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Automated Hazard Rating Assessment of Roadside Trees Using MUTIS ver 1.0

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ABSTRACT

Despite providing benefits in the forms of green landscape, human health, storm water management, carbon storage, etc., roadside trees are also potentially hazardous to their surroundings. Hence, there is a need to determine hazardous severity of these trees. Hazard rating assessment in the context of urban trees is the evaluation of the hazard by trees and how likely they are to fail as well as how severe in terms of damages that they could cause to their surroundings. In this study, roadside trees hazard rating was assessed automatically using a customized ArcMap™ and Visual Basic for Applications (VBA), known as Malaysian Urban Trees Information System (MUTIS), developed by Faculty of Forestry, Universiti Putra Malaysia (UPM). The study determined the accuracy of MUTIS in generating hazard rating assessment. The study area covered parts of UPM's academic zone. Results depicted that out of 909 trees assessed, 99.8% (907 trees) were categorized as 'Medium' hazard, while no trees had 'Low', 'High', and 'Severe' hazard rating. In this study, MUTIS assessment achieved 93.75% accuracy. Upon deriving hazard rating assessment, abatement activities were subsequently prescribed, in which the activities were mainly tree pruning with specified direction and intensity. This study indicated that MUTIS ver 1.0 can be an alternative tool to determine hazard rating of roadside tree.

Keywords: Tree hazard rating assessment, GIS, urban trees, MUTIS

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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, etc. (Hauer & Johnson, 1992).

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However, they are bound to be hazardous to their surroundings. Hazardous trees are trees that have structural defects in their roots, stem, or branches, which may cause the trees or parts of the trees to fail, where such failures may cause property damages or personal injury (Joseph, 1992).

Hazard rating assessment or tree risk inspection in the context of urban forest or roadside trees is the evaluation of the hazard of trees and how likely they are to fail, as well as how severe in terms of damages 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 risks posed to public safety and in prioritizing the implementation of corrective actions (Albers, 1993).

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

Geographic information system (GIS) software is therefore a logical choice for storing and manipulating urban tree resource data. In particular, GIS provides a logical foundation for any data collection, analysis and planning initiative related to a community's urban and community forest. GIS programmes 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, GIS provides a strong backbone to any useable system (David *et al*., 2003). Hence, the best solution is to acquire a comprehensive urban forest management system that integrates relational database with GIS and decision support system.

MUTIS ver 1.0 (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, Universiti Putra Malaysia (UPM). The programme was established to assist tree technicians in their daily-routine management activities of the urban forest. It is a comprehensive urban tree inventory and urban tree management system that provides decision support system in determining hazard risks and suggesting abatement for subsequent actions as well generating conforming reporting (Alias, 2009).

The objectives of this study are:

i. to determine the hazard rating of roadside trees; and,

ii. to determine the efficiency of MUTIS in evaluating hazard risks of roadside trees.

METHODOLOGY

Study Area

The study was conducted at Universiti Putra Malaysia (UPM), Serdang, which covers about 105.22 ha that encompasses parts of the academic area. These area was divided into four zones; A, B, C and D, as shown in Fig.1 below.

Methods

This study utilized the QuickBird satellite image of UPM, which has spatial resolution of 0.6 m as the base map. Digital vector layer of UPM's boundary was acquired from UPM's University Agriculture Park office to demarcate its boundary on the satellite image. Roadside trees were digitized using ArcMap™ to produce a tree vector layer and each tree was given identification number and tagged on the ground. Tree inventory and hazard assessment form were prepared to assist in ground data collection. The ground data collection consisted of two parts: i) hazard assessment and (ii) tree inventory. Hazard assessment parameters were filled in the form according to the International Society of Arboriculture (ISA). ISA form format was based on the handbook "A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas" (Matheny & Clark, 1994). Ground activities include collecting basic tree information such as height, tree performance, GPS location,

