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HAZARD-RATING ASSESSMENT OF ROADSIDE TREES AT UPM USING GEOSPATIAL TOOL

JONATHAN TENG YI CHUON[1], ALIAS MOHD. SOOD[1*], AMAT RAMSA YAMAN[1], ISMAIL ADNAN ABDUL MALEK[1] AND KASAWANI IBRAHIM[2]

[1]*Faculty of Forestry, Universiti Putra Malaysia.*
[2]*Faculty of Science and Technology, Universiti Malaysia Terengganu, Malaysia.*

**Corresponding author: ms_alias@putra.upm.edu.my*

Abstract: Roadside trees provide benefits in the form of green landscape, human health, storm-water management, carbon storage and etc. However, they are potentially hazardous to their surroundings. Hence, there is a need to evaluate these trees as to whether they are hazardous or not. Hazard-rating assessment in the context of urban trees is the evaluation of the hazard of trees and how likely they are to fail as well as how severe in terms of damage that they could cause to their surroundings. In this study, roadside trees hazard rating was assessed automatically using a customised ArcMap™ application using Visual Basic for Applications (VBA), known as UPM-Malaysian Urban Trees Information System (UPM-MUTIS), developed by Faculty of Forestry, UPM. The study is to determine the capabilities of UPM-MUTIS in generating hazard-rating assessment. The study area covered part of UPM's academic zone. Result depicted that out of 909 trees assessed, 99.8% (907 trees) were categorised as 'Medium' hazard rating and no trees with 'Low', 'High', and 'Severe' hazard rating. Upon deriving hazard-rating assessment, abatement activities were subsequently proposed in which was mainly various degrees and types of pruning. This paper details out the hazard-rating assessment process of roadside trees and the succeeding abatement activities proposed at the study site.

KEYWORDS: tree hazard-rating assessment, GIS, urban trees

Introduction

Roadside trees provide benefits such as rainfall interception and tempered release into surface waters, reduced air pollution through leaf uptake of pollutants, positive effects on the psychological health of people and etc (Hauer and Johnson, 1992). However they are bound to be hazardous to their surroundings. These hazardous trees may have structural defects in the roots, or branches. Hazard trees are trees that have structural defects in the roots, stem, or branches which may cause the trees or trees' part to fail, where such failure may cause property damage or personal injury (Joseph, 1992).

Hazard-rating assessment or tree-risk inspection in the context of urban trees is the evaluation of the hazard of trees and how likely they are to fail as well as how severe in terms of damage that they could cause to their surroundings. The purpose of tree-risk inspections is to identify defective trees in target areas, assess the severity of the defects, and recommend corrective actions before tree failure occurs. Tree-risk ratings can assist communities in quantifying the level of risk posed to public safety and in prioritising the implementation of corrective actions (Albers, 1992).

The word hazard, for both lay-people and professionals, denotes that some threshold of risk has been surpassed. Hazard also conveys the immediacy of structural failure as determined by a tree professional. The hazard concept demands a complete evaluation and assessment of risk which reaches a management threshold where the situation cannot be allowed to continue. This demands an evaluation that is based on spatial information for better visualisation and data management.

Geographic information system (GIS) software is therefore a logical choice for storing and manipulating urban tree-resource data. GIS provides a logical foundation for any data

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collection, analysis and planning initiative related to a community's urban and community forest. GIS programs such as ArcGIS and ArcPad are powerful and important tools to consider, whether looking at the overall urban forest, or managing individual trees growing along streets or in parks. Whether looking at the urban forest from a broad scale, or more closely examining individual trees, a GIS provides a strong backbone to any useable system (David *et al.,* 2003). Consequently, the best solution is to acquire a comprehensive urban forest-management system integrating relational database with GIS and decision support system.

UPM-MUTIS (Universiti Putra Malaysia-Malaysian Urban Trees Information System) is a programme jointly designed by the certified arborists from International Society of Arboriculture (ISA) and GIS specialists from the Faculty of Forestry, UPM. The programme was established to assist the tree technicians in their daily-routine management activities of the urban forest. It's a comprehensive urban tree inventory and urban tree management system that provides decision support system in determining the hazard risk and suggesting abatement for subsequent actions as well as generating conforming reporting (Alias, 2009).

The objectives of this study are: i) to determine the hazard rating of roadside trees at UPM academic zone and ii) to determine the efficiency of UPM-MUTIS in evaluating hazard risk of roadside trees at UPM academic zone.

