Damaging Agents and Tree's Health Condition in an Urban Forest

Luz de Lourdes Saavedra-Romero[1], Tomás Martínez-Trinidad[2], Dionicio Alvarado-Rosales[1]*, Patricia Hernández-de la Rosa[2], Jaime Villa-Castillo[3]

[1]Postgrado en Fitosanidad-Fitopatología, Colegio de Postgraduados, Campus Montecillo, Texcoco, Estado de México
[2]Postgrado en Ciencias Forestales, Colegio de Postgraduados, Campus Montecillo, Texcoco, Estado de México
[3]Consultor Independiente, Colegio de Postgraduados, Campus Montecillo, Texcoco, Estado de México
Email: *dionicio@colpos.mx

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Abstract

Urban trees are subjected to different damaging agents throughout their lifetime. The aims of this study were to identify tree damaging agents, and to obtain a Damage Severity Index (DSI) in order to categorize tree health condition at San Juan de Aragon Park. Each tree was identified at species level in 28 randomly established plots in ten sections of the study area. Up to two types of damage were recorded per tree, based on the FIA (Forest Inventory an Analysis Program) protocol, and a DSI was obtained for each damaged tree considering location of damage, nature of the damaging agent and severity. A total of 753 trees were assessed and 12 species and 27 damaging agents were identified. Cankers, galls, the pepper tree psyllid and the red gum lerp psyllid were the most frequent damaging agents. Australian pine, red gum, Mediterranean cypress, Mexican white cedar, and California pepper were the most affected species. The DSI ranged from 3 to 17 and the average was 7.9. Sections J and H and the species California pepper, Australian pine, and Mexican white cedar presented the highest DSI. The tree population had a moderate health condition, while the aforementioned sections and tree species showed the poorest.

Keywords

Damaging Agents, Urban Trees, Bleeding, Cankers, Galls, Health Categories, Damage Severity Index

1. Introduction

Trees have adapted to different environments and are the most important component of the urban environment due to their size, beauty, and close connection with people (Konijnendijk et al., 2005; Samson, 2017). However, tree health is negatively affected under urban conditions (Stone et al. 2003a) causing a reduction in their vitality and life expectancy (Nowak et al., 2004; Roman & Scatena, 2011). Tree vitality (ability to grow, to reproduce, and to adapt to the surrounding), is reduced due to the limited and modified space in which trees are established (Pretzsch et al., 2015). The lack of vital resources for growth, such as water, organic matter, and nutrients in soils (Klieber et al., 2019) causes chronic stress which becomes worse over time. Besides, exposure to different damaging agents such as pathogens, insects, air pollution, vandalism and lack of management also undermine tree vitality. Along with these adversities, the species planted are generally not the most appropriate for the site. Selecting the right species for an urban area requires careful examination (i.e., potential constraints, tree ecophysiology, aesthetic and functional attributes, otherwise, the trees will be more susceptible to diseases and pests, and thus leading to extra-maintenance costs (removal and replacement, pruning, fertilization, etc.) (McPherson, 1993; Roman & Scatena, 2011; Johnston & Hirons, 2014; Bravo-Bello et al., 2020).

The identification and analysis of damaging agents can be expressed based on the incidence of biotic and abiotic factors (Ferretti, 1997). Any factor that negatively affects vitality and environmental and economic tree value is known as a damaging agent (Wulff, 2011). These, may act individually or synergistically, causing direct tissue loses, and the rot of cortex tissues in the stem, branches, and roots (Stone et al., 2003a). Regarding that, there are many examples about damaging agents causing urban tree stress and death (Alvarado-Rosales et al., 2007). Some of these include the emerald ash borer (*Agrilus plannipenis* Fairmaire), responsible for the death of 20 million ash trees in the United States alone (USDA, 2009). In Mexico, a case that attracted public attention was the effect of true mistletoe *Cladocolea loniceroides* Van Tieghem in Xochimilco Mayoralty, where approximately 2500 bonpland willows (*Salix bonplandiana* Kunth) died, and over 50 thousand had to be pruned to reduce infection levels (Alvarado-Rosales & Saavedra-Romero, 2005).

