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Tree architecture models, canopy maintenance, and associated root problems of angsana (*Pterocarpus indicus* Willd.) in the urban trees of Yogyakarta

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Abstract. Troll's architecture model of angsana (*Pterocarpus indicus* Willd.) serves as a shading tree in most of the main roads in Yogyakarta. However, its lateral roots potentially damage sidewalks and cause accidents to people. This research was aimed to understand the damage types associated with the root problem, the relationship between stem diameter and root development, and angsana maintenance. Data were collected during January-July 2015 by inventory, tree identification, and interview. We categorized the types of damage into three scales, respectively: scale 1. Cracks in pots if the trees grow in pots, slight cracks on the road surface; scale 2. Roots start to slightly appear on the road surface and cause cracks in the road or damage the pots; scale 3. Roots appear on the road surface and cause a bend that harms road users or pots raised by roots. There is a relation between the size of stem diameter and its damage. Angsana starts to cause damage with a diameter of 20–29 cm on the divider and 30–39 cm on the sidewalk. We suggest that i) angsana should be planted in areas where the roots could grow freely, ii) applying alternate planting between the young and the old angsana, iii) root cutting.

1. Introduction

A city is a densely populated area [1] and a center for human activities [2]. A city also represents the interests of some land-based elites [3]. In Indonesia, the interest of microclimate, aesthetic, and water catchment areas, according to Regulation No. 41/1999 regulated in Article 9 paragraph (1) [4], is designated as a certain area as an urban forest. The development of urban forests is based on the location and size of the forests in which the arrangement is carried out by the government in municipalities and districts. Due to the limited area and different types of land use, the conflict of land use interests from various sectors is a common matter [5]. The issue of land availability in the city and the effectiveness of land management is the key to urban forest development [6].

Corridor and patch areas have the greatest effect on urban forest biodiversity [7]. The vegetations that grow in these areas play an important role in order to support the ecological processes [8,9] and the health of the social ecosystem [10,11]. According to the ecological point of view, the biodiversity of

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species can also help to keep the population genetic process under the various landscape structures required for the greater importance of genes flow and the genetic basis in nature [12].

In the urban forest of Indonesia, angsana (*Pterocarpus indicus* Willd., Fabaceae) is one of tree species that serves as a shading tree and a Pb gases absorber from the atmosphere [13]. This drought-tolerant tree that Southeast native has a troll architecture model, plagiotropic branches, sympodial trunk, and umbrella crown [13] (see figure 1 and figure 2). The aesthetic value of angsana come from its yellow flower. Its flowers compound bunches located at the end of the twig or emerged from the axillary leaf [14]. Angsana produces a lot of flowers from May to August. The flowers live shortly and are fragrant. New leaves are bright green and bloom in the rainy season [15]. The shape of the leaves is oval, the tip is tapered, dull and shiny, ranging 4-10 cm in length and 2.5-5 cm in wide, the petiole is approximately 0.5-1.5 cm [14]. Growing rates of this tree are rapid with the size of mature height is about 18 m or more. A crown diameter could expand to approximately 13.5 m (45 ft) [16].

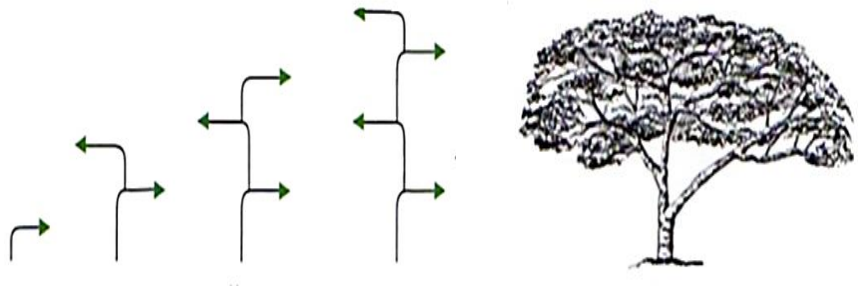


Figure 1. A troll architecture model with plagiotropic branches, sympodial trunk, and an umbrella crown (image source: [17]).



Figure 2. Angsana trees in UGM.