Methodology

Study Area

The study area was conducted at Universiti Putra Malaysia (UPM), Serdang. The total area is 105.22 ha encompassing part of academic area which was divided into four zones; A, B, C and D (Figure 1).

Method

This study used the QuickBird satellite image of UPM which has spatial resolution of 0.6 m. Vector layer of UPM's boundary was obtained

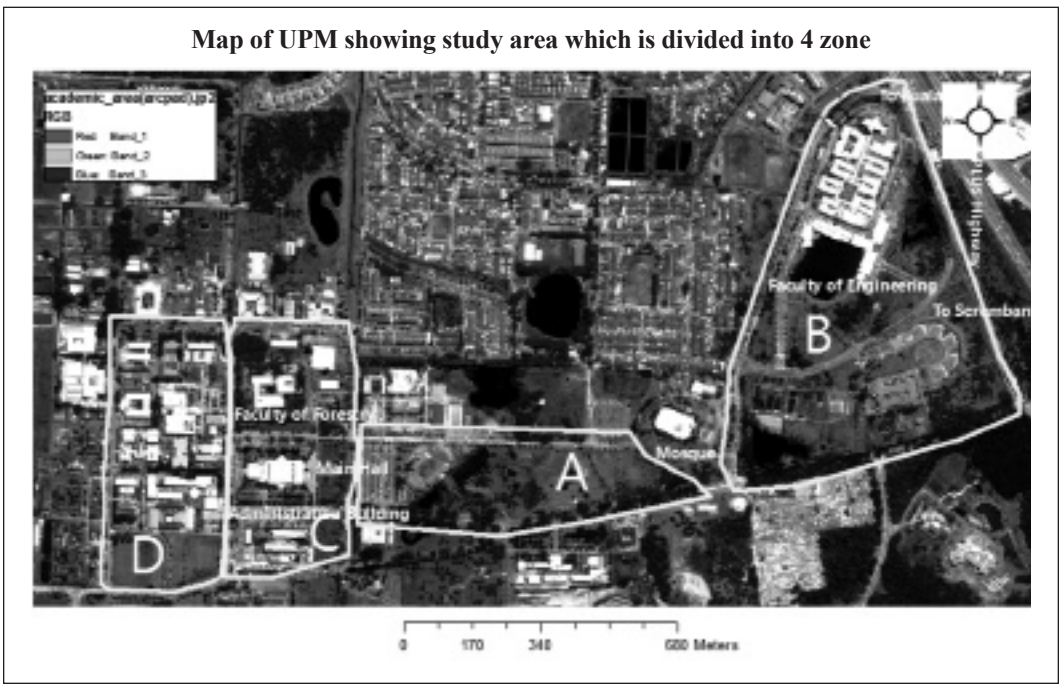

Figure 1. Study area at UPM which is divided into 4 zones.

from Taman Pertanian Universiti (TPU), UPM to identify the boundaries of UPM in the satellite image. Screen digitising of trees in UPM was done using ArcMap™ to produce a tree vector layer and trees were given an identification number and tagged on the ground. Tree-inventory and hazard-assessment form were prepared to assist in ground-data collection (Figure 2). Ground-data collection consisted of two (2) parts: i) hazard assessment and (ii) tree inventory. Hazard-assessment parameters were filled in the form following the International Society of Arboriculture (ISA) suggested format and hazard rating for each tree were determined during ground checking. ISA form format was based on the handbook "A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas" (Matheny and Clark, 1994). Ground activities included collecting basic information of trees such as height, GPS and coordinates. Upon finishing ground data collection, the data, except for hazard rating (which were evaluated earlier on the ground) was input into the customised ArcMap™ application, UPM-MUTIS system to generate the system's hazard rating which is based on the formula for hazard rating.

Hazard rating is derived from three (3) components: (a) Failure Potential (FP); (b) Size of Parts (SOP) and; (c) Target Rating (TR). Component a) has 3 sub modules: (i) site conditions; (ii) tree defects and; (iii) tree health. In the sub modules, there were attributes for each parameter. These attributes were given a scoring based on the status, magnitude or severity of each parameter. The accumulated scores of each sub module were totalled up to calculate failure potential. The formula of hazard rating is as follows:

Hazard rating (HR) = Failure potential (FP) + Size of parts (SOP) + Target rating (TR)

According to the Standards & Specifications Palo Alto Municipal Code, Chapter 8.10.030 (Anon, 2001) failures (FP) do not occur at random, but are the result of a combination of defects and aggravating conditions. The scope of the professional evaluation will include structural defects in the tree (including branches, trunk and roots; and, if necessary, shall employ the use of the most current methods of internal decay inspection available); soil/slope and/or creek bank stability; individual species susceptibility to failure; pruning; history; decay weaknesses and any other compromising or pertinent factors considered by the consultant. FP scoring is based on accumulation score ranges from 95 – 342 with least failure at lower range.

