Urban Forest for Green University Campus: Identifying Area Covered in Vegetation as Forest at Kasetsart University, Bangkok, Thailand

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Abstract: Universities are places that vigorously contribute to the UN Sustainable Development Goals (SDGs). The green university concept that reflects the fundamental principles of the university on environment and sustainability has become well-established among universities' campus planning and design worldwide. The UI GreenMetric World University Rankings is one of the green university indexes that aims to measure campus sustainability efforts. This study focuses on an indicator calculating the total area on campus covered by forest vegetation because it is a crucial landscape component that provides ecosystem services and environmental benefits for Kasetsart University (KU). However, the practical methodology to assess areas covered in vegetation in the form of forest was unavailable. Therefore, we applied definitions of the forest from 1) Global Forest Resources Assessments (FRA) of the Food and Agriculture Organization (FAO) and 2) the United Nations Framework Convention on Climate Change (UNFCCC) to the campus context, an area of 10x10 m, over 10% of which was covered by a canopy of trees at least 5 m in height was considered to be a forest area. Campus tree datasets – tree height, average tree canopy width, and location – were used for spatial analysis in ArcGIS. The results revealed a variation of results from 3 analysis methods. The study using Monte Carlo Simulation on a 10x10 m grid layer map revealed that 24.44 ha of the total campus area of 140.51 ha was covered in vegetation in the form of forest (17.39%). The Monte Carlo Simulation increases the validity of the forest area assessment. Groups of large trees located on the campus provide ecosystem services. Therefore, it is recommended that these urban forests be conserved as living labs to benefit the university campus's stakeholders and Bangkok's residents.

Keywords: Green university campus, urban forest, UI GreenMetric, GIS

1 Introduction

Nowadays, environmental and sustainable issues are fundamental principles among universities worldwide. Universities are places that vigorously contribute to the UN Sustainable Development Goals (SDGs) by cultivating the next generation of skilled and sustainable citizens (BRANDLI et al. 2020, WORLD ECONOMIC FORUM 2023). University campuses themselves are their living labs for research and implementation of sustainable living (BERCHIN et al. 2020, LEAL FILHO 2020). A sustainable concept, the green university campus has become well-established for university campus planning and design. Indexes and guidelines to assess and encourage universities to become green and sustainable have been developed, for example, the United Nations Environment Program (UNEP)'s Greening University Toolkit, International Sustainable Campus Network (ISCN), and UI GreenMetric (UNEP 2014, ISCN SECRETARIAT 2018, UI GREENMETRIC SECRETARIAT 2023).

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UI GreenMetric World University Rankings is one of the green university indexes developed by Universitas Indonesia (UI) to measure campus sustainability efforts. It has been recognized among the first-world universities ranking in sustainability, with more than 1,000 universities from 85 countries worldwide participating in this ranking. Measuring categories are based on the conceptual framework of the environment, economy, and equity. Six measuring categories are 1) setting and infrastructure (SI), 2) energy and climate change (EC), 3) waste (WS), 4) water (WR), 5) transportation (TR), and 6) education and research (ED) (UI GREENMETRIC SECRETARIAT 2023).

The green area on the campus is one of the measuring indicators in the UI GreenMetric to assess landscape components on the university campus. The landscape of green areas on the campus plays a vital role as a physical manifestation of the overall value of university campus life (SISRIANY & FATINAH 2017). UI GreenMetric's indicators relevant to the green area on the campus under the setting and infrastructure (SI) category are divided into areas covered by forest vegetation (SI2) and planted vegetation (SI3). This study focused on calculating the total area on campus covered by forest vegetation because it is a crucial landscape component that provides ecosystem services and environmental benefits (VARGAS 2009, NEDAL et al. 2023). However, the practical methodology to assess the provided definition of "area covered in vegetation in the form of forest" is unavailable (UI GREENMETRIC SECRETARIAT 2023).

