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ASSESSMENT OF THE SAFETY OF URBAN GREEN AREAS USING GIS

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Abstract

This paper aims to present a GIS-aided safety map related to the non-invasive assessment of trees in urban green areas. The goal is to create an urban GIS-based evidence of the green areas focused on hidden tree pathology, in order to increase the safety of urban parks and provide an instrument for decision-making to eliminate trees that pose a danger to citizens due to hidden pathology. This is especially important in light of the tremendous physical destruction, injury, loss of life, and economic damage caused by wind disasters, as well as concurrent heavy rains and flooding, which have become increasingly common in recent decades. Improved observational capabilities and recordings of such events have led to greater public awareness of severe weather events.

***Key words**: Urban safety, Urban Green, GIS.*

INTRODUCTION

Climate change is an undeniable reality that is transforming the world as we know it. Among its wide-ranging consequences, one of the most concerning is the intensification and increased frequency of wind disasters. Wind patterns are intricately linked to climate systems. The alteration of climate patterns due to global warming has resulted in shifts in wind intensity, direction, and distribution. Warmer oceans, for instance, provide the fuel for tropical storms to develop into more powerful hurricanes and typhoons. Additionally, changes in temperature gradients and atmospheric conditions can influence the formation and behaviour of tornadoes. These alterations in wind patterns have led to an increased occurrence of extreme wind events across the globe. Climate change has contributed to a rise in extreme weather events having serious effects in the urban green areas.

This paper explores the application of Geographic Information System (GIS) in establishing a comprehensive database for managing green spaces in urban areas. It discusses the responsibility of local governments to conduct inventories of public green spaces and create an evidence registry for efficient management (Grecea, C. et al., 2012). The focus is on auditing the green areas within administrative boundaries, considering factors such as area coverage, vegetation quality, accessibility, and safety. By adopting an individualized approach for each green space entity, a more accurate understanding of the entire green infrastructure within territorial administrative units can be achieved, enabling effective measures for maintenance and management (Muntean et al., 2016).

THE URBAN GREEN AREAS

In 2015, the total area of urban green spaces in Romania was 25,778 hectares. This represents an increase of 4,145 hectares compared to 1991. This information is provided by the National Institute of Statistics (2017) Figure 1 and refers to the area of green spaces developed in the form of parks, public gardens, squares, plots with trees and flowers, forests, cemeteries, grounds of sports grounds and facilities that are located in the buildable perimeters of the localities, i.e. public green spaces. These figures reflect an increase in urban green spaces in Romania over some 24 years. It is important to note that these data refer only to green spaces officially developed and recognised as public green spaces. Other forms of green spaces, such as undeveloped natural areas or agricultural land in or near

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localities, may not be included in these statistics.

This increase in the amount of urban green space may reflect the efforts of authorities and communities to promote and develop green areas to improve the quality of life in the urban environment and conserve biodiversity. However, it is important to continue efforts to conserve and sustainably develop green spaces within cities to ensure a healthy and balanced urban environment for residents.

Looking at the county scale, according to Figure 1, 27 counties in Romania show an increase in the amount of urban green space. This indicates that efforts have been made in these counties to develop and expand green spaces in urban areas. These increases may be the result of local initiatives and policies promoting environmental protection, improved quality of life and sustainable development of cities. County and local authorities can implement programs and projects aimed at developing parks, public gardens and other green spaces within communities (Oprea, L., 2018). It is gratifying to see that there is interest and commitment to increasing the amount of urban green space in most counties in Romania. This can contribute to healthier, more pleasant and sustainable urban environments, providing recreational and leisure opportunities for communities and promoting biodiversity (Marulli, J., 2005). However, it is important to continue to monitor and support the development of urban green spaces in all counties to ensure an appropriate balance between the needs of urban development and environmental conservation.

