REVISTA FLORESTA
Engenharia Florestal
ISSN 1982-4688
Edição 54
Universidade Federal do Paraná
Setor de Ciências Agrárias

METHODOLOGIES FOR MANAGING THE TREEFALL RISK OF URBAN TREES

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Received for publication: 19/07/2023 – Accepted for publication: 01/12/2023

Resumo

Methodologies for managing the treefall risk of urban trees. Recentemente, a preocupação com o risco de árvores, desencadeada por vários acidentes fatais envolvendo quedas em ambiente urbano, aumentou o interesse de gestores de todo o mundo para o desenvolvimento de técnicas efetivas de avaliação para a prevenção de acidentes. O objetivo do estudo foi comparar diferentes métodos de avaliação visual do risco de queda de árvores urbanas em indivíduos de *Spathodea campanulata*. Para isso, foram analisados 43 indivíduos, por meio de cinco metodologias de análise visual de risco. A coleta de dados foi realizada entre dezembro/2020 e janeiro/2021, por meio de formulário criado no *Google Forms*. A classificação do grau de risco foi padronizada em alta, média e baixa para todas as metodologias e foram realizados testes estatísticos a fim de verificar a semelhança entre as mesmas. O tempo gasto para análise foi cronometrado e as dimensões de DAP da árvore foram medidas para verificar a correlação com o grau de risco. Observou-se que 41,8% das árvores foram incluídas na classe de alto risco por todas as metodologias, tendo a metodologia II apresentado a menor variação entre os indivíduos. Estatisticamente, I diferiu de todas as metodologias, enquanto II se mostrou igual apenas com a IV, já as demais se mostraram semelhantes. A V é a mais rápida e I mais demorada. Não foi encontrada alta correlação entre tempo gasto e grau de risco de queda de árvores ou DAP.
Palavras-chave: potencial de falha, gestão de risco, grau de risco

Abstract

Recently, the concern about the risk of falling trees, triggered by several fatal accidents involving falls in urban environments, has increased the interest of managers worldwide in developing effective risk assessment techniques for accident prevention. The objective of this study was to compare different methods for visual urban treefall risk assessment of *Spathodea campanulata.* To do so, 43 individuals were studied using five different methodologies for visual risk analysis. Data collection was conducted between December/2020 and January/2021 through Google Forms. Risk was classified as low, medium, and high in all different methodologies. Statistical tests were conducted to determine the similarity between them. The time taken for analysis was measured using a stopwatch and tree DBH dimensions were measured in order to verify the correlation with the risk level. As a result, 41.8% of the trees were classified as high-risk by all methodologies. Methodology II had the lowest variation among individuals. Statistically, it can be said that: Methodology I differed from all the other methodologies; Methodology II only matched the results found using Methodology IV, while the others presented similar results. Regarding the analysis time, Methodology V is the fastest and Methodology I is the slowest. No significant correlation was found between analysis time and treefall risk level or DBH.
Keywords: failure potential, risk management, risk level

INTRODUCTION

It is widely known that the presence of green areas in cities brings numerous benefits given their environmental functions, which include reducing temperature, preventing landslides, air purification, beautifying cities, increasing soil permeability, protecting against soil compaction and impoverishment, among other advantages. However, little has been discussed about the risks associated with the presence of trees in these environments and their quality, which is directly linked to urban sustainability, as a condition for achieving more ecological and sustainable cities (OLIVEIRA, ROSIN, 2017).

In turn, cities subject trees to a series of specific challenges arising from urbanization, such as the supply of water and nutrients limited by compacted and impermeable soil, in addition to competition with other individuals and species. The space available for roots and crown development is often insufficient, which can lead to disordered and/or unbalanced growth.

Furthermore, urban trees are also subject to air and noise pollution, thermal stress and extreme weather events such as storms and strong winds, which consequently increase the probability of collapse and minimize their benefits. Therefore, it is essential to seek a deeper understanding of the afforestation conditions in these environments to promote an expansion of urban greenery in a more sustainable and safer way (LOCASTRO *et al*., 2017).

