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Proportions of Green Area and Tree Health on University Campus: The Impact of Pavement Presence

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ABSTRACT

Sustainable urban ecosystems require healthy green spaces that provide ecological services to meet social and environmental needs. This study evaluates the proportion of green areas in the urban campus and assesses the effects of pavement on the health of *Samanea saman*. The MAPIR Normalised Difference Vegetation Index (NDVI) camera mounted on a drone captured a proportion of green areas of approximately 27.80%, which is roughly a quarter of the total study sites. However, the significance of green areas depends on the health of the trees. Therefore, the pavement effects on the health status of trees in green areas were studied using Visual Tree Assessment (VTA) and aerial image analysis using the MAPIR (NDVI) camera on a drone. Although both methods evaluate health status, the final outputs differed. VTA produced categorical outputs, which assigned trees into health categories based on a visual assessment of factors. In contrast, NDVI produced linear outputs, which provided a numerical value to demonstrate tree health. Both methods indicate that trees in non-paved areas are healthier, particularly for the excellent trees identified by the VTA, which suggests that pavement negatively impacts tree health. However, the effects of paved and non-paved areas on tree health status analysis using the aerial image are not significant ($p>0.05$), which may be due to the low quality and accuracy of the images. The study provides insights into the importance of green areas and tree health in creating sustainable urban ecosystems.

Keywords: Green areas, non-paved, normalised difference vegetation index, paved, tree health, visual tree analysis

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INTRODUCTION

Universiti Sains Malaysia (USM) is an urban space incorporating green areas and infrastructure as part of the landscape. USM green areas are predominantly surrounded by mature trees characterised by various trees such as *Samanea saman*, *Andira inermis*, and *Millettia pinnata*, including *Peltophorum petrocarpum* and *Pterocarpus indicus*. Considering that the ornamental trees in USM were planted, typically at the ages of 1 to 3, and the institution was established in 1969, the ornamental trees planted in the area may range from 54 to 60 years old. This age may be considered old for some species, depending on various factors such as their general lifespan, environmental conditions, basic needs, and other factors. Additionally, it is worth noting that naturally occurring trees that have been preserved may be older.

The potential problem that arises from the tree is inevitable, especially during storms. For example, according to Hauer and Peterson (2016) and Vogt et al. (2015), trees can cause damage to grey infrastructure, and managing tree-infrastructure conflicts is a significant concern of arboriculture practitioners. Tree problems generally include conflicts with infrastructure, potential impacts on human health and safety, and cultural, aesthetic, and social concerns. Moreover, these problems are compounded by environmental and energy-related challenges, resulting in a complex set of problems (Rotherham, 2020; Vaz et al., 2017). Research on tree risk management is essential to evaluate and reduce these disadvantages (Klein et al., 2019). When trunks and tree limbs fall on people, vehicles, and structures, big trees cause fatalities and injuries (Schmidlin, 2009). On the other hand, in Toronto, Canada, residents express storm-related safety worries, although deaths are uncommon (Conway & Yip, 2016).

Samanea saman, P. pterocarpum, Cinnamomum iners, Ficus benjamina, and other trees have been recorded as Malaysian cities' most prevalent ornamental trees (Hasan et al., 2018). *S. saman,* commonly called Rain Tree, is not native to Malaysia, but this species' existence is not harmful to native species. On the contrary, this species provides beneficial effects for urban ecosystems. This vast tree provides shade with its wide canopy. Matured *S. saman* is usually large, with a dome-like crown. However, this tree species tended to cause problems such as split branches and exposed roots that cause cracks in the pavement or, even worse, exacerbate the buildings' foundation. Concerns were raised due to the age and large tree size. In Malaysia, trees with a large diameter at breast height (DBH) are often considered large (Seng et al., 2004). Therefore, health monitoring of the affected trees is required. Despite being a time-consuming and demanding process, Visual Tree Assessment (VTA) remains a reliable traditional method for determining the health status of trees.

VTA takes into account numerous parameters. For example, tree characteristics which are the shape and density of the crown structure, the colour, texture, and density of the foliage, the texture and density of the bark, the presence of visible wounds, decay, or cavities in the trunk, the presence of any visible roots, the size, structure, and signs of root damage. Furthermore, other parameters are structural defects such as in the tree, such as cracks, split or leaning, and site conditions. In addition, pest and disease status is one parameter that impacts overall health. Considering all the above factors, the final parameter is the tree's overall health and vigour. Another method, the Normalised Difference Vegetation Index (NVDI), which describes the difference between visible and near-infrared reflectance of plant cover, only considers green foliage pigment. Unlike NVDI, VTA considers the health of root systems, trunks and branches, hazards, and surroundings. Roots' health is affected by ground conditions.

However, the observations depend on the arborist or researcher, increasing the possibility of human errors. Besides the VTA's credibility in forecasting tree health, the NDVI concept is the difference between visible and infrared reflectance of vegetation. It can also estimate the density of green foliage from the leaves on an area of land (Weier & Herring, 2000). Moreover, NVDI has been used to observe the impacts of climate on vegetation biomass and phenological trends (Wang et al., 2003). Unlike other remote sensing devices, drones operated with the NVDI concept produce reliable data for health monitoring with fast and easy handling. Furthermore, lightweight drones are low in cost and have high flexibility for vegetation evaluation and deployment in harsh environments (Assmann et al., 2019; Duffy et al., 2018).

Urban green space loss threatens environmental sustainability and human health. Therefore, university campuses significantly contribute as urban sites that might promote sustainability and green infrastructure. This study evaluates the proportions of green space on USM's main campus using a drone equipped with NVDI technology. It examines how pavement affects the health of raintrees (*S. saman*). Assessing green space proportions is essential for understanding urban areas' environmental sustainability and quality of life and can inform urban planning and management strategies. Pavements can significantly negatively impact tree health by restricting water and nutrient absorption, leading to soil compaction and root damage. The results of this study can also contribute to broader efforts to promote the health and sustainability of urban green spaces.

The project involved collecting health data on paved and non-paved trees by performing aerial imagery analysis and VTA on Rain trees as the tree model to have a different perspective and investigate potential correlation. Furthermore, by providing insights into the relationship between pavement coverage and tree health, this study aims to inform the development of more effective urban planning and management strategies for promoting the health and sustainability of urban green spaces. The results of this study can also contribute to the broader field of knowledge on the benefits of urban green areas for environmental sustainability and human health.

MATERIALS AND METHODS

Study Site

This study was conducted on the main campus areas of the USM, located in Penang, Malaysia. The main campus areas of USM comprise a variety of green spaces such as gardens, parks, and natural reserves. Additionally, USM is in Penang, a rapidly urbanising area in Malaysia, making it a particularly relevant site for studying the effects of urbanisation on natural environments. Based on the USM website = the whole campus is 240.13 hectares, including the RST compound, which is not included in this study. The calculations based on Google Maps are about 145 hectares (Figure 1).

