Assessing Sustainable Green Areas based on Ecological Niche Role in Urban Education Institute

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Abstract

Green areas are so critical in urban communities for making environments healthier and more livable. The objectives of this study were to assess sustainable green areas and to study their ecological niches in an urban education institute. Rajamangala University of Technology Isan (RMUTI) at Nakhonratchasima City Municipality (NCM) was selected as the study area. The spatial assessment of sustainable green areas used guidelines of the policy action plan for sustainable urban green area management by the Office of Natural Resources and Environmental Policy and Planning (ONEP) and then sustainable green areas were analyzed by the Ecological Niche Model (ENM) in Biomapper to check the distribution and durability of the existing trees to the current environment.

The study found that sustainable green area in RMUTI at NCM is about 54.23% with 1,176 trees, which is in accordance with the policy action plan of ONEP that has suggested at least 30% of the land parcel being the sustainable green area in urban education institute. In the area of RMUTI, we mostly found type 2 (multiple-use) and type 3 (environmental preservation), respectively. Such two-green type was not only confirmed by assessing the highest accuracy of ENM (AVI and CVI =1.00) but they also preferred niche factors: annual precipitation for type 2 and annual temperature for type 3. Consequently, tree distribution in type 2 and 3 will have more ability of highly sustainable green areas than other green types. These results are explicitly showed that if green type has many distributions of studied trees, it will be a possibility of sustainable green areas. Furthermore, knowledge of ENM will help to plan the suitable tree species to right green areas and their current environment. Consequently, this study can be an example for assessing sustainable green areas-based ENM and implementing in other urban education institutes.

Keywords: green university, sustainable green area, ecological niche model, urban education institute

1. Introduction

Presently, there is 55% of the world's population lives in urban areas, a proportion that is expected to increase to 68% by 2050 (United Nations, 2018). This urban population growth will affect global climate and ecosystems. Therefore, urban green area is highly required on the policy agenda of cities (Haas et al., 2021) that provides a wide range of ecosystem services that could help combat many urban ills and improve life for city dwellers especially their health (Wolch et al., 2014). Worldwide biodiversity loss is severe and accelerating, resulting in a loss of ecosystem services that benefit humanity (Bongaarts, 2019; Reichel and Boonyaputthipong, 2021). Urban green areas are important components in any community development, be it adjacent to housing, business, leisure areas, education institute, etc. (Baycan and Nijkamp, 2009). Similarity, public space represents the concerning of social, economic and environmental of the country where should lead to sustain the urban development (Kongphunphin et al., 2018). Considering the importance of green areas for sustainability, universities have potential to contribute to it while improving the use of green areas in their campuses (Brandli et al., 2019). A university serves not only as a place of formal education and as a large-scale employer, but also provides an environment in which students develop their personal and social identity at a significant stage in their lives (Abercrombie, et al., 1998). Serving as a setting for physical activity and recreation, a place of identity as well as a place of social encounter and exchange, academic green space may potentially enhance health in place by enabling effective breaks on campus to reduce mental and attention fatigue (Abraham, et al., 2010). Green areas and other nature-based solutions offer innovative approaches to increase the quality of urban settings enhance local resilience and promote sustainable lifestyles, thus improving both the health and the well-being of urban residents (World Health Organization, 2017). Moreover, the density of vegetation enhances the ability of urban green areas to mitigate air pollution (Dadvand et al., 2015). The ecological niche role can help to prove tree distribution and tolerance for sustainable green areas that it gives us know the distribution and durability of the existing trees to the current environment. Hirzel et al. (2006) mentioned to niche-based modelling, statistically related field observations to a set of environmental variables, presumably reflecting some key factors of the niche, like climate, topography, geology, or land-cover. The ecological niche model was based primarily on a conceptual model of environmental factors that control the distribution of a species (Soberón et al., 2017). In summary, the following elements are necessary for the ecological niche model (Gutierrez-Hernandez and Garcia, 2021): (1) data on species occurrences in geographical space; (2) data on environmental variables representing those factors thought to control species distributions; and (3) the use of a Geographic Information System (GIS), which is necessary to integrate all spatial data.

