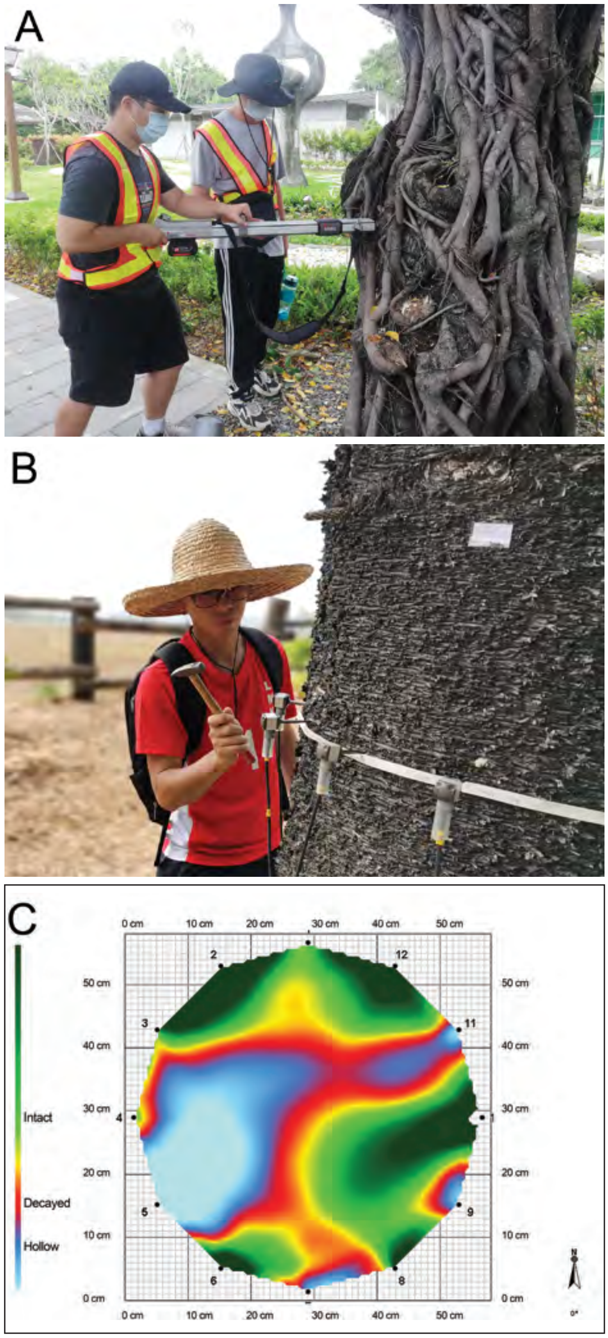

Figure 2. (A) Tree decay and detection with non-destructive inspection instruments (IML; Instrumenta Mechanik Labor System GmbH); (B) Tree decay and detection by sonic decay detection; (C) There was obvious decay inside the trunk after sonic decay detection.

acquire 3D information of the forest and can provide substantial benefits to urban forest management (Zhang and Qiu 2012; Alonzo et al. 2016; Iqbal et al. 2017; Estornell et al. 2018; Ciesielski and Sterenczak 2019; Kwong and Fung 2019).

This research on roadside tree measurements in Kinmen, Taiwan, is separated into 2 portions: (1) the tree coordinates and DBH are directly measured by a point cloud, and (2) the tree heights are extracted from the normalized digital surface model (NDSM). The LiDAR data can be used to digitize the roadside tree database with related photos after the adjustment has been corrected. Then, the NDSM values, which are extracted from the point cloud data, can be used to calculate the tree height with forward results. After the measurement and correction of tree data, the trees along the roadside are numbered in sequential order from left to right, and the trees with reflections are recorded in the panoramic photos. The tree records still must be transferred into the vector records along with input attribute data to finish digitizing the roadside information. The new records will be utilized by a future management system. The system samples 15 main types of roadside trees to measure their DBHs and heights. These data are compared with the same data observed by in-vehicle LiDAR to analyze the measurement error. The mean absolute error (MAE) and standard deviation of absolute error are used in this research. The MAE is calculated by the mean of LiDAR and the absolute measured value, and the latter parameter is calculated using the standard deviation of LiDAR and the absolute measured value. The MAE of DBH of these trees is between 1.31 and 2.43 cm, the mean error is 1.82 cm, and the standard deviation of absolute error is 1.68 cm. These errors are all in the acceptable range. Therefore, we can conclude that LiDAR measurement is a feasible method to measure the DBH (Figure 3). The MAE of the height of these trees is between 0.65 and 2.74 m, the mean error is 1.10 m, and the standard deviation of absolute error is 1.42 m. These errors are all in the acceptable range. Therefore, we can conclude that in-vehicle LiDAR measurements can measure the DBH, height, and coordinate data of a tree.