Figure 1. Google map of USM, Gelugor

Drone Mapping

The data collection for Unmanned Aerial Vehicle (UAV) mapping was conducted from the 17th to 19th of November 2021 around the property of USM, Gelugor (5.3559° N, 100.3025° E), with an estimated area of 188.52 hectares. The methodology flowchart in Figure 2 shows the steps to acquire the proportions of green areas. We used a DJI Phantom 4 Drone. DJI Ground Stations (GS) Pro was used as the ground control app to create the waypoints for flight at 120 m height. OFO Sdn Bhd, a local drone survey company, provided proper flight permits and protocols.

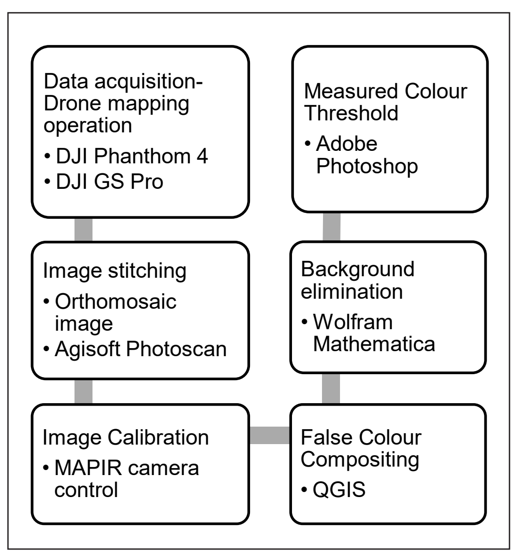


Figure 2. Flowchart of NVDI to easure Green Area Proportion

Identification of Green Area Composition

The images were captured with a resolution of around 20 megapixels in multiple spectral bands. The mapped UAV data was stitched using Agisoft Photoscan for the first objective. Next, the overlapped images were collected in each flight mission to cover the whole area as ortho-mosaic images. Then, NVDI images were calibrated using MAPIR camera control software (https://www.mapir.camera/) and FIJI (https://www.mapir.camera/pages/calibrating-survey-images) and further analysed by QGIS. Later, the SeparateColour command in Wolfram Mathematica Image processing was applied to simplify the data to reduce background colour bias. The resulting images are in digital formats, such as JPEG or TIFF, with around 20 megapixels in multiple spectral bands. Finally, the Photoshop colour threshold command was used to calculate the percentage of a green area. The green space in this project refers to the regions occupied by vegetation from the aerial view.

Tree Health Status on Paved and Non-paved Surface of *S. Saman*

To assess the effects of pavement on tree health, we employed a two-pronged methodology. For the second objective, we comprehensively evaluated the health of *S. saman* trees in scattered locations on the USM campus, given that 30 trees were covered by pavement and the other 30 were not. It involved a VTA, directly observing and measuring tree health indicators. Additionally, we used the NDVI analysis of aerial imagery to extract pixel density information, which was used to calculate a quantitative measure of tree health. VTA provide qualitative data on tree health, and the NDVI analysis provides quantitative data on pixel density and overall tree health. VTA uses several parameters, such as the health of roots, trunk, leaves, crown and brunches structures, tree characteristics and surrounding hazards. In addition, crown class, tree shapes, leaf density, and tree fertility were also assessed. Out of the 184 *S. saman* individuals, a random sample of 60 was chosen for the study. Thirty trees were selected in the areas covered with pavement, while the other thirty were not covered by pavement. The trees were recorded and analysed from 1/3/2021 to 15/3/2021 around six varying ecological landscape spots in the USM Gelugor Campus.

Two different surface conditions were assessed: paved and non-paved areas. Both conditions were studied in 3 different spots but shared the same characteristics. Paved spots are usually near the road, pavement, and footpath. Besides, they are commonly located in the central area where heavy traffic and vehicles are. In comparison, the non-paved area is located near the open space near the lake, field, and the edge of the university compound. The trees were diverse regarding species, but only the urban trees, *S. saman*, were studied. *S. saman* is abundant and easy to access throughout the property. It is an urban tree with a large umbrella canopy providing shade to pedestrians. This tree landscape was designed along the road on a paved area and in the lake's open spaces, including the fields. In paved areas, the trees were planted for pedestrians, while in non-paved areas, *S. saman* was planted around the recreational place, especially the lakes and fields. These trees were planted in both areas, most likely for shade and to maintain thermal conditions.

The information from the landscape condition of the trees is valuable as an indication of a landscape condition influencing tree health. Thus, the paved and non-paved areas' trees health was compared. The NVDI in black and white bands was further evaluated using the ImageJ measure command with integrated density and then compared with the Visual Tree Assessment (VTA) to see the correlations. VTA depends on several chosen parameters that significantly influence the well-being status classified in tree characteristics, hazards and, most importantly, tree health. Intensity values are parametric; meanwhile, VTA produced non-parametric data. Finally, visual tree assessment was examined by ranking vegetation into excellent, good, fair and poor according to the conditions in Table 1.

ImageJ software was used to measure the integrated density of each tree. First, the sample area selected from tree-covered was retained by 22 × 22 square pixels of covered portions to maintain linear variables. Then, the covered portions were utilised to measure integrated density individually. Afterwards, the images were assessed using the false-colour features, black and white. Comparatively, the other method utilised stitched drone orthomosaic images.

Table 1
List of tree health status and the conditions

Tree health status	Conditions
Excellent	• Mature specimen • Well-balanced grand or outstanding appearance and structure • No evidence of insect or parasitic attack or disease, epicormic growth or dead wood and physical damage
Good	• Mature specimen • Tree structure, appearance form and balance are considered typical. • Little evidence of insect or parasitic attack, epicormic growth or dead wood
Fair	• Mature specimen • Sparse or pale-coloured foliage • Epicormic growth or deadwood throughout the crown • Evidence of some branch fall
Poor	• Limited life expectancy (less than 5–10 years) • Limited habitat value • Poor form, health and condition, significant dieback or sparse canopy. • Physical damage, disease, decay, and susceptibility to large limb drops, including bark forks.

