Revista Mexicana de Ciencias Forestales Vol. 13 (72)
Julio - Agosto (2022)

DOI: 10.29298/rmcf.v13i72.1227

Article

Caracterización de árboles de riesgo en el Parque Nacional Viveros de Coyoacán, Ciudad de México

Risk trees in *Viveros de Coyoacán* National Park, Mexico City

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Fecha de recepción/Reception date: 25 de octubre de 2021
Fecha de aceptación/Acceptance date: 14 de junio de 2022

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Abstract

Trees in cities may be a high risk for the human population and its infrastructure, due to their age, poor development, deficient aerial and root physical structure, and from plagues and diseases that can cause slight to fatal accidents. The objective of this study was to evaluate the risk that trees in *the Viveros de Coyoacán* National Park at Mexico City mean for visitors. Different indicators were used to determine the condition of the site, mensuration characterization, condition and vigor of the trees, classifying them as: 1) extreme risk, 2) high risk, 3) moderate risk and 4) low risk. Twenty-one species were identified with 299 individuals, of which only three species make up 53 % of the total number. In terms of developmental stages, 84.6 % are young trees and 15.4 % adults. 30 % have a *DN* <20 cm and a height under 15 m, while 51 % are taller than 18 m. 12 % interfere with the electrical network, 37 % with signals and 9 % obstruct the walking paths. 70 % of the trunks show mechanical damages, 50 % have weak unions in the branches and 60 % ulcers or cankers. From their hazard, 32 % are of extreme risk and 12 % of high risk. It is recommended to carry out sanitation pruning and soil decompaction. The criteria and indicators used allow a precise diagnosis of the current state of the trees in the park.

Key words: Urban green areas, urban forestry, evaluation, state indicators, risk level, urban vegetation.

Resumen

El arbolado puede representar un riesgo alto tanto para la población humana, como para la infraestructura por su edad, mal desarrollo, deficiente estructura aérea y radical, como por afectaciones de plagas y enfermedades que ocasionan accidentes de leves, hasta fatales. El objetivo fue evaluar el riesgo hacia los usuarios por el arbolado del Parque Nacional Viveros de Coyoacán, Ciudad de México. Se emplearon diferentes indicadores para determinar la condición del sitio, caracterización dasométrica, condición y vitalidad del arbolado, clasificándolos como: 1) riesgo extremo, 2) alto riesgo, 3) riesgo moderado, y 4) bajo riesgo. Se identificaron 21 especies con 299 individuos, de las cuales solo tres taxones constituyen 53 % del total. En cuanto a las etapas de desarrollo: 84.6 % corresponde a juveniles y 15.4 % a maduros. Respecto al *DN*, 30 % presentan menos de 20 cm y una altura inferior a 15 m,

en tanto que 51 % tienen alturas superiores a 18 m. De los individuos, 12 % interfieren en la red eléctrica, 37 % con señalamientos y 9 % obstruye los andadores. Respecto a los troncos, 70 % presentan daños mecánicos, 50 % tienen uniones débiles en las ramas y 60 % tienen úlceras o cancros. Por la condición evaluada, 32 % evidencian riesgo extremo y 12 % riesgo alto. Se recomienda realizar podas de saneamiento y descompactación del suelo. Los criterios e indicadores empleados permiten caracterizar e identificar las condiciones actuales del arbolado del Parque.

Palabras clave: Áreas verdes urbanas, dasonomía urbana, evaluación, indicadores de condición, nivel de riesgo, vegetación urbana.

Introduction

Society requires a sufficient area of urban forests and green areas that allow it to carry out and develop social, educational, cultural, and civic activities (Ruiz-Montiel *et al.*, 2014); in particular, urban trees offer many benefits, as they improve the quality of the environment (air and water), produce a sense of well-being, promote lower temperatures and reduce ultraviolet radiation (Nowak *et al.*, 2006). However, they face stress conditions caused by the action of man, particularly in areas where pedestrian and vehicle traffic is frequent. For this reason, it is important to assess the state of the trees and know if they are in optimal conditions and if the risk they mean to people is minimized (Vogt *et al.*, 2015), as well as damage to infrastructure (Koeser *et al.*, 2016).

