ORIGINAL ARTICLE

An Assessment of Urban Canopy Cover over Chiang Mai Municipality

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ABSTRACT

Total canopy cover and canopy cover over Chiang Mai City Municipality (CMCM) was made based on the results of aerial photography interpretation. Canopy cover of the city varied between 21.5% and 33.9% by subdistrict, averaging 31.1% citywide. The interpretation of urban tree canopy cover distribution from aerial photographs has provided a geographical baseline for understanding the current situation, including future planning and management of the urban forest of the city. Meanwhile, there were potential patch of natural vegetation located within Chiang Mai University where is covered with remnant of original vegetation of mixdeciduous and dry evergreen forests. That area contains significant potential for developing to be large green space close to the city centre.

Key words: canopy cover, urban forest, aerial photogragraph interpretation, Chiang Mai

INTRODUCTION

Tree canopy cover, or in the other hand, the amount and distribution of leaf area, is the major factors behind the urban forest's ability to produce benefits for the urban community. When tree canopy increases, the benefits derived by leaf area: climate control and energy saving; improvement of air, soil, and water quality; mitigation of storm water runoff; reduction of the greenhouse gas; provision of wildlife habitat; and real estate value are also increased.

The amount of community tree canopy cover is one indicator of urban forest sustainability (Clark *et al.*, 1997). It is generally said that the more canopy cover the better the benefits affording to urban environment. Apart from providing aesthetic appeal to the city, canopy of urban trees can mitigate the 'heat island' effect and lower local air temperature through their evapo-transpiration and shading of the ground surface (Gordon *et al.*, 1990). Urban trees play significant roles in rainfall interception and reduce surface runoff by intercepting and storing rainfall on their leaf and branch surfaces to delay the peak flow of water (Rowntree and Norwak, 1991; McPherson, 1994; Norwak, 1994; Qi *et al*., 1998; Backett *et al*., 2000). More importantly, trees can reduce atmospheric carbon dioxide - the most important heat trapping gas (Jo and Mc Pherson, 1995). Trees situated close to busy roads can capture more significantly larger particle size fraction than those situated in the rural locations (Backett *et al*., 2000). Clump of trees also provides habitat, food, and shelters for urban wildlife (Vilkitis, 1978; Johnson, 1990; Gordon *et al*., 1990; DeGraaf, 1991; Jokimaki and Suhonen, 1998).

Frequently canopy cover analysis can assist urban forester and related responsible bodies to understand the current urban tree situation in the city, including the need to explore appropriate management approaches to achieve sustainable urban forest management in particular areas. Up to the present, urban tree canopy cover has become widely recognized as an important component in urban communities (Summit and McPherson, 1998; Lorenzo *et al*., 2000). It has been well assessed and documented in North America and Europe that trees planted in urban areas perform significant services to urban inhabitants (Cumming *et al*., 2001), whilst no such information is documented in Thailand. The problem might come from the fact that tree canopy cover assessment in any given areas has proven a difficult task due to differences in ground surface cover and relate issues such as resource structure, land use patterns climate, management practices, and urban inhabitants' attitudes (Maco and Mcphereson, 2003). This paper describes how estimation of tree canopy cover of the city can be calculated by using aerial photogrammetry examination. Meanwhile, the objective of this study was to demonstrate a simple way to quantify the city's total canopy cover. Results will give quantitative information as well as provide an overview of current urban forest situation of the city.

MATERIALS AND METHODS

General Feature of the Study Area

Geographically, the city of Chiang Mai is situated on terrain that was formerly flood plain and bounded by mountain ridges of Suthep-Pui National Park in the west edge of the city. The mountain rising to 950 m above mean sea level before sloping down to 304 m at the Ping River banks at the middle of the city (Figure 1). The river runs through the city from northwest separates the city apart and causes the area occupies a long basin of floodplain along the length of river. Pre-urbanization natural vegetation was broadleaf dry evergreen and mixdeciduous forests that have long been eradicated after centuries of human impact. Remnants of original vegetation can be seen in Huay Kaew

Botanical Garden and Chiang Mai University (CMU). Soil types of the hilly platforms in the West of the city are covered by typical humid tropical soils, whereas in the floodplain areas have a mixture of sediments including fine and coarse sandy soil with alluvial. Furthermore, most areas in the centre of the city are either sealed by concrete or filled soil due to human influence.