Source. Dunster et al. (2017)

RESULTS AND DISCUSSION

Proportions of Green Areas in an Urban Compound

The NDVI image, calibrated using MAPIR software and generated by QGIS, has been stitched together using Agisoft Photoscan (Figure 3). The colour has been colour-corrected in QGIS, and the level of red intensity depicts the health status of the trees. However, this image also encompasses the Minden Sports field and the USM stadium's main football field. The most common method to calculate the area uses the threshold method, manually moving the saturation and brightness and then measuring the area using the Measure command in ImageJ. This method has drawbacks as it is subjective to the researcher's perception. Furthermore, QGIS generated a yellow background in the map to complicate things further, resulting in an extra colour channel in the image. We implemented an extra step to reduce the bias using the SeparateColour command in Wolfram Mathematica Image processing. Mathematica will extract different colour channels from the original image. The red colour extraction is done automatically using the software's predetermined method deemed best. Then, we used the Adobe Photoshop colour threshold method to calculate the percentage of the areas covered by tree grass in USM. We first outlined the exact map area using the smart selection tool and measured the number of pixels in that area. Only the red colour wavelength was selected, and the number of red pixels in that selection was measured. To illustrate this method, Figure 4 shows the red colour selection.

We then calculated the percentage of the red pixels from the total pixel number of the USM map. The method was repeated three times to increase the calculation accuracy by 95%. Finally, the red areas calculated are 27.80% of the studied urban areas. From the estimated 145 hectares, the green areas with vegetation are 39.15 hectares. This calculation considers the caveat of including the Minden Field and the USM main football stadium. In

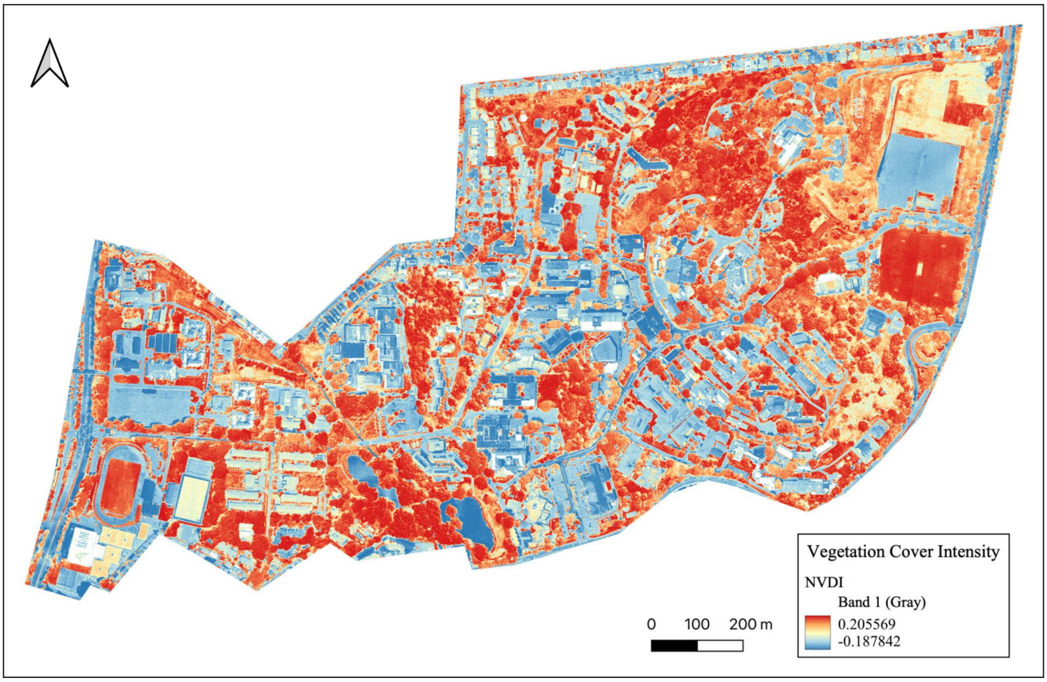


Figure 3. NVDI map of USM in RGB colour ramp

Figure 4. Map of USM in black and red

general, the proportion of green areas that are biologically active influences many aspects of the urban ecosystem. The university campus, specifically Universiti Sains Malaysia (USM), is an urban compound with a densely constructed infrastructure, roads, and others. According to the definition, urban areas have more than 50% built-up area in every 1 km by 1 km area, without considering the continuity of the built-up area (Schneider et al., 2010). Therefore, the compound is deemed urban, with only 27.80% green area. However, the urban environment here is surrounded by maintained trees.

"Green area" is partially or entirely covered with grass, trees, shrubs, or other vegetation. The proportion of green areas indicates the ability to provide green space efficacy services depends mainly on the ratio of green space to the city's total area (Bihuňová et al., 2021). The polygon has 188.52 hectares here, including biologically active regions that can support or promote biological activity, such as non-biologically active regions that lack the environmental conditions necessary to support biological activity or are devoid of life. The USM campus's green area covers 27.80% of the total area. According to previous studies, a city's optimal proportion of green areas is 50% (Gupta et al., 2012). Therefore, compared to this optimal percentage, the percentage of green areas on the USM campus is not ideal. The policies of the urban area are usually established according to government green area goals. For instance, the optimal urban green areas targeted by the Indonesian government were around 30%, referring to Indonesia Law No. 26/2007.

However, the green area in Jakarta City in 2014 was only about 9.84% (Listyarini et al., 2014). Therefore, the government of Indonesia needed some improvement in the management to meet the goals. Researchers in Malaysia suggest that the urban green cover target should be 30% (Kanniah, 2017). In 2001, the green cover of Kuala Lumpur was around 27%, then reduced to 24% in 2013, followed by an increment to 30% in 2016. In comparing Kuala Lumpur's green area coverage in 2016 to USM, Kuala Lumpur's green coverage was slightly higher. However, the small difference in percentage indicates that USM green area coverage was decent. The increase in green area coverage in Malaysia in 2016 was due to the government initiative to plant trees along the streets and many other locations (Kanniah, 2017). However, Indonesia, for example, is limited in developing green areas as huge funds are required due to the land price skyrocketing, according to Listyarini et al. (2014), similar to cities in Malaysia such as Kuala Lumpur and Penang.

In another city, Changchun City was a green area in 2014 grounded on the National Economy and Society statistical bulletin was about 36.5% after undergoing rapid urbanisation (Yang et al., 2017). Compared to these cities, the proportion of green spaces in this urban campus is average. Therefore, there were more improvements in maintaining and increasing the green spaces on the campus. Large green areas provide ecological services to benefit humans and maintain a healthy ecosystem from ecological, social, and economic perspectives (Semeraro et al., 2021). According to respondence perfective on green spaces, most of them perceived good perception towards the benefits of these spaces, especially health (Gashu et al., 2019). The most substantial health benefit of green space in Hong Kong is obesity (Lachowycz & Jones, 2011). It is interconnected with the accessibility of green areas to provide spaces for recreation. Shades from trees provided comfort for society to have a healthy lifestyle. Urban green areas commonly refer to any natural or man-made areas covered with vegetation, such as parks, gardens, and street trees. While citizens tend to associate green spaces with parks, it is important to note that green spaces can take on various forms and have been shown to provide numerous benefits to cities regarding liveability and sustainability (Lyytimäki & Sipilä, 2009). USM is one of the types of urban green space that benefits the community without being labelled as a park. However, it has been established that the health advantages of green spaces are proportional to urbanisation (Milligan & Bingley, 2007; Mitchell & Popham, 2007).