For several years, previous research has mentioned the variables that can be used to evaluate and characterize the current health condition of natural and urban forests (Ferretti, 1997); however, these variables must be scientifically valid and economically feasible to collect (Stone et al., 2003b); some of the most studied variables are foliar discoloring, defoliation percentage, crown density, leaf and needle size, and damaging agents (one or more types of damage) (Conkling et al., 2005; Coulston et al., 2005). Although identifying tree damaging agents could be a simple task, expressing the damage in numerical terms is a complicated assignment because of the lack of linkages and thresholds, and the difficulty in interpreting damage (Conkling et al., 2005). Not to mention the DSI or other indexes, which integrate information from multiple variables in a single value, for example, the RUSI index for urban landscapes (Scharenbroch et al., 2017). Another, is the Canopy Damage Index (CDI) generated for Red gum plantations, for example, it was developed for plantation managers and forestry experts, who often need to quantify the degree of tree damage, whilst generating reliable data for an inventory of their resource condition, calculating losses, and implementing immediate management activities in the most heavily impacted sites (Stone et al., 2003a).

Regarding natural forests, the ICP Forest (International Cooperative Program on Assessment and Monitoring of Air Pollution Effects on Forest) is currently applying a protocol to determine damage to forest species, implementing three simple steps: (a) Description of the symptom (devoured, broken, tanned); (b) Determination of the causes (fungi, bacteria, insect, abiotic agent) and (c) Quantification of the symptom (extension of damage) focusing exclusively on the damage that could affect the tree as a complete entity (Lorenz, 2013; Michel et al., 2014). However, we still need additional studies focused on trees under urban environments.

Tree health assessment must be seen as a comprehensive process based on a visual and complete inspection of its organs (Alexander & Palmer, 1999; Stone et al., 2003b). Damaging agents that affect the root and stem have a greater potential to affect the overall physiology of the tree, hence their presence is considered more dangerous (Conkling et al., 2005). Under other conditions, damage caused to active growth organs (small branches and foliage) may be temporary, since the leaves, sprouts, and reproductive structures can be replaced in the short or medium term (Conkling et al., 2005, Winn et al., 2011). Finally, the aims of this study were to identify tree damaging agents, and to obtain a Damage Severity Index (DSI), in order to categorize tree health condition of the San Juan de Aragon Park.

2. Material and Methods

2.1. Study Area

This study was carried out in the San Juan de Aragon Park, located northeastern Mexico City (19˚27’32"N; 99˚04’17"W). This urban park is the second most important in the city with 114 ha of green area and about 3.5 million visitors annually. Out 14 sections that conform to the park, ten were chosen (B, C, E, F, G, H, J, K, L, and M) (**Figure 1**) which in the past were classified according to their use and service (e.g. cultural and recreational activities, low impact sports, facilities, etc.) (SMA, 2012). In this sense, 28 circular plots of 0.1 hectare were established (2 to 6 plots per section), using a sampling intensity of 2.5%. All plots were georeferenced and all trees (alive and dead) within their limits were numbered clockwise, starting from the geographic North; each tree was also identified taxonomically (Saavedra-Romero et al., 2019a).

2.2. Damage Assessment

The tree damage indicator protocol proposed by the Forest Inventory and Analysis Program and Conkling et al. (2005) was implemented. Beforehand, the field