This study proposes assessing sustainable green areas and ecological niche role in the education institute of the urban community. Rajamangala University of Technology Isan (RMUTI) situated in Nakhonratchasima City Municipality (NCM) of Nakhon Ratchasima (NK) province was selected as the study site. The output of ecological niche role has made us know the distribution and durability of the existing trees to the current environment in RMUTI at NCM. Furthermore, this paper can be an example for assessing sustainable green areas with ecological niche role in other education institutes or other locations of the urban community. Also, the Ecological niche role will help to increasingly know about the persistence of the existing trees in the green areas and current environment. Consequently, we will be able to plan the suitable tree species to right green areas and their environment.

2. Literature review

2.1 Sustainable urban green areas

Khongouan and Sitaji (2011) mentioned to a sustainable green area of education institute was considered by tree characteristics (crown canopy with greater than 5 m^2, tree height with higher than 5 m., and DBH at 1.30 m with greater than 30 cm.), were seen and received continuous care in green areas. Similarly, Office of Natural Resources and Environmental Policy and Planning (2007) formally reported about green areas in sustainable community areas that is open spaces in municipalities which has vegetation as the main constituent, is managed according to the academic methodology and landscape architecture principles. These mentioned details above were enhanced by the landscape, to facilitate recreation and to enhance the urban environment to be a green city is shady, beautiful and pleasant to live forever. Then, they have helped to make sustainable green areas in urban such as education institutes, public and private parks and other lands. Moreover, there are many related papers that mentioned to sustainable green areas in education institute e.g., Schipperijn et al. (2010), Arvanitidis (2007), Haq (2011) etc. These papers focused on spatial studying based on GIS and survey trees in their education institutes to do database for biogeographical educators and researchers.

2.2 Ecological niche role

In concept of green areas' assessment, there are two widely mentioned concepts (Rotherham Metropolitan Borough Council., 2017): Ecosystem Services (ES) and Green Infrastructure (GI). The ES concept synthesises human–environmental interactions through a series of combined components of biodiversity and abiotic elements, linking ecological processes and functions (Semeraro, et al., 2021). They are the benefits people obtain from ecosystems, and thus they can be used to represent the environmental interrelations between the three sectors of sustainability (Muller et al., 2015). GI is a concept aimed at realizing a strategically planned network of valuable natural and seminatural areas, designed and managed to deliver a wide range of ecosystem services and to protect biodiversity in rural and urban settings (Wirth et al., 2018). However, the applications of green infrastructure are limited and not applied to the potential urban spaces such as roofs and gardens in dense urban contexts (Semeraro, et al., 2021). Consequently, this study focused on literature review in term of ecosystem services concept, has been used for assessing green areas or areas. The Millennium Ecosystem Assessment defined ES generated by the functions of ecosystems as theoretical concept, although they were implicitly discussed and analyzed by ecologists and environmental experts a long time before (Harrison and Hester, 2010). Modelling ES is an essential tool for the development of strategies that will ensure their future supply, provision and quantification (Olostean, 2015). Many ES modeling tools (e.g., InVEST, ARIES) rely on the categorical representation of land use and cover to predict the supply of an ecosystem service via a production function (Seppelt et al., 2011; Tallis and Polasky, 2009). Moreover, the construction of mathematical models of ES and of their relations with various parameters is a relatively new approach, with various paper published in the last few years, and a systematization of the existing information in the field is highly needed (Olostean, 2015).

In this work, I reviewed studies that have modeled and assessed based on ecological data. Ecological modeling was set by seven classes-based ecological presence and presence-absence data for habitat suitability (Elith and Burgman, 2003). Ecological Niche Modeling (ENM) was one of them that had been studied for assessing green areas. In ecology, the dimensions of an environmental niche vary from one species to another the relative importance of specific environmental variables for one species, may vary according to the geographic and biotic contexts (Peterson et al., 2011). A species' niche encompasses both the physical and environmental conditions it requires (like temperature or terrain) and the interactions it has with other species (like predation or competition) (National Geographic, 2022). The niche of a species depends on both biotic and abiotic factors, which affect the ability of a species to survive and endure (Dotson, 2019). Sillero et al; (2021) reported about available software for ENM such as Maxent (Phillips et al., 2006; 2017), Biomapper (Hirzel et al., 2002), ModEco (Guo and Liu, 2010), OpenModeller (Enrique et al., 2009), and R (R Core Team, 2019).