Recently, concern about the risk of falling trees, triggered by several fatal accidents involving falls in urban environments, has increased the interest of managers around the world in developing effective assessment techniques for accident prevention, since, unlike other structures which make up cities such as pipes and wiring, there are no acceptable risk levels for trees, as pointed out by Brobowski (2016).

The probability of a tree or part of it failing and causing problems is considered to depend on the intrinsic resistance of the wood, its geometry and the load to which it is subjected. Together, the last two factors govern the applied stress, which, when exceeding the strength of the wood, induces failure. Defects, such as deterioration, cracks and injuries, increase the failure probability by reducing the wood strength, but it is up to the evaluator to define their degree of importance correctly (KANE *et al* ., 2015).

In this sense, a visual assessment is only efficient if the manager understands the factors that contribute to the real risk of falling trees considering local and environmental characteristics and the management history; for example, being able to identify potential targets, particular patterns of the species, health conditions and vigor (ANSI, 2011; COELHO-DUARTE *et al.,* 2021).

Furthermore, the composition of the evaluation method used is important for decision making. These methods are generally developed to be applied in local contexts and used in different countries without validation or adaptation, compromising their reliability (KLEIN, KOESER, 2016). This can only be resolved by developing ways to confirm the effectiveness of a method in predicting risk and comparing different proposals on the same sample of trees. In doing so, it is possible to identify the method which has better applicability and presents an adequate level of reliability and repeatability (KOESER *et al.*, 2017; KOESER; SMILEY, 2017; REYES DE LA BARRA *et al.*, 2018).

Visual analysis methodologies for assessing the risk of falling trees can be classified as belonging to Level 2 (basic), as suggested by the International Society of Arboriculture (ISA). This analysis consists of a 360-degree visual inspection of a tree at ground level and considering its surroundings (DUNSTER *et al.* , 2013). Although there are more advanced risk assessment methodologies using technology, most assessments are conducted visually (KLEIN *et al.*, 2019).

Basic visual assessments have been proven to be an efficient and reliable means of identifying compromised trees (DUNSTER *et al.,* 2013). However, there is no method accepted as a standard for all situations which would enable consistency between evaluations, and potentially reduce the individual responsibility of evaluators (KLEIN *et al.*, 2019).

Although current tree risk assessment models serve their purpose (KLEIN *et al.,* 2019), the effectiveness of visual assessments in predicting failures has been investigated (KOESER *et al.*, 2017). Thus, the importance of analyzing the effectiveness of these methodologies mainly consists of improving the system trends, precision, replicability and general impact on the prescribed management measures with tests (KLEIN *et al.*, 2019).

The objective of this work was to compare different visual treefall risk assessment methods for urban trees in *Spathodea campanulata* individuals in order to present the advantages and disadvantages of each methodology.

MATERIAL AND METHODS

Spathodea campanulata present in the urban afforestation of an important road on the Federal University of Viçosa campus, in the municipality of Viçosa, Minas Gerais, Brazil, were visually evaluated. The municipality is located in the northwestern portion of Zona da Mata, between the geographic coordinates of 20°45´14´´south latitude and 42°52´54´´west longitude (AMARAL, REIS, 2017), comprising the Morphoclimatic Domain of Mares de Morros, with a climate classified as tropical at altitude (AMARAL, REIS, 2017). The region is characterized by having a well-defined period of heavy rainfall and higher temperatures and another with low rainfall and mild temperatures (BATISTA, RODRIGUES, 2010). The municipality is located in the Rio Doce hydrographic basin, being supplied by the Turvo Sujo river and mainly by the São Bartolomeu river that intersects the central urban area (ROQUE, 2013). Its vegetation cover consists of secondary remnants of the Semi-deciduous Seasonal Forest from the Atlantic Forest biome (AGUIAR, TEIXEIRA, 2015).The UFV *campus* in Viçosa emerged as a Post-secondary Agriculture and Veterinary School (*Escola Superior de Agricultura e Veterinária - ESAV*) in 1926, and today it is considered one of the most beautiful schools in Brazil, mainly due to the large number of tree-lined roads with high scenic value. The *Spathodea campanulata* species is one of the most planted in the area, being among the seven most used (ALVES, MARTINI, 2020). This species is popularly known as *Espatódea* or *Tulipeira*, originates from Tropical Africa, Kenya and Uganda, can reach 25 m in height, and has a high crown density (COSTA, LIMA, 2010). In turn, numerous disorders have been caused at UFV by the species in recent years due to falls of individuals or parts of them, as reported by the University's Waste Management Division (ALVES, MARTINI, 2020).