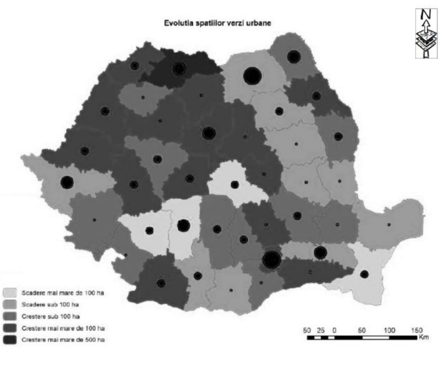

Figure 1. Evolution of the area of urban green infrastructure between 1991 and 2015 (INS, 2017)

Creation of GIS databases related to green cadastre

Today, Geographic Information Systems (GIS) are one of the main tools used to analyse green spaces and vegetation in urban areas. These systems are used for green cadastre databases, integrated management plans and the establishment of intervention phases for urban vegetation (Coppock, 1991).

One of the major advantages of GIS systems is their ability to produce complex, geo-referenced databases that can be dynamically revised and updated (Wade, T., 2006). These databases offer the possibility to manage detailed information about green spaces and urban vegetation, facilitating informed decision-making and appropriate planning of interventions. Another important advantage of GIS systems is their versatility, allowing direct communication with specific technologies for top-down approaches to green cadastre as well as bottom-up mapping methods (Gavrilidis et al., 2015). This means that data from a variety of sources can be integrated, from satellite images and orthophotos to locally collected user data. The system can therefore be used to get a complete and detailed picture of green spaces and vegetation in the urban environment.

In addition, modern technology allows the use of UAVs to collect GIS data. These UAVs can be equipped with various instruments such as high-performance cameras, temperature and humidity sensors, infrared sensors and others. This allows much more complex and comprehensive databases to be obtained than with traditional methods.

To register trees in a GIS database, an approach is used to include different attributes relevant to each group/entity (Norme Tehnice pentru aplicarea Legii nr. 24/2007).

- Unique ID - each tree can have a unique identifier to allow individual identification and management of each tree in the database.
- Species - attribute indicating the species of the tree (e.g. oak, spruce, acacia, etc.).
- Trunk diameter - the attribute that records the diameter of the tree trunk, either at the base or at the height of 1.3 metres from the ground. Useful for assessing tree maturity and for planning appropriate care.

- Trunk girth - the attribute that records the girth of the trunk of the tree measured at a given height above the ground (e.g. 1.3 metres above the ground). This quantification is relevant for assessing tree size and maturity.
- Trunk height - the attribute that records the height of the tree trunk, measured from the base of the tree to the first quarter or main branch. This can be useful for determining the structure of the tree and its vertical dimension.
- Crown diameter - the attribute that records the diameter of the crown of the tree, usually measured at the widest part of the crown. This can be useful for assessing the horizontal size of the tree and the area the crown occupies.
- Shaft deviation - the attribute that records the deviation of the shaft axis from the vertical. It can be expressed in degrees and indicates whether the tree is vertical or inclined to the vertical. This information is important for assessing shaft stability and determining potential structural problems.
- Health status - an attribute that indicates the overall health of the tree, including assessment of possible disease, damage or other problems.
- Geographic location - the attribute that contains the tree's geographic/geographic/ rectangular coordinates (latitude and longitude) to allow accurate positioning of the tree on the map within the GIS database.
- Year planted - attribute that records the year the tree was planted or established to allow the age and history of the tree to be tracked.

When designing the database, specific codes will be assigned to each attribute, depending on the type of information it will contain.
- Text - this data type is used to store textual information, such as tree species name, street name or any other textual description. In general, a maximum length is specified for the text field as needed.
- Integer - is used to store whole numbers, such as trunk circumference or trunk height. A minimum and maximum value is specified to limit the range of values accepted.
- Real number - is used to store real numbers such as crown diameter or crown height. A precision (number of digits after the decimal point) is also specified to control the detail of the real values.
- Date - is used to store calendar dates, such as the date of planting or the date of the last record. It allows chronological operations and comparisons to be made.
- Boolean - this data type is used to store logical values, such as tree health status (yes/no, true/false). It allows the representation of binary information.