A risk tree is described based on its instability due to a defect in its structure, that is, any part of the specimen: trunk, branches or crown can collapse and fall on a person or infrastructure causing them injury or damage (National Tree Safety Group, 2011). Therefore, the evaluation of urban trees aims to identify and qualify such structural condition, in order to determine its potential risk and probability of causing damage (Matheny and Clark, 2009).

The challenge is to provide the right tree management to ensure a low level of risk (Tomao *et al.*, 2015). A long-lived specimen without maintenance is more likely to become harmful (Albers *et al.*, 2003); thus, it is important to identify the specimens that represent a risk as a result of their deterioration due to water or thermal stress, atmospheric pollution, urbanization, attack by pests or diseases (Restrepo *et al.*, 2015), or also as a result of a bad management (Hauer and Johnson, 2003). Tree defects are evaluated through a visual inspection to identify and understand the indicators of potential danger (Calaza and Iglesias, 2016).

Seven categories of potential damage features are identified: decayed wood, cracks, root problems, weak branch joints, cankers, architecture, branches and crown or dead individuals (Pokorny and Albers, 2003).

In the *Coyoacán* mayoralty, there is the *Viveros de Coyoacán* National Park, which is one of the parks with the greatest flow of people, who use the space to carry out sports activities (athletics, mainly), family or single recreation, school education and academics, among others; it is estimated that around 2 500 to 3 000 people attend daily (Semarnat, 2018). There is no formally published information on the condition of the trees and management; thus, and from the importance of the Park, the objective of this study was to identify and evaluate risk trees in the *Viveros de Coyoacán* National Park, in Mexico City.

Materials and Methods

Study area

The *Viveros de Coyoacán* Park is located in the *Coyoacán* mayoralty, Mexico City, between 19º21'14" north and 99º10'19" west, at 2 240 masl (Gobierno de la CDMX, 2016). At the beginning of the last century, in *Coyoacán*, Federal District, Mexico, Mr. Miguel Ángel de Quevedo installed a private forest nursery, with an area of one hectare. In 1907, with the support of the Mexican government, it became the first forest nursery in the country. Later, in 1938, "*Coyoacán* Historic National Park" was declared, which included the nursery, with an area of 584 ha (Departamento Forestal y de Caza, 1938), and in the mid-1970s, the "Central Nursery of *Coyoacán*" with a size of 42 ha, was declared federal public domain. Currently, it is administered by the Federal Government through the *Secretaría de Medio Ambiente y Recursos Naturales* it has a plant production capacity (forestry and fruit trees) of just over two million (Gobierno de la CDMX, 2016).

Sampling design

A random sampling design of 14 circular sites representing the center of the sampling units was used, which were 500 m^2 (12.62 m radius). The sampling intensity was 2 % accepted for urban areas (Schreuder *et al.*, 2004) (Figure 1). These units were located in the work areas using a Global Positioning System (GPS) 12XL model Garmin geopositioner, with a <10 m error; the dimensions of each site

were delimited with a longimeter and rope. All the trees within each sampling site were evaluated.