Kasetsart University (KU) is a public university with its main campus in Bangkok, Thailand. KU is one of the universities aiming for best practice on green university and sustainability issues. The campus's green areas, especially the urban forest that consists of large trees essential for enhancing ecosystem services, were one of the study targets as they directly implied the concept (DAVIVONGS et al. 2021). The urban forest is a type of metropolitan green area that provides an ecosystem of forest patches with diverse tree and plant species and associated animals in or around the city where urban residents can live, work, and play, thus enjoying benefits from the provided ecosystem services. (NILSSONN et al. 2001, WEIR-SUM & SANDS 2013, VOGT 2020, DAVIVONGS & ARIFWIDODO 2023).

In Bangkok's new urban open space plan for 2024, green areas in KU are classified as open spaces for recreation and environmental conservation (BANGKOK METROPOLITAN ADMINISTRATION 2024). Therefore, urban forests on campus could become multi-beneficial to nearby urban neighborhoods. Identifying areas covered in vegetation in the form of forest in the UI GreenMetric is essential not only for the campus master plan assessment and revision but also for indicating urban forest areas for the Bangkok metropolitan area.

2 Methods

The data presented in this paper is part of a more extensive study on the green area at Kasetsart University, Bang Khen campus, which was used to revise the campus master plan. The main focus here is to identify forest areas on the campus based on the green university index – UI GreenMetric.

2.1 Study Area

The study was conducted in Kasetsart University (KU) main campus at Bang Khen, located in the northern suburb of Bangkok, Thailand, between latitudes 13°51'21.6" N and 13°50'31.7" N, longitude 100°33'42.9" E and 100°34'21.0" E (Fig. 1). KU at Bang Khen (KUBK) is surrounded by urbanized neighborhoods that attract commercial and residential mixed-use with convenient access to the main north-south and east-west road corridors and three metro lines.

KU was established in 1943 as a public university focusing on agriculture and natural resources disciplines. Currently, there are four campuses, including Bang Khen, which is the main campus. KUBK is home to 17 faculties, one college, and one graduate school. KUBK's total area is 140.51 ha.

For 80 years after the establishment of the university, both existing and later incrementally planted trees covered the area of the present KUBK with large trees that are beneficial to the campus environment and the surrounding urban neighborhoods. Some trees were planted for use as windbreaks and to provide shading on farmlands for cultivation classes and experiments. Some trees were gathered from different parts of the country as specimens for studies, i. e., courses in forestry, botany, and horticulture. Some trees were planted for beautifying the campus area and recreational purposes.