MATERIALS AND METHODS

Hidden tree pathologies

Rotting of trees refers to the natural decay process that occurs when a tree's organic matter breaks down over time. It is a natural part of the life cycle of trees and is primarily caused by fungi and bacteria. When a tree dies or is injured, the process of decomposition begins, leading to the breakdown of the tree's structural components.

The rotting process typically starts from the inside of the tree and progresses outward (Figure 2). Fungi, especially wood-rotting fungi, play a crucial role in decomposing the tree's wood fibers. These fungi secrete enzymes that break down the complex molecules in the wood into simpler compounds, such as carbon dioxide and water. This process helps recycle nutrients back into the ecosystem.

Figure 2. Internal rotting

The rotting process can also pose risks and challenges. Trees that are extensively decayed may become structurally weak and more prone to falling, posing a safety hazard. This is particularly concerning in urban areas where falling trees can damage property or endanger

people. Therefore, regular tree inspections and maintenance are important to identify and address potential risks associated with rotting.
It's worth noting that not all rotting is visible from the outside. Trees may appear healthy and robust on the surface while experiencing significant internal decay. Thus, the use of specialized tools and techniques, such as sonic tomography or resistograph, can help arborists and tree experts assess the internal condition of trees and make informed decisions regarding their management and safety (Fote, K.E., 1995).

NON-INVASIVE ASSESSMENT

The speed of sound measured perpendicular to the fiber can serve as a diagnostic tool for detecting various anomalies that affect the path of sound waves (Divós et al., 2015). Such abnormalities can include internal cavities, rot, or long cracks within the material. In healthy and intact wood, the speed of sound traveling perpendicular to the fiber typically ranges from 1800 to 2000 m/s.
However, when a fiber run crack is present, the speed of sound is significantly reduced, leading to an increase in the measured propagation time. This change in propagation time can indicate the presence of defects within the wood. Additionally, this measurement technique can also be utilized to determine the depth of a crack. While the depth of a crack on the surface can be estimated by observing the penetration depth of a thin plate, the crack path is not always linear. Consequently, the obtained measurement may not accurately represent the actual crack depth.
To calculate the crack depth (C), the propagation time over the crack and the propagation time over the same distance in an unaffected area without a crack are compared. The formula for determining the crack depth is described by Divós & Szalai (2002) and can be employed for this purpose:

$$C = \frac{D}{2}\sqrt{\left(\frac{Tcrack}{Tsolid}\right)^{2} - 1} \quad (1)$$

where:
- D is the length of the propagation path;
- T crack is the Propagation time in the cracked surface;
- T solid is the propagation time in the crack free surface.

It works based on sound velocity measurements between several sensors around the trunk (Figure 3). The basic measurement principle is that sound velocity drops if there is a hole or density difference occur between sensors.

Figure 3. Sound velocity measurement

RESULTS AND DISCUSSIONS

The detection of defects through measurements conducted perpendicular to the fiber has proven to be effective. This method is particularly useful when the sound waves propagate along an alternative path between the sensors. However, when aiming to identify defects that are not visible externally, it may be necessary to utilize more than two sensors. This technique, known as acoustic tomography, has been successfully employed in the examination of urban trees and is valuable for studying large cross-section timber and living trees, using the Arbosonic 3D software (www.fakopp.com/en/product/arbosonic).
Acoustic tomography relies on measuring the speed of sound between multiple sensors placed around the trunk or structure. By comparing the sound velocity measurements, valuable insights can be obtained. Specifically, if there is a void or hole between two sensors, the sound velocity will decrease. This principle forms the basis of the measurement technique

and offers a powerful approach for detecting hidden defects. By employing multiple sensors and measuring sound velocities, this technique proves beneficial for studying large cross-section timber and living trees, as well as examining urban tree health and integrity.
By tapping the sensors, we can measure the propagation speed on all possible routes, for N = 12 sensors on N (N-1)/2 = 66 routes. From this 66 sound speed measurements, the 3D device restores the speed map of the examined cross-section. This is seen in Figure 4 showing the time passing data through the trunk between the sensors and Figure 5 the imaging expression of the processing of physical data obtained from the sensor. It only contains example text and proper formatting.