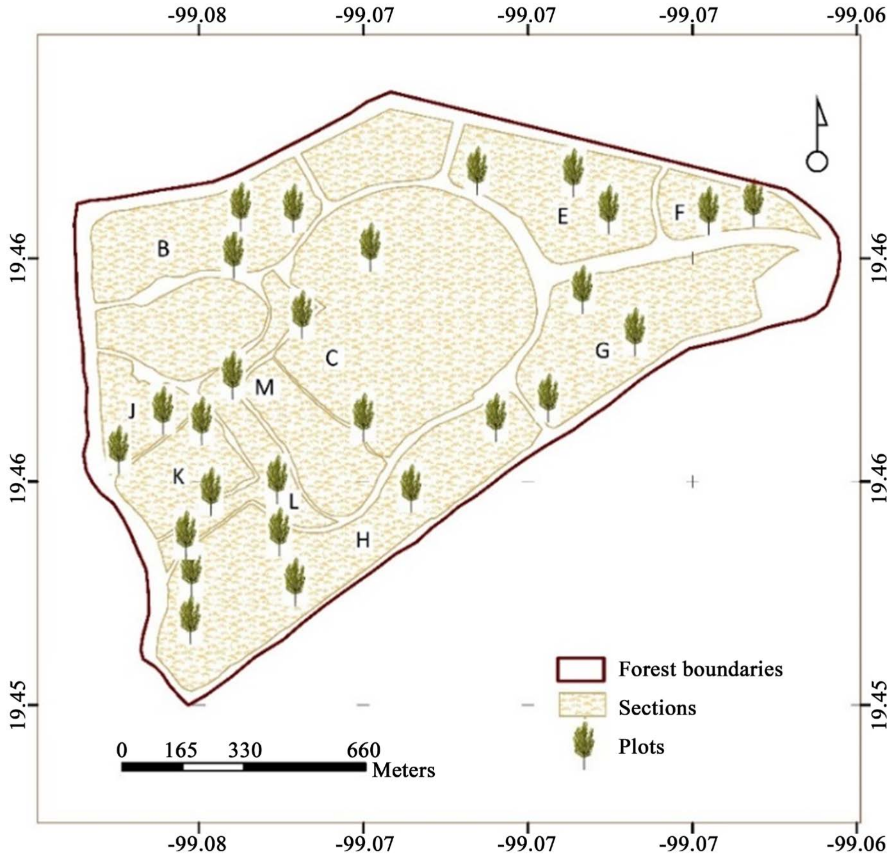

Figure 1. Map of San Juan de Aragon Park, Mexico City (Saavedra-Romero et al., 2019a).

crew integrated by three people (two Biologists and one Forest Engineer) was trained to identify the main symptoms and to calibrate some of the more subjective measures, like damage severity. In this survey, up to two damaging agents per live tree were recorded (Type 1 and Type 2) as well as the location and severity of each damage. Type 1 represents the causal agent with the greatest damage caused to the tree (highest severity), and Type 2 represents the causal agent with lesser damage (lowest severity). Each tree was visually inspected at 360˚ to obtain a complete view with an ascending order of evaluation: root and root collar>stem>branches and foliage. Only damage considered serious enough to increase the probability of death (e.g. by infection of lethal pathogens through open wounds) (Coulston et al., 2005) or premature fall (Saavedra-Romero et al., 2019b) of the trees were considered, as well as those which could affect their growth and reproductive potential (e.g. pathogens that cause foliar diseases and consequently high defoliation) (Coulston et al., 2005). Because of this, a minimum threshold of 20% was considered for a damage to be recorded. Damage severity observed in the field was recorded in 5% class intervals. On the stem, the percentage of the circumference damaged was evaluated, whereas in the canopy the percentage of branches or foliage affected was estimated. To record data, a field guide was used for each damaging agent, and a recording key and codes for the nature of the agent. This information was enriched with observations made during field trips and finally grouped into six general categories and 34 damaging agents (Saavedra-Romero et al., 2015).

2.2.1. Location of Damage

Damage location affects differently the overall health of the tree (Coulston et al., 2005), for this reason, damages identified on lower organs (root, root collar and stem) were considered more threatening to structural integrity and were weighted as follows: 1) Foliage (leaves or needles); 2) Branches; 3) Stem, and 4) Root and root collar area.

2.2.2. Nature of the Damaging Agent

The effect of the damaging agent on individual trees was rated according to the danger it represented to its health and integrity, that is, lower values mean less dangerous (e.g. the birds), and higher values mean more dangerous (e.g. the Seiridium canker). Values from 1 to 4 were employed, where 4 represents the highest danger (**Table 1**).

2.2.3. Damage Severity

Regarding this component and considering the established threshold (20%), seven categories were set up according to the percentage of stem circumference or affected canopy: code 1 (≥20% - 29%), code 2 (30% - 39%), code 3 (40% - 49%), code 4 (50% - 59%)... code 7 (>80%).

2.3. Damage Severity Index (DSI) and Health Categories

According to Conkling et al. (2005), a damage severity index (DSI) score was determined for each damaged tree. The DSI score was determined based on three variables collected a priori in the field: 1) the location of the damage on the tree, 2) the nature of the damaging agent, and 3) the severity of the damage. A DSI

Table 1. Codes employed for the nature of the damaging agent for San Juan de Aragon Park, Mexico City.