The efficiency of the use of in-vehicle LiDAR measurements is indicated in the example of the Kinmen street tree survey, in which vehicle-mounted radar was used to scan (back and forth once each) a total of 20,906 trees at a speed of 40 km/hour, with a total road length of 70 km. Without considering other factors, such as the control point placement, traffic signal stops, and the distance between street trees, among others, the in-vehicle LiDAR measurement can scan 5,973 trees per hour, which is a very high field efficiency. However, there is no estimation of the subsequent data processing time in this study, as it only examined the efficiency of the field operation.

Calders et al. (2020) pointed out that more ways need to be developed for the use of tripod-based ground light sources in urban forests, and the data and parameters collected through tripod-based ground light sources are used as training samples to estimate urban forest structure at this stage. However, new 3D measurement techniques, such as Structure from Motion (SfM), can be integrated to effectively obtain

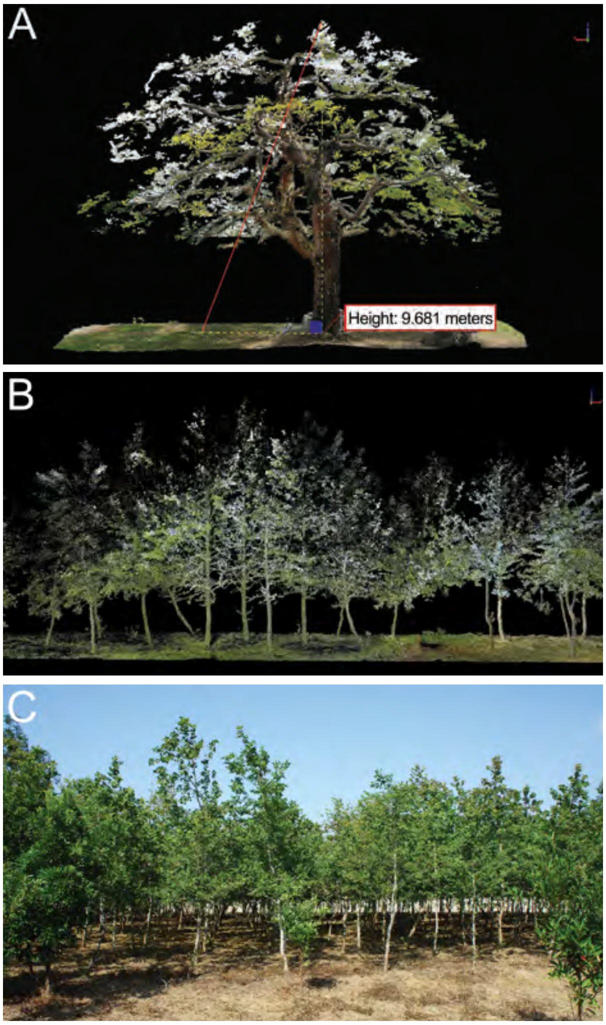

Figure 3. (A) LiDAR data of protected tree; (B) LiDAR data of roadside trees; (C) photograph of site sampled by LiDAR.

data from airborne aerial imagery or LiDAR sensors on (driverless) cars (Figure 4).

Applications of Radio Frequency Identification (RFID) for Urban Forest Management

Luvisi and Lorenzini (2014) indicated that urban forest management can become smarter and more environmental, and it can achieve the policy objective for further development. In addition, it can provide some related ecological benefits for urban residents. The Internet of Things (IoT), which can be generated by introducing the RFID into communication networks, labels different types of trees to protect and manage them, enabling more contribution to the management of urban forests.

The RFID monitoring technology developed by the United States Department of Agriculture (USDA) Forest Service (Farve 2014) is one of the most important forest survey technologies. Hakli et al. (2010) and Bjork et al. (2010) also used RFID technology to track log supply chain benefits.