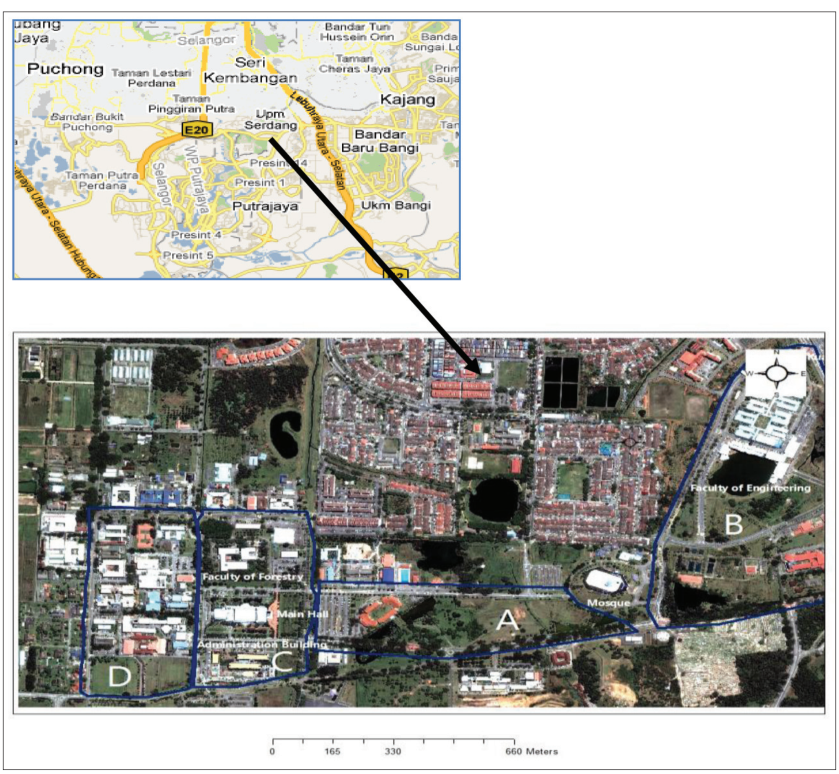

Fig.1: Study area at UPM which was divided into 4 zones A,B,C, and D

etc. Ground data were keyed into MUTIS to calculate hazard rating. The overall activity flowchart is shown in Fig.2.

In this study, hazard rating was derived from three components: (a) Failure Potential (FP), (b) Size of Parts (SOP) and (c) Target Rating (TR). Component FP has three 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 scoring based on the status, magnitude or severity of each parameter. The accumulated scores of each sub modules were summed up to compute failure potential. The conclusive formula of hazard rating is as follows:

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

The explanations for FP, SOP and TR given by Matheny and Clark (1994) are as follows:

Failure Potential (FP)

Failure potential identifies the most likely failure and rates the likelihood that the structural defect(s) will result in a failure within the inspection period. Examples of the ratings are:

1. low: defects are minor (e.g. dieback of twigs, small wounds with good wound wood development)
2. medium: defects are present and obvious (e.g. cavity encompassing 10 – 25% of the circumference of the trunk, co-dominant stems without included bark)
3. high: numerous and/or significant defects present (e.g. cavity encompassing 30 – 50% of the circumference of the trunk, multiple pruning wounds with decay along a branch)
4. severe: defects are very severe (e.g., heart rot decay fungi along the main stem, cavity encompassing more than 50% of the circumference of the trunk)

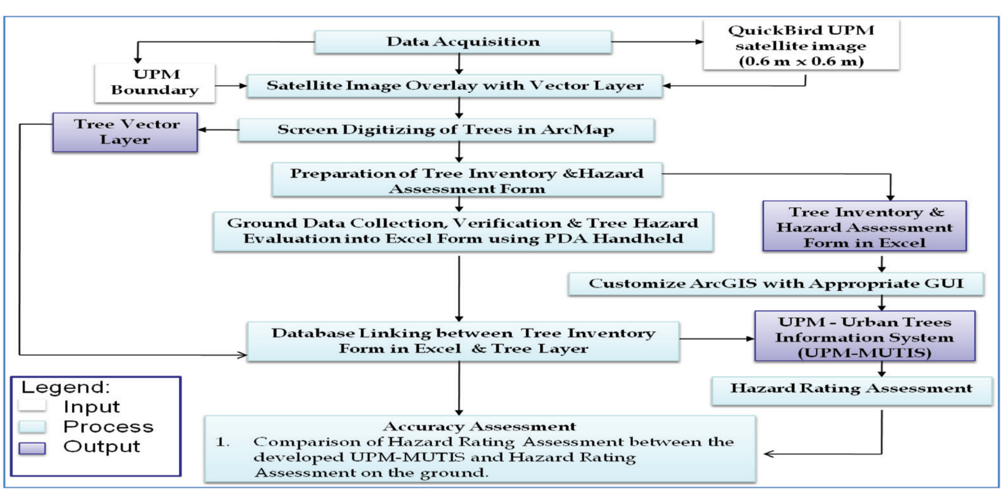

Fig.2: A flowchart showing the overall activities carried out in this study

Size of Part (SOP)