Tree Health Status Between Paved and Unpaved Ground Surfaces

The effects of pavement on the overall health of 60 *S. saman* trees were evaluated using both NVDI image analysis and VTA. A comprehensive evaluation of the impact of pavement on tree health was carried out using these two methods. Six different patches were assessed, which were Math School (MS), Aman Damai (AD), Minden (MD), Rumah Staff (RS), Fajar Harapan (FH) and Tapak Convex (TC). The initial approach involved evaluating the health of trees on an individual level using NVDI aerial imagery for both paved and non-paved soil surfaces. In Figures 5(a), 5(b), and 5(c), as well as Figures 6(a), 6(b), and 6(c), images were generated using ImageJ in black and white. The yellow squares within each image indicate the covered portions extracted to measure integrated density. Each square within the images represents a single tree.

Table 2 below shows the value of max, min, and mean integrated density based on surface conditions (Paved and Unpaved). Statistically, the pixel's values were insignificant at the t-value of 1.58686, and the p-value was more than 0.5 by 0.58991. Thus, the result is insignificant at $p < 0.05$ between paved and non-paved areas. The health of the trees is determined by the pixels retrieved from the photos. The foliage colour has been altered from the tones of green to grayscale's false colour. The darker green becomes dark grey, whereas the lighter green becomes light grey. The greyish tones were observable. However, the integrated density generated from ImageJ visualises the colour into numbers. Integrated density measures luminescence or commonly describes the emission of light by a substance. Therefore, integrated density area is the product of area and means intensity. Besides, the results may be influenced by limiting factors affecting the quality of images. The higher resolution and quality contribute to more accurate analysis and vice versa. One of the limiting factors is flight altitude. Studies show that flight at low altitudes produces more reconstruction details and better precision than at high altitudes, especially with high image overlaps (Seifert et al., 2019). When drones fly at a relatively high altitude, they can take low-quality photos while observing many target nodes and edges. On the other hand, high-quality photos and narrow observation areas can be captured from a relatively low altitude.

Nonetheless, the images used in this work were orthomosaic imagery assembled from overlapping the images into the complete USM map. It may lack accuracy and quality as orthomosaic images require a slightly higher altitude to yield the whole area due to high-rise infrastructure requiring UAVs to fly higher than the trees and infrastructure for a comprehensive aerial view. Regarding altitude, rather than using an orthomosaic map for the integrated density extraction, a single aerial image for an individual tree is suggested. It yields better images and resolutions as the flight altitude will be much shorter and higher in quality. However, it is much more applicable for small sample sizes. Therefore, this method would be inefficient in sampling tree health for a vast area with many trees. However, an orthomosaic image is still applicable by increasing the overlap

Table 2
Integrated density based on surface conditions (paved and unpaved)

Locations	Max (pixels)	Min (pixels)	Mean (pixels)
Paved	22706.0	4753.0	12234.3
Non-Paved	22291.0	3225.0	10312.0

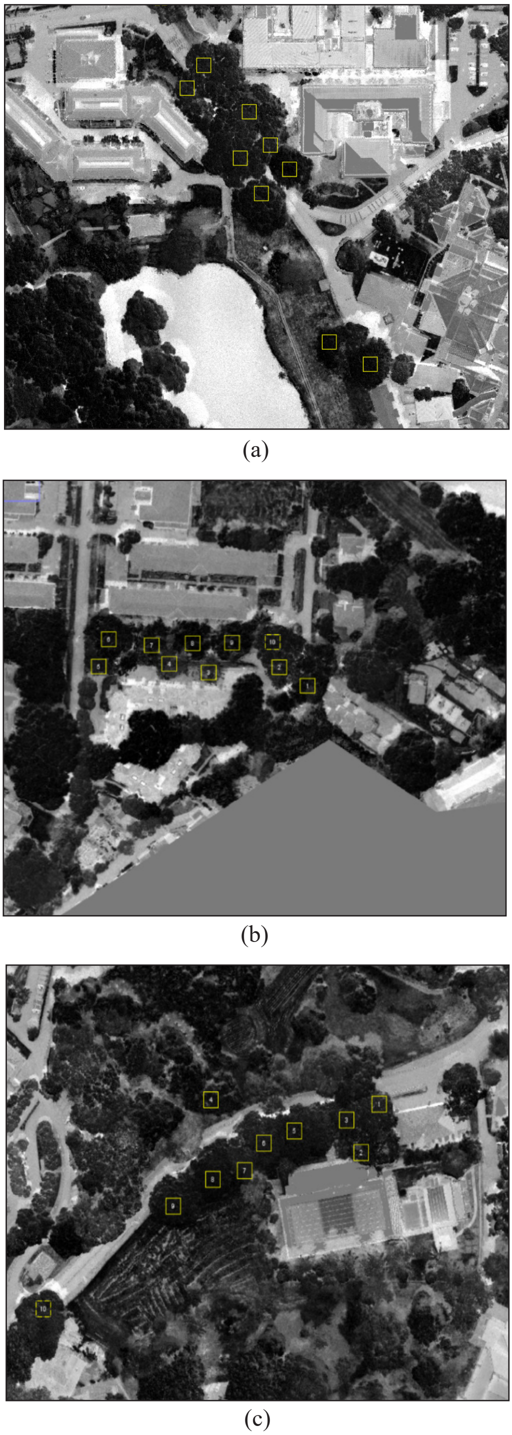


Figure 5. ImageJ tree selection of paved area: (a) Math School; (b) Aman Damai; and (c) Minden