Codes/Damaging agents			
1	**2**	**3**	**4**
Unknown agent	Cytospora canker	*Struthanthus* sp.	Pitch canker
Phyllosticta leaf spot (*Phyllosticta* sp.)	Tubercularia canker	*Cladocolea* sp.	Seiridium canker
Cephaleuros leaf spot (*Cephaleuros* sp.)	Airplant (*Tillansia* sp.)	*Cuscuta* sp.	Root rot
Ash plant bug (*Tropidosteptes* sp.)	Red gum lerp psyllid (*Glycaspis* sp.)	Stem insects	Wood decay
Pepper tree psyllid (*Calophya* sp.)	Bleeding	Galls	Wind
Defoliating insects	Sooty molds	Cavities	Girdling
Birds	Water excess	Cracks	
Rodents	Mechanical wounds	Fire	
Salinity	Vandalism		
Air pollution	Topping		
Inadequate cultural practices			

for tree species and sections were calculated. Finally, based on this, health categories were established. The following Equations (1) and (2) were applied:

$$\text{DSI by tree} = (L_1 + D_1 + S_1) + (L_2 + D_2 + S_2) \tag{1}$$

$$\text{DSI by section or species} = \frac{1}{n}\left[(L_1 + D_1 + S_1) + (L_2 + D_2 + S_2)\right] \tag{2}$$

where:

L_1 y L_2 = Location of damage (1 and 2);

D_1 y D_2 = Type of damaging agent (1 and 2);

S_1 y S_2 = Severity of damage (1 and 2);

n = number of trees per section or species.

2.4. Data Analysis

The DSI data obtained were compared among tree species and sections with non-parametric analysis using the Kruskall-Wallis test and the Wilcoxon rank sum test using the SAS software v. 9.4.

3. Results

The Damage Severity Index (DSI) was obtained for 753 live trees in San Juan de Aragon Park (SJAP). Ten botanical families were identified, with the most representative being Casuarinaceae (23.60%), Proteaceae (17.50%) and Cupressaceae (17.24%), in addition to 12 species (10 broadleaves and two conifers). The frequency of each one was as follows: Australian pine (*Casuarina equisetifolia* L.) (23.60%), silk oak (*Grevillea robusta* A. Cunn. Ex. R. Br.) (17.24%), Mexican white cedar (*Hesperocyparis lusitanica* (Mill.) Bartel (13.66%), red gum (*Eucalyptus camaldulensis* Dhnh.) (12.06%), California pepper (*Schinus molle* L.) (9.68%), tropical ash (*Fraxinus uhdei* (Wenz.) Lingelsh. (8.09%), everblooming acacia (*Acacia retinodes* Schltdl. (7.55%), Mediterranean cypress (*Cupressus sempervirens* L.) (3.84%), tamarisk (*Tamarix gallica* L.) (3.05%), glossy privet (*Ligustrum lucidum* Aiton) (0.79%), Chinese elm (*Ulmus parvifolia* Jacq.) and boxelder (*Acer negundo* L.) (0.13%) (Saavedra-Romero et al., 2019a).

3.1. Incidence of Tree Damage

Of the total number of trees, 48.50% showed no significant damage, or they were below the established ≤ 20% threshold. On the other hand, of the 388 remaining trees, 29.60% showed one type of damage (223) (type 1) and 21.90% showed two (165) (type 2).

3.2. Damaging Agents and Affected Organs

At least 27 damaging agents were identified. **Figure 2** shows only 18 of them which affected more than 15 trees (n ≥ 15). The affected organs were the stem with 61%, branches with 32%, foliage with 4% and root collar area with only 3% (**Figure 3**).