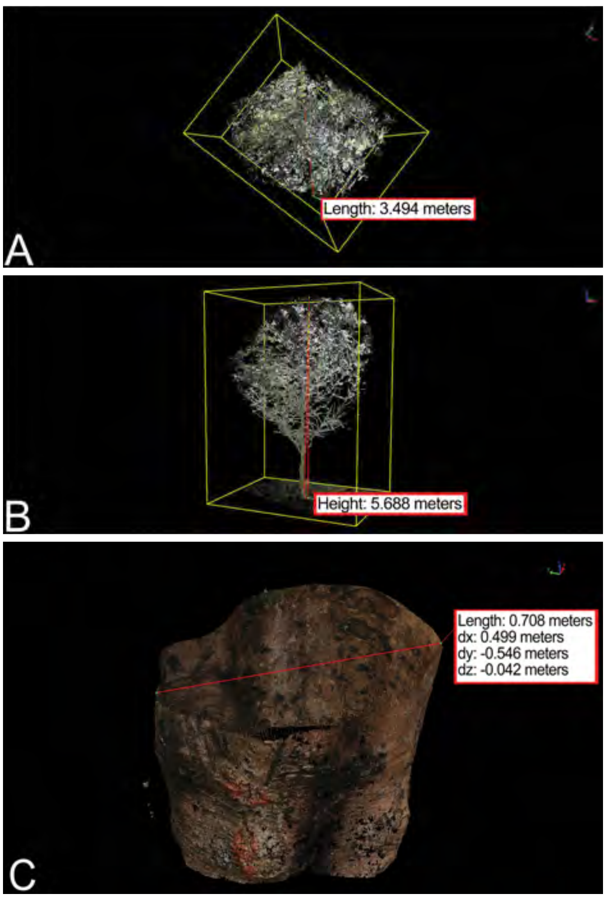

Figure 4. (A) Measuring tree crown size by LiDAR point cloud data; (B) Measuring tree height by LiDAR point cloud data; (C) Measuring DBH by LiDAR point cloud data.

This research is primarily about rechecking the RFID system on protected trees in Kinmen and updating the survey data. The survey RFID tags are pasted on the tree brand. The RFID reader reads the data of an RFID tag when the survey of protected trees starts. Many types of interfaces provide the attributes of the location of protected trees, forest tree conditions, health conditions and evaluations, and field conditions, among others, to update the related data. The rechecking can be quickly finished at this point. Simultaneously, managers can evaluate how well the RFID tags have aged, renew the damaged tags, and conveniently learn the forest's conditions by reading the data. We also use an urban forest information management system, which can be updated online or offline, to integrate technologies and gain information on forests, with the exception of the RFID tags.

At this stage, Taiwan does not have a standard operating procedure for urban forestry surveys. From our experience in assisting the government with surveys, most local governments will set a budget and indicate the information they wish to obtain; the professional team advises on what method should be used and then conducts surveys to acquire the requested data. Whether it is through direct survey or the use of GIS, non-destructive detection, photovoltaic technology, or RFID, we hope to master the analysis of foundation and health management of trees and move toward the intelligent management and application of urban forestry in overall spatial planning (Figure 5).

URBAN FOREST INFORMATION MANAGEMENT SYSTEM

Schipperijn et al. (2005) indicate that the management of urban forests differs from that of other green spaces. Different plans and designs will be developed for different demands. Therefore, the management methods can be analyzed by known information, which indicates that the decision of the whole system is the most vital part. Also, it verified that the urban forest information can be clearly observed by the information system.

GIS-integrated information systems for data management can effectively collect various spatial data on urban forests. These systems include basic operation,

Figure 5. (A) Protected tree; (B) RFID reader and tag; (C) Tree tag with detailed information.

information resource management, urban forest plans, and ecological benefit analysis, among others. The whole system can intellectually and scientifically realize decisions, resulting in decreased administrative costs and a comprehensive analysis of the ecological benefits (Tasoulas et al. 2013; Wang et al. 2015).