In this study, ENM was focused on Biomapper program because the ENFA proved to be a suitable method for modelling environmental species distributions, regardless of the presence-only dataset size (Costa et al. 2013). Biomapper is a kit of GIS and statistical tools designed to build habitat suitability (HS) models and maps for any kind of animal or plant that it is centered on the Ecological Niche Factor Analysis (ENFA) that allows to compute HS models without the need of absence data (Université de Lausanne, 2007). There are a variety of papers for studying ENFA based on Biomapper. For example, Rosas et al. (2022) assessed multi-taxon biodiversity and tested their efficiency to support conservation decision at Patagonia; Esfanjani et al. (2021) compared ENFA and Artificial Neural Networks (ANN) to determine the optimum threshold of plant species in rangelands of Ardabil province; Lausch et al. (2011) studied ENFA for the importance of the presence of deadwood areas for 32 habitat variables to occur bark beetle was quantitatively recorded.

3. Materials and methodology

3.1 Study area

This study focuses on the area of RMUTI in NCM where locates between 14°58'30'' - 14°59'30'' N and 102°6'30'' - 102°7'30'' E in NCM (it is in NK province and northeastern region of Thailand) as Figure 1. Currently, RMUTI in NK is the central education institute that comprises 4 campuses established in 4 provinces of northeastern Thailand namely Surin, Khon Kean, Sakon Nakhon, and Roi Et at Thung Kula Ronghai (Rajamangala University of Technology Isan, 2020a). In addition, the area of RMUTI in NK is legally and formally reported as 330 Rai with the north adjoining to Suranarai road (or Highway no. 205) and next to Suranarai community, the east adjoining to Mahachai community, the south adjoining to Takhong canal and Tao Sura community and the west adjoining to Nakhon Ratchasima Rajabhat University (Rajamangala University of Technology Isan, 2022b).

3.2 Sustainable Assessment of Urban Green Areas based on Ecological Niche Role

This study demonstrated the method for assessing sustainable green areas and learning their ecological niches in the education institute of urban communities. RMUTI was selected as the study area for the case study. Overall of methods is shown in Figure 2 and more details as below:

3.2.1 Defining sustainable urban green areas

This sustainable green area for education institute of city community was based on the policy action plan for sustainable urban green area management, was reported by ONEP (2007). ONEP mentioned the definition of sustainable urban green area and types of urban green area as follows:

1) Sustainable urban green area means natural and modified areas in urban communities that are covered by trees (crown canopy with greater than 5 m2, tree height with higher than 5 m., and DBH at 1.30 m with greater than 30 cm.).

2) Types of the urban green area include:

2.1) Recreation and landscape outlook consists of 3 sub-types: exercise indoor and outdoor, parks and recreation activities.

2.2) Multiple-use consists of 3 sub-types: agricultural area, natural and artificial water bodies, and public utilities and facilities.

2.3) Environment preservation area is a green area that helps environmental value such as reducing temperature.

2.4) Narrow stripe along traffic way is a green area that has characteristics along roads including traffic islands in the middle of the road.

2.5) Abandoned area is a green area that is left or undeveloped area.