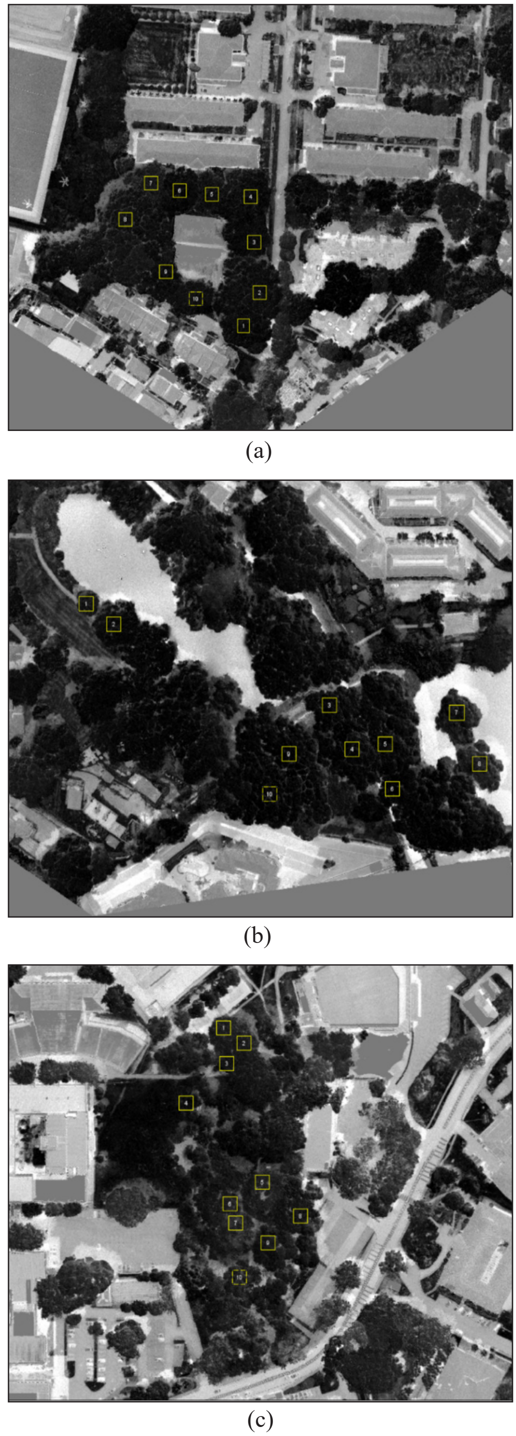
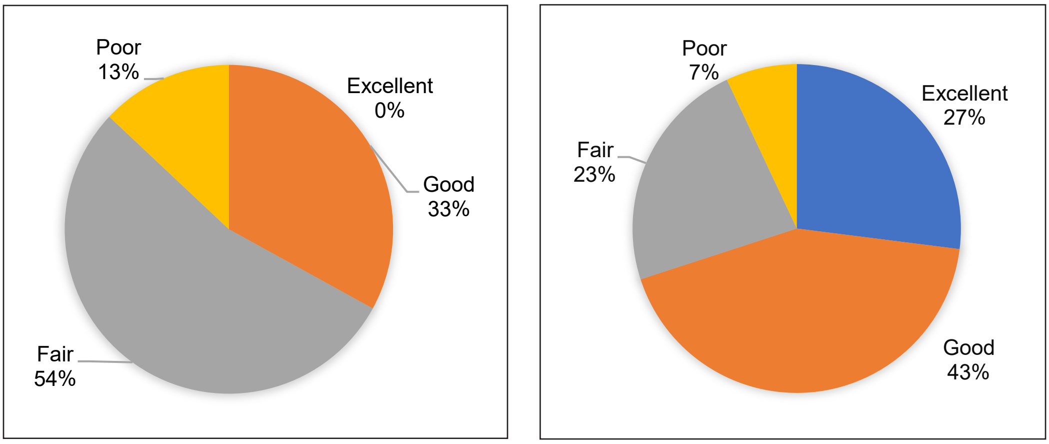


Figure 6. ImageJ tree selection of unpaved area: (a) Rumah Staff; (b) Fajar Harapan; and (c) Tapak Convex

percentages, which can offer more details of the vegetation geometry (Seifert et al., 2019). For example, a quality photogrammetric model requires 80% on-lap and 60-80% side-lap overlap. On-lapping means overlapping images in the flight direction while side-lapping overlaps perpendicularly (Colomina & Molina, 2014). Therefore, increasing overlapping percentages are suggested to yield significant results.

Figures 7(a) and 7(b) show the health status of trees planted in paved and non-paved areas using field assessment (VTA) according to four classes: excellent, good, fair and poor. In this project, both VTA and aerial images were used to evaluate the health status. However, the final health status rating was determined solely by the results of the VTA survey, which classified the area as ranging from excellent to poor.

The health status between paved and non-paved soil surfaces in VTA (Visual Tree Assessment) shows different compositions between all four statuses divided into excellent, good, fair, and poor. VTA status for paved soil surface health is visibly lower than in non-paved land. Thus, the pavement surrounding the trees affects the health and growth of the trees. The trees grown on paved surfaces tend to lose their optimal needs of water, oxygen and nutrients from the impermeable surface that restricts ecological processes (Mullaney, 2015). Therefore, excellent status was difficult to achieve. However, due to other factors, the good status is achievable by 33%, making it fair at 54%, leaving the lowest health status, poor, with 13%. It is clearly shown that paved areas lead to poorer health than non-paved land. Non-paved land attains better health for 27% of the population, which is excellent. Besides, good status is a majority of 54%. Therefore, it leaves fair and poor at 23% and 7%, respectively. The methodologies used in this study generate several health statuses from qualitative and quantitative evaluations. Even though the methods applied were different, the result was intended for the same purpose, which is to evaluate health.



(a) (b)

Figure 7. Health status percentages: (a) paved areas; and (b) non-paved areas

Overall, the results from both methodologies suggest that trees growing in non-paved or open areas are far healthier than trees growing in close-knit paved patches. The pavement is one of the parameters used to evaluate the health of individual trees in VTA based on observable evidence.

Despite the prominent importance of trees providing oxygen and reducing heat, the trees were grown along the pavement to provide shade. The paved surface, such as the black surface of asphalt pavement, absorbs more heat from the atmosphere and provides pedestrians for urban citizens. Pavements serve as a pedestrian-friendly surface for urban residents. However, pavements with dark asphalt surfaces absorb more heat from the sun, leading to higher temperatures on the pavement surface. As a result, the urban heat island effect worsens. Moreover, the impervious nature of these pavements reduces water infiltration, resulting in dry soil conditions, lower evapotranspiration rates, and ultimately affecting urban forestry (Cheela et al., 2021). Dryer soil reduces the water availability, leading to dehydration among the trees. Hence, deteriorating the optimal environment provides a better tree health status. The pavement here was primarily made of impervious materials such as asphalt. There were two materials widely used, classified as impervious and previous pavement. Pervious pavements have the same strength as impermeable pavements but are more permeable to air and water. Because of these functional properties, it has been suggested that previous paving, rather than impervious asphalt, could benefit urban trees (Mullaney et al., 2015). Asphalt is the primary pavement type based on previous research (Guo et al., 2018). The pavement primarily affected the soil condition.