This research can build the spatial database of the information on trees in Excel, MySQL, and other related formats. It can also reveal the numbers, seeds, ages, and health conditions of protected trees using spatial images. The urban forest tables of each administrative region can then be summarized. The pest infestations, human damages, or brand losses are labeled on the errata table, and the tree numbers of the protected trees are shown on the map for the convenience of management. This research team built the management system entitled "The protected and roadside trees management system" for Kinmen Island, Taiwan (in 2015) and Penghu Island, Taiwan (in 2020) (Figure 6). This system integrates the tree tables, street view photos, database of roadside and protected trees, information query system, management system, and Web GIS. The differences in the location of logs, seed configurations, and other details can be shown through a comparison between the historical plans and future surveys.

There are some types of advice suggested based on the seed configurations:

1. The number of roadside tree types is too large in both the single road sections and all of the road sections. The needless trees should be gradually adjusted.
2. Most of the afforestation on the roadsides is in a single layer. We suggest that multilayer afforestation should be used in villages, fringe areas, and other large areas to build multilayer ecological green verges.
3. Since many forest trees are becoming old, they will require updating in the future. We can gradually update these trees from nursery stocks in the future.
4. We suggest that some plant nursery stocks be added to fill the gaps on some roadsides.
5. Future multilayer afforestation can introduce some trees with different flowering phases, so that there are features in each season.

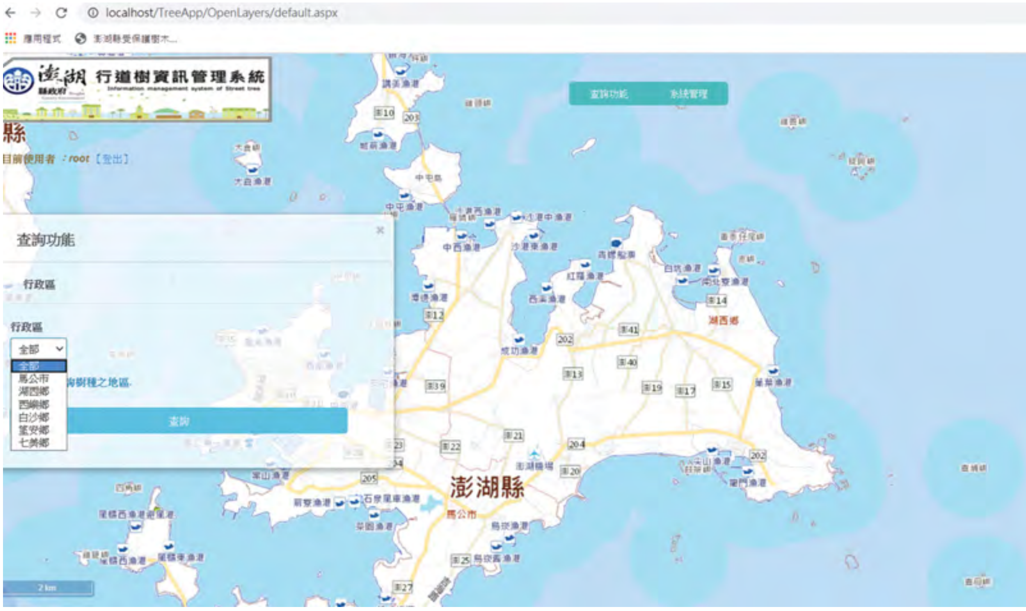

Figure 6. Information management system interface of tree maps.

URBAN FOREST SURVEY AND INTELLIGENT OPERATION AND MANAGEMENT IN TAIWAN IN THE FUTURE

Ordóñez et al. (2020) discussed how to evaluate management and be consistent with the decisions of the managers. For example, most managers agree that the developments and climate changes of a city bring new challenges and opportunities owing to their urban forest protection and expansion policy. The urban forests will be removed or rebuilt in the future. Thus, many challenges are focused on solving these problems. It is very important to share the problems of developments and environmental threats with local administrators, so that they can reach a consensus for urban forest management. This research can conclude that good communication will promote a transparent platform, complete the revealing data, encourage reasonable discussion, and reach a consensus for urban forest management.

There are 22 administrative regions in Taiwan. This research surveyed 6 regions with 85,000 trees, including 2,768 protected trees and 82,232 roadside trees since 2010. Some trees were surveyed in 2021, but we estimate that more than 15,000 trees were counted. The contents of the tree survey include basic information and processing, health and risk assessments, information management system building, trimming standards, environmental education events, NDT, and detailed detection for termite invasions. The results of the street tree survey can be used by management agencies to inform tree management decisions. If the street trees should be felled and replaced, the number and location of the replacement species should be planned in advance. In addition, good management will reduce the conflicts between residents and forest managers.