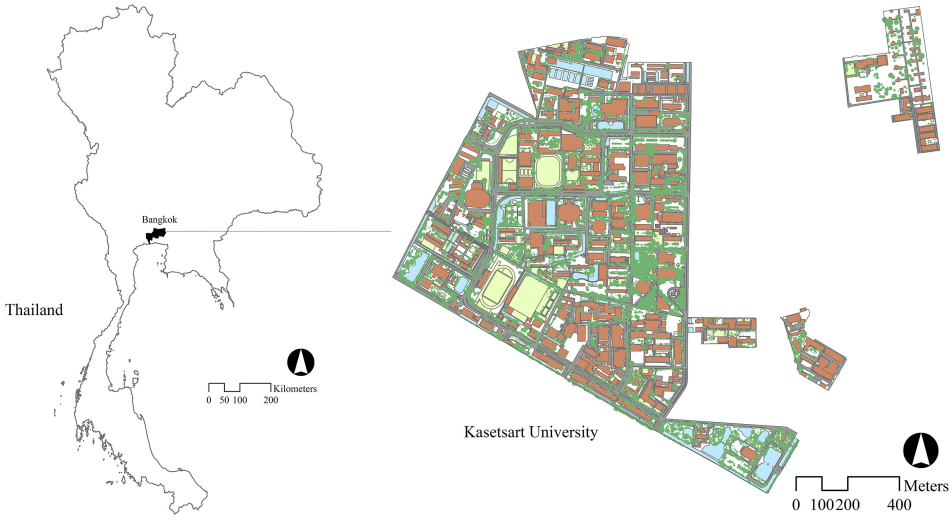

Fig. 1: Location maps of Kasetsart University at Bang Khen in Bangkok, Thailand

2.2 Vegetation Survey

The total area on campus covered in forest vegetation is one of the crucial indicators in the UI GreenMetric, which aims to measure the percentage of green area on campus covered in vegetation in the form of forest (UI GREENMETRIC SECRETARIAT 2023). Although the guideline from UI GreenMetric Secretariat has defined this indicator as "an area covered mainly with big trees and its biodiversity, natural and planted, a large amount of dense mass of vertical growth and undergrowth for conservation purposes" (UI GREENMETRIC SECRETARIAT

2023). However, these are still vague and unclear definitions, which are challenging to assess practically for the forest area on the campus. Therefore, we adopted definitions of forest from 1) Global Forest Resources Assessments (FRA) of the Food and Agriculture Organization (FAO) and 2) the United Nations Framework Convention on Climate Change (UNFCCC) for properly measuring green areas on the campus scale. Tree height and tree canopy cover were the essential factors regarding forest area assessment.

Forest definition from FRA is a land area of more than 0.5 ha, with a tree canopy cover of more than 10% of which is covered by a canopy of trees at least 3 m high (UNEP 2009). For UNFCCC, a forest is defined by a land area of 0.01-0.1 ha, with 10-30% minimum tree canopy cover of 2-5 m tree height (UNEP 2009). By applying these definitions of forest to the campus context, an area of 10x10 m, over 10% of which was covered by a canopy of trees at least 5 m high, was considered a forest area in this study.

A base map of the campus was made for the vegetation survey process. The campus base map was reproduced in the form of a Geographic Information System (GIS) by compiling two sources of information which are 1) a digital vector shapefile map in Computer-Aided Design (CAD) format acquired from the Division of Physical Planning, KU, and 2) satellite images acquired from the Geo-Informatics and Space Technology Development Agency (GISTDA) and Google Earth Pro software (Version 7.1; Google Llc.; Mountain View, CA, USA).

Graduate students from the Faculty of Forestry, KU, were asked to work on vegetation surveying. We conducted a two-day training session for surveyors in measuring tree height and tree canopy cover. Tree location, height, canopy width, and species were collected. A handheld Global Positioning System (GPS) was used to acquire the exact location of each tree. A laser measuring tool was used to measure the tree dimensions. Tree guidebooks were used to identify the tree species correctly (VEESOMMAI & JENJITTIKUL 2006, GARDNER et al. 2007, VEESOMMAI & KAEWDUANGTIEN 2009). Sometimes, leaves and flowers were collected with photographs for further consultation with experts to identify the tree species. The collected tree information was entered into the GIS campus base map for further analysis.

2.3 Data Analysis to Identify the Campus Area Covered by Vegetation in the Form of Forest

In identifying the campus area covered by vegetation in the form of forest, surveyed tree datasets – tree height, average tree canopy width, and location – were used for spatial analysis. ArcGIS 10.4 was used for the data preparation. Data from trees at least 5 m in height were used for analysis. The canopy cover area of each tree was generated in ArcGIS as a layer map based on the collected average canopy width data. Then, this canopy layer map was superimposed on a 10x10 m fishnet grid layer map. The percentage of tree canopy cover in each cell was analyzed using the zonal statistics tool in ArcGIS 10.4. If the percentage of tree canopy cover is equal to or exceeds 10% of 10x10 m cells, these trees were considered as vegetation in the form of forest.

However, there could be some inaccuracy in the results that occurred on how the 10x10 m fishnet grid layer map was placed on the campus base map. Therefore, the Monte Carlo Simulation has been applied in the analysis to increase the validity of the results. The Monte Carlo Simulation is a mathematical technique invented by John von Neumann and Stanislaw

Ulam to improve the decision-making process from an uncertain incident by averaging the possible outcomes (IBM 2023). The total area of the campus covered in vegetation in the form of forest was calculated from 100 possible scenarios by small incremental moves of a fine grid of 1 m towards the east and south. The results were summed and averaged. Therefore, each 1x1 m square has a value from the calculation – and if this value exceeds 1 – it means that the cell is considered a forest. On the contrary – if the value is less than 1 – the cell is considered non-forest.