The road where the studied trees are located constitutes an important access within the university campus, being characterized by a large flow of people and vehicles, and used daily to provide access to several important points of the university, including benches, class pavilions, gymnasium, sports infrastructure, parking and restaurants. In addition, it also serves as a stopping point for several bus lines and is an important access highway for neighboring municipalities. In 2019, it was hit by an extreme weather event that caused significant damage to its trees. As a result, many of its trees had to be removed to ensure the safety of users, and a careful analysis was required to determine which trees could be retained and which needed to be replaced to ensure user safety.

Thus, the following five methodologies were used to evaluate the remaining arboreal specimens from this event in order to visually analyze the treefall risk:

I. Tree Risk Assessment Qualification (TRAQ) - detailed visual inspection of the tree with the aim of quantifying the defects that affect the probability of failure in its various fractions. This is the assessment recommended by the *International Society of arboriculture* (ISA) and is widely used in several countries around the world. This method further combines the tree's probability of failure with the probability of impact in one matrix and then combines this probability with the consequences of failure in a second matrix (KOESER; SMILEY, 2017), generating a final degree of fall risk that defines the best management to be adopted.

II. Failure Risk Assessment created by Seitz (2005) - conducted through visual diagnosis of the general conditions of trees and their risk factors for falling in their different fractions (crown, trunk and base). Each item receives a score from 1 to 5, where 1 represents the lowest contribution to risk and 5 represents the maximum contribution. The author also considers the potential target and its side effects in the event of a tree falling, varying by 1, 3 or 5 depending on the degree of local human occupation. Thus, a unique degree of risk is obtained through the sum of the highest value found in the visual assessment of the tree's general conditions and the risk attributed to the target and side effects, ranging from 3 (low risk) to 15 (very high risk). high).

III. Risk assessment for historic trees in urban Hong Kong (JIM; ZANG, 2013) – recording form designed, tested and refined to enable systematic field data collection, seeking to minimize subjectivity, ensure consistency and facilitate entry and data analysis. It considers the tree's habitat and the occurrence of defects and disorders, grouping 30 main diseases between the crown, trunk and base. The failure risk rating is the sum of the probability of failure, the size of the part that can fail and its potential target.

IV. Assessment of the Failure Potential of Urban Trees created by the Municipal Secretariat for Conservation and Environment of Rio de Janeiro (2018) - aims to provide guidelines for assessing the specimen's condition regarding its balance, structure, conflicts and phytosanitary status; as well as its compliance considering the target, species suitability and factors associated with the site. Each subitem of these categories is divided into classes that are numbered 0 (zero), 1 (one), 3 (three) or 5 (five), depending on the situation verified, with 0 being the absence of a certain characteristic and 5 being its maximum expression, in order to generate the general condition of the specimen through the sum value in each subitem, varying between satisfactory, regular, unsatisfactory or critical. In turn, it is possible that the best management for the situation found will be recommended at the end of the assessment.

V. Parameters for Linden Analysis proposed by Dos Santos *et al*. (2019) – this methodology was proposed to analyze the falling risk of *Tilia tomentosa* in Portugal through simple and purely visual assessments divided into trunk inclination, base irregularity and problems in the branches. A score is assigned for each defect associated with these fractions which varies between 0 (minimum) and 3 (maximum). This allows a final grade to be obtained through a simple summation, which infers the state of the tree ranging from 0 to 9, where the range between 0 and 3 expresses good status, and between 6 and 9 high risk.

