Tree distribution and diversity along sidewalks in roads of Nakhon Ratchasima City Municipality, Thailand

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Abstract

This study examined the distribution and diversity of street trees along sidewalks in the roads of Nakhon Ratchasima City Municipality (NCM), Thailand, in response to the rapid urbanization that has led to the loss of green spaces, declining air quality, and increased vulnerability to PM2.5 pollution. Data was collected using Google Street View and field surveys conducted from November 2021 to January 2022. Each sidewalk of NCM roads was plotted by sampling in every 1 km. to measure tree presence. The surveyed data modified from Office of Natural Resources and Environmental Policy and Planning (ONEP), was converted to excel program for tree diversity analysis-based Shannon-Wiener Index (S-W I). As a result, there were a total of 1,556 trees, 171 tree species (they were identified by genus and species-based Forest Herbarium of Department of National Parks, Wildlife and Plant Conservation), and S-W I of 28.029 (average 3.817). The highest sum and average of S-W I (2.551, 0.159) were found in Phonlan Rd. and the lowest sum and average of S-W I (0, 0) were found in 3 roads: Vatcharasarid Rd., Kudan Rd. and Det Udom Rd. The S-WI score for these three roads was 0, indicating the presence of only one species. Based on these results above, they could be assessed that at least 1 tree and tree species would occur every 1-2 km on sidewalk in NCM road. Moreover, Among the recorded species, one was listed as endangered (EN) on the IUCN Red List, and ten were identified as exotic species.Consequently, findings provide critical insights for enhancing urban greenery and guiding green city initiatives to support planning green space network (GSN) in NCM roads, for example, 3 dominant species: *Tamarindus indica*, *Pithecellpbium dulce*, and *Murraya paniculata* will be recommended on the Phonlan road etc.

1. Introduction

Thai society has increasingly faced the severity of PM2.5 air pollutants, has become more severe every year. Therefore, green cities are designed with consideration for a healthy environment. This is a key issue in SDG 11 that is relevant to making cities and human settlements inclusive, safe and sustainable, and then will help promote health and well-being [1]. Sustainability of urban and suburban forests contributes to ecosystem restoration and helps stop and restore biodiversity loss [2]. However, Thai cities are still facing dramatic increases in urbanization. As a result, cities are covered with impermeable road surfaces, for example sidewalks. Especially planting street trees creates attractive and vibrant public spaces within the urban environment but tree growth can be limited when tree spaces are not properly designed to reduce water stress [3]. Street trees play a critical role in supporting a healthy and environmentally sound urban community that affect a positive social impact because it helps restore human health [3,4]. Recently, the role of geospatial technology has not only provided more convenience for preliminary surveying street trees such as Google Street View in Google Earth, but other spatial tools (e.g., ArcGIS Survey123, i-Tree Tools) are also used for collecting tree data in field. For example,

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using Google Earth software for observing trees along streets in Lubumbashi city, Congo [5]; implementing i-tree tools for spatial decision support [6] and for quantifying ecosystem services from trees [7]; using ArcGIS Survey123 for collecting urban trees in public spaces [8]. Although there are papers, have studied street trees (e.g., Sikuzani et al. [4], Kjelgren et al. [9], Sjöman et al. [10], Thomsen et al. [11], Wang et al. [12], Galle et al. [13]), but it is still not enough knowledge especially presenting tree diversity index. 3 of 6 concerned papers (Sikuzani et al. [5], Thomsen et al. [11] and Galle et al. [13]) analyzed tree diversity index but they offered various equations for calculating diversity index such as Simpson's index [14], Shannon-Weiner index [15-17], Evenness index [18].

For this study, we selected Shannon-Wiener Index because it is stated to be widely used in population genetics studies. and has been demonstrated to have negative bias in small sample sizes. This reason was proven by research of Kutintara [15], Marod [16] and Konopinski [13].