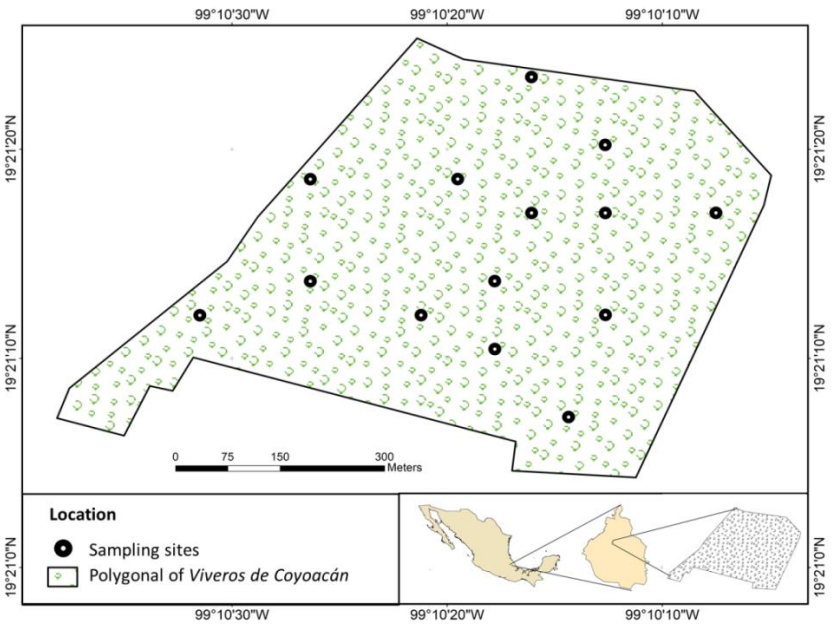

Figure 1. Location of the sampling and polygonal sites of the *Viveros de Coyoacán* Park, Mexico City.

Definition of criteria and indicators

For the definition of the criteria, the methodologies used by Coelho-Duarte *et al*. (2021a, 2021b) were adjusted through basic visual evaluations, and in some cases, detailed visual evaluations adapted from Pokorny and Albers (2003); three groups

were determined: 1) site condition, 2) dasometric characterization, and 3) condition and vitality of the trees.

The site condition indicators used were: 1) location of the tree: building, parking lot, walkway, gardens or sidewalks, 2) visual characteristics of the soil: drainage or compaction, and 3) obstructions present: signs, power lines and walkways.

The mensuration indicators were: 1) common name, 2) scientific name, 3) total height (m), 4) clear stem height (m), 5) normal diameter (*DN*, m) and 6) crown cover (*Cob*, m). The instruments used for the measurements were: for heights, Haga™ Gun, and tape measure for *DN* and Cob, the latter was measured in two perpendicular dimensions of north-south and east-west, and was estimated from the average of the recorded measurements. To obtain the crown diameter (*Avg* C), by using the following formula:

$$Cob(m^2) = \Pi\left(\frac{Prom\ C}{2}\right)^2$$

Where:

Cob = Crown cover

Π = 3.1416

Prom C = Crown diameter

In terms of the condition and vitality, the following criteria were considered: stage of development (juvenile or old), state of the trunk (cracks, rot, cavities), condition of the root (rotten or exposed) and phytosanitary (presence of pests,

diseases or parasitic plants). Technical assessment formats for urban trees were designed to collect information in the field, and the data wwere analyzed using Microsoft Excel spreadsheets.

Defects and risk categories of urban trees

The criteria used were defined according to Pokorny and Albers (2003) and Albers *et al.* (2003). Table 1 lists the four risk categories: 1) extreme risk (red), 2) high risk (orange), 3) moderate risk (yellow) and 4) low risk (green).

Table 1. Categories, risk code and tree defects for their identification and classification.

Risk category	Code	Tree defects
Extreme risk	Red	The tree shows signs of root, trunk or branch failure and is possibly leaning. It has imminent falling potential.
High risk	Orange	Trees with root problems, poor architecture of the tree (trunk and branches). The potential for failure is highly probable.
Moderate risk	Yellow	The potential for failure, mainly of branches, is likely due to the presence of cracks or fissures, cankers and dead wood in different parts of the tree.
Low risk	Green	Failure of some part of the tree due to weak branch joints is possible.

Results and Discussion

A total of 299 trees of 21 different species were counted, of which *Cupressus lusitanica* Mill., *Fraxinus uhdei* (Wenz.) Ligelsh and *Liquidambar styraciflua* L. represented 53 % of the total (Table 2). The most abundant stage of development corresponded to juvenile individuals (84.6 %), while 15.4 % were mature. The latter mostly corresponded to *Alnus acuminata* Kunth, *Casuarina cunninghamiana* Miq., *Cupressus lusitanica*, *Eucalyptus globulus* Labill., *Fraxinus uhdei*, *Pinus ayacahuite* Ehrenb. ex Schltdl., *P. greggii* Engelm. ex Parl., *P. oocarpa* Schiede ex Schltdl. *and Ulmus parvifolia* Jacq. This indicates that there is a diversity of species, but only a few dominate, and they are generally exotic, including: *Ficus* sp., *Casuarina* sp., *Ligustrum* sp., *Cupressus* sp. and *Eucalyptus* sp., genera that predominate in the *Viveros de Coyoacán* park, and also prevail in other green areas of Mexico City, with a latent risk due to pests and diseases (Román-Guillén *et al.*, 2019, Saavedra-Romero *et al.*, 2019b).