CONCLUSION

This research proposes that the urban forest survey and intellectualization management focus on 3 main parts in Taiwan: (1) urban forest basic survey, (2) urban forest information management system, and (3) urban forest action tutorial system.

Urban Forest Basic Survey

The basic survey of an urban forest includes information on tree species, diameter at breast height, tree height, tree health assessment, etc. Number labels are written and hung on each tree. Completing periodic inspections ensures the condition of trees and labels. The trees will be rechecked every 5 years to determine their conditions of health and growth. The detailed contents include field surveys, data measurements to include in-vehicle LiDAR if the cost and environment permit it, image registration, health evaluation, and data processing, which are the bases of urban forest management.

Urban Forest Information Management System

The urban forest information will be digitized to build the management system. The function of this system includes the introduction of basic data and photos, search functionality, and the addition, modification, and removal of them. Establishing an online street tree management system can effectively grasp the distribution of street trees, inform for pest and disease prevention, and prevent street trees from being encroached or removed. The management agencies can update the database based on the survey data, and the accumulated data can be used as the basis for future improvement. This system integrates the basic tree tables, street view images, database of roadside trees, information inquiry system, management system, and Web GIS.

Urban Forest Action Tutorial System

After acquiring the basic survey data, an action information database will be built. The action tutorial service can be provided by a mobile application with the functions of GPS and internet access on smartphones. The software will provide pictures, text, or audio based on the features of a road section, allowing for visitors, whether on foot, bike, or vehicle, to gain more knowledge of the urban forest when traveling and improve their overall experience.

Based on the 3 main axes described above, we can quickly obtain urban forest tree census data using photovoltaic or drone technologies, digitize urban forest tree cadastral data using geographic information systems, and establish a management system to assess the urban forest resources under our control.

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Jan-Chang Chen (corresponding author)
Department of Forestry
National Pingtung University of Science and Technology
Shuefu Road, Neipu
Pingtung, Taiwan
+886-87703202-7147
zzzjohn@mail.npust.edu.tw

Chun-Hung Wei
Department of Forestry
National Pingtung University of Science and Technology

Yi-Ta Hsieh
General Research Service Center
National Pingtung University of Science and Technology

Shang-Chuan Huang
Graduate Institute of Bioresources
National Pingtung University of Science and Technology

Ping-Hsun Peng
Graduate Institute of Bioresources
National Pingtung University of Science and Technology
Taiwan Forestry Research Institute

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Résumé. Contexte: Les arbres en bordure de route jouent un rôle important dans l'aménagement urbain. Ils sont non seulement liés aux paysages urbains, à la sécurité de la circulation, à la qualité de vie et de la santé, mais ils sont aussi étroitement liés à l'écologie et au développement culturel. Par conséquent, la gestion efficace et intelligente d'une zone d'arbres bordant une route urbaine deviendra un sujet important. Méthodes: Cet article évalue les technologies d'enquête et les techniques de gestion utilisées dans plusieurs villes de Taiwan, incluant les investigations sur les arbres en bordure de route, l'évaluation des risques et l'étude des arbres de valeur protégés. Une base de données sur la gestion des arbres en bordure de route a été construite à l'aide d'un système d'information géographique (SIG). Résultats: Le nombre d'arbres de la forêt urbaine a dépassé 100 000 dans notre base de données et de nombreux types d'instruments d'analyse intelligents ont été utilisés pour étudier les arbres, comprenant des instruments de détection cinématique en temps réel (DCTR) et sans perturbation, l'identification par radiofréquence (IDRF), la détection et la télémétrie par la lumière (LiDAR) dans les véhicules et les systèmes panoramiques de paysages urbains. Un système de gestion des arbres peut être développé en introduisant l'information numérisée, basée sur un inventaire de base des arbres. La phase d'inventaire repose principalement sur des enquêtes manuelles, le LiDAR dans les véhicules et la IDRF. Par la suite, un système d'extraction de la base de données visualisée sera proposé à l'aide d'un SIG. Ce système peut être utilisé, entre autres, pour les fondements de la gestion et de la santé des arbres et pour l'entière planification spatiale des forêts urbaines. Conclusion: Cette recherche tente de résumer les tendances en gestion intelligente des forêts urbaines à l'aide de nos expériences pratiques, avec l'objectif qu'elle soit une référence pour le futur établissement intelligent des forêts urbaines.