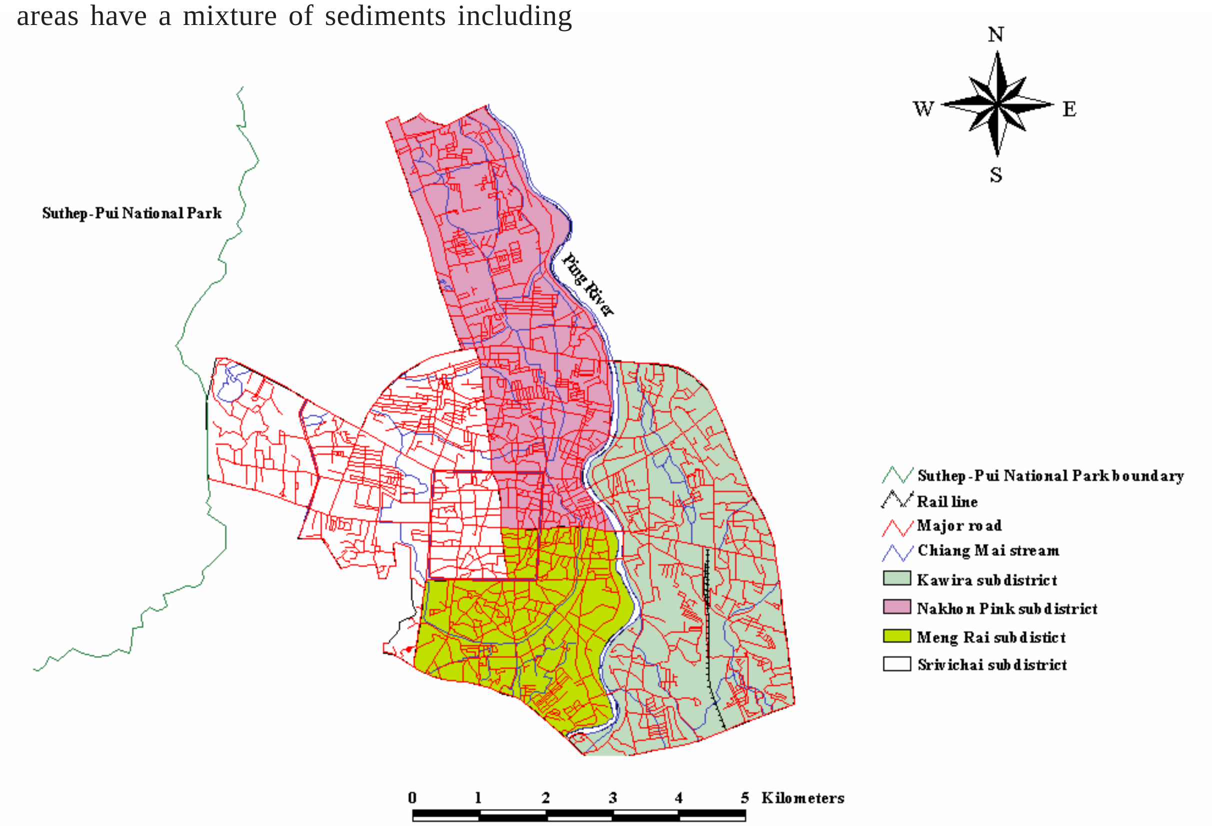

Figure 1. Location of the study site in relation to Suthep-Pui National Park and Ping River showing subdistricts.