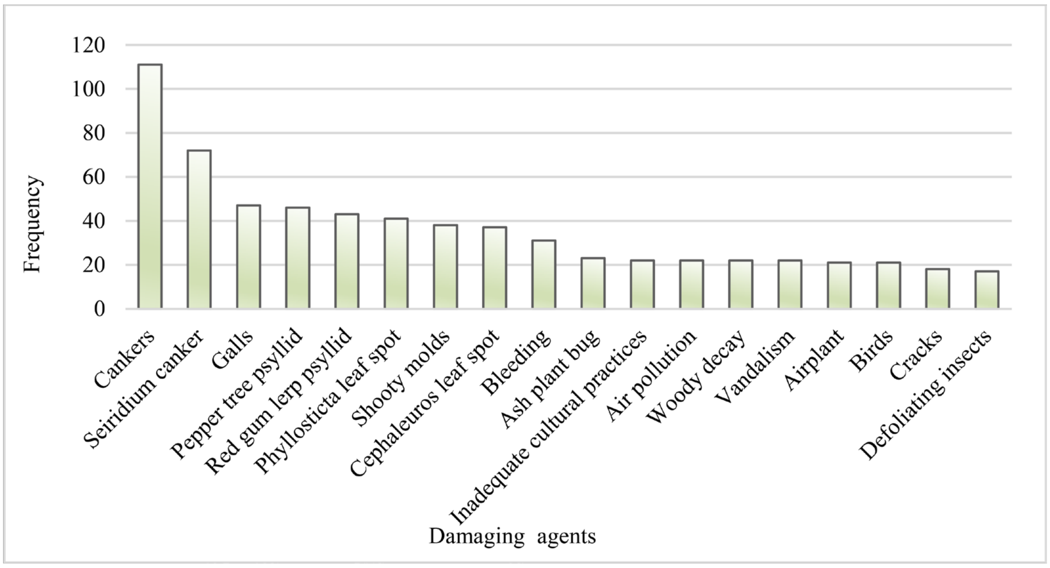

Figure 2. Frequency of damaging agents identified in San Juan de Aragon Park, under the criterion n ≥ 15 affected trees.

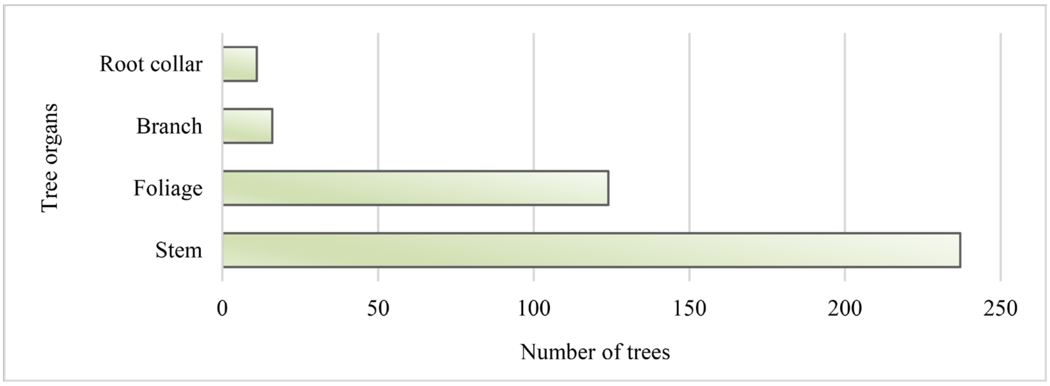

Figure 3. Number of damaged trees depending of the affected organ.

3.3. Damaging by Tree Species and by Sections

Tree species with the most damaging agents' number were: Australian pine, red gum and California pepper. Regarding tree species with the highest number of damaged trees were Mexican cedar, Mediterranean cedar, California pepper, red gum and silk oak (Table 2).

Stem damage caused by Seiridium canker was the most important damaging agent with 53% incidence on Mexican white cedar and 62% on Mediterranean cypress. Three species showed serious foliar damage: Everblooming acacia by Cephaleuros leaf spot (*Cephaleuros* sp.), with and incidence of 64.9%; red gum tree by sooty molds and the red gum lerp psyllid, with incidences of 45% and 57%, respectively, and finally, California pepper by pepper tree psyllid. Regarding the sections of the SJA Park included in this study, cankers were found to be the most frequent damage; for example, 28% of the trees in section E were affected, followed by Sections H and B with 11.86% and 10.97%, respectively. The rest of sections showed lower values.

3.4. Damage Severity Index and Health Categories by Sections and Species

According to the gross DSI scores obtained, the minimum was 3 and the maximum 17, with an average population score of 7.90. Of the total number of damaged trees, 71.90% presented damage severity indexes between 3 and 9. Damage Severity Indexes showed significant differences between sections ($p = 0.0001$) and tree species ($p < 0.0001$) of the SJA park (Table 3). The DSI for sections E, H and J were significantly greater than sections G and K, while sections B, C, F,

Table 2. Frequency of damaging agents by tree species in San Juan de Aragon Park, Mexico City (included those affecting more than 15 trees).