Angsana is easy to cultivate from seed handling to germination or from vegetative propagation [18]. Its lateral root with inner spreading root system capable of supporting roots to absorb water and nutrients [19]. However, the root of angsana grows fast, enormously and near the soil surface. Therefore, this species is not recommended to be planted in the sidewalk and other related public facilities [20]. Since 2005, the choice of angsana as a roadside species in Indonesia is decreasing because the branches are weaker, fragile, and could break easily. It would likely endanger people and the pedestrians [21]. Angsana is suitable to be planted in parks, garden, and avenues where there is a room for the roots. It could grow well in the most dominant type of soils but grows best in deep, well-drained soils in humid areas. Although deeply rooted, angsana often develops superficial roots that potentially damage sidewalks. The dense shade keeps most of the other plants from growing beneath it. The falling leaves and pods may cause a litter problem [16]. Therefore, this study is required with the objectives: i) to understand the damage types associated with the root problem, ii) to understand the relationship between the stem diameter and the root development, and iii) to improve the maintenance of angsana.

2. Method

2.1. Inventory

Data on the angsana species have been collected by inventory during January-July 2015 on seven roads in Yogyakarta. Those are Sudirman, Kusumanegara, Laksda Adisucipto, Glagahsari, Affandi, Brigjen Katamso and Suryotomo. The selected angsana on the seven roads have been planted in the median and the sidewalk and have caused infrastructure damage. The data gathered are the diameter, the width of the canopy, the damage scoring, and the planting type on a predetermined path. The measurement of the stem diameter was determined by measuring the 1.3 m altitude using a tape meter. The results of the diameter measurement of trees can be categorized into five classes: 20-29 cm, 30-39, 40-49, 50-59, and more than 60 cm.

This study also used scoring methods in order to assess the variation of damage level. The score level is based on the results of survey in the field. Mukhlison [22] has also done the scoring method in order to assess the fulfilment of silvicultural requirements in the selection of tree species for the urban forests of Yogyakarta. This study used a score of 1-3.

2.1.1. Score 1. Score 1 is reserved for trees growing in the pots that have roots causing cracks in pots (figure 3) or trees grow in the roadside that has roots causing slightly cracks on the road surface.

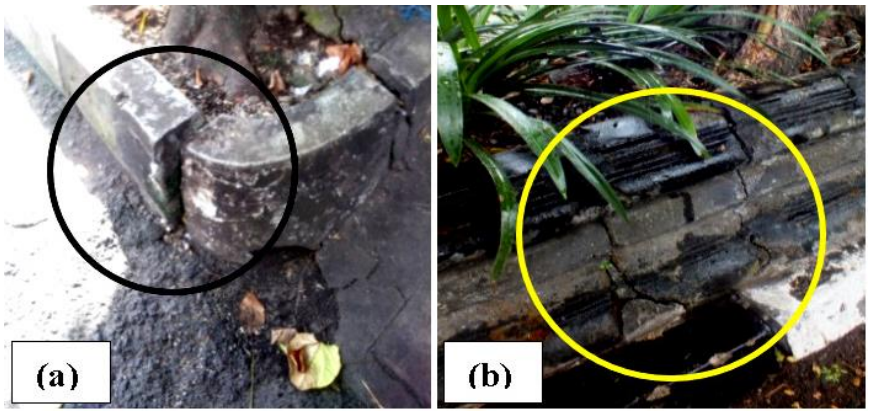


Figure 3. Damage score 1: roots cause cracks on pots (a) & (b) (image source: [23]).

2.1.2. Score 2. Score 2 is reserved for trees with roots that start to slightly appear on the surface and damage the pots or roots slightly appear on the road surface (figure 4) and cause the road become cracks (figure 5).



Figure 4. Damage score 2: roots start to slightly appear on the surface and damage the pots (image source: [23]).



Figure 5. Damage score 2: Roots slightly appear on the surface of the road and cause cracks in the road (image source: [23]).

2.1.3. Score 3. Score 3 is reserved for trees that have roots that appear to the surface of the road and have the pots raised (figure 6) or cause a bend that can harm road users (figure 7).



Figure 6. Damage score 3: roots appear to the road surface and make the pots raised (image source: [23]).



Figure 7. Damage score 3: roots appear to the road surface and cause a bend that can harm road users (image source: [23]).

2.2. Interview

The interview was focused on finding out some data on the maintenance of angsana in Yogyakarta, including how big the influence of angsana's roots on the road damage and the presence or absence of action to deal with the damage caused. The selected respondents were a person in charge of 1) Residential Service and Regional Infrastructure of Yogyakarta and 2) Environment Agency of Yogyakarta.

Interview with the person in charge of the Environment Agency was carried out to know the role of the Environment Agency in managing urban open space in Yogyakarta and the maintenance activities do. Two interviewed persons were Mrs. Indiya Widyastuti as the head of the section of gardening the city and one of her staff. In the department of Residential Service and Regional Infrastructure, we interviewed Mr. Sigit as the head of a section for road and bridges (figure 8).