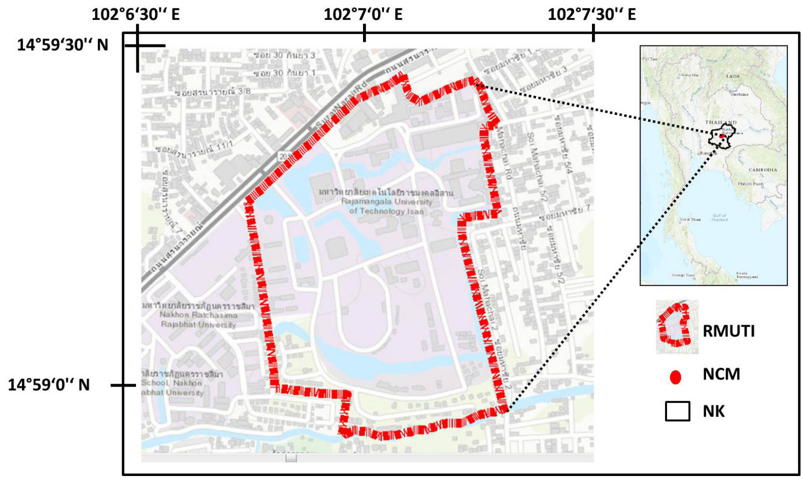

Figure 1 The location of RMUTI in NCM

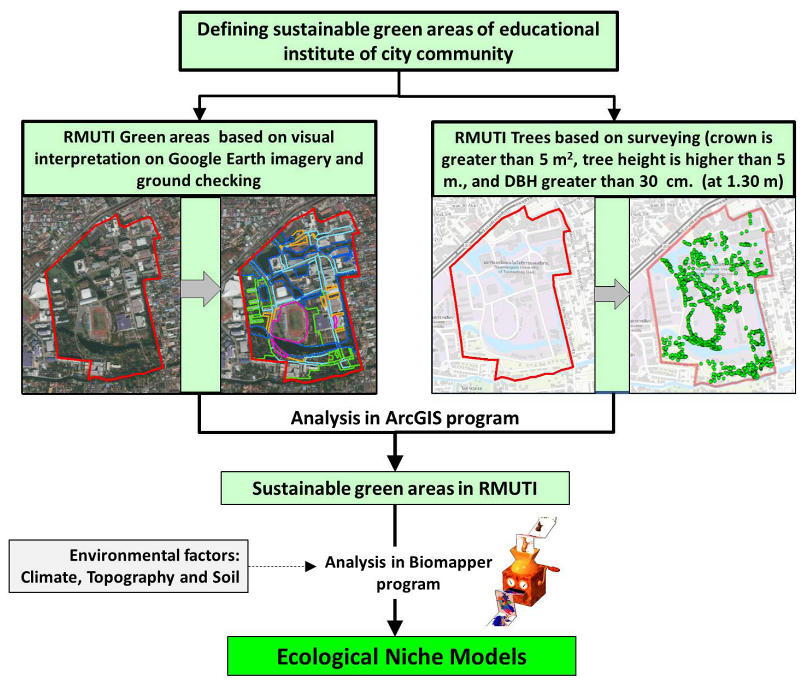

Figure 2 Assessment of sustainable green areas in education institute of urban community

3.2.2 RMUTI-green areas and trees

This study has performed the assessment of RMUTI-green areas and trees under the research project of year 2021 named; 'Sustainable Development Approach of Green University in A Case of Rajamangala University of Technology Isan' was funded by Thailand Science Research and Innovation (TSRI). Data of RMUTI-green areas and trees comprised of details as follows:

1) RMUTI-green areas were visually interpreted on the available satellite imagery in Google Earth Pro that was recorded on January 19, 2021. This visual interpretation used principle of Jensen (2007) and Jantakat, Y. & Juntakut, P. (2020) that includes 8 main components: tone and color, size, shape, texture, pattern, height and shadow, site and association. In addition, this study used academic paper of Jantakat and Juntakut (2020) for visual interpretation in RMUTI-green areas.

2) RMUTI trees were surveyed in RMUTI-green areas from March to April 2021. RMUTI trees were defined by crown canopy with greater than 5 m^2, tree height with higher than 5 m, and DBH at 1.30 m with greater than 30 cm.

Results of RMUTI-green area and surveyed trees were obtained, were converted into the form of GIS database. Data of RMUTI-green area and trees, and were transformed into polygon and point layer. These prepared data were used for analyzing RMUTI-sustainable green area.