Based on mentioned above, this study explores the distribution and diversity of street trees along sidewalks in roads under the Nakhon Ratchasima City Municipality (NCM), located in Nakhon Ratchasima province. The quantity and diversity of trees were analyzed at species level with data from the tree survey. Findings provide critical insights for enhancing urban greenery and guiding green city initiatives to support planning green space network (GSN) in NCM (the published research of Jantakat and Srithumma [19]).

2. Materials and Methods
2.1 Study site
This study surveyed appearance and contents of street trees along their pavements in NCM, Thailand.

The site was selected based on strategy for creating growth on environmentally friendly quality of life of Local Development Plan (2023 - 2027) for office of NCM [20]. The NCM area is about $37.50 \, km^2$ which is located in Ni-Muang sub-district, Muang district, Thailand with latitudes 14.92-14.99 °N and longitudes 102.02 - 102.15 °E as Figure 1. In NCM, there are a total of 31 roads including the total length of the road is 261.500 km. such as Chumphol Rd., Jaggree Rd., Vatcharasarid Rd., Manat Rd., Chainarong Rd., Prajak Rd., Kudan Rd., Phonsen Rd., Yommarat Rd., Phonlan Rd., Asadang Rd., Chomphon Rd., Mahatthai Rd., Sanphasit Rd., Kamhaeng Songkhram Rd., Chang Phueak Rd., Sueb Siri Rd., Sirinakhon Rd., Payapthit Rd., Ratchanikun Rd., Ratchadamnoen Rd., Suranaree Rd., Pho Klang Rd., Chomsurang Yat Rd., Mukmontri Rd., Burin Rd., Phibun Laead Rd., Det Udom Rd., Ratchasima-Chokchai Rd. (a part of Highway no. 224), Suranarai Rd. (a part of Highway no. 205), and Mittraphap Rd. (a part of Highway no. 2). Road characteristics consist of road length between 1 and 35 km., an asphalt and concrete road surface, traffic lanes between 2 and 6 lanes and sidewalks about 2-3 m.

2.2 Surveying data of trees along sidewalks of NCM roads
Data was collected using the latest Google Street View (GSV) and field surveys were operated from November 2021 to January 2022. In urban tree survey, we modified the approach of Office of Natural Resources and Environmental Policy and Planning (ONEPP) [21,22], comprised of (1) using a line plot system in every 1 km. along NCM roads as Figure 2 and (2) measuring trees' component with a height of not less than 5 m and Girth at Breast Height (GBH) at 1.30 meters from ground level of not less than 50 cm. as Figure 3. In addition, tree data in field were recorded with web of ArcGIS Survey123 (https://survey123.arcgis.com/), included 2 parts: 1) general data (e.g., surveyor, date, and environmental conditions) and 2) tree data (e.g., tree common and scientific name, tree location, size of tree canopy covering, measurement of tree circumference at 1.30 m from ground level and tree height), and then they were converted and stored into an excel program for spatial displaying in QGIS.
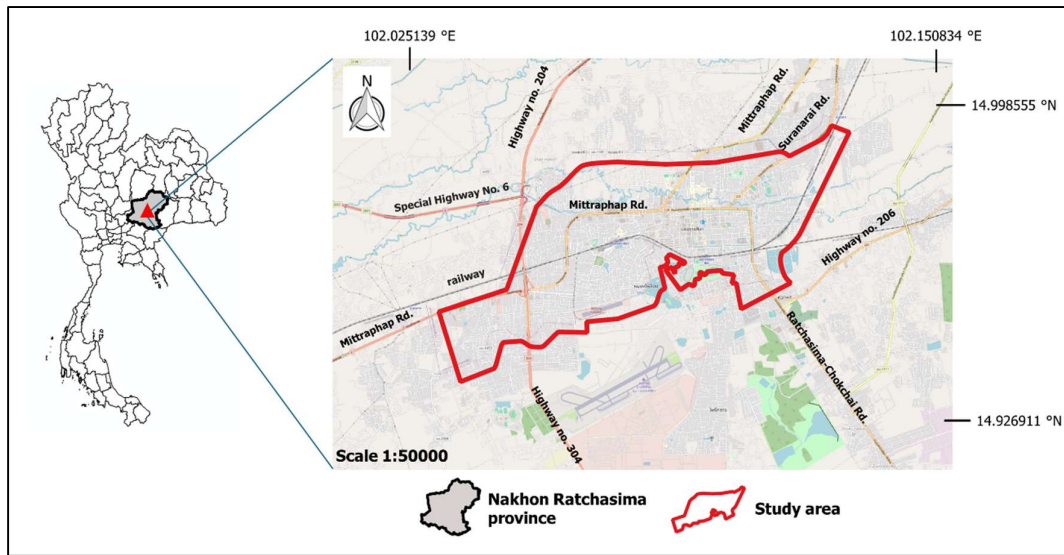
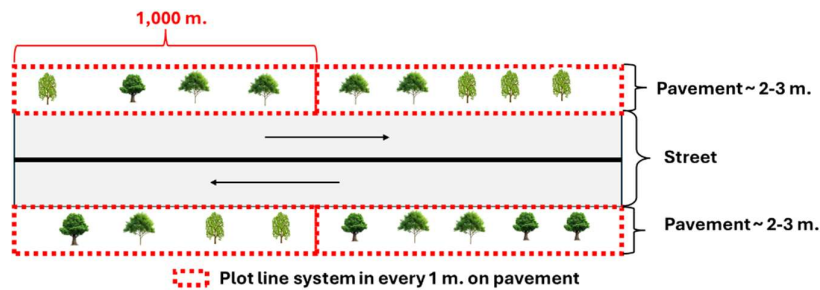**Figure 1.** The geographical location of NCM area