The inner city is characterized by narrow streets and very dense housing including old temples and government buildings, while suburban areas are quite sparse of residential settlements and built-up facilities. Vehicle traffic during working hours is moderate-to-heavy in the city, with a high proportion of motorcycles. A dominant feature is national highway route 11, a major road leading into the city from the South and connecting the city to other provinces of the country. The presence of this highway makes the city not only a major gateway to other provinces, but also to neighboring countries such as Myanmar, Lao People Democratic Republic, and southern China.

The climate is tropical, characterized by three seasons: summer, rainy, and winter. In 2003, average annual rainfall was 889.6 mm with 97 rainy days and 92.5 and 52.1 percent of mean maximum and minimum of relative humidity, respectively. The maximum summer temperature exceeds 38.0 °C, dropping to a minimum of 12.5 °C in winter with a mean annual temperature of 21.5 °C (National Statistical Office, 2004).

In case of socio-economic and demographic information, the city contained 158,720 people with 74,407 male and 84,313 female in 2003. Average population density was 4,427.46 persons per km^2 (44.3 persons per ha). Total of dwellings was 69,075 household with average household size of 2.9 persons per household compared to 3.5 persons per household at national level. Total income and expenditure in 2003 were 239.55 and 211.63 USD per month, respectively (National Statistical Office, 2004).

Method

With an attempt to achieve the objective, the use of aerial photogrammetry interpretation is chosen to examine tree canopy cover over Chiang Mai City Municipality (CMCM) in this study. According to Norwak *et al.*, (1996), interpretation of aerial photographs is the most detailed and cost-effective way of assessing urban tree distribution. An advantage of using aerial photography is that flights can be scheduled as desired such as at solar noon that can reduce inaccuracies caused by shadows of clouds (Akbari *et al.*, 2003). Furthermore, using aerial photography at the appropriate scale is possible to identify clearly the aspect of tree canopy cover that makes up to be urban area.

In order to understand the structure of urban forest, a first step could be to describe the spatial distribution of tree canopy cover (Rowntree, 1998) which is typically expressed as a percentage of tree canopy cover across a city when viewed from above (Dwyer and Miller, 1999). The information yields the more extensive view of urban forest than inventories do. However, information of tree canopy cover distribution plus data derived from urban tree ground inventory would enhance opportunities for comprehensive management (Norwak *et al.*, 1996).

CMCM is the only major city municipality within the northern region of the country, covering and area of 35.849 km^2. Information regarding current tree canopy cover is needed for further urban forestry planning and development. Unfortunately, information about such spatial distribution within the city has been limited so that assessment is now regared as priority for further urban forest management. In this study, physical attributes of tree canopy cover of CMCM was visually inspected by interpreting the latest available version of true color aerial photography of the whole city (taken in 2005) scale 1:5 000 derived from Royal Thai Survey Department (RTSD). The exact boundary of each tree canopy cover was placing in fixed polygons on individual transparent sheets that were overlaid on the aerial photographs (Nowak *et al.*, 1996). During the interpretation process, the study was consulted by Chiang Mai City Municipality Office (CMCMO) and Department of Community Development (DCD) combining with ground check during the street tree inventory conducted in order to ensure the right interpretation of the aerial photographs. Areas covered by tree canopy were estimated by using the dot grid technique. Meanwhile, reference of land use features was based on the categories used in KU/FF (2003).

Data Analysis

The interpretation procedure was adopted from a technique developed by the Florida Division of Forestry for assessing overall land use type and tree canopy cover in urban areas (Theobald, 1978 cited by Miller, 1997) and was used by many researchers e.g. McBride and Jacobs (1976), Rowntree (1986), and Norwak *et al.* (1996). The technique involves the use of a dot grid overlaid on existing photograph. The total number of dots that fall on each area or a tree crown is counted, and the area is then calculated to be area in km^2 by using a conversion table. Meanwhile, tree canopy cover is also calculated into percentage by employing the following formula:

$$\% \text{ Tree canopy cover} = \frac{\text{Dots on tree canopy cover}}{\text{Total number of dots}} \times 100$$

In particular, the calculation for estimates of percent tree canopy cover was conducted by applying standard errors calculation. An increase in analyzed number of dots would lower the result of standard error calculation and also increase the confidence in tree canopy cover estimation (Norwak *et al.*, 1996).