Table 2. Total number and percentage of species in 14 sampling sites in the *Viveros de Coyoacán* Park, Mexico City.

Scientific name	Common name (in Spanish)	Individuals (number)	Percentage (%)	Number of trees rated at risk†
Alnus acuminata Kunth	*Aile*	4	1.3	4
Casuarina cunninghamiana Miq.	*Pino australiano*	13	4.3	6
Celtis occidentalis L.	*Palo blanco*	2	0.7	0
Crataegus mexicana DC	*Tejocote*	1	0.3	0
Cupressus lusitanica Mill.	*Cedro blanco*	62	20.7	33

Eucalyptus camaldulensis Dehnh.	*Eucalipto*	3	1.0	3
Eucalyptus globulus Labill.	*Eucalipto azul*	4	1.3	2
Fraxinus uhdei (Wenz.) Lingelsh.	*Fresno*	48	16.1	14
Ligustrum lucidum W. T. Aiton	*Trueno*	10	3.3	7
Liquidambar styraciflua L.	*Liquidámbar*	48	16.1	13
Morus celtidifolia Kunth	*Mora*	3	1.0	1
Phoenix canariensis Neubert	*Palma abanico*	8	2.7	0
Phytolacca dioica L.	*Fitolaca*	1	0.3	1
Pinus ayacahuite C. Ehrenb. ex Schltdl.	*Pino blanco*	5	1.7	2
Pinus engelmannii Carrière	*Pino real*	8	2.7	4
Pinus greggii Engelm. ex Parl.	*Pino prieto*	6	2.0	4
Pinus oocarpa Schiede ex Schltdl.	*Pino ocote*	25	8.4	17
Pinus patula Schltdl. & Cham.	*Pino colorado*	3	1.0	2
Populus alba L.	*Chopo*	1	0.3	0
Ulmus parvifolia Jacq.	*Olmo chino*	35	11.7	18
Yucca elephantipes Regel ex Trel.	*Yuca*	9	3.0	0
Total	21	299	100	131

† Risk trees classified with categories and extreme risk code (red) and high risk (orange).

In relation to the previous results, four species constitute 64.1 % of all the individuals inventoried. This figure is very close to that obtained by Velasco-Bautista

et al. (2013) in the *Bosque de San Juan de Aragón* urban park, in Mexico City, where seven species represent 74 % of the total trees; and similarly, Saavedra-Romero *et al*. (2019a) recorded five taxa with the highest frequency (76.2 %) of plantation in the same park. Likewise, Castillo-Islas *et al.* (2008), on the campus of the *Universidad Autónoma Chapingo*, cite that 74 % of the total population belongs to four species. Pérez *et al.* (2018) on the campus of the *Instituto Tecnológico Superior Venustiano Carranza* document 143 individuals, and only 12 taxa.

In the *Tezozómoc* Cultural and Recreational Park (PCyRT), 3 758 trees were counted, belonging to 30 species grouped into 16 families; the most abundant and with the greatest cover were *Eucalyptus camaldulensis* Dehnh., *Populus tremuloides* Michx., *Pinus radiata* var. *binata* (Engelm.) Lemmon, *Fraxinus uhdei*, *Schinus molle* L. and *Cupressus lusitanica* (Reséndiz *et al.*, 2015). The general trend is that a large number of trees of five or six genera are planted in the urban parks of Mexico City, including: *Casuarina* sp., *Eucalyptus* sp., *Fraxinus* sp., *Cupressus* sp., *Ligustrum* sp. and *Grevillea* sp. In this regard, Santamour (1990) recommends that no species should predominate above 10 %, no more than 20 % of a genus and 30 % of a family.