Standards & Specifications Palo Alto Municipal Code, Chapter 8.10.030 (Anon, 2001) stipulated that evaluation of target rating (TR) shall include people, structures or property use and occupancy that are imminently threatened. Property use shall consider what structures or activities are under or around the tree (e.g. building, parking, pedestrian, recreational, utility lines, hardscape, etc.). Occupancy shall consider frequency of the use (occasional, intermittent, frequent or constant), and whether the *target* will be present when failure occurs. TR scoring is based on accumulation score ranges from 1 – 4 with least frequent at lower range. Evaluation of other factors that contribute to aggravating conditions shall also be considered, such as: size of part (SOP) of the affected defect (i.e. a small branch vs. the entire tree uprooting); significant potential of fire, utility line contact or catastrophic effects, etc. SOP scoring is based on accumulation score ranges from 15 – 75 with smallest size (in cm) at lower range.

HR is categorised into four levels of summation based on the cumulative points for each component as follows: (i) low, (ii) medium, (iii) high and (iv) severe. Details of the HR levels are shown in Table 1 (Albers, 1992).

A sample of 32 trees with 8 trees from each zone selected to compare the hazard rating of the system with the hazard rating on the ground as accuracy assessment of the UPM-MUTIS system.

Results and Discussions

In the study site, there were 36 species of planted roadside trees. The most dominant was *samanea saman* with 149 trees (16.4%), followed by *tamarindus indica* with 124 trees (13.6%).

Analysis from UPM-MUTIS depicted that, out of 909 trees assessed, 99.8% (907 trees)