Figure 2. Method of line plot system for collecting trees' data along pavement in NCM-road
(modified from ONEPP [21,22])

Figure 3. Characterizing tree measurement on pavement in NCM roads

Based on the surveyed data above, they were analyzed by using approach of Kutintara [15] and Marod [16] for tree diversity as Table 1. This Shannon-Wiener Index (S-W I) can increase when the number of species in plant community is regularly increased in the distribution of the number of plants in each species, but it should not exceed 5 [21,22]. If this diversity index equals 0, all plant populations in the community will have just one species. Moreover, this research checked tree

species of IUCN red list [23], native and exotic species in global assessment.

Table 1. Tree diversity analysis of trees along sidewalks of NCM roads

No.	Items, unit	Measurements
1	Density (D), trees	The total number of tree species appears in each sample plot, which is divided by all surveyed areas of sample plots.
2	Frequency (F), trees	The number of sample plots where tree species appears, which is divided by all surveyed areas of sample plots.
3	Dominance (Do), Canopy area	The total canopy area of tree of each species in each sample plot is divided by all surveyed sample plots.
4	Relative Density (RD), %	The relative density value of each tree species, which is divided by the sum of density value of all tree species in the sample plots and then multiplied by 100.
5	Relative Frequency (RF), %	The relative frequency value of each tree species, which is divided by the sum of frequency value of all tree species in the sample plots and then multiplied by 100.
6	Relative Dominance (RDo), %	The relative dominant value of each tree species in canopy area, which is divided by the sum of dominant value of all tree species in the sample plots and then multiplied by 100.
7	Importance Value Index (IVI)	The sum of relative values of tree species consists of RD, RF, and RDo.
8	Shannon-Wiener Index (S-W I)	$$H = - \sum_{i=1}^{s} p_i \, log_2 p_i$$ Where H is index value of plant species diversity p_i is proportion between the number of trees' species i for all trees. S is total tree species

3. RESULTS

Tree distribution and diversity along sidewalks on NCM roads was collected from 229 sample plots (the total road length about 229 km. and the total area of pavement about 11.221 km^2). Trees had densely occurred in the old moat location as Figure 4 and data of tree diversity in Table 2. From Table 2, interval of S-W I was between 0-2.551, this study arranged 3 levels of diversity values on sidewalks of NCM roads: Low (L), Medium (M), and High (H), as shown in Table 3. The group of low intervals of tree diversity index was the highest quantity (9 roads) and group of high (8 roads) and medium (6 roads) interval respectively. It is worth noting that all 8 NCM-road of the high S-W I interval,