In the study area, it was estimated that 30 % of the trees have DN <20 cm and a height of less than 15 m, 51 % reach heights greater than 18 m; while 26 % have diameters >30 cm. The average height of the clean shaft was 5.80 m, which corresponds to the height at which the electrical wiring is located, and below this the signs are located within the park. The crown cover showed that they are unbalanced or incomplete, mainly due to the high tree density throughout the park and the lack of maintenance (Table 3).

Table 3. General statistics of the mensuration variables of the trees in the *Viveros de Coyoacán* Park, Mexico City.

Variable	Sum	Mean	Variance	Standard desviation	Median	Mode	Max	Min
A (m)	5 567	18.6	61.5	7.8	18.0	14.0	39.0	3.0
AFL (m)	1 743	5.8	17.1	4.1	5.0	3.0	24.0	0.0
DN (cm)	7 146	23.9	345.4	18.6	19.0	15.0	155.0	4.0
Cob (m^2)	8 509	8.5	938.6	30.6	17.7	11.0	212.0	0.0

A = Height; *AFL* = Clean-stem height; *DN* = Normal diameter; *Cob* = Crown cover; Max = Maximum, Min = Minimum.

Based on the number of trees, the number of species represented and the stages of development, most of which are juveniles, it can be stated that according to Baró *et al.* (2014), is a green area that provides quality ecosystem services, such as the removal of atmospheric pollutants, carbon sequestration and storage capacity, water infiltration and noise reduction, among others.

Regarding the location of the trees, they predominated inside the gardens, which have a high density and competition for nutriments; there are trees established throughout the area of free transit for visitors; therefore, the soils have a high degree of compaction. In this regard, Martins-Nieri *et al.* (2018) indicate that in compacted soils the main factor considered is the loss of aeration due to the decrease in pore spaces and organic matter, therefore, the roots do not have a good development, consequently, growth is weak. Hernández *et al*. (2011) point out that soil compaction is the main cause of death in urban trees, since their roots need permeable or grass-covered soils to promote greater infiltration and the development of secondary roots.

The presence of some insects in *Eucalyptus camaldulensis* and fungi in *Cupressus lusitanica*, *Eucalyptus globulus*, *Pinus ayacahuite* and *Ulmus parvifolia* was

observed. It should be noted that few studies have been carried out on pests and diseases in urban trees in Mexico City; thus, Reséndiz *et al.* (2015) identified in the PCyRT several species with foliage damage caused by different fungi, in particular, *Fusarium* sp., which exhibits chlorotic staining. In a similar way, in the Third Section of the *Chapultepec* Forest, it was determined that the condition of the trees, in general, is poor due to the presence of phytophagous insects that damage its vegetative structure (Cervantes *et al.*, 2019).

In the trees of *Viveros de Coyoacán* Park, in particular, low affectation was observed to the urban infrastructure inside, since only 12 % of the individuals interfere with the electrical wiring, 37 % with signs and 9 % obstruct the walk paths. Velasco *et al.* (2013) recorded in the *San Juan de Aragón* Forest that 7.9 % of the trees had some risk associated with electricity cables, fences, sidewalks and constructions such as fences or planters. These conditions are different from what is recorded for other urban areas, such as gardens, parks or in medians where the main damage to infrastructure is directly related to the incorrect selection of species, due to ignorance of their biology. development and poor management (Román-Guillen *et al*., 2019).

Nevertheless, the conditions in the *Viveros de Coyoacán* Park are similar to those of other forests or parks in Mexico City, such as the *Chapultepec* Forest (Benavides and Fernández, 2012) and the *San Juan de Aragón* Forest (Velasco *et al*., 2013; Saavedra-Romero *et al*., 2019a and 2019b), or in alignment trees (Román-Guillen *et al.*, 2019), all located in limiting conditions due to water supply, induced opening of the space below the canopy for security reasons and for recreational activities.