Figure 8. The interview process with the head of the road and bridge section (Mr. Sigit, left side), Residential Service and Regional Infrastructure of Yogyakarta (image source: [23]).

Results of interviews were then analyzed through qualitative description by doing a comparison between the diameter size and damage score at each road, as well as describing the types of maintenance performed on the angsana in the urban open space of Yogyakarta.

3. Result and discussion

3.1. The Characteristics of damage

3.1.1. Affandi road. Affandi road has a total length of 333 meters with a road width of 13 meters. The length of the urban open space is approximately 289.01 meters. There are 28 trees. Angsana dominates this road with planting type placed on the median road in buis concrete and pots 68 cm in height (figure 9). Characteristics of damage on this road are scores 1 and 2. Damage score 1 is higher than score 2 (figure 10).



Figure 9. Angsana grows in Affandi road on the median road in the buis concrete and pots 68 cm in height (image source: [23]).

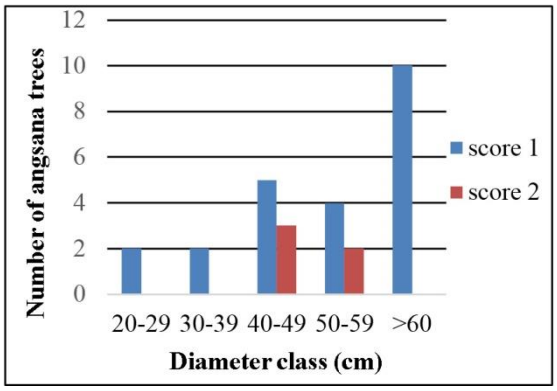


Figure 10. Characteristics of damage by the angsana root in Affandi road. *S*core 1 is higher than score 2.

Figure 10 displays score 1, which is the lowest level of damage, found in each grade of the diameter with the highest diameter class is > 60 cm. However, score 2 is only found in two classes of diameter, which is the 40–49 cm class, and the 50–59 cm class, with the highest grade at 40–49 cm. The trees categorized in score 1 amounts up to 23 trees, and trees with score 2 amounts up to 5 trees.

3.1.2. Glagahsari road. The total length of Glagahsari road is 1.093 meters with a road width of 10 meters. We observed 94.41 meters (8.6%). The trees are on the right-left of the road or in the sidewalk area (pedestrian). The space between the trees is about 1–2 meters (figure 11).



Figure 11. Angsana grows in Glagahsari street on the right-left side of the road (image source: [23]).



Figure 12. Damage characteristics of score 3 by the root of angsana in Glagahsari street (image source: [23]).

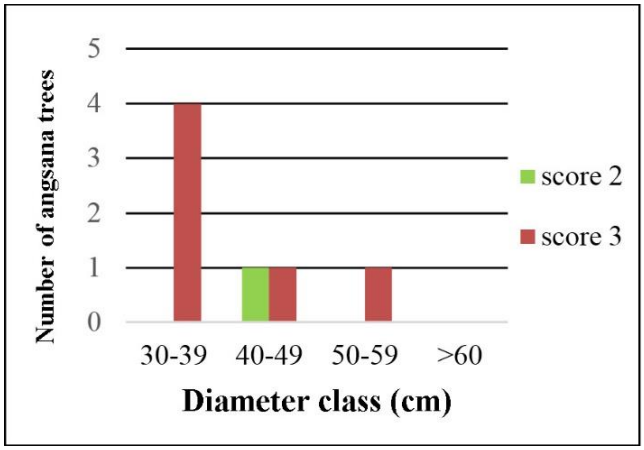


Figure 13. Damage characteristics by the root of the angsana in Glagahsari street is dominated by score 3.

We recorded 51 angsana trees, but only 7 trees that caused damage at Glagahsari street. Figure 12 and figure 13 displays the extent of damage encountered on this road is score 2 and score 3. Six trees have a score of 2 with a diameter range of 30–39 cm. One tree has a score of 3, which has the highest level of damage. This tree is categorized in the diameter class of 40–49 cm.

3.1.3. Kusumanegara street. Kusumanegara street is a two-way traffic lane, 2.400 meters long, 12 meters wide with sidewalks on two of the roadsides; each sidewalk has a width of 2 meters. The length of the observed road was 724.59 meters (30,2%). There are 186 trees with a space between the trees of 2–3 meters.

In Kusumanegara street, score 1 has the largest number of all scores. Score 1 almost exist in all diameter classes in which the biggest diameter size could be classified in diameter class ≥60 cm (figure 14). Trees included in score 2 are fewer, but the largest diameter size from this score can be classed in ≥60 cm of the diameter class. Score 3 has 5 trees and all those trees have been included in ≥60 cm diameter class. The characteristics of damage caused by angsana roots are displayed in figure 15-figure 17.