is in zone of NCM-old moat. This zone presently, is developed as cultural tourism because there are Thai important heritage such as Thao Suranaree Monument (as the center of faith of Korat people) and 6 old ancient temples (Bueng, Sakaeo, Bon, E-San, Phra Narai Maharat, and Phayap).
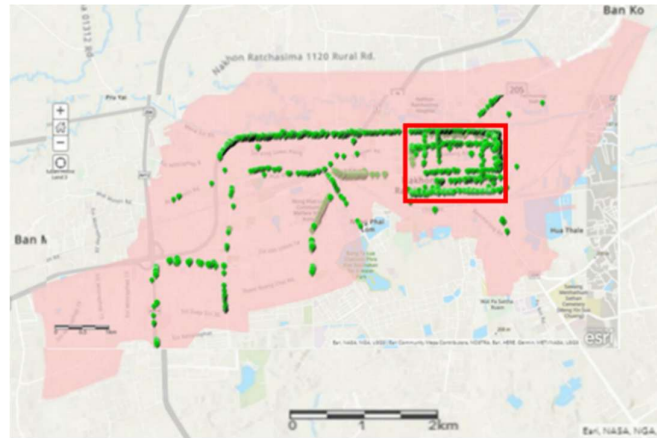

Figure 4. Distribution of street trees along pavements in NCM roads
(Pink area as NCM bound, Green point as tree and Red frame as the NCM old moat)

Table 2. Data of tree species diversity along pavements in 24 NCM roads in year 2021-2022

Road names (total trees and tree species)	Details for each tree species (number of trees, S-W ID)	S-W I (Total, Average)
1. Chumphol (85, 12)	*Pterocarpus macrocarpus* (22, 0.350), *Ficus macrocarpa* (12, 0.276), *Mimusops elengi* (12, 0.276), *Cassia fistula* (8, 0.222), *Lagerstroemia speciosa* (7, 0.206), *Melia azedarach* (6, 0.187), *Diospyros ehretioides* (3, 0.118), *Millingtonia hortensis* (2, 0.088), *Caesalpinia pulcherrima* (2, 0.088), *Lagerstroemia floribunda* (1, 0.052), and *Plumeria obtuse* (1, 0.052)	2.155, 0.180
2. Vatcharasarid (7,1)	*Mimusops elengi* (7, 0)	0,0
3. Manat (40, 2)	*Tabebuia a*urea (10, 0.347) and *Cassia Fistula* (30, 0.216)	0.562, 0.281
4. Kudan (2, 1)	*Tabebuia rosea* (2, 0)	0,0
5. Phonsen (146, 16)	*Cassia fistula* (48, 0.366), *Melia azedarach* (32, 0.333), *Terminalia catappa* (15, 0.234), *Saribus rotundifolius* (14, 0.225), *Plumeria obtuse* (8, 0.159), *Lagerstroemia speciosa* (7, 0.146), *Borassus flabellifer* (5, 0.116), *Caesalpinia pulcherrima* (5, 0.116), *Pterocarpus macrocarpus* (3, 0.080), *Tamarindus indica* (3, 0.080), *Ixora chinensis* (1, 0.034), *Ficus religiosa* (1, 0.034), Tabebuia rosea (1, 0.034), *Diospyros ebenum* (1, 0.034), *Mimusops elengi* (1, 0.034), and *Azadirachta indica* (1, 0.034)	2.057, 0.129
6. Yommarat (72, 4)	*Cassia fistula* (22, 0.362), *Peltophorum pterocarpum* (43, 0.308), *Lagerstroemia floribunda* (5, 0.185), and *Tamarindus indica* (2, 0.100)	0.955, 0.239
7. Phonlan (33, 16)	*Tamarindus indica* (6, 0.310), *Pithecellpbium dulce* (6, 0.310), *Murraya paniculata* (2, 0.170), *Wrighta arborea* (2,0.170), *Bauhinia purpurea* (2,0.170), *Lagerstroemia floribunda* (2,0.170), *Flacourtia rukam* (2,0.170), *Peltophorum ptercarpum* (2,0.170), *Cassia fistula* (2,0.170),	2.551, 0.159