Methodologies I and II were chosen because they are the best known and applied in Brazil. The other three are the most recent found in literature, both national and international. Next, a specific form was created for each methodology via *Google Forms*, following the field form model proposed by the authors of the methodologies. This form was completed during a field expedition during the months of December/2020 and January/2021 with a M9-3G NB248 tablet manufactured by Multilaser.

The study carefully evaluated each of the 43 individuals selected through the five protocols, sequentially. The time spent applying each form per individual was recorded to ensure that assessments were carried out accurately and appropriately. Then, the data was tabulated and organized to generate a risk classification assigned to each tree in each methodology. The risk classification made it possible to identify the number of individuals included in each risk class, providing a clear view of the differences between the methods used.

Originally, each methodology has its own terminology and different number of classes. Methodology I classifies trees into 4 risk levels: very unlikely, unlikely, likely and very likely. Then, Methodology II classifies trees into 3 levels: low, medium and high; III into 4 levels: high, moderate, low and insignificant; IV into high, medium, low and very low; and Methodology V into good condition, risk potential, high risk potential and immediate risk. Therefore, it was necessary to establish the same nomenclature and number of classes for all of them to enable comparison between methodologies. The number of classes was defined according to the smallest number found among the methodologies and the adaptations made were as follows:

a) Low – very unlikely and unlikely class of methodology I; low of methodology II; low and insignificant from methodology III; very low and low in methodology IV; and good condition in methodology V.

b) Medium - likely class of methodology I; medium of methodology II; moderate from methodology III; medium of methodology IV; and risk potential of methodology V.

c) High - very likely methodology class I; high of methodology II; high of methodology III; high risk of methodology IV; and high risk potential and immediate risk of methodology V.

With the same number of classes defined for each methodology, a tree-by-tree comparison was carried out in order to verify the differences and similarities between their results. The analysis was performed separately for each methodology, meaning when methodology I was analyzed, the result of each tree was compared with the result of II, then III, IV and V. The comparison was performed in a paired way resulting in the following reclassification : equal – when the risk class of the analyzed methodology was the same as the result of the other methodologies; lower risk – when the result of other methodologies was lower than the risk class of the analyzed methodology; higher risk – when the result of other methodologies was greater than the risk class of the analyzed methodology. The final value assigned referred to the average presented by the evaluation of all trees in each class of the respective methodology.

Next, a statistical analysis was performed to verify the existence of differences between the methodologies. The Kruskal-Wallis test was applied at 5% significance, since the data did not follow a normal distribution. Then, the data was subjected to the Wilcoxon test, capable of indicating which methodologies differ from each other. All tests were performed on the Rbio program. Both are non-parametric tests, with Kruskal-Wallis being used to compare three or more populations in order to test the null hypothesis that all populations have equal distribution functions against the alternative hypothesis that at least two of the populations have different distribution functions (CABRAL JÚNIOR; LUCENA, 2020), and Wilcoxon is used when you want to compare repeated measures in the same sample to assess whether the average population ranks differ from each other (COELHO BARROS; MAZUCHELI, 2005). The input values were the risk classes established by the different methodologies applied for each individual assessed, namely: low (1), medium (2) and high (3).

A Pearson's correlation analysis was also carried out between the parameters to assess the degree of association between the time spent on the assessment and the risk class and DBH of the trees, aiming to help understand possible influences on the risk of failure and size of the individual.

RESULTS

Methodology II showed that 100% of the trees evaluated presented a high risk of falling, followed by methodologies IV, III, V and I, which, respectively associated 95.3%, 83.7%, 79% and 44.18% of trees at a high degree of risk (Figure 1).