The characteristics that can be defined as defects associated with the trees (Figure 2) showed that just over 70 % of the trunks of the sampled population have cracks and dead wood caused by cankers, weak unions of branches, injuries due to mechanical damage or by vandalism. These factors caused the formation of cavities, which in most of them were the entrance point for pathogenic agents that caused

the deterioration or reduction of the stability and the physical-mechanical properties of the standing tree, since the phytopathogens were present in branches, trunks and roots. In half of the trees, weak unions were recorded in the branches, which include the branches produced by epicormic shoots in response to injuries or environmental stress, and 60 % developed ulcers or cankers in the branches. Fractures or cracks often originated in these areas, with a high risk of causing the specimen to fall.

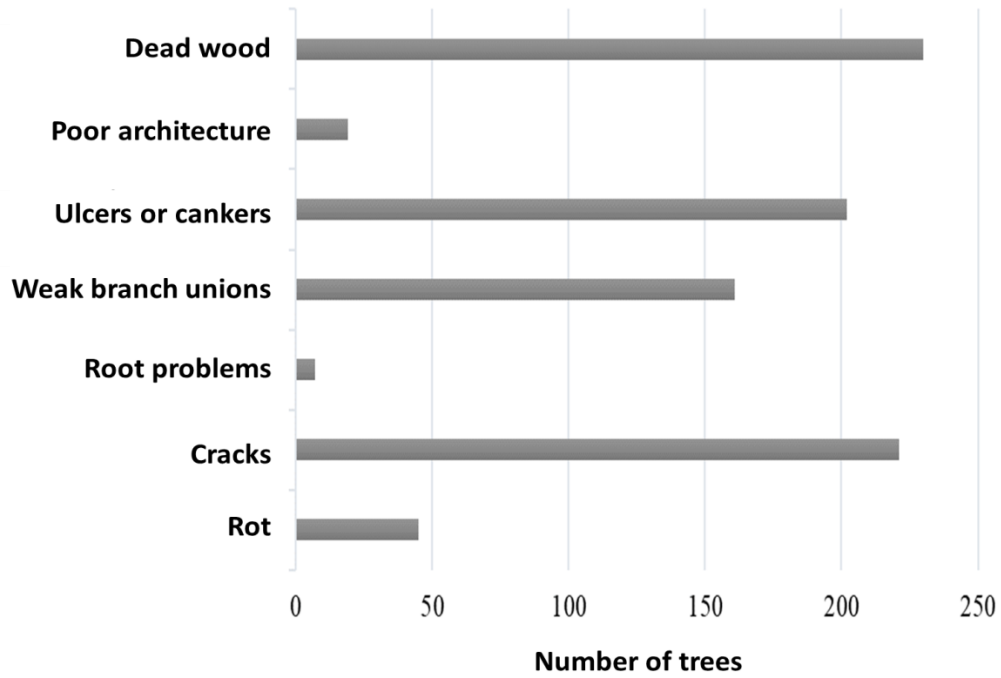

Figure 2. Defects presented by risk trees in the *Viveros de Coyoacán* Park, Mexico City.

Regarding the degree of risk, it was determined that 131 trees of the total represent extreme risk (32 %) and high risk (12 %) (Table 2, Figure 2). Related defects are rot, cracks, weak branch joints, cankers and dead wood. Pokorny and Albers (2003)

indicate that these characteristics are the main causes of a high risk for the population in any urban area. Likewise, root rot caused by fungi constitutes an additional factor for the potential fall of the tree individual (Calaza and Iglesias, 2016).

Regarding the risk categories, the species with the highest percentages of red and orange codes (extreme risk and high risk, respectively) were *Cupressus lusitánica* (25 %), in addition to the *Pinus* genus (22 %), *Ulmus parvifolia* (13.7 %), *Fraxinus uhdei* (10.7 %) and *Liquidambar styraciflua* (9.9 %); those with the lowest percentage were *Alnus acuminata*, *Casuarina cunninghamiana*, *Eucalyptus camaldulensis*, *E. globulus*, *Ligustrum lucidum* W. T. Aiton and *Morus celtidifolia* Kunth.