RESULTS AND DISCUSSION

Results

Mean tree canopy cover of the city was highest in Kawira and lowest in Srivichai with the mean for the whole city was 31.13% (Figure 2). Distribution of canopy cover throughout the city is presented in Figure 3.

Based on calculation of overall mean canopy cover by land use categories, patches of dense canopy cover within other land use type showed highest percent tree cover than those situated in the rest categories (Table 1). Furthermore, city parks contained high canopy cover especially in Huay Kaew Aboretum and Suan Lung Lanna Rama IX.

Open spaces, where principally considered as abandoned by prior uses and now then covered with woody stands in some areas, showed slightly different from golf courses in percent canopy cover. Water surfaces were also in the case to reveal considerable richness of green cover area where mostly located along Ping River's banks. Furthermore, less than 20% of mean canopy cover appeared within the developed area where was mostly covered with built up and developed infrastructures of the city. City sport ground accounted for 16% of canopy cover although most areas were designed as recreational grounds for inhabitants of the city with always covered with artificial surfaces. The least value of canopy stocking of land use categories as a whole is agricultural area that occupied approximately 12% for all four subdistricts. These land use type was typically most found within Nakhon Pink located at the North of the city.

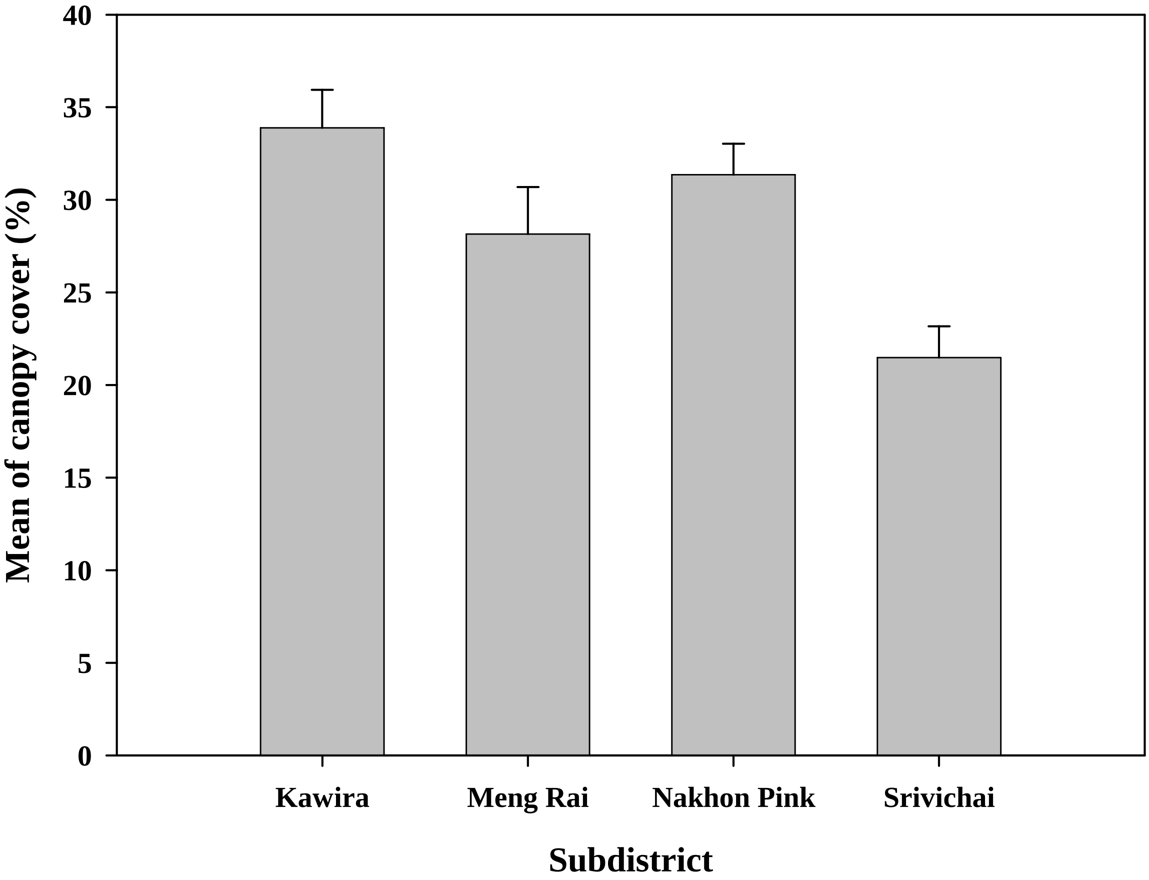

Figure 2. Tree canopy covered by subdistricts. Bars represented means and vertical lines represented standard errors. Site sharing a letter not significantly different from one another, as determined by LSD to means separation test (P < 0.05).

Discussion

The citywide assessment of tree canopy cover distribution provided baseline data about physical features of urban forest distribution of the city (Welch, 1994). Derived information will generate useful records of specific information that planners, managers, elected officials, and other parties interested in land use planning of the city can use for further green-space planning of the city.

Within a city, tree canopy cover and available growing space are generally determined by land use (Rowntree, 1986). According to the data derived from aerial photographs interpretation, although developed area was made up more than half of the city's area, the city was covered by 33% of canopy cover. This figure is a useful numerical measure and can be used to compare to different cities in western countries regardless