Species	Total of trees	Cracks	Wood decay	Cavities	Bleeding	Cankers	Galls	Defoliator insects	Air pollution	Inadequate management	Vandalism	Seiridium canker	Phyllosticta leaf spot	Cephaleuros leaf spot	Sooty molds	Red gum lerp psyllid	Pepper tree psyllid	Ash plant bug	Airplant	Birds
Australian Pine	178	11	3		13	18	1		1	4	4								17	19
Silk oak	130	1			22	25			20	5	5									
Mexican white cedar	103	2				15				2	8	52								
Red gum	91					4		17		2	2		40		37	43				
Californian pepper	73	1	15	9		11	27										46		4	1
Tropical ash	61	1				12				3	3							23		
Everblooming acacia	57	2				12								37	1					
Mediterranean cypress	29					3				1		29								1
Tamarisk	23		4	1			19													

Table 3. Mean values of Damage Severity Index (DSI) by sections and tree species of San Juan de Aragon Park, Mexico City.

Sections	DSI	Tree species	DSI
G	$6.20^{a\dagger}$	Tropical ash	5.86^{a}
K	6.71^{ab}	Red gum	6.43^{a}
L	7.34^{abc}	Everblooming acacia	6.54^{ab}
B	7.56^{bc}	Silk oak	7.89^{bc}
F	7.71^{bc}	Mediterranean cypress	7.85^{bcd}
C	7.86^{abc}	Australian pine	8.55^{cd}
E	8.52^{c}	Mexican white cedar	8.73^{cd}
J	8.68^{c}	Tamarisk	9.17^{cd}
H	8.82^{c}	California pepper	9.84^{d}

†Different letters within columns indicate differences between sections ($p = 0.0001$) and tree species ($p < 0.0001$) using Wilcoxon rank sum test.

K, and L were significantly equal to each other and had an average DSI ranging from 6.71 to 7.86. In the case of species, California pepper, tamarisk, Australian pine, and Mexican white cedar presented the highest DSI (8.55 to 9.84) and were significantly different from tropical ash, red gum and everblooming acacia, which presented the lowest values (DSI = 5.86 to 6.54). The remaining species, Silk oak, Australian pine, and Mediterranean cypress, had very similar values ranging from 7.85 to 8.73. Mexican cedar and California pepper, the most frequent species in sections J and H.

In this study, the general health condition was grouped into three categories based on average DSI values (**Table 4**). Sections J and H, and Mexican white cedar, tamarisk, and California pepper species showed the poorest health condition. Meanwhile tropical ash, everblooming acacia and red gum showed a good health condition.

4. Discussion

Most trees are planted in their definitive place within the urban setting and they have been exposed to the onslaught of different damaging agents throughout its different growth stages; therefore, identifying damaging agents is a priority in an effort to maintain and prolong what is collectively now known as ecosystem services (Johnston & Hirons, 2014; Morgenroth et al., 2016; Thom & Seidl, 2016; Bravo-Bello et al., 2020).

4.1. Incidence of Tree Damage

Currently, most studies worldwide on damaging agents specify the affected surface and spatial distribution of general or specific agents (USDA, 2009). Unfortunately, few assess the amount of individual damage, their diversity, incidence, and severity. In 2012, the ICP Forest carried out an evaluation of damage on 64 thousand trees in 25 European countries, and their results showed that 72% (46,500 trees) presented some kind of damage. However, due to one individual being able to host more than one damaging agent, the total number of cases recorded at the end was 62 thousand (Michel et al., 2014). In a similar study, damaging

Table 4. Health categories for sections and tree species of San Juan de Aragon Park, Mexico City, according to the average value of the Damage Severity Index.

Health condition	DSI	Description of damage and thresholds	Sections	Species
Good	≤6.6	Damage mainly in foliage, and minor in branches or trunk, and severity percent (20 and 29).	G	Tropical ash Everblooming acacia Red gum
Moderate	>6.6 to 8.6	Damage mainly in branches and trunk, and severity percent of 30 to 49.	B, C, E, F, K, L	Silk oak Mediterranean cypress Australian pine
Poor	>8.6	Damage mainly in trunk and root collar, and severity percent > 50%.	J, H	Mexican white cedar Tamarisk California pepper

agents were recorded on 251 trees at three sites in Tanzania, two nature reserves (Kimboza and the teachers' college) and a mountainous area in Usambara. The percentage of trees with damage were 32%, 53% and 23%, respectively, while the percentage of trees with two types were 3%, 29% and 9%, respectively (Madoffe et al., 2006). In our study, 51.50% of the trees showed damage. Leastways 29.60% displayed one type of damage, and 21.90% showed two. These results were similar to the ones previously mentioned.