Road names (total trees and tree species)	Details for each tree species (number of trees, S-W ID)	S-W I (Total, Average)
8. Asadang (69, 7)	*Lagerstroemia speciosa* (57, 0.158), *Cassia fistula* (3, 0.136), *Cerbera odollam* (2, 0.136), *Tabebuia rosea* (2, 0.103), *Mimusops elengi* (2, 0.103), *Ficus be*njamina (1, 0.061), and *Senna siame*a (1, 0.061)	0.758, 0.126
9. Mahatthai (36, 8)	**Pterocarpus macrocarpus* (13, 0.368), *Mimusops elengi* (10, 0.356), *Alstonia scholaris* (4, 0.244), *Terminalia catappa* (4, 0.244), *Tabebuia rosea* (2, 0.161), *Wrightia religiosa* (1, 0.100), *Peltophorum pterocarpum* (1, 0.100), and *Cassia fistula* (1, 0.100)	1.671, 0.209
10. Sanphasit (49, 10)	*Peltophorum pterocarpum* (20, 0.366), *Peltophorum pterocarpum* (8, 0.296), *Mangifera indica* (7, 0.278), *Terminalia catappa* (6, 0.257), *Cassia fistula* (3, 0.171), *Codiaeum variegatum* (1, 0.079), *Ficus religiosa* (1, 0.079), *Tabebuia rosea* (1, 0.079), *Syzygium malaccense* (1, 0.079), and **Pterocarpus macrocarpus* (1, 0.079)	1.765, 0.176
11. Kamhaeng Songkhram (55, 9)	*Cassia fistula* (25, 0.358), Mimusops elengi (8, 0.280), *Terminalia catappa* (7, 0.262), *Pithecellobium dulce* (4, 0.191), *Cerbera odollam* (4, 0.191), *Ficus religiosa* (2, 0.121), *Tamarindus indica* (2, 0.121), *Caesalpinia pulcherrima* (2, 0.121), and *Phyllanthus acidus* (1, 0.073)	1.717, 0.191
12. Chang Phueak (4, 2)	*Ficus religiosa* (1, 0.347) and *Peltophorum pterocarpum* (3, 0.216)	0.562, 0.281
13. Sueb Siri (50, 11)	*Sindora siamensis* (17, 0.367), *Samanea saman* (10, 0.322), *Cassia fistula* (6, 0.254), *Cerbera odo*llam (6, 0.254), *Lagerstroemia speciosa* (3, 0.169), **Pterocarpus macrocarpus* (2, 0.129), *Tamarindus indica* (2, 0.129), *Millingtonia hortensis* (1, 0.078), *Mimusops elengi* (1, 0.078), *Pithecellobium dulce* (1, 0.078), and *Terminalia catappa* (1, 0.078)	1.937, 0.968
14. Ratchanikun (79, 9)	**Pterocarpus macrocarpus* (66, 0.150), *Amarindus indica* (3, 0.124), *Samanea saman* (2, 0.093), *Cassia fistula* (2, 0.093), *Terminalia catappa* (2, 0.093), *Senna siamea* (1, 0.055), *Millingtonia hortensis* (1, 0.055), *Cocos nucifera* (1, 0.055), and *Lagerstroemia speciosa (1, 0.055)*	0.775, 0.086
15. Ratchadamnoen (38, 10)	*Borassus flabellifer* (18, 0.354), *Lagerstroemia speciosa* (5, 0.267), *Ficus benjamina* (3, 0.200), **Pterocarpus macrocarpus* (3, 0.200), *Tamarindus indica* (3, 0.200), *Cassia fistula* (2, 0.155), *Millingtonia hortensis* (1, 0.096), *Casuarina junghuhniana* (1, 0.096), *Syzygium cumini* (1, 0.096), and *Terminalia catappa* (1, 0.096)	1.760, 0.176
16. Suranaree (12, 3)	*Samanea saman* (1, 0.207), *Peltophorum pterocarpum* (1, 0.207, and *Lagerstroemia speciosa* (10, 0.152)	0.566, 0.189
17. Pho Klang (4, 2)	*Bauhinia purpurea* (1, 0.347) and *Lagerstroemia floribunda* (3, 0.216)	0.562, 0.281
18. Chomsurang Yat (49, 7)	*Lagerstroemia floribunda* (15, 0.362), *Lagerstroemia duperreana* (14, 0.358), *Pterocarpus indicus* (7, 0.278), *Bauhinia purpurea* (6, 0.257), *Peltophorum pterocarpum* (5, 0.233), *Cassia fistula* (1, 0.079), and *Tabebuia rosea* (1, 0.079)	1.647, 0.235
19. Mukmontri (21, 6)	*Lagerstroemia speciosa* (10, 0.353), *Terminalia catappa* (4, 0.316), *Tamarindus indica* (3, 0.278), *Tebebuia rosea* (2, 0.224), *Ficus religiosa* (1, 0.145), and *Pithecellobium dulce* (1, 0.145)	1.461, 0.244
20. Det Udom (35, 1)	*Peltophorum pterocarpum* (1, 0)	0, 0
21. Ratchasima-Chokchai (175, 11) (A part of Highway no. 224)	*Lagerstroemia speciosa* (89, 0.344), *Tabebuia rosea* (35, 0.322), **Pterocarpus macrocarpus* (26, 0.283), *Alstonia scholaris* (10, 0.164), *Ficus religiosa* (3, 0.070), *Ficus benjamina* (3, 0.070), *Wrighta arborea* (2, 0.051), *Lagerstroemia duperreana* (2, 0.051), *Diospyros ebenum* (2, 0.051), *Lagerstroemia floribunda* (1, 0.030), *Terminalia ivorensis* (1, 0.030), *Termianlia catappa* (1, 0.030)	1.494, 0.031