Zusammenfassung. Hintergrund: Straßenbäume spielen eine wichtige Rolle bei der Gestaltung des Stadtbildes. Sie sind nicht nur für das Stadtbild, die Verkehrssicherheit, die Lebensqualität und die Gesundheit von Bedeutung, sondern stehen auch in engem Zusammenhang mit der Ökologie und der kulturellen Entwicklung. Ein effektives und intelligentes Management von städtischen Straßenbäumen wird daher zu einem wichtigen Thema. Methoden: In diesem Beitrag werden die in vielen Städten Taiwans angewandten Erhebungs- und Bewirtschaftungstechniken bewertet. Dies umfasst Erhebungen von Straßenbäumen, Risikobewertungen und die Erhebung wertvoller geschützter Bäume. Mit Hilfe eines geografischen Informationssystems (GIS) wurde eine Datenbank zur Verwaltung von Straßenbäumen erstellt. Ergebnisse: Bei unseren Erhebungen wurden mehr als 100.000 städtische Waldbäume erfasst, und es wurden viele Arten von intelligenten Vermessungsinstrumenten eingesetzt, darunter kinematische Echtzeit- (RTK) und störungsfreie Erfassungsinstrumente, Radiofrequenz-Identifikation (RFID), fahrzeuginterne Lichterkennung und -entfernungsmessung (LiDAR) und Panoramastraßenbildsysteme. Ein Baummanagementsystem kann durch die Einführung der digitalisierten Informationen aufgebaut werden, die auf einer grundlegenden Erfassung der Bäume basieren. Die Erhebungsphase stützt sich in erster Linie auf manuelle Erhebungen, LiDAR im Fahrzeug und RFID, und anschließend wird ein visualisiertes Datenbanksystem mit GIS vorgeschlagen. Dieses System kann unter anderem für das Gesundheits- und Fundamentmanagement von Bäumen und die gesamte Raumplanung von städtischen Wäldern eingesetzt werden. Schlussfolgerung: Diese Studie versucht, die Trends in der intelligenten Bewirtschaftung von städtischen Wäldern, anhand unserer praktischen Erfahrungen zusammenzufassen. Ziel ist es, eine Referenz für den zukünftigen intelligenten Aufbau von städtischen Wäldern zu schaffen.

Resumen. Antecedentes: Los árboles de carretera juegan un papel importante en el paisajismo urbano. No solo están relacionados con las escenas urbanas, la seguridad vial, la calidad de vida y la salud, sino que también están estrechamente relacionados con la ecología y el desarrollo cultural. Por lo tanto, la gestión efectiva e inteligente de un área de árboles urbanos al borde de la carretera se convertirá en un tema importante. Métodos: Este documento evalúa las tecnologías de encuesta y las técnicas de gestión utilizadas en muchas ciudades de Taiwán, incluidos los inventarios de árboles al borde de las carreteras, la evaluación de riesgos y árboles preciosos protegidos. Se construyó una base de datos de gestión de árboles en las carreteras utilizando un sistema de información geográfica (SIG). Resultados: El número de árboles forestales urbanos superó los 100,000 en nuestros censos y se utilizaron muchos tipos de instrumentos de levantamiento inteligentes para inspeccionar los árboles, incluidos los instrumentos cinemáticos en tiempo real (RTK) y de detección no interrumpida, la identificación por radiofrecuencia (RFID), la detección y alcance de luz en el vehículo (LiDAR) y los sistemas panorámicos de paisaje urbano. Se puede construir un sistema de gestión de árboles mediante la introducción de la información digitalizada, que se basa en un estudio básico de los árboles. La etapa de censo se basa principalmente en encuestas manuales, LiDAR en el vehículo y RFID y luego se propondrá un sistema de recuperación de base de datos visualizada utilizando SIG. Este sistema se puede utilizar para la gestión sanitaria y de establecimiento de árboles y toda la planificación espacial de los bosques urbanos, entre otros. Conclusión: Esta investigación intenta resumir las tendencias en la gestión inteligente de los bosques urbanos utilizando nuestras experiencias prácticas con el objetivo de que sea una referencia para la futura construcción inteligente de los bosques urbanos.