3.2.3 RMUTI-sustainable green areas based on ecological niche role

GIS polygon layer of RMUTI-green areas and GIS point layer of RMUTI trees were overlaid (intersect) in ArcGIS program to Initially analyze sustainable green areas (that they were complied with tree characteristics in sustainable green areas from ONEP). Later, ecological niche role was used for studying between the studied trees' distribution and environmental effects on RMUTI-sustainable green area. These data were called, 'ecogeographical factors' that included trees in each type of RMUTI-green area, rainfall, temperature, topography and soil. Ecological niche was analyzed in Biomapper program (download at https://www2.unil.ch/biomapper/products.html). These outputs were made us know the distribution and durability of the existing trees to the current environment in each green area type. This was steps for modeling ecological niche with ENFA in Biomapper as follows:

1) Discrepancies checking: all 6 datasets of GIS layer (tree, sustainable green space, rainfall, temperature, topography and soil) were converted into the raster format with 30 x 30 m. resolution. And then all studied GIS layers were simultaneously overlaid to verify discrepancies (same area, same spatial unit and cell value).

2) Modeling ecological niche with ENFA: output of 1) was computed (in each cell) by marginality coefficient (it measures the distance between trees in green areas' niche and the mean environmental conditions of study area) and specialization coefficient (it measures how trees in green areas tolerate environmental variations in the analyzed territory that can be shown in equation of Université de Lausanne. (2007) as:

Marginality coefficient (mi):

$$m_i = \frac{|m_G \mp m_S|}{1.96\sigma_G} \quad \text{(e.q.1)}$$

Where m_G is the mean of global distribution
m_S is the mean of tree species distribution
σ_G is the variation of the global distribution

Specialization coefficient (S_i):

$$s_i = \frac{\sigma_G}{\sigma_S} \quad \text{(e.q.2)}$$

Where σ_G is the standard deviation of the global distribution
σ_S is the standard deviation of the focal tree species distribution

3) Computing ecological niche models: median algorithm was used for calculating to compare distribution of physical factor each green area type (ecological niche factor) in form of totally marginality and specialization with tree species distribution in green area. Equation was shown in equation of Université de Lausanne. (2007) as:

$$\mathrm{H(c)} = \frac{1}{\sum \mathrm{W_f}} \sum_{\mathrm{f=1}}^{\mathrm{N_f}} \mathrm{W_f Hm(f, c)} \quad \text{(e.q.3)}$$

Where H(c) is total niche index for each green area type
Hm(f,c) is a partial niche for each factor (f)
Wf is automatically weighted for each factor (f)

The niche value varies between 0 and 100 or 0 and 1, from unsuitable to optimal niche.

4) Accuracy assessment of ENM: evaluation of Hirzel et al. (2006) was modified by all derived niche indices (from output 3) above) in each green area type, were randomly checked (50 points in each green type) in true ground. Generally, two simple evaluators (Hirzel et al., 2004) are the Absolute Validation Index (AVI) and Contrast Validation Index (CVI). The AVI is accuracy value between the assessed value (from Biomapper) and the true value in field, it was determined by varies from 0 to 1. The CVI is the AVI minus wrongly assessed value. If both AVI and CVI value are closely or equal 1, they will be expected as a better or best way for ENM.

4. Results and Discussion

4.1 RMUTI-sustainable green areas

This study used the guidelines of ONEP (2007) defining the sustainable green areas in urban that natural and modified areas are determined by covering tree characteristics (crown canopy with greater than 5 m^2, tree height with higher than 5 m., and DBH at 1.30 m with greater than 30 cm.). Therefore, it was observed that all RMUTI areas (528,000 sq.m.) have total sustainable green areas 288,352.00 sq.m. (54.23%) with 1,176 trees that consists of 5 green area types: recreation and landscape outlook (38,867.20 sq.m. or 7.36%) with 117 trees, multiple-use (112,275.20 sq.m. or 21.26%) with 411 trees, environmental preservation (58,158.40 sq.m. or 11.01%) with 308 trees, narrow strips along the traffic ways (65,342.40 sq.m. or 12.38%) with 279 trees and abandoned area (11,708.80 sq.m. or 2.22%) with 61 trees, as shown in Table 1 and Figure 3. This study found that type 2 and 4 are mostly covered in RMUTI but the studies trees' distribution and quantity have are mostly seen in type 2 and 3. Therefore, such existing trees in each green type were modelled by ENM, to statistically check and confirm sustainable green areas that were presented in 4.2 next.