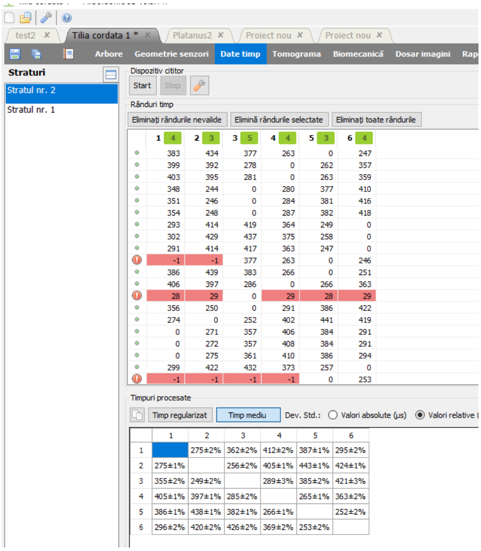

Figure 4. Get the time passing data through the trunk between the sensors

The colours indicate the condition of the tree. Red areas indicate damaged areas and blue indicates a cavity.

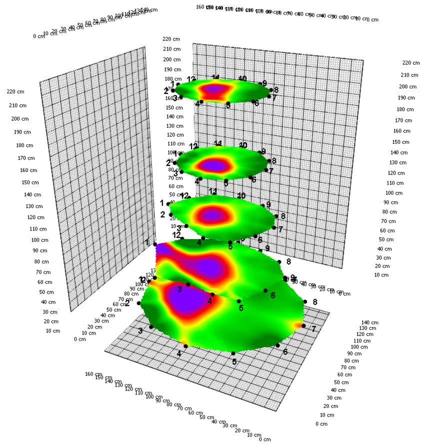

Figure 5. Example of internal assessment on different heights

In Figure 6 we can see the *Platanus acerifolia* sound velocity measurement and processed data.

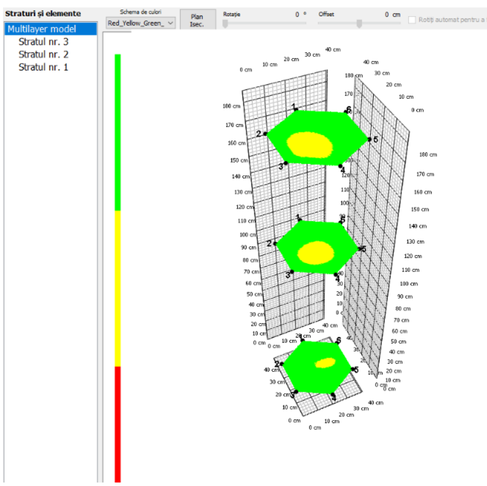

Figure 6a. *Platanus acerifolia* data processed

Figure 6b. *Platanus acerifolia*

CONCLUSIONS

The acoustic tomography technique was applied at urban green areas to evaluate its probability in detecting internal decay in high-value trees. Based on the preliminary analysis of acoustic tomograms, we conclude that:

- Acoustic tomography proved to be an effective tool for detecting internal structure change in urban trees,
- The tomogram can show the location and the relative size and shape of internal rotten areas,
- Green cadastre should record special data in green cadaster related to the hidden pathology of the trees.
- the concept of Urban Green Safety must be considered in any assessment and data recordings related to the urban green/forest.

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