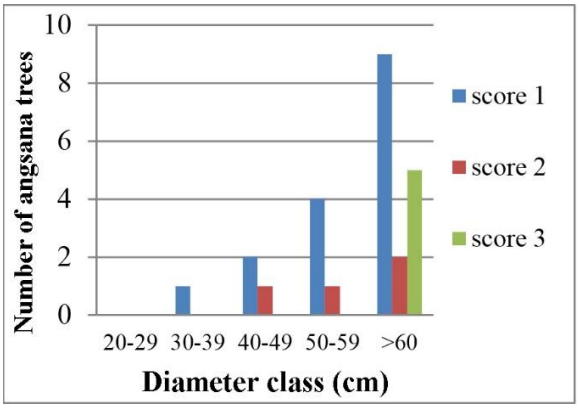


Figure 14. Damage score by angsana roots in Kusumanegara road, Yogyakarta.



Figure 15. Damage characteristics of score 1 by angsana roots in Glagahsari road (image source: [23]).



Figure 16. Damage characteristics of score 2 by angsana roots in Glagahsari road (image source: [23]).



Figure 17. Damage characteristics of score 3 by angsana roots in Glagahsari road (image source: [23]).

3.1.4. Laksda Adisucipto road. The Laksda Adisucipto road has a total length of 414 meters, width of 14 and a sidewalk of 2 meters on two sides of the road. We observed the distance of 53.31 meters (12,9%) and recorded 3 trees with damages characteristics of score 2 and score 3 (figure 18). Two trees, which are categorized in score 3, have the range diameter class of 50-59 cm and ≥60 cm, while the other one (score 2) has a diameter class of ≥60 cm. In Laksda Adisucipto street, the angsana root damaged the sidewalk (figure 19) and cracked the asphalt in the roadside (figure 20).

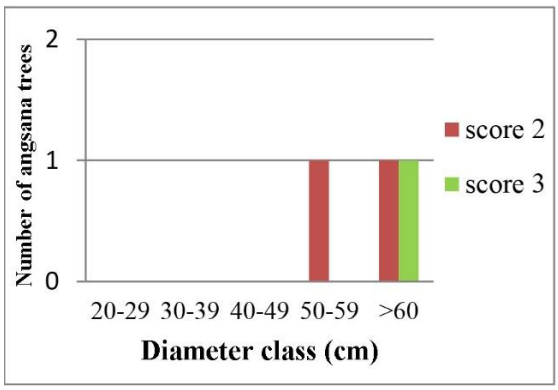


Figure 18. Damage score by angsana roots in Laksda Adisucipto road, Yogyakarta.



Figure 19. Damage characteristics of score 2 by angsana roots in Laksda Adisucipto street (image source: [23]).



Figure 20. Damage characteristics of score 3 by angsana roots in Laksda Adisucipto road (image source: [23]).

3.2. Relation between the size of the diameter and the characteristics of the damage

According to Tubbs [24], the tree rooting system spreads following the size of the crown diameter, however its distribution under the ground is uneven. One side of the root may grow more elongated up to the drains, while on the other side of the roots it may grow shorter than half the size of the crown diameter. All the related studies about the tree canopy and root system using a variable diameter size of trees are less than 18 cm. This indicates that the relationship between the tree canopy and the root system will likely change in the bigger and older tree. Wagar and Barker [25] argue that tree, which has a larger size are more likely to cause conflicts or damage public facilities. As a majority, size variations can be

reflected from the diameter size. Wong et al. [26] discovered that a large number of trees begin causing potential damage to the infrastructure when the diameter size reaches 11–20 cm in dbh, except in the oak tree (*Quercus* sp.) and *Aesculus* sp. Those two trees begin to cause damage when the diameter reaches above ≥20 cm.

Smaller diameter trees have numerous lateral roots scattered as a form of self-defense to compete with other trees in absorbing nutrients from the soil. Field observations also show that angsana is highly potential to damage when it reaches the diameter size of 20–29 cm. Intense competition for absorbing nutrients in the soil has begun when angsana reaches the size of those diameter class.