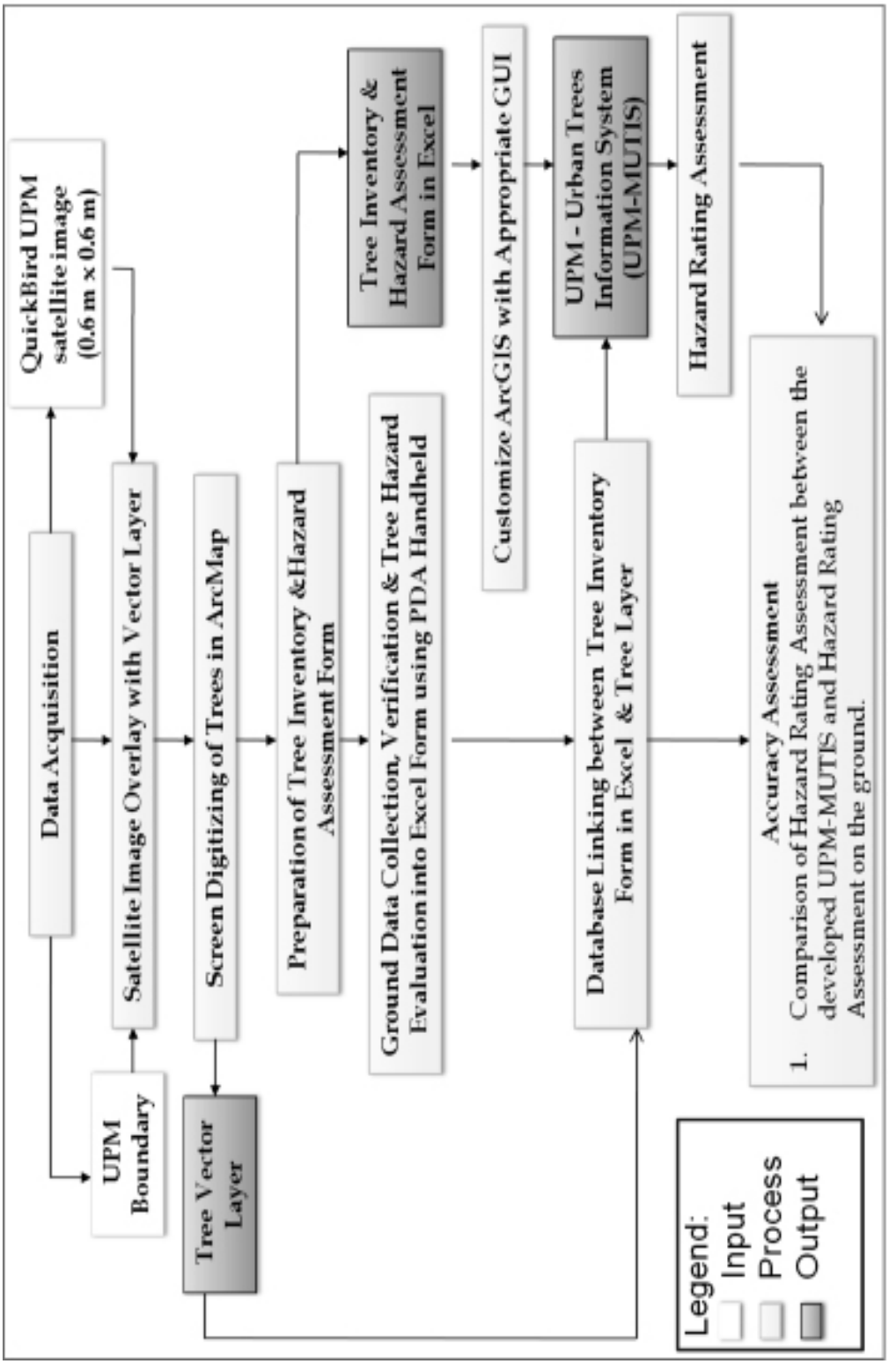

Figure 2. The flowchart of the overall activities carried out in this study.

Table 1. Details of the HR level and their descriptions.

Level	Points	Classified	Remarks
1	3-4	Low	A tree present with no or minimal risk assessment or associated risks
2	5-7	Medium	A tree present with known risk assessments, or as yet undetermined associated risks
3	8-10	High	A tree "at risk" of catastrophic failure or with a significant target profile potentially leading to great injury and harm. A "tree at risk" has potential for becoming a hazard tree.
4	11-12	Severe	A tree that has a major structural fault that could lead to catastrophic loss and it has an identifiable target (people or property).

were categorised as 'Medium' hazard rating and no trees with 'Low', 'High' and 'Severe' hazard ratings. This was because most of the trees in the study area were roadside trees which had TR of '3'. Table 2 showed the hazard rating of trees in the study area according to zones.

From Table 2, there were 832 trees and 75 trees which had hazard rating of 6 and 7 respectively. Zone B has the highest number of trees with hazard rating 7 (medium). This was because all of these trees are from *roystonea regia* species and had high SOP factor. There were 2 trees which do not have hazard rating as they were removed by the authorities. Table 3 showed the result of hazard rating of trees according to species.

From the Table 3, there were only three species with hazard rating of 7 in which the highest was *roystonea regia* (67 trees) followed by *samanea saman* (6 trees) and *callerya atropurpurea* (2 trees). Table 4 showed the accuracy assessment of hazard rating between UPM-MUTIS and ground evaluation.

The formula to calculate accuracy assessment of hazard rating is as follow:

Accuracy assessment = (Number of trees with correct hazard rating/ Total number of sampled trees) X 100

Hence, the accuracy assessment for this study
= (30/32)*100%
= 93.75%

Conclusions

The tree hazard assessment process has provided some very useful and informative tools for evaluating and planning of roadside trees. The GIS platform of UPM-MUTIS provides better visual understanding of the hazard situation. This study concludes that most of the roadside trees at the academic area of UPM are safe in which 99.8% (907 trees) of total trees inventoried are classified as medium hazard rating. Based on the high accuracy assessment achieved by UPM-MUTIS, it is perceived as a potentially suitable tool for accurate hazard-rating evaluation of roadside trees.

Table 2. Result of hazard rating of trees according to zones.

Zone/Hazard Rating	3	4	5	6	7	8	9	10	11	12	None*	Total
A	0	0	0	167	6	0	0	0	0	0	0	173
B	0	0	0	65	67	0	0	0	0	0	0	132
C	0	0	0	257	1	0	0	0	0	0	0	258
D	0	0	0	343	1	0	0	0	0	0	2	346
Total	**0**	**0**	**0**	**832**	**75**	**0**	**0**	**0**	**0**	**0**	**2**	**909**

*Trees removed by the authority after been tagged.