Size of defective part rates the size of the parts that most likely to fail within the inspection period. The larger the part that fails, the greater the potential for damages. Therefore, the size of the failure affects the hazard potential. Examples of the ratings are:

1. most likely failure less than 15 cm in diameter
2. most likely failures, 15 – 45 cm in diameter
3. most likely failures, 45 – 75 cm in diameter
4. most likely failures greater than 75 cm in diameter

Target Rating (TR)

Target rating rates the use and occupancy of the area that would be struck by the defective part. Examples of the ratings are:

1. occasional use (e.g. jogging or cycle trail)
2. intermittent use (e.g. picnic area, day-use parking)
3. frequent use (e.g. seasonal camping area, storage facilities)
4. constant uses, structures (e.g. year round use for a number of hours each day, residences)

The points in each category are added to obtain the overall hazard rating:

HR was categorized into four levels of summation, based on the cumulative scores for each component, as follows: (i) low, (ii) medium, (iii) high, and (iv) severe. Details of the HR levels are shown in Table 1 below.

Accuracy assessment of the MUTIS system was carried out by using a sample of 32 trees. Eight trees were selected from each zone. Accuracy percentage was calculated using the following formula:

$$\text{Accuracy percentage (\%)} = \frac{\text{number of correct trees}}{32} \times 100$$

TABLE 1
Description of Hazard Rating levels

Level	Scores	Classified	Remarks
1	3-4	Low	A tree presents with no or minimal risk assessment or associated risks
2	5-7	Medium	A tree presents 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).

RESULTS AND DISCUSSION

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

Analysis from MUTIS depicted that out of 909 trees assessed, 99.8% (907 trees) were categorized as 'Medium' hazard rating and no trees with 'Low', 'High' and 'Severe' hazard ratings. This was due to most trees were roadside which had Hazard Rating value of '3'. Table 2 shows the hazard rating of trees according to zones.

From Table 2, there were 832 trees and 75 trees which had hazard rating of 6 and 7, respectively. Zone B had the highest number of trees with hazard rating of 7 (medium). Ground observation revealed that all these trees are *roystonea regia* species which has high SOP factor. Two trees were without any hazard rating as they were removed by the authorities. Table 3 shows the results of hazard rating of trees according to species.

Table 3 depicts that 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). Meanwhile, Table 4 shows a comparison of hazard ratings that were generated through MUTIS system and manual rating from ground evaluation.

This comparison can determine the accuracy assessment of hazard rating by MUTIS by applying the following formula:

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%

CONCLUSION

The tree hazard assessment process has provided a useful tool and information for evaluating and planning of roadside trees. The GIS platform of MUTIS ver 1.0 provides a better visualization of hazardous trees distribution. This study concluded that 99.8% of the roadside trees at the academic

TABLE 2
Results of hazard rating of trees according to zones

Hazard Rating	Low			Medium				High		Severe	None*	Total
Zone	3	4	5	6	7	8	9	10	11	12		
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
Results of hazard rating of trees according to species

Hazard Rating / Species Name	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 MUTIS and ground evaluation

No	Tag_No	MUTIS	Ground Evaluation
1	A0054	medium	medium
2	A0294	medium	medium
3	A0322	medium	medium
4	A0452	medium	medium
5	A0461	medium	medium
6	A0531	medium	medium
7	A0594	medium	high
8	A0610	medium	medium
9	A0615	medium	medium
10	A0672	medium	medium
11	A0696	medium	medium
12	A0734	medium	medium
13	A0760	medium	medium
14	A0816	medium	medium
15	A0875	medium	medium
16	A0880	medium	medium
16	A0897	medium	high

No	Tag_No	MUTIS	Ground Evaluation
17	A0914	medium	medium
18	A0930	medium	medium
19	A0947	medium	medium
20	A0962	medium	medium
21	A0974	medium	medium
22	A0983	medium	medium
23	A0993	medium	medium
24	A1008	medium	medium
25	A1011	medium	medium
26	A1019	medium	medium
27	A1026	medium	medium
28	E0004	medium	medium
29	E0029	medium	medium
30	E0033	medium	medium
31	E0036	medium	medium
32	E0039	medium	medium

area of UPM are safe, where the trees are classified as imposing medium hazard. Hazard rating assessment by MUTIS ver 1.0 is 93.75% as accurate compared with manual assessment. Based on the high accuracy assessment achieved by MUTIS ver 1.0, it can be recommended as a potentially suitable tool for accurate hazard rating evaluation of roadside trees.

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