Trees growing under pavement show lower health than those in non-paved areas. In the paved area, the lack of healthy trees in the excellent category suggests that the trees could not achieve optimal health overall. Additionally, the proportion of trees in the lowest health category is higher (about 13%) than in non-paved areas, suggesting a greater risk of health deterioration in paved areas. These results demonstrate a decline in tree health on paved surfaces. Conversely, the prominent percentage of health status, excellent and suitable for non-paved land, was about 70%. VTA results leaned towards the non-paved land surface rather than the land covered by pavement. The matured trees in this urban campus grew much better on an open surface as they were free from disturbance in an asphalt bed. However, the health of non-paved still trees was listed in the poor classes. These conditions may occur owing to other parameters of the trees.

Researchers assessed every part of VTA, such as roots, trunks, branches, leaves, and hazards. To conclude the overall health status, all the factors were considered. Guided from raw VTA data for the trees with poor health, the main factor affecting the trees' condition was the condition of the roots. Exposing roots was explicitly common, but the concern parts of roots was the infestation of ants and termites from the nest close to the root systems.

The infestation can be seen on the surface of exposed roots. Besides, the exposed roots among matured *S. saman* were common as they have shallow root systems (Staples & Elevitch, 2006). Therefore, it is most likely to be visible on the soil surface. A root was declared infested if it bores characteristic dark scarred spots on the root's surface, which are a common indication of weevil penetration and feeding. Roots that were undamaged on the surface were considered uninfested (Stathers et al., 2003).

Although the effects of pavement on tree health have been demonstrated through the outcome of health assessments, other factors may still influence overall health. Evaluating the overall health of trees solely based on pavement factors may not be sufficient. However, it shows that the pavement seems to have been influenced by modifying micro-environmental conditions (e.g., soil nutrients, temperature, and aeration). Other studies also agreed that enclosed surfaces could significantly alter microclimate conditions (Rahman et al., 2020; Rahman et al., 2017). Thus, paved surfaces were known to influence the growth potential and affect the biomass allowances. Likewise, the water usage of vegetation in city areas was also affected (Wang et al., 2020). For example, the rate of water availability of plant life was modified by the permeability rate of the pavement(de la Mota Daniel et al., 2018; Rahman et al., 2013). In addition, some claim that the soil structure was also shifted exponentially, accountable to changes in the growth and transpiration rate (Rahman et al., 2011).

On the other hand, as this pavement study was done in an urban setting, some patches were not entirely covered by pavement. Allow the ecological process to occur optimally at the open edges. Compared to experiment settings, this study tends to be more lenient. It permits the lack of precision. Still, the study should also be done in actual conditions for researchers to learn about the tree's health in its natural state. It makes it possible to estimate the mitigation for better management. *Samanea saman* is a deciduous tree on this campus. However, impervious pavement has been proven to limit deciduous tree species' development, restrict plant photosynthesis, and increase leaf budburst (Chen et al. 2018). Nevertheless, it has been shown that the strength of pavement's effects on plant physiological and growth features varies by tree species (Song et al., 2015; Wang et al., 2019).

Rain trees, on the other hand, threatened the pavement's durability as it aged, as the tree's shallow roots tended to heave up and damage the pavement. Although the pavement break improves water flow and aeration, it also greatly reduces the utility of the pavement and detracts from urban areas' aesthetics. Overall, the integrated density values from modified NVDI images were reciprocal to VTA, suggesting that non-paved trees were healthier than paved ones. The diversified values were expected as the intensity of chlorophyll pigment from the leaf differed from each. Good health status is anticipated to establish a low Integrated density value and vice versa. Even so, the maximum value point indicating the worst health was found on the non-paved land. The differences in maximum values between each land were minor. The data observation demonstrates that the cause was from the root's conditions. Thus, using aerial images to assess tree health was not entirely accurate.

Based on the data observations, it appears that the cause of the issue lies with the root conditions of the trees. Therefore, relying solely on aerial images to assess tree health may not be entirely accurate as the aerial image may not be able to capture the details of the root system due to perspective and may not provide a complete understanding of the root conditions. The same goes for other parts, such as trunks (Xiao & McPherson, 2005). Even with less data at the individual level, it would still be useful. On the other hand, large, difficult-to-reach areas can be monitored more effectively and more cheaply. It facilitates traditional monitoring (Booth et al., 2008). However, visual assessment methods are considered adequate for evaluating the likelihood of urban tree breakage (de La Barra et al., 2018). It is also very time-consuming and labour-intensive.

According to the study, physical and aerial sampling results may contradict because remote sensing techniques' ability to deliver relevant data on vegetation structure is limited (Hestir et al., 2008). For example, the intensity calculated by ImageJ of colour relies on the intensity of green chlorophyll pigment, indicating the capacity of a tree to undergo photosynthesis and the rate of tree growth. However, does green leaf pigment enough to assess tree health? Leaf colour and density are fundamental parameters in assessing tree health. However, it does not represent the whole tree rank. For example, Kaewkhow and Srivanit (2020) discovered 35 parameters to assess the tree. However, through the studies, 11 parameters scored 1.00 IOC values from damage to trees, mechanical damage, insects, or disease. Discoloured leaves are one of the parameters. Hence, indicating leaves provides health information but only as a portion.

Depending solely on leaf colour intensity to assess tree health is may not enough to indicate the whole tree's health rank since remote sensing is most sensitive to detecting changes in the health of the foliage. Depending on the species, the changes in leaves occur depending on the adaptation of the tree itself. For example, after a dry period, trees such as the Rain Tree or *S. saman* are semi-deciduous, shedding their leaves for a short period. During a specific dry season, they may remain leafless for weeks. However, if there is adequate moisture, they will quickly resprout. In moister climates, it appears that rain tree is "evergreen." Therefore, the density and intensity of the leaves of raintrees do not reflect the tree's health. Besides, the changes on the leaves might appear as an adaption to reduce moisture loss and maintain their well-being. However, assessing tree health based on foliage is still helpful. Most diseases or abiotic stresses to the roots or bole are ultimately expressed as changes in the foliage's density, chemistry, colour, and moisture content.

CONCLUSION

The findings of this study highlight the importance of maintaining an optimal proportion of green areas in urban settings to support a sustainable urban ecosystem. Using drone-mounted NVDI technology provided insight into the green area proportion of USM's main campus, approximately 27.80%. However, to maintain the proportion of green space, the health of the trees in these green spaces is also important. The pavement was found to negatively impact the health of *S. saman* trees, with non-paved areas exhibiting better tree health than paved areas. A combination of VTA and the NVDI aerial image analysis provided a more comprehensive understanding of tree health, emphasising the importance of using multiple methods to ensure accuracy. Further research on additional urban tree species in real-world contexts is needed to better understand the degree of pavement effects between species. Overall, this study provides insights into the importance of green areas and tree health in creating sustainable urban ecosystems, which can inform urban planning and management strategies for promoting the health and sustainability of urban green spaces.