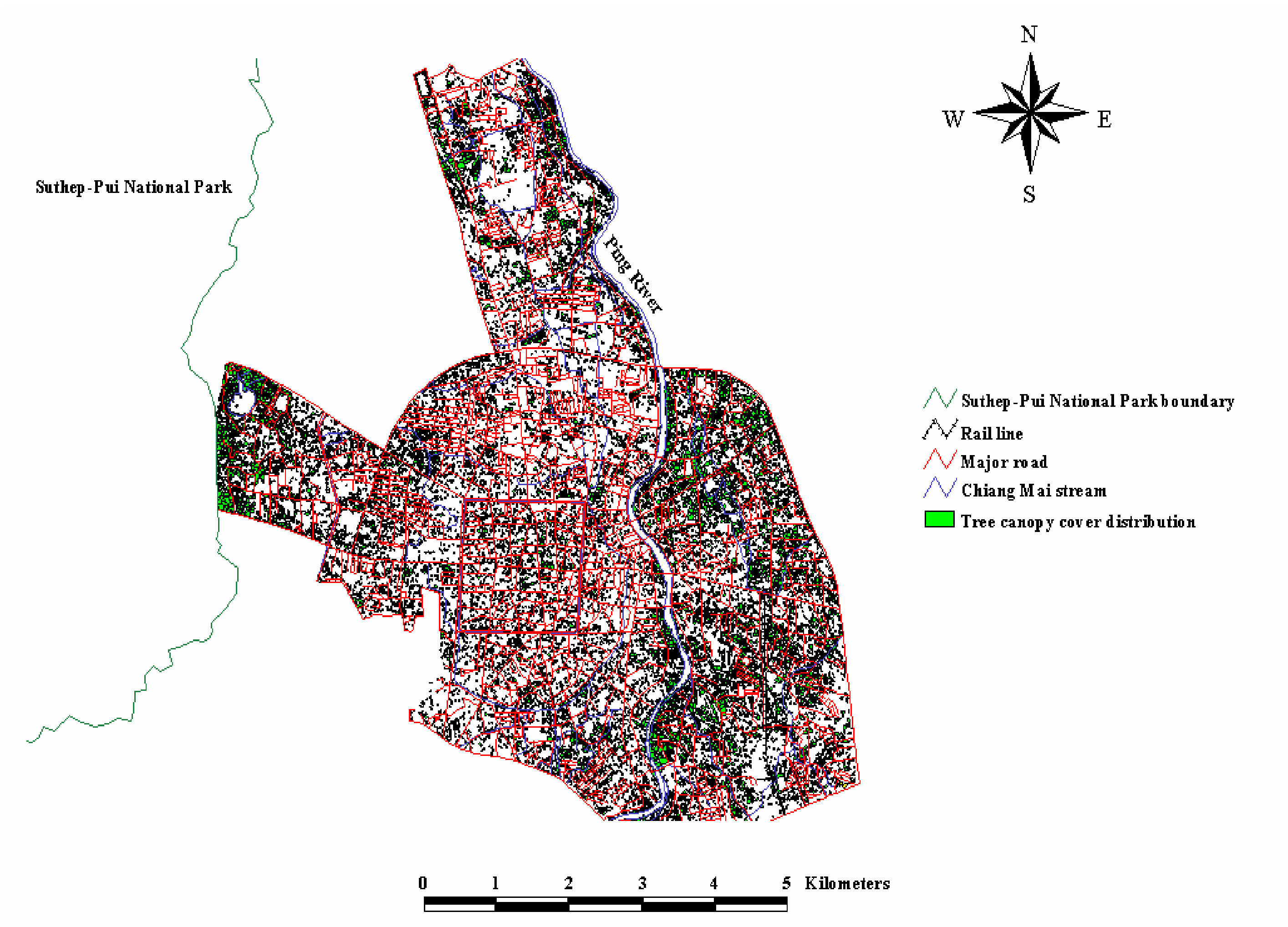

Figure 3. **Distribution of tree canopy cover within Chiang Mai City Municipality (CMCM). Subdistricts are demonstrated in Figure 1.**

Table 1. Mean percent tree canopy covered by land use type and standard error for Chiang Mai City Municipality (CMCM) by subdistrict

	Proportion of the city																	
Sub-district	**Dev.**		**Park**		**Sport**		**Open**		**Golf**		**Agri.**		**Water**		**Other**		**Total**	
	Mean	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**	**Mean**	**SE**
Kawira	29.71	3.38	46.15	n/a	12.19	2.95	36.5	2.49	18.02	n/a	20.24	14.31	12.19	15.49	56.15	11.82	33.89	2.05
Meng Rai	12.87	1.23	67.01	17.57	24.09	5.81	21.98	2.44	n/a	n/a	13.88	8.97	49.14	13.21	56.47	5.41	28.15	2.54
Nakhon Pink	15.15	2.27	29.31	14.76	13.16	8.45	19.67	2.77	33.81	n/a	13.40	2.31	10.37	2.39	50.03	3.58	31.16	1.67
Srivichai	16.28	3.15	52.34	21.52	16.29	4.43	18.95	1.71	n/a	n/a	10.42	2.49	21.66	4.39	66.71	3.31	21.48	1.69
Mean	**19.00**	**1.41**	**37.55**	**8.67**	**15.56**	**2.69**	**26.43**	**1.40**	**25.92**	**7.87**	**11.87**	**1.99**	**22.62**	**2.52**	**53.98**	**3.28**	**31.13**	**1.01**