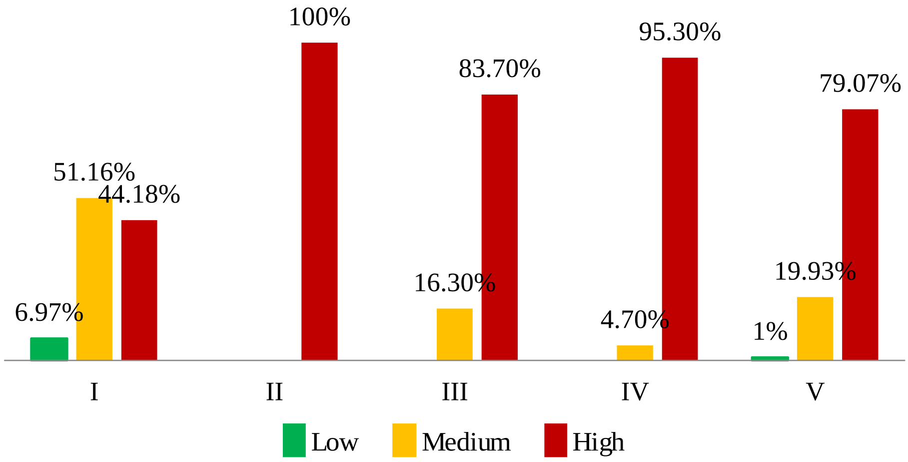

Figure 1. Risk classification of *Spathodea campanulata* trees assessed according to different methodologies.
Figura 1. Classificação de risco das árvores de *Spathodea campanulata* avaliadas segundo as diferentes metodologias.

Methodology I was best able to differentiate the trees evaluated, which characterized individuals as being at medium risk to the detriment of the highest class (51.15%) and was also the one which most considered individuals in the lowest risk class. Regardless of this variation, 41.8% of the trees evaluated were classified as high risk by all methodologies.

By comparing the results of each methodology individually, it was possible to verify that methodology III showed the greatest similarity with the others. On average, 75.0% of the results found by this methodology were the same as all the others, ranging from 60.5% with methodology I to 81.4% with methodologies II and IV (Figure 2). Next came methodologies II and IV, both with 73.8% of results equal to all the others, followed by methodology V (72.7%). Methodology I showed the least similarity with the others, with only 53.5% of the results being similar to those indicated by the other methodologies (Figure 1).

When comparing methodology, I with the others, it was possible to verify that all the others resulted in higher risk classes than that indicated by it, presenting a greater difference with methodology II (58.1%) and smaller with V (34.9%). Methodology II presented the opposite, with all others resulting in lower risk classes, with a smaller difference for IV (4.7%). In other words, it is possible to state that methodology I tends to classify trees in better conditions when compared to the others. Methodology II tends to classify trees in worse conditions, attributing a greater risk of falling to the individual evaluated.