Therefore, we can categorize the analysis to identify the campus area covered by vegetation in the form of forest into three analysis methods for comparison. They are A) Calculation from 10x10 m grid without the Monte Carlo Simulation, B) Calculation from 10x10 m grid without the Monte Carlo Simulation (Select only canopy cover area), and C) Calculation from 10x10 m grid with the Monte Carlo Simulation

3 Results

Surveyed tree data was spatially analyzed to identify the campus area covered by vegetation in the form of forest using forest definitions from FRA and UNFCCC. Results from analysis Method C using the Monte Carlo Simulation on 10x10 m grid layer map revealed that 24.44 ha of the total campus area of 140.51 ha was covered in vegetation in the form of forest (17.39%) (Tab. 1). However, there are some variations of results from different methods of calculation. For example, the direct calculation of the trees' total canopy cover area higher than 5 m was 29.74 ha (21.17%). Method A – which was calculated from 10x10 m grid without the Monte Carlo Simulation – revealed 56.93 ha (40.52%) covered in vegetation in the form of forest (Tab. 1 and Fig. 2). Method B – selecting only the canopy cover area of trees on the calculation from 10x10 m grid without the Monte Carlo Simulation – revealed 28.92 ha (20.58%) covered in vegetation in the form of forest (Tab. 1).

Table 1: Results from different analysis methods to identify the campus area and percentage covered by vegetation in the form of forest

Analysis Method	Area (ha)	Percentage
A. Calculation from 10x10 m Grid without the Monte Carlo Simulation	56.93	40.52
B. Calculation from 10x10 m Grid without the Monte Carlo Simulation (Select only Canopy Cover Area)	28.92	20.58
C. Calculation from 10x10 m Grid with the Monte Carlo Simulation	24.44	17.39