Road names (total trees and tree species)	Details for each tree species (number of trees, S-W ID)	S-W I (Total, Average)
22. Suranarai (106, 5) (A part of Highway no. 205)	*Tabebuia rosea* (64, 0.305), *Cassia fistula* (17, 0.294), *Lagerstroemia floribunda* (12, 0.247), **Pterocarpus macrocarpus* (7, 0.179), *Lagerstroemia speciosa* (6, 0.163)	1.187, 0.237
23. Mittraphap Rd. (389, 18) (A part of Highway no. 2)	*Lagerstroemia speciosa* (120, 0.363), *Tabebuia rosea* (83, 0.330), **Pterocarpus macrocarpus* (79, 0.324), *Cerbera odollam* (51, 0.266), *Tabebuia aurea* (11, 0.101), *Plumeria pudica* (11, 0.101), *Lagerstroemia duperreana* (10, 0.094), *Ficus religiosa* (4, 0.047), *Terminalia c*atappa (4, 0.047), *Gliricidia sepium* (3, 0.038), *Livistona rotundifolia* (3, 0.038), *Cassia fistula* (3, 0.038), *Millingtonia hortensis* (2, 0.027), *Ixora chinensis* (1, 0.015), *Senna siamea* (1, 0.015), *Tamarindus indica* (1, 0.015), *Pithecellobium dulce* (1, 0.015), *Azadirachta indica* (1, 0.015)	1.889, 0.105
	Overview of S-W ID total and average	3.817, 0.159

Remark: - Details for each tree type (number of trees, S-W ID) are arranged from highest to lowest.