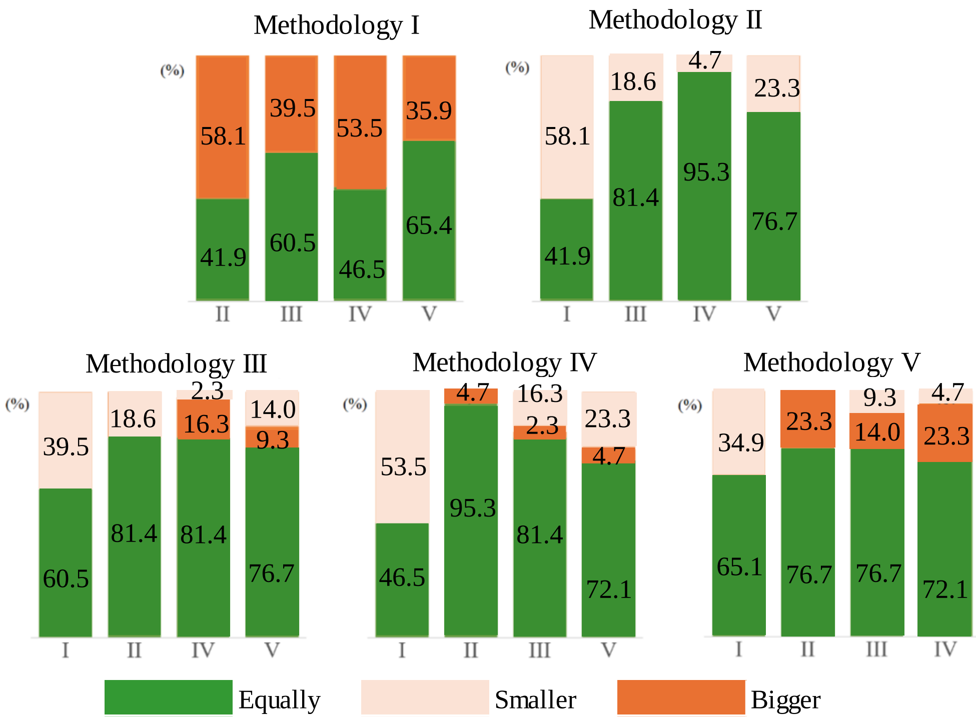

Figure 2. Similarity of each treefall risk analysis methodology regarding the risk classification of *Spathodea campanulata* individuals.
Figura 2. Semelhança de cada metodologia de análise de risco de queda de árvores quanto classificação de risco de queda dos indivíduos de *Spathodea campanulata*.

Although Methodology III presented the greatest similarity with the others on average, the tendency when it differs is for it to register a lower risk of falling (except in relation to I). The tendency for Methodology IV is for the others to register lower risk; and higher risk for Method V (except I). Thus, it is understood that methodologies III and V classify trees in better conditions when compared to the others, and IV in worse conditions.

Statistically, for a value of p = 3.443.e $^{-11}$, it was observed that there is a difference between the visual analysis methodologies according to the Kruskal-Wallis test, followed by the Wilcoxon test; this shows at 1% significance that the methodologies III, IV, V do not present significant differences between them, while methodology I differs from all the others, and II only does not differ from IV (Table 1).

Table 1. P-values obtained with the Wilcoxon test for paired data between the means of different methodologies.
Tabela 1. Valores de p obtidos com o teste de Wilcoxon para dados pareados entre as medianas das diferentes metodologias.

Methodology	I	II	III	IV
I				
II	**4.6 $^{-08}$**			
III	**4.3 $^{-04}$**	**5.4 $^{-03}$**		
IV	**5.7 $^{-07}$**	1.7 $^{-01}$	5.7 $^{-02}$	
V	**2.3 $^{-03}$**	**2.1 $^{-03}$**	5.7 $^{-01}$	**1.8 $^{-02}$**

*Statistically significant p-values at 1% significance (p<0.01), **Statistically significant p-values at 5% significance (p<0.05), by the Wilcoxon test for paired data.

The risk score using methodology II showed zero variation between the individuals assessed. Regarding the average time to carry out the assessment using each form per individual, methodology V had shortest time, followed by III, IV, II, and I, respectively (Figure 3).

The methodology that took the longest to apply (I) was also the one which allowed the trees analyzed to be differentiated more, as well as being different from the others. The methodologies with the fastest application (III, IV and V) coincided with those that did not differ from each other in terms of results. Thus, due to the speed and practicality of methodology V, it may be more suitable than III and IV, as their results do not differ.

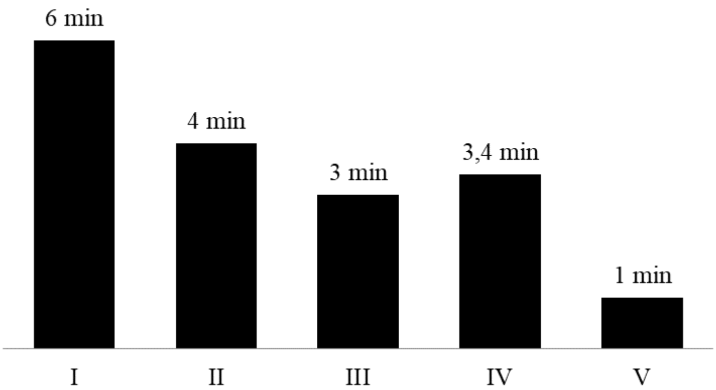

Figure 3. Average time spent (minutes) for the evaluation of each Spathodea campanulata individual for different visual treefall risk assessment methodologies.
Figura 3. Tempo médio gasto (minutos) para a avaliação de cada indivíduo de Spathodea campanulata para as diferentes metodologias de avaliação visual de risco de queda.