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REFERENCES

Assmann, J. J., Kerby, J. T., Cunliffe, A. M., & Myers-Smith, I. H. (2019). Vegetation monitoring using multispectral sensors - best practices and lessons learned from high latitudes. *Journal of Unmanned Vehicle Systems, 7*(1), 54-75. https://doi.org/10.1139/juvs-2018-0018

Bihuňová, M., Supuka, J., Tóth, A., Šinka, K., & Kuczman, G. (2021). Urban green areas and woody plant composition: Dwelling space quality factor in the Klokočina Housing Estate. *Ekológia(Bratislava), 40*(1), 80-90. https://doi.org/10.2478/eko-2021-0010

Booth, D. T., Cox, S. E., Meikle, T., & Zuuring, H. R. (2008). Ground-cover measurements: Assessing correlation among aerial and ground-based methods. *Environmental Management, 42*(6), 1091-1100. https://doi.org/10.1007/S00267-008-9110-X/TABLES/5

Cheela, V. R. S., John, M., Biswas, W., & Sarker, P. (2021). Combating urban heat island effect - A review of reflective pavements and tree shading strategies. *Buildings, 11*(3), 1-21. https://doi.org/10.3390/BUILDINGS11030093

Chen, Y., Wang, X., Jiang, B., & Li, L. (2018). The leaf phenophase of deciduous species altered by land pavements. *International Journal of Biometeorology, 62*(6), 949-959. https://doi.org/10.1007/s00484-018-1497-3

Colomina, I., & Molina, P. (2014). Unmanned aerial systems for photogrammetry and remote sensing: A review. *ISPRS Journal of Photogrammetry and Remote Sensing, 92*, 79-97. https://doi.org/10.1016/j.isprsjprs.2014.02.013

Conway, T. M., & Yip, V. (2016). Assessing residents' reactions to urban forest disservices: A case study of a major storm event. *Landscape and Urban Planning, 153*, 1-10. https://doi.org/10.1016/j.landurbplan.2016.04.016

de La Barra, J. R., Ponce-Donoso, M., Vallejos-Barra, O., Daniluk-Mosquera, G., & Coelho Duarte, A. P. (2018). Comparison of four methods of visual risk tree assessment in urban areas. *Colombia Forestal, 21*(2), 161-173. https://doi.org/10.14483/2256201X.12604

de la Mota Daniel, F. J., Day, S. D., Owen, J. S., Stewart, R. D., Steele, M. K., & Sridhar, V. (2018). Porous-permeable pavements promote growth and establishment and modify root depth distribution of Platanus × acerifolia (Aiton) willd. in simulated urban tree pits. *Urban Forestry and Urban Greening, 33*, 27-36. https://doi.org/10.1016/j.ufug.2018.05.003

Duffy, J. P., Cunliffe, A. M., DeBell, L., Sandbrook, C., Wich, S. A., Shutler, J. D., Myers-Smith, I. H., Varela, M. R., & Anderson, K. (2018). Location, location, location: considerations when using lightweight drones in challenging environments. *Remote Sensing in Ecology and Conservation, 4*(1), 7-19. https://doi.org/10.1002/rse2.58

Dunster, J. A., Smiley, E. T., Matheny, N., & Lilly, S. (2017). *Tree Risk Assessment Manual* (2nd ed.). International Society of Arboriculture.

Gashu, K., Gebre-Egziabher, T., & Wubneh, M. (2019). Local communities' perceptions and use of urban green infrastructure in two Ethiopian cities: Bahir Dar and Hawassa. *Journal of Environmental Planning and Management, 63*(2), 287-316. https://doi.org/10.1080/09640568.2019.1578643

Guo, M., Tan, Y., Wang, L., & Hou, Y. (2018). A state-of-the-art review on interfacial behavior between asphalt binder and mineral aggregate. In *Frontiers of Structural and Civil Engineering* (Vol. 12, Issue 2, pp. 248-259). Springer. https://doi.org/10.1007/s11709-017-0422-x

Gupta, K., Kumar, P., Pathan, S. K., & Sharma, K. P. (2012). Urban neighborhood green index – A measure of green spaces in urban areas. *Landscape and Urban Planning, 105*(3), 325-335. https://doi.org/10.1016/j.landurbplan.2012.01.003

Hasan, R., Othman, N., & Ismail, F. (2018). Developing Malaysian roadside tree species selection model in urban areas. *Planning Malaysia Journal, 16*(3), 248-260. https://doi.org/10.21837/pm.v16i7.515

Hauer, R. J., & Peterson, W. D. (2016). Municipal tree care and management in the United States: A 2014 urban & community forestry census of tree activities. *Special Publication, 16*(1), 1-71.

Hestir, E. L., Khanna, S., Andrew, M. E., Santos, M. J., Viers, J. H., Greenberg, J. A., Rajapakse, S. S., & Ustin, S. L. (2008). Identification of invasive vegetation using hyperspectral remote sensing in the California Delta ecosystem. *Remote Sensing of Environment, 112*(11), 4034-4047. https://doi.org/10.1016/J.RSE.2008.01.022

Kaewkhow, S., & Srivanit, M. (2020). Aggregation of Thai arborist judgments on urban tree hazard inventories used to determine tree health at single-tree level. *IOP Conference Series: Materials Science and Engineering*, *910*, Article 012023. https://doi.org/10.1088/1757-899X/910/1/012023

Kanniah, K. D. (2017). Quantifying green cover change for sustainable urban planning: A case of Kuala Lumpur, Malaysia. *Urban Forestry & Urban Greening, 27*, 287-304. https://doi.org/10.1016/J.UFUG.2017.08.016

Klein, R. W., Koeser, A. K., Hauer, R. J., Hansen, G., & Escobedo, F. J. (2019). Risk assessment and risk perception of trees: A review of literature relating to arboriculture and urban forestry. *Arboriculture and Urban Forestry*, *45*(1), 26-38. https://doi.org/10.48044/JAUF.2019.003

Lachowycz, K., & Jones, A. P. (2011). Greenspace and obesity: A systematic review of the evidence. *Obesity Reviews, 12*(5), e183-e189. https://doi.org/10.1111/J.1467-789X.2010.00827.X

Listyarini, S., Warlina, L., Indrawati, E., & Pardede, T. (2014). Optimization model for predicting green areas in Jakarta to minimize impacts of climate change. *WIT Transactions on Ecology and the Environment, 191*, 305-315. https://doi.org/10.2495/SC140261

Lyytimäki, J., & Sipilä, M. (2009). Hopping on one leg – The challenge of ecosystem disservices for urban green management. *Urban Forestry & Urban Greening, 8*(4), 309-315. https://doi.org/10.1016/J.UFUG.2009.09.003

Milligan, C., & Bingley, A. (2007). Restorative places or scary spaces? The impact of woodland on the mental well-being of young adults. *Health & Place, 13*(4), 799-811. https://doi.org/10.1016/J.HEALTHPLACE.2007.01.005