4.2. Damaging Agents and Affected Organs

Regarding damaging agents, cankers, galls, the pepper tree psyllid (*Calophya rubra* (Tuthill)) and the red gum lerp psyllid (*Glycaspis brimblecombei* Moore) were the most frequent. With lower incidence, the parasitic plant, *Struthanthus* sp., and the epiphyte, *Tillandsia* sp. were identified. The latter, despite being epiphytic, competes with its host for space and light, and some studies report that it affects the reproductive potential of its host (Castellanos-Vargas et al., 2009). Concerning mistletoe, trees presented low levels of infection; unfortunately, these two damaging agents could, in the short term, become a major problem due to the existence of trees with high levels of severity in areas adjacent to the SJA Park. Similar studies conducted by Applegate and Steinman (2005), report six damaging agents for the species Virginia pine (*Pinus virginiana* Mill.), loblolly pine (*Pinus taeda* L.) and the oaks (*Quercus* spp.) on army training fields at Fort A.P. Hill in Virginia, U.S.A. being the most frequent are those that cause trunk rot and different types of wounds. Whit regard to the present study, the stem was also one of the most damaged organs, followed by branch damage (**Figure 3**). On the other hand, other studies pointed out 12 damaging agents, including cankers, rots, wounds and broken branches in the high part of the canopy (Rogers, 2002). Meanwhile, decay and vines were considered the most serious damaging agents in Kimboza forest reserve (Madoffe et al., 2006). Another studies on damage assessment carried out in Trentino, Italy, reports the presence of 13 specific agents; the most frequent were anthracnose of the oaks (*Gnomonia quercina* Kleb.) and common spruce bell (*Epinotia tedella* (Clerk)), four abiotic agents (snow, lightning, drought, and frost) and two types of mechanical damage (Maresi & Salvadori, 2004).

Meanwhile, in United Kindom, information about the main tree damage agent was gathered through the use of an extensive questionnaire answered by administrators and people responsible for green areas in 17 European countries. Some of the most noteworthy results include insects that produce scales and aphids, diseases such as anthracnosis, powdery mildew and Dutch elm disease, environmental pollution and damage by salts; but without a doubt, the most significant result was the vandalism inflicted on 30% of the trees (Pauleit et al., 2002). In comparison with the precedent studies, the number of damaging agents identified in the SJA park was greater, since the identification in some cases was at a specific level. Even though the identification of a greater number of damaging agents per tree implies a greater effort, but it has the advantage of providing a most complete picture of all damages that can be diminishing tree health and which are the most frequently damaged organs (**Figure 3**). Finally, this information will allow establishing prompt management actions.

4.3. Damaging by Tree Species and by Sections

Canker Seiridium was the most aggressive damaging agent on Mexican white cedar and Mediterranean Cypress. This kind of damage is known to affect trees growing under stress conditions (García-Díaz & Cibrián-Tovar, 2007). In the infected trees, the size of the wounds sometimes surpasses 50% of the circumference of the trunk. Fungi that are active on the surface of the wound can also deteriorate the structures of lower woody tissues, weakening the tree. A weak and structurally useless tree can die and become a hazard to people nearby (Purcell, 2014; Saavedra-Romero et al., 2019b). This type of disease is known to have a long-term effect and is favored by poor soil conditions, inadequate cultural practices (wounds caused by mowing) and a high plantation density, which favors the spreading of the pathogen. An additional factor that may be contributing to the increase in Seiridium canker incidence in the SJA urban forest is the lack of preventive measures, since there are no programs for cutting down and tree removal of diseased or dead trees, leading to the year-round presence of inoculum.

Australian pine and silk oak were the species with the highest bleeding incidence. In the short term, in the last species, it could be increased by the excessive moisture, exacerbated by the organic residues incorporation at the root collar area and the inadequate planting. This kind of information will help to implement better management strategies for this species, since it could be a bacterial disease. In Californian pepper the presence of galls reached an incidence of 42% and the causal agent identified in previous studies is *Agrobacterium tumefaciens* Smith El Townsed (Fucikovsky, 2007).