Other analyzes were carried out to provide greater detail on the time spent applying each methodology. The correlation between the time spent for the assessment and the degree of risk found was low in all methodologies, which suggests that there is no influence of the risk class on the time spent performing the visual analysis (Table 2). In other words, it was not found for any of the methodologies that more time is spent on trees that are more compromised, and consequently more prone to collapsing.

It is observed that the correlation of time with the degree of risk for methodology II was null, since the standard deviation between the degree of risk data was 0, with all individuals classified as high risk. Methodology III showed a negative correlation, indicating that the assessment time was inversely proportional to the degree of risk of falling identified by visual analysis.

Table 2. Pearson's correlation values between the time spent on each methodology for evaluation with the risk level and DBH of Spathodea campanulata trees in Viçosa/MG, Brazil.
Tabela 2. Valores da correlação de Pearson entre o tempo gasto com cada metodologia para avaliação com o grau de risco e DAP das árvores de Spathodea campanulata em Viçosa/MG

Methodology	I	II	III	IV	V
Degree of risk	0.163	0.00	-0.155	0.384	0.205
DBH	0.522	0.230	0.243	0.542	-0.269

The correlation between the time spent for evaluation and the DBH of the trees was low in methodologies II, III and V and medium in methodologies I and IV. This result suggests that tree size (DBH) explains approximately half of the time spent on visual evaluation of methodologies I and V. However, it is not evidence for the majority of methodologies applied.

The number of risk classes proposed by III is four classes: high, moderate, low and insignificant, differing from I, with five classes, and II, with three classes. When applying them, it was possible to realize that the greater the number of classes in the methodology, the greater the experience of the evaluator needed.

In turn, Methodology I is the most expensive to apply, given the large number of criteria to be evaluated and the high degree of knowledge required for the analysis.

All methodologies present factors regarding subjectivity that lead to the analysis being greatly influenced by the evaluator; however, the form of methodology III characterizes its elements in a more direct way, establishing greater homogeneity in the perception of the defect between different evaluators. Furthermore, it is a highly practical methodology, not requiring much time for observation, avoiding calculations and large measurements, in addition to requiring little prior knowledge, as it uses terms that are easy to understand and locate, denoting its good operability.

DISCUSSION

Studies such as the one by Norris (2007) comparing visual treefall risk assessment forms define an association greater than 70% between results as high. Considering this, it is understood that methodology I is different from the others tested, which showed greater similarities between them.

Other comparative studies, such as that by Reyes De La Barra (2018), obtained similar results when using methodology I in conjunction with other visual analyses, where it distributed individuals more broadly across different fall risk classes, concentrating those results at lower levels compared to the others.

The relative weight of each component of the tree influences the risk classification (KOESER; SMILEY, 2017; REYES DE LA BARRA *et al.*, 2018); therefore, methodologies which do not consider this aspect can generate an overvaluation of the results, since the risk classification would be independent of the size of the part with the greatest potential for failure and its possible damage (COELHO-DUARTE *et al.*, 2021). This may explain the fact that methodology II included the most individuals in the class with the highest risk of falling, since it does not use the aforementioned evaluation criteria.

Methodology IV presents the same limitation as II, as it does not consider the size of the part subject to failure in the tree. Moreover, Methodology III and V present similar results in other studies, as in the case of Jim and Zhang (2013), where III classified only 4% of individuals assessed as high risk, 51% as moderate and 45% as low. In turn, De Carvalho *et al.* (2019) obtained only 6% of their sample in a high-risk condition using Methodology V, 58% in moderate risk and 36% in low risk, highlighting the tendency of these methods to classify individuals evaluated in better conditions, minimizing the risk of falling. It is worth noting that V does not include the use of the location in the analysis process, which is related to the probability of a tree or part of it reaching a target, such as people or properties (COELHO-DUARTE *et al.*, 2021), which can lead to an underestimation of an individual's potential for failure, as assessments improve when pedestrian and vehicle traffic data are incorporated (KLEIN , KOESER, 2016).