The majority of trees have roots near the soil surface, as the nutrients are obtainable there. However, for certain species, growing roots tends to cause damage to the public facilities because appearing in the surface. Considering the trees roots is an important factor due to reducing the impact of the damage. This tree should be planted in the area where the roots could grow freely i.e. in the median road which is wide enough. Other methods that can be taken include: applying silviculture techniques with alternate planting between young angsana and old angsana. If the old angsana has reached a diameter and can damage the road, it will be cut down and replanted with a young angsana. Cutting the roots could also be done when the angsana root begins to lift the asphalt. If such treatment is not possible, the tree species may replaced with local native species that serve shading, filtering, etc. In the case of Yogyakarta, the selection of this species can refer to the historical species on the philosophical axis of Yogyakarta, such as *Mimusops elengi*, *Tamarindus indica*, *Manilkara kauki, Inocarpus fagifer*, *Stelechocarpus burahol,* and *Ficus benjamina* [27].

3.3. Maintenance of angsana tree

The management of the open spaced areas of the urban part of Yogyakarta is not decently done only by the Environment Agency, because the urban forest in terms of its existence is part of an urban planning so that the affairs contained therein must intersect with other agencies within the government. The Environment Agency (*Badan Lingkungan Hidup*) performs almost all the maintenance activities of the trees in the open spaced area of the urban parts of Yogyakarta. The activities in managing open space in the urban areas include fertilizing, watering, pruning, monitoring and planting. For the implementation, due to limited tools, Environment Agency mandates the maintenance by third parties based on the standard operating procedure. Maintenance activities undertaken by third parties also include installation of the traffic signs, crown pruning, removal of the tree trunks, and weeds.

The third parties prune it 3 times for 10 months for the angsana in the divider with a height of less than 7 meters. Pruning can also be done when the angsana has reached the age of 5 years or the condition of its branch has for a length of more than 2.5 meters to the road, due to its possibility to block the view of the road users. Maintenance of the angsana crown is done by cutting out the canopy so it does not disturb the power cord that is visible for lighting in the city (figure 21). According to the regional regulation of the Yogyakarta Special Province number 1/1962 concerning intermediation against the dangers of strong power flows above the surface upon the request of the state electrical company, the governor can give an order to dismantle the towering objects or cut the trees that can harm and disrupt the flow of electricity.



Figure 21. The cutting of the crown of angsana due to an electric wire problem (image source: [28]).

After finishing the pruning on the tree crown, the third party continue to clear the rest of the tree cutting and weeding quickly. The trash from pruning and weeding are removed by putting it in transport vehicles out of the site. The next step is watering every two days in the morning or afternoon, especially during the dry season by using a watering vehicle. Watering in the morning aims to prepare the plants to face maximum temperatures during the day, to maintain water supply, humidity, the optimal temperature for maximizing the process of photosynthesis. The watering must be done carefully to reduce the extent of damage to the vegetation and does not interfere with people passing through the watering site.

The treatment of roots is different with canopy treatment. Root treatment activities are only done when it is needed. For instance, when angsana roots have emerged to the surface of the road and disrupt people who pass by. Residential and Regional Infrastructure Service will monitor this condition every two days. Furthermore, through monitoring activities, the damage impact caused by the angsana roots can be recognized through the reports of the surrounding communities. We acknowledge that not many activities are conducted specifically to prevent rooting to the surfacing and cause damage to the public facilities. Related agencies such as the Environment Agency and the Residential and Regional Infrastructure Service acknowledge that they used of concrete buis in the beginning of planting activities as an effort to minimize damage to the infrastructure in the future. Despite the soil that cover the trees with asphalt, concrete, or other materials, it might inhibit the supply of water and air to the roots. Supporting better site condition surrounds the trees will help them thrive in good condition.

The last activity done is supervision and monitoring conducted periodically for one year by the third parties together with the Environmental Agency. They will check the conformity of the work with the aspects of the letter of a contract agreement. We hope this contract letter is certainly in accordance with silvicultural treatments of trees in the urban open space. Limited accomplishments referring to this matter could affect the trees which are not surviving [29]. Seven to 10 years is an average age of planted trees in the street and this number proves the negative return on investment [30].

4. Conclusion

Raised asphalt, crack pavement and crack pot walls on the divider are some damage types that derived from surfacing roots of the angsana (*P. indicus* Willd.) in the urban open area of Yogyakarta. The size of the tree diameter is correlated with the condition of angsana root in terms of assessment score of damage characteristics. Angsana is potentially damaging when it reaches the diameter class of 20–29 cm for tree planting in the divider section of the road and the diameter class of 30–39 cm for the tree in

the median road. In order to reduce the impact of the damage, we suggest: i) angsana should be planted in the area where the roots could grow freely, ii) applying silviculture techniques with alternate planting between the young and the old angsana, iii) cutting the roots can also be done when the angsana root begins to rise in the asphalt.

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