Regarding stem damage, inappropriate cultural practices, for example, damage by the mowers, poor irrigation practices (too much or too little water), inadequate planting depth (too shallow or too deep), among others (Costello et al., 2003), could be contributing to the damage recorded in SJA park. Finally, from the perspective of management, it may be possible in the short term to prioritize the allocation of resources to improve the condition of these species and sections of the park.

These results show that the most frequent species, and therefore those with the highest predisposition to this type of cortex damage, exert a considerable effect on the percentages found in each section. In general terms, a large proportion of the damage identified in the SJA urban park also includes other factors, like poorly implemented management activities and increasing stress caused by the thousands of visitors who visit this park annually. In this sense, in some sections of the site, it was observed that sports and recreational activities favor tree damage (Saavedra-Romero et al., 2019b). Two important factors that could be increasing the incidence of damage is the aging of those trees that are now around 50 years old and site conditions since trees were planted in saline soils (SMA, 2012).

4.4. Damage Severity Index and Health Categories

The Damage Severity Index was implemented as a tool to evaluate the degree of damage caused by multiple damaging agents in urban trees (**Table 1**). This index integrates all the scores of the variables assessed in the field, in a single additive value (Andrews et al., 2004, Conkling et al., 2005). The combination of scores of each variable (Equations (1) and (2)) express in a numerical way the severity of the damage *in situ*. The final DSI score reflects health condition of the tree and for practical purposes, that one, or more damaging agents are present, so, the higher the value (ISD average > 8.6), the greater the damage (**Table 4**). High scores were associated with damage circumscribed to the stem and root collar area, in combination with severities greater than 50%. While low scores (<6.6) defined the trees with foliar damage mainly, and to a lesser extent in branches and trunk, and damage severity less than 29%. Regarding species and sections of the forest, the following was found (**Table 3**). In the first group, that is, with high IDS scores, Mexican white cedar, tamarisk and California pepper were found, as well as sections J and H, with low scores, tropical ash, everblooming acacia, red gum, and section G.

Finally, the general health condition for species and sections of the park, was grouped into three categories (**Table 4**). The first, classified as good health, was for ash tree, red gum and everblooming acacia. In opposition, the poor health was for Mexican white cedar, tamarisk and California pepper.

The generation of indexes to explain biological topics is diverse worldwide. These include, for example, those to determine quality of agricultural and forest soils, trends in their health, promote and improve management practices and to make them more sustainable (Andrews et al., 2003, 2004; Amacher et al., 2007). More recently, the Soil Conditioning Index (SCI), like a predictive tool to assess trends in soil organic carbon (Karlen et al., 2008). On the other hand, in commercial forest plantations, they have been created to determine the extent of damage and estimate future losses (Stone et al., 2003a), among others. These indexes, however, have limited application in urban landscapes where geographic conditions, diversity of tree species, and site conditions differ substantially. Among the indices that have been generated for urban green areas, the Rapid Urban Site Index (RUSI) stands out, which accurately relates the health and growth of the urban tree (Scharenbroch et al., 2017). In the future, these indexes may become attractive and fruitful as monitoring tools. With this background, the DSIs obtained in the present study allowed in a simple way, determine the current tree health status, and in the long term help in the selection of tree species, and improve management activities, in order to extend the lifespan of trees and to preserve their benefits.

5. Conclusion

The tree damage indicator was applied to assess urban tree health at the SJA Park. Using this protocol, 27 damaging agents were identified. In 29.60% of the trees, one type of damage was recorded, and 21.90% presented two. Trunk and branches were the most affected organs. Cankers, galls, the pepper tree psyllid and the red gum lerp psyllid were the most frequent damaging agents. Australian pine, red gum, Mediterranean cypress, Mexican white cedar, and California pepper were the most affected species.

The DSI ranged from 3 to 17 and the average was 7.90. Sections J and H and the species California pepper, Australian pine, and Mexican white cedar presented the highest DSI. Based on the health categories established in this study, the tree population had a moderate health condition, while the aforementioned sections and tree species showed the poorest. Finally, tree damage identification and DSI scores will help to identify tree species and urban green areas in danger of having their potential growth decreased or mortality rates increased. Counting with this information, will help plan activities, allocate resources, and train the staff in charge of carrying out management practices in the best possible way.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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