4.2 Ecological niche role for RMUTI-green areas

This study used the ecological niche role (Hirzel et al., 2006) for supporting the persistence of sustainable green areas in RMUTI. Result of the ecological niche checks relationship of the existing tree distribution and the currently important environment. In ecological niche, tree distribution is studied by deviation from global mean, called 'marginality (as equation no.1)' and tree durability is studied by niche breadth, called 'specialization (as equation no.2).' The result of ecological niche in each type of RMUTI-sustainable green area has details as Table 2 and can be explained as below.

- Type 1 (recreation and landscape outlook) included 79% of marginality and 21% specialization. This output showed the existing trees have the high distribution but they have a low tolerance with annual temperature (niche factor).
- Type 2 (multiple-use) included 51% of marginality and 49% specialization. This output showed the existing trees have the high distribution but they have a low tolerance with annual rainfall (niche factor).
- Type 3 (environmental preservation) included 56% of marginality and 44% specialization. This output showed the existing trees have the high distribution but they have a low tolerance with annual temperature (niche factor).
- Type 4 (narrow stripes along traffic ways) included 12% of marginality and 88% specialization. This output showed the existing trees have the low distribution but they have a high tolerance with soil (niche factor).
- Type 5 (abandoned area) included 18% of marginality and 82% specialization. This output showed the existing trees have the low distribution but they have a high tolerance with soil (niche factor).

For this ENM evaluation in each RMUTI-green type, it was found that AVI varies from 0.86 to 1.00 and CVI varies from 0.62 to 1.00. Type 2 (multiple-use: natural and artificial water bodies and public utilities and facilities) and type 3 (environmental preservation) have the highest accuracy (AVI and CVI = 1.00). For reasons, the modeled data of tree and environmental factors in type 2 and 3 had more quantity than other types. Contrary, type 5 (abandoned area) has the lowest accuracy (AVI = 0.86 and CVI = 0.62). Consequently, type 2 and 3 have the highest chance of being a sustainable green area or the most persistence.

Table 1 This is types of sustainable green areas and trees

No.	Types	Green areas (sq.m.)	Sustainable green areas (sq.m.)	Trees
1	Recreation and landscape outlook	43,824.00	38,867.20 (7.36%)	117
1.1	Exercise indoor and outdoor	38,796.80	38,796.80	116
1.2	RMUTI parks	4,070.40	70.40	1
1.3	Recreation activities	956.80	0.00	0
2	Multiple-use	128,537.60	112,275.20 (21.26%)	411
2.1	Agricultural area	0.00	0.00	0
2.2	Natural and artificial water bodies	111,900.80	100,836.80	342
2.3	Public utilities and facilities	16,636.80	11,438.40	69
3	Environmental preservation	88,942.40	58,158.40 (11.01%)	308
4	Narrow strips along traffic ways	76,977.60	65,342.40 (12.38%)	279
5	Abandoned area	11,708.80	11,708.80 (2.22%)	61
6	Others (to not be considered to be green area)	178,009.60	0.00	0
	Total green areas and sustainable green areas	348,390.40	288,352.00 (54.23%)	1,176
	Total RMUTI areas	528,000.00	-	1,176

Remark: Sustainable urban green area means natural and modified areas, are determined by covering tree characteristics (crown canopy with greater than 5 m2, tree height with higher than 5 m., and DBH at 1.30 m with greater than 30 cm.).