Mitchell, R., & Popham, F. (2007). Greenspace, urbanity and health: Relationships in England. *Journal of Epidemiology & Community Health, 61*(8), 681-683. https://doi.org/10.1136/JECH.2006.053553

Mullaney, J. (2015). *Using Permeable Pavements to Promote Street Tree Growth*. [Doctoral dissertation]. University of the Sunshine Coast, Queensland. https://doi.org/10.25907/00454

Mullaney, J., Lucke, T., & Trueman, S. J. (2015). The effect of permeable pavements with an underlying base layer on the growth and nutrient status of urban trees. *Urban Forestry & Urban Greening, 14*(1), 19-29. https://doi.org/10.1016/j.ufug.2014.11.007

Rahman, M. A., Moser, A., Rötzer, T., & Pauleit, S. (2017). Microclimatic differences and their influence on transpirational cooling of Tilia cordata in two contrasting street canyons in Munich, Germany. *Agricultural and Forest Meteorology, 232*, 443-456. https://doi.org/10.1016/j.agrformet.2016.10.006

Rahman, M. A., Smith, J. G., Stringer, P., & Ennos, A. R. (2011). Effect of rooting conditions on the growth and cooling ability of *Pyrus calleryana*. *Urban Forestry and Urban Greening, 10*(3), 185-192. https://doi.org/10.1016/j.ufug.2011.05.003

Rahman, M. A., Stringer, P., & Ennos, A. R. (2013). Effect of pit design and soil composition on performance of *Pyrus calleryana* street trees in the establishment period. *Arboriculture and Urban Forestry, 39*(6), 256-266.

Rahman, M., Haque, S., & Rahman, Z. (2020). Identifying and categorizing opinions expressed in Bangla sentences using deep learning technique. *International Journal of Computer Applications, 176*(17), 13-17. https://doi.org/10.5120/ijca2020920119

Rotherham, I. D. (2020). Routledge handbook of urban forestry. *Arboricultural Journal, 42*(3), 180-183. https://doi.org/10.1080/03071375.2020.1738787

Schmidlin, T. W. (2009). Human fatalities from wind-related tree failures in the United States, 1995-2007. *Natural Hazards, 50*(1), 13-25. https://doi.org/10.1007/s11069-008-9314-7

Schneider, A., Friedl, M. A., & Potere, D. (2010). Mapping global urban areas using MODIS 500-m data: New methods and datasets based on 'urban ecoregions.' *Remote Sensing of Environment, 114*(8), 1733-1746. https://doi.org/10.1016/J.RSE.2010.03.003

Seifert, E., Seifert, S., Vogt, H., Drew, D., van Aardt, J., Kunneke, A., & Seifert, T. (2019). Influence of drone altitude, image overlap, and optical sensor resolution on multi-view reconstruction of forest images. *Remote Sensing, 11*(10), Article 1252. https://doi.org/10.3390/rs11101252

Semeraro, T., Scarano, A., Buccolieri, R., Santino, A., & Aarrevaara, E. (2021). Planning of urban green spaces: An ecological perspective on human benefits. *Land, 10*(2), Article 105. https://doi.org/10.3390/land10020105

Seng, H. W., Ratnam, W., Noor, S. M., & Clyde, M. M. (2004). The effects of the timing and method of logging on forest structure in Peninsular Malaysia. *Forest Ecology and Management, 203*(1-3), 209-228. https://doi.org/10.1016/J.FORECO.2004.07.050

Song, Y., Li, F., Wang, X., Xu, C., Zhang, J., Liu, X., & Zhang, H. (2015). The effects of urban impervious surfaces on eco-physiological characteristics of Ginkgo biloba: A case study from Beijing, China. *Urban Forestry and Urban Greening, 14*(4), 1102-1109. https://doi.org/10.1016/j.ufug.2015.10.008

Staples, G. W., & Elevitch, C. R. (2006). Samanea saman (rain tree). In C. R. Elevitch (Ed.), *Species Profiles for Pacific Island Agroforestry* (pp. 1-14). Permanent Agriculture Resources (PAR).

Stathers, T. E., Rees, D., Kabi, S., Mbilinyi, L., Smit, N., Kiozya, H., Jeremiah, S., Nyango, A., & Jeffries, D. (2003). Sweetpotato infestation by *Cylas* spp. in East Africa: I. Cultivar differences in field infestation and the role of plant factors. *International Journal of Pest Management, 49*(2), 131-140. https://doi.org/10.1080/0967087021000043085

Vaz, A. S., Kueffer, C., Kull, C. A., Richardson, D. M., Vicente, J. R., Kühn, I., Schröter, M., Hauck, J., Bonn, A., & Honrado, J. P. (2017). Integrating ecosystem services and disservices: Insights from plant invasions. *Ecosystem Services, 23*, 94-107. https://doi.org/10.1016/j.ecoser.2016.11.017

Vogt, J., Hauer, R. J., & Fischer, B. C. (2015). The costs of maintaining and not maintaining the urban forest: A review of the urban forestry and arboriculture literature. *Arboriculture and Urban Forestry, 41*(6), 293-323.

Wang, J., Rich, P. M., & Price, K. P. (2003). Temporal responses of NDVI to precipitation and temperature in the central Great Plains, USA. *International Journal of Remote Sensing, 24*(11), 2345-2364. https://doi.org/10.1080/01431160210154812

Wang, X. M., Wang, X. K., Su, Y. B., & Zhang, H. X. (2019). Land pavement depresses photosynthesis in urban trees especially under drought stress. *Science of the Total Environment, 653*, 120-130. https://doi.org/10.1016/j.scitotenv.2018.10.281

Wang, X., Wang, X., Sun, X., Berlyn, G. P., & Rehim, A. (2020). Effect of pavement and water deficit on biomass allocation and whole-tree transpiration in two contrasting urban tree species. *Urban Ecosystems, 23*(4), 893-904. https://doi.org/10.1007/s11252-020-00953-z

Weier, J., & Herring, D. (2000). *Measuring Vegetation (NDVI & EVI). Earth Observatory*. National Aeronautics and Space Administration.

Xiao, Q., & McPherson, E. G. (2005). Tree health mapping with multispectral remote sensing data at UC Davis, California. *Urban Ecosystems, 8*(3-4), 349-361. https://doi.org/10.1007/s11252-005-4867-7

Yang, C., He, X., Wang, R., Yan, F., Yu, L., Bu, K., Yang, J., Chang, L., & Zhang, S. (2017). The effect of urban green spaces on the urban thermal environment and its seasonal variations. *Forests, 8*(5), Article 153. https://doi.org/10.3390/F8050153