In a similar study by Castillo-Islas *et al.* (2008), estimated that 37 and 26 % of the trees were classified as red and orange, respectively, and the species that prevailed were *Fraxinus uhdei, Cupressus lusitanica* and *Casuarina cunninghamiana* in three high attendance areas of the *Universidad Autónoma Chapingo*; the foregoing implies a potential or severe risk, with rotten wood and cavities, severe root damage, weak unions between branches, tips and dead branches, high density and old specimens. A similar situation occurs in areas near the *Venustiano Carranza* Higher Technological Institute, where 52 % of the trees are of high risk to the population because they are in poor condition, are prone to falling branches or entire individuals on users and real estate (Pérez *et al.*, 2018).

In the present work, the highest proportion of the inventoried individuals were classified with a yellow code (47 %), that is, moderate risk (Figure 3). Finally, only 9 % corresponded to the category without any risk, and the species that made up this group were *Phoenix canariensis* Chabaud and *Yucca elephantipes* Baker.

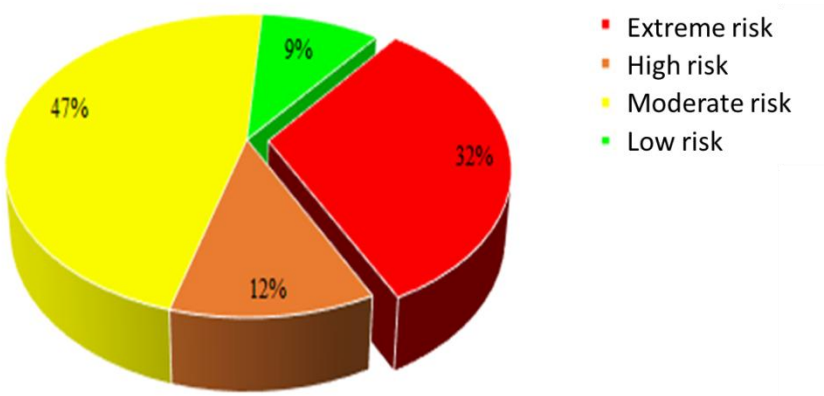

Figure 3. Percentage of trees at risk in the *Viveros de Coyoacán* Park, Mexico City.

Based upon the results, the management actions are basic to improve the conditions of the Park and provide security to the users; formation and sanitation pruning, surgeries in the hollows and cavities of the trees are recommended, in addition, carry out work to loosen the soil inside the planters. On the other hand, in future programs of planting or replacement of specimens, it is suggested to diversify the species; therefore, it is important to undertake a training program for the operating personnel, with the advice of engineers or technicians who participate in the work of the Park, with proper work and safety equipment.

Conclusions

The criteria and indicators used for the characterization of the risk trees in the *Viveros de Coyoacán* Park allow visually identifying and evaluating the defects and

risks of the individual trees that represent a danger to the user population of the Park. The most frequent defects are rot, cracks, brittle branch joints, cankers and dead wood. The species with the highest percentages of extreme risk and high risk are *Cupressus lusitánica*, *Pinus* sp., *Ulmus parvifolia*, *Fraxinus uhdei* and *Liquidambar styraciflua*. There is little impact on the Park's infrastructure. This information is relevant for administrators responsible for implementing preventive measures to mitigate or avoid potential damage to Park visitors.

Acknowledgements

The authors thank the *Secretaría de Medio Ambiente y Recursos Naturales* which, through the administration of the *Viveros de Coyoacán* National Park, supported them with the permits to carry out this work.

Conflict of interests

Liliana Muñoz Gutiérrez declares that she did not participate in the editorial process of this manuscript, since she is Section Editor of the *Revista Mexicana de Ciencias Forestales*.

Contribution by author

Liliana Muñoz Gutiérrez: definition of methodology, data analysis and writing of the document; Ramiro Pérez Miranda: image processing, review and correction of the manuscript; José Francisco Reséndiz Martínez: management of permits in the *Viveros de Coyoacán* National Park, review and correction of the manuscript; Rodolfo Reyes Robles: field work, capture and processing of information, writing of the document.

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