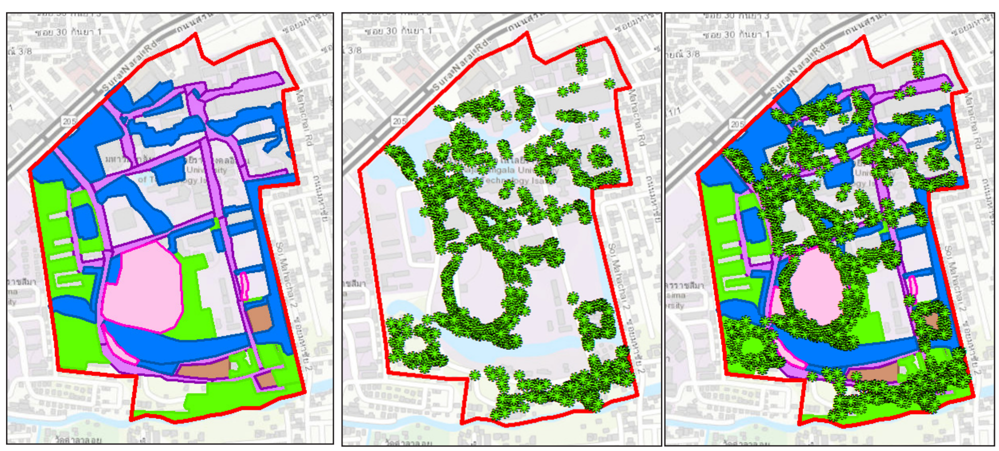

Figure 3 This is types of RMUTI green areas and the studied trees

Type	Ecological niche models (ENM)	AVI	CVI
1	[1/(1.79+0.21)] x [1.79(marg.) + 0.21(spec.)]	0.95	0.90 (missing 0.05)
2	**[1/(1.51+0.49)] x [1.51(marg.) + 0.49(spec.)]**	**1.00**	**1.00 (not missing)**
3	**[1/(1.56+0.44)] x [1.56(marg.) + 0.44(spec.)]**	**1.00**	**1.00 (not missing)**
4	[1/(1.12+0.88)] x [1.12(marg.) + 0.88(spec.)]	0.97	0.94 (missing 0.03)
5	[1/(1.18+0.82)] x [1.18(marg.) + 0.82(spec.)]	0.86	0.62 (missing 0.72)

Remark: - RMUTI-green areas include type 1 (recreation and landscape outlook), type 2 (multiple-use), type 3 (environmental preservation), type 4 (narrow stripes along traffic ways) and type 5 (abandoned area).
- Outputs of ENM equations always have not to excess 1 that niche value varies between 0 and 100 or 0 and 1, from unsuitable to optimal niche (Université de Lausanne, 2007).
In ecological niche model (Hirzel et al., 2006), marg. is marginality (deviation from global mean) and spec. is specialization (niche breadth).
- The AVI is accuracy value between the assessed value (from Biomapper) and the true value in field, it was determined by varies from 0 to 1. The CVI is the AVI minus wrongly assessed value. If both AVI and CVI value are closely or equal 1, they will be expected as a better or best way for ENM.

Table 2 This is ecological niche model for each RMUTI-green areas

5. Conclusions

Overview of sustainable green area in RMUTI at NCM about 54.23% with 1,176 trees, which is in accordance with the policy action plan for sustainable urban green area management (ONEP, 2007). Guideline of ONEP (2007) has suggested that the education institute needs at the least 30% of the land parcel being sustainable green area. The study area was assessed by the assigned tree of ONEP action plan and ecologically modelled-based ENFA. The outputs showed that two green types: (multiple-use) and type 3 (environmental preserve) were mostly seen. These mention two-green type was not only confirmed by assessing the highest accuracy of ENM (AVI and CVI =1.00) but they also preferred marginality (they showed the existing trees have the high distribution but they have a low tolerance with niche factors such as annual precipitation for type 2 and temperature for type 3). Consequently, tree distribution in type 2 and 3 will have more ability of highly sustainable green areas than other types.

These results are explicitly showed that if green type has many distributions of studied trees, it will be a possibility of sustainable green areas. Furthermore, knowledge of ENM will help to plan the suitable tree species to right green areas and their current environment. Consequently, this study can be an example for assessing sustainable green areas-based ENM and implementing in other urban education institutes.

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