Since the main objective of visual analysis is to measure the risk of a tree falling, it is assumed that there must be a strong similarity between different assessment methodologies (NORRIS, 2007), especially when used together by the same evaluator. However, there is generally a distinction in the results due to the structural differences in the methods, since the multidimensionality that the risk represents in the assessment is expressed in the different parameters and their relative weight (NORRIS, 2007; KOESER, SMILEY, 2017; REYES DE LA BARRA, 2018).

The fact that methodology II did not characterize individuals differently in relation to variation in the risk score can be explained by the fact that it is based on an ordinal scale, which is not very sensitive to changes in different assessment categories. On the other hand, methodology I works on a nominal scale, where small variations are captured and significantly alter the result of the risk class (NORRIS, 2007); thus, there would be a wider distribution of individuals in different risk classes when using the form I, which could be considered more sensitive to changes in the normality of the characteristics evaluated.

Instead, numerical ratings allow users to prioritize risk reduction efforts by first addressing trees that pose the greatest potential threat to people and property, then narrowing the list to lower-rated trees (KLEIN, KOESER, 2016).

Nominal classification systems equally categorize parts of the tree with obvious differences, failing to capture the degree of risk. An example is the comparison between a smaller branch with a high probability of failure being classified as low risk and a larger branch with a low probability of failure being classified as high risk just because of the size of the part, with numerous cases of accidents involving people involving smaller branches, which have a greater association with the immediate risk of failure (DUNTEMANN; STUART, 2014).

The time spent on evaluation was a limiting factor in form I when considering the inspection of large populations of trees; however, it should decrease as the evaluator becomes familiar with it, as noted by Klein and Koeser (2016), who recorded time spent up to 20 minutes for 360º observation of an individual using the same methodology.

The similarities in time spent for assessment in II, III and IV serve as an indication that any method may be suitable for assessing fall risk in the field. However, the additional location data, encodings, and refinements to the process of deriving the final risk class is what can make a specific method stand out for a particular group of users, depending on needs and resources on a case-by-case basis. Nevertheless, care must be taken so that the speed of data collection does not result in a loss of precision and consistency of the method, which are essential for effective risk classification (KLEIN, KOESER , 2016).

There are no studies that indicate evidence of interference of the degree of risk of falling in the tree assessment time; however, it is possible that trees with large defects take less time to be assessed, since the perception of risk occurs more quickly and direct.

It is important to highlight that the analyzes performed do not allow us to infer the effectiveness of the methodologies, but they can help in choosing them, as they point out their advantages and disadvantages. Thus, the application of methodologies I and II differ from III, IV and V, with I resulting in a lower risk classification and II in a higher risk. As there is no difference in the results between methodologies III, IV and V, the choice for the fastest methodology (V) is recommended.

By including analysis of location and domain of the individual, target, health and size of the part that could fail, methodology III follows a pattern among the others and stands out in relation to V, which does not consider the target in the risk classification.

Furthermore, risk classification in a matrix format is also a factor of attention, given the demand for time and degree of technical understanding. On the other hand, it is very advantageous when considering several targets for a single tree, enabling multifaceted scenarios to be considered, which makes the risk classification better distributed between classes (KLEIN, KOESER, 2016).

CONCLUSION

- The fall risk classification can vary considerably depending on the methodology used to evaluate the trees.
- In total, 41.8% of trees were classified at high risk of falling by all methodologies.
- Methodology II showed the least variation among the trees evaluated, while methodology I had the greatest distribution among the risk classes.
- Methodology III was the most similar to the others, while methodology I was the most different.
- Statistically, methodology I was different from all the others, and had a greater discrepancy from methodology II, which does not differ from IV.
- Methodologies III, IV and V did not show significant differences between them.
- Methodology I tends to classify trees in better conditions, underestimating the degree of risk of falling.
- Methodology II tends to classify trees in worse conditions.
- Methodology V required the least time to apply, while methodology I required more time.
- The assessment time showed a low correlation with the degree of fall risk associated with the individual assessed, as well as with the DBH.
- Although the analyzes carried out do not allow us to infer the effectiveness of the methodologies, they can help in choosing the most appropriate ones for each case, considering their advantages and disadvantages.

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