Table 3. Result of hazard rating of trees according to species.

Species/Hazard Rating	3	4	5	6	7	8	9	10	11	12	None*
Azadirachta excelsa	0	0	0	8	0	0	0	0	0	0	0
Borassus flabellifer	0	0	0	1	0	0	0	0	0	0	0
Callerya atropurpurea	0	0	0	62	2	0	0	0	0	0	0
Callistemon citrinus	0	0	0	15	0	0	0	0	0	0	0
Calophyllum inophyllum	0	0	0	36	0	0	0	0	0	0	0
Caryota mitis	0	0	0	1	0	0	0	0	0	0	0
Casuarina equisetifolia	0	0	0	6	0	0	0	0	0	0	0
Casuarina nobilis	0	0	0	34	0	0	0	0	0	0	0
Cinnamomum iners	0	0	0	4	0	0	0	0	0	0	0
Cinnamomum verum	0	0	0	33	0	0	0	0	0	0	0
Cocos nucifera	0	0	0	40	0	0	0	0	0	0	0
Cynometra ramiflora	0	0	0	4	0	0	0	0	0	0	0
Fagraea fragrans	0	0	0	9	0	0	0	0	0	0	0
Filicium decipiens	0	0	0	5	0	0	0	0	0	0	0
Firmiana malayana	0	0	0	7	0	0	0	0	0	0	0
Hopea odorata	0	0	0	2	0	0	0	0	0	0	0
Hura crepitans	0	0	0	20	0	0	0	0	0	0	0
Juniperus chinensis	0	0	0	4	0	0	0	0	0	0	0
Licuala grandis	0	0	0	1	0	0	0	0	0	0	0
Livistona chinensis	0	0	0	25	0	0	0	0	0	0	0
Melalueca alternifolia	0	0	0	8	0	0	0	0	0	0	0
Mesua ferrea	0	0	0	93	0	0	0	0	0	0	0
Mimusops elengi	0	0	0	21	0	0	0	0	0	0	0
Peltophorum pterocarpum	0	0	0	8	0	0	0	0	0	0	0
Pinus caribaea	0	0	0	4	0	0	0	0	0	0	0
Polyalthia longifolia 'Temple Pillar'	0	0	0	13	0	0	0	0	0	0	0
Pongamia pinnata	0	0	0	14	0	0	0	0	0	0	0
Pterocarpus indicus	0	0	0	1	0	0	0	0	0	0	0
Ptychosperma macarthurii	0	0	0	1	0	0	0	0	0	0	0
Roystonea regia	0	0	0	61	67	0	0	0	0	0	0
Samanea saman	0	0	0	143	6	0	0	0	0	0	0
Swietenia macrophylla	0	0	0	1	0	0	0	0	0	0	0
Syzygium jambos	0	0	0	4	0	0	0	0	0	0	0
Tamarindus indica	0	0	0	122	0	0	0	0	0	0	2
Veitchia merillii	0	0	0	21	0	0	0	0	0	0	0
Total	**0**	**0**	**0**	**832**	**75**	**0**	**0**	**0**	**0**	**0**	**2**

*Trees removed by the authority after been tagged.

Table 4. Comparison of hazard level between UPM-MUTIS and ground evaluation.

Tag_No	UPM-MUTIS	Ground Evaluation	Comments
A0054	medium	medium	Correct
A0294	medium	medium	Correct
A0322	medium	medium	Correct
A0452	medium	medium	Correct
A0461	medium	medium	Correct
A0531	medium	medium	Correct
A0594	medium	high	Wrong
A0610	medium	medium	Correct
A0615	medium	medium	Correct
A0672	medium	medium	Correct
A0696	medium	medium	Correct
A0734	medium	medium	Correct
A0760	medium	medium	Correct
A0816	medium	medium	Correct
A0875	medium	medium	Correct
A0880	medium	medium	Correct
A0897	medium	high	Wrong
A0914	medium	medium	Correct
A0930	medium	medium	Correct
A0947	medium	medium	Correct
A0962	medium	medium	Correct
A0974	medium	medium	Correct
A0983	medium	medium	Correct
A0993	medium	medium	Correct
A1008	medium	medium	Correct
A1011	medium	medium	Correct
A1019	medium	medium	Correct
A1026	medium	medium	Correct
E0004	medium	medium	Correct
E0029	medium	medium	Correct
E0033	medium	medium	Correct
E0036	medium	medium	Correct
E0039	medium	medium	Correct

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