      - For checking tree species of IUCN red list: * is globally assessed by 1 endangered species (EN) and 10 exotic trees: *Ficus macrocarpa*, *Caesalpinia pulcherrima*, *Tabebuia aurea*, *Borassus flabellifer*, *Caesalpinia pulcherrima*, *Tamarindus indica*, *Diospyros ebenum*, *Tamarindus indica*, *Codiaeum variegatum*, and *Pithecellobium dulce*

Table 3. Ranking for tree diversity index on sidewalks of 23 NCM roads

Rank	Interval of S-W I	Quantity	Road names
L	0.000-0.850	9	Vatcharasarid, Manat, Kudan, Asadang, Chang Phueak, Ratchanikun, Suranaree, Pho Klang, and Det Udom
M	0.850-1.700	6	Yommarat, Mahatthai, Chomsurang Yat, Mukmontri, Ratchasima-Chokchai Rd (A part of Highway no. 225), and Suranarai Road (A part of Highway no. 205)
H	1.700-2.551	8	Chumphol, Phonsen, Phonlan, Sanphasit, Kamhaeng Songkhram, Sueb Siri, Ratchadamnoen, Mittraphap Rd. (A part of Highway no. 2)
	Total	23	

4. Discussion

When we considered the concerned papers about analyzing S-W I for street tree from a recent study of Sikuzani et al. (2022), street trees' data in Lubumbashi city in the Democratic Republic of the Congo (DR Congo) were analyzed by S-W I, presented about 2.426. In year 2012, there were a survey in the Nordic region or Northern European countries (Sjöman et al., 2012), they had been calculated by S-W I along pavements as: 2.150 of Helsinki, Finland; 5.150 of Malmö, Sweden; 5.800 of Aarhus, Denmark; 4.800 of Copenhagen, Denmark. These tree diversity values of S-W I were compared with this study (3.817 of NCM, Thailand), our results are within the range of Lubumbashi city, Congo and the Nordic countries. For Asian region, at the time of the study we reviewed the related literature, there were not have calculation of tree diversity index along sidewalks of city. There is only a survey of the number of trees, tree species, and abundance, for example, Kjelgren et al. (2011), Wang et al. (2018) etc. For checking tree species

of IUCN red list: *Pterocarpus macrocarpus* is globally assessed by 1 endangered species (EN) and 10 exotic trees: *Ficus macrocarpa, Caesalpinia pulcherrima, Tabebuia aurea, Borassus flabellifer, Caesalpinia pulcherrima, Tamarindus indica, Diospyros ebenum, Tamarindus indica, Codiaeum variegatum,* and *Pithecellobium dulce.*

5. Conclusion

Tree distribution and diversity along sidewalks in NCM roads were surveyed using GSV and field surveys conducted from November 2021 to January 2022. Trees had densely occurred in the old moat location and they were non-native species. Overview of tree diversity along sidewalks on such NCM roads consisted of 1,556 trees (~50 trees/road or 5.824 trees/km^2), 171 tree species (5 tree species/road or 1 tree species/km^2), density 166.542 trees (~7 trees/road or 0.576 trees/km2), frequency 18.743 trees (~1 trees/road or 0.072 trees/km^2), dominance 0.036 trees (~0.001 trees/road or 0.0001 trees/km^2), the sum of the IVI 300 (average 12.500) and the sum of the S-W I 28.029 (average 3.817). Based on results of S-W I in each pavement of NCM roads, the highest sum and average of S-W I (2.551, 0.159) were seen on Phonlan Rd. while the lowest sum and average of S-W I (0, 0) were seen on 3 roads (Vatcharasarid Rd., Kudan Rd. and Det Udom Rd.). These 3 roads S-W I equals 0, indicated that they had just one species. It has more significantly concluded that every 1 km^2 on the sidewalk in a road in NCM has a possibility that it may be found about 1 tree or without tree. Consequently, this study provides valuable information about tree population along sidewalks in 31 NCM roads. For benefits, NCM officers and policy makers will be able to use the obtained results for planning green city and tree maintenance including extending the results and the obtained outputs in this study to new roads that are being planned to be built in NCM in terms of guidelines for planting and selecting tree types. For checking tree species of IUCN red list: *Pterocarpus macrocarpus* is globally assessed by 1 endangered species (EN) and 10 exotic trees:

Ficus macrocarpa, Caesalpinia pulcherrima, Tabebuia aurea, Borassus flabellifer, Caesalpinia pulcherrima, Tamarindus indica, Diospyros ebenum, Tamarindus indica, Codiaeum variegatum, and *Pithecellobium dulce.*

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