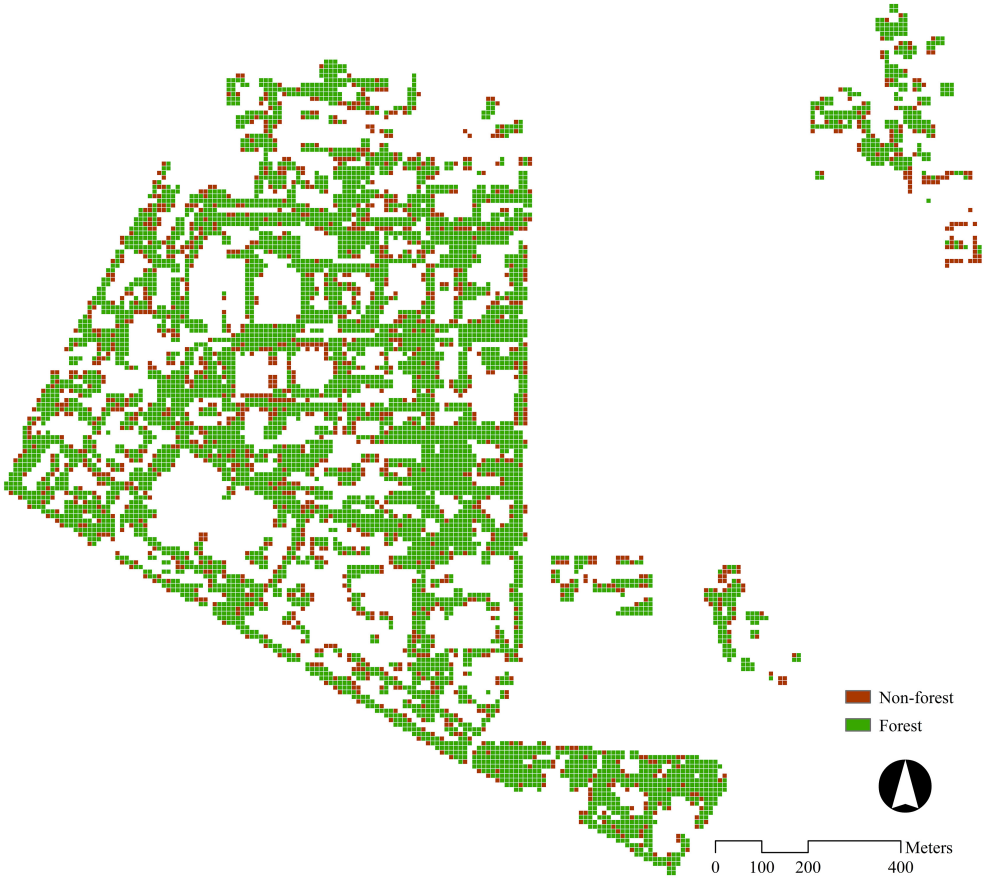

Fig. 2: Kasetsart University's area is covered in vegetation in the form of a forest using analysis Method A from a 10x10 m grid without the Monte Carlo Simulation

4 Discussion

The analysis results using forest definitions from FRA and UNFCCC found variations depending on the analysis methods applied. The result from the analysis Method A, which is the direct calculation from 10x10 m grid, revealed up to 40.52% of the campus area is covered in forest vegetation. From this result, the KUBK campus can be classified at the highest level (> 35%) of the area covered in vegetation in the form of forest based on the UI GreenMetric's guideline (UI GREENMETRIC SECRETARIAT 2023). However, the results from other analyses were classified differently. Both analysis Methods – B and C – revealed that around one-fifth of the campus area is covered in vegetation in the form of forest, which can be classified in the middle level (> 9-22%) from the UI GreenMetric's guideline. The result from analysis Method B – which was also calculated from 10x10 m grid but counted only the canopy cover area – revealed that 20.58% of the campus area is covered in forest vegetation. The result from the 10x10 m grid calculation with the Monte Carlo Simulation in analysis Method C revealed that 17.39% of the campus area is covered in forest vegetation.

By comparing these results with the total area tree canopy cover of trees higher than 5 m – which was 21.17% (29.74 ha) – the analysis Method A could be considered as an overestimation. Therefore, more reliable analysis methods should be focused on B and C. Similar to the analysis Method C, the Monte Carlo Simulation was performed to increase the validity of results in previous studies. The Monte Carlo Simulation was applied in GIS spatial analysis for decision support systems to deal with uncertainties in variables and parameters, and significant accuracy improvement was found (QI & ALTINAKAR 2011, SHOKATI & FEIZIZADEH 2019).

Since KUBK is located in the urbanized area of Bangkok, areas covered in vegetation in the form of forests are considered urban forests. The analysis made it possible to pinpoint where the urban forest areas on the campus are. The concentration of areas covered in vegetation in the form of forest was found mainly along the roadside, in the ample open green space, and between campus buildings that benefit from ecological services to nearby areas. Massive groups of large trees in the urban forest provide shade on the ground from their continuous and expanded canopies which are suitable for the tropical dense urban environment of campus in the Bangkok metropolitan area.

5 Conclusions

UI GreenMetric provides essential indicators as guidance for KU as a contribution to SDGs by increasing greenness and sustainability on the university campus. The total area on campus covered in forest vegetation is a crucial indicator for assessing the forest area that provides ecosystem services. Practical calculation of the area using FRA and UNFCCC forest definitions made the result more accurate and transparent for comparison among participating universities. However, carefully applying these forest definitions with more reliable analysis methods – such as Methods B and C – is necessary to properly assess and compare campus performance for the green university concept.

Green areas in KUBK are already included in Bangkok's Urban Open Space Plan for 2024 as open spaces for recreation and environmental conservation (Bangkok Metropolitan Administration 2024). Therefore, forest areas in KUBK are simultaneously considered urban forests on the campus and in the metropolitan areas. These urban forests on the campus are recommended to be conserved as living labs for the benefit of the university campus's stakeholders and also Bangkok's residents.

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