Remark: Dev. = Developed area, Park = City parks, Sport = City sport ground, Open = Open space, Golf = Golf course, Agri. = Agricultural area, Water = Water surface, Other = other with different sizes of the places (Poracsky and Scott, 1999). For examples, compare to 2.2% in Maxico City, 5% in Madrid, 14% in Brussels (Stanners and Bourdeau, 1995 as cited by Nilsson and Randrup, 1997), 23% in Copenhagen (Nilsson and Randrup, 1997), 25% in Seattle, 17% in New York, 21% in Boston, 22% in Philadelphia, and 33% in Atlanta (Welch, 1994). However, the distribution of tree canopy cover across the city reflects land use and land development patterns (Poracsky and Scott, 1999). In particular, canopy cover was high among developed area within Nakhon Pink where old residential settlements were located along riparian of Ping River. The potential land use type for greening the city like agricultural area, where mostly located within Nakhon Pink, has tended to decrease due to the expansion of the city outward. Since the Fourth National Economic and Social Development Plan (1977-1981) designated the city as a regional centre for development, brought the phase of rapid urbanization and further encroachment into surrounding suburban areas of dense built-up areas such as residences, industrial, commercial and shopping complexes, hotels, and infrastructure. Demand for more land to facilitate urban activities has dramatically increased property value that motivated landowner's point of view to sell land would provide much more economically benefit than keeping on agriculture practice (TDRI, 1990). Only 1.78% of approximately 37 000 households in the city has maintained their land for producing agricultural products so far (National Statistical office, 2004).

Decline in tree cover occurred when moving to inward to the center of the city where the largest part of land use was determined principally by the density of artificial surfaces (Dywer and Miller, 1999). Densely built up parts of the city, where new residential settlements and commercial building were located, made trees scattering in small groups or single tree form. Furthermore, woody vegetation was also sparse in the broad ring of developed areas around the inner part of the city. However, results of the study indicate that there were potential patch of natural vegetation located within CMU where closely to Suthep-Pui National park. That area was covered with remnant of original vegetation of mix-deciduous and dry evergreen forest types with significant potential for developing to be large green cover close to where urban inhabitants live (Konijinendijk *et al.*, 2004) if combined with Huay Kaew Arboretum where situated nearby. Examples cities in Southeast Asia that embrace tropical rain forest within their boundaries are Kuala Lumpur and Singapore (Konijinendijk *et al.*, 2004). Thus, the extension of that area, if implemented, would increase the proportion of city parks area per inhabitant of the city that has still be low so far (2.7 m^2 per habitant) when compare to other cities such as Tokyo (5.4 m^2/habitant), Singapore (10.9 m^2 per habitant), Warsaw (15 m^2 per habitant), Maxico City (20.8 m^2 per habitant), and London

(23.0 m^2 per habitant) (KU/FF, 2003).

Knowing urban tree canopy distribution may help regional foresters and responsible organizations to determine what approach should be applied for sustaining urban forest management. In the future, the city will use aerial photography as basic information for the GIS data to mark the positions of parcels, including urban tree positions, more accurately. Moreover, historical documents, archival records and old aerial photographs of the city taken some decades ago should be examined and analysed to show the change in urban tree cover over the past period (McPherson, 1998; Rowntree, 1998) in city area. This will make the information of greater value for local planning projects and better support the urban forestry program. Training staff to enhance their skills in aerial photograph interpretation and use of the city GIS systems is also needed to achieve this aim.

This study also includes an identification of opportunities for a coordinated effort to sustain urban development. For example, potential corridor linkage between scattered green spaces can be identified and a program for connecting such green spaces may be established. These corridors will promote habitat connectivity not only for urban vegetation but also improve wildlife habitat for birds and small mammals (Galvin, 1999). Following from the analyses, dense, old stands of trees in temples, cemeteries, and in old residential areas as well as old orchards along Ping River banks within Nakhon Pink and Kawira should be mentioned as potential habitats for urban forest corridor linkage. Well-developed and preservation stands of trees in such areas may bind the fragmented remnants of urban tree cover distribution together to be large patches of continuous forest cover mosaic of the city (Clark *et al.*, 1997).

CONCLUSION

The purpose of this study is to figure out the canopy cover of the city of Chaing Mai. The preliminary finding has shown that, the city's canopy cover has created significant diversity in its urban tree resource. However, with urban development is quickly expanding into rural areas, there is a need to examine the existing urban forest resource and devise appropriate patterns to guide the development and maintain urban tree canopy for the city. The interpretation of urban tree canopy cover distribution from aerial photographs has also provided a geographical baseline for understanding the current situation, including future planning and management of the urban forest of the city.

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