ว.วิทย. มข. 42(4) 792-805 (2557) KKU Sci. J. 42(4) 792-805 (2014)

ความหลากชนิดและการสะสมคาร์บอนเหนือพื้นดินของไม้ต้นในหย่อมป่า ที่มหาวิทยาลัยขอนแก่น วิทยาเขตหนองคาย

Species Diversity and Above Ground Carbon Stock of Trees in Forest Patches at Khon Kaen University, Nong Khai Campus

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บทคัดย่อ

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อประเมินและเปรียบเทียบความหลากชนิดและปริมาณการสะสมคาร์บอนเหนือพื้นดินของไม้ต้นระหว่างหย่อมป่าในมหาวิทยาลัยขอนแก่น วิทยาเขตหนองคาย ซึ่งเป็นข้อมูลที่สำคัญสำหรับการจัดการที่ดินในพื้นที่วิทยาเขต โดยในปัจจุบันมีหย่อมป่าขนาดใหญ่เหลือเพียง 3 แห่งในพื้นที่ ดังนั้นจึงเลือกหย่อมป่าทั้ง 3 แห่งเป็นพื้นที่ศึกษา การศึกษานี้ใช้การวางแปลงขนาด 25x15 ตารางเมตร จำนวน 3 แปลงต่อหย่อมป่า 1 แห่ง ทำการจำแนกต้นไม้ทุกต้นในแปลงที่มีขนาดเส้นผ่านศูนย์กลางที่ระดับความสูงเพียงอกมากกว่า 4.5 เซนติเมตร พร้อมทั้งบันทึกขนาดของเส้นผ่านศูนย์กลาง และจำนวนต้นไม้ในแต่ละชนิด จากผลการศึกษา แม้ว่ากราฟเส้นโค้ง rarefaction แสดงให้เห็นว่าความหลากชนิดของไม้ต้นในหย่อมป่าทั้ง 3 แห่งไม่แตกต่างกันอย่างมีนัยสำคัญ อย่างไรก็ตามจำนวนชนิดของไม้ต้นทั้งหมด ตัวประเมินจำนวนชนิดแบบ Jackknite 1 และดัชนีความหลากชนิดของ Shannon ได้แสดงแนวโน้มว่า ความหลากชนิดของไม้ต้นในหย่อมป่า A มีแนวโน้มสูงกว่าหย่อมป่า B และ C ยิ่งกว่านั้นผลจากการวิเคราะห์การจัดกลุ่มแสดงให้เห็นว่าองค์ประกอบของชนิดไม้ต้นในหย่อมป่า A ครอบคลุมเกือบทั้งหมดของชนิดไม้ต้นที่พบจากหย่อมป่าทั้ง 3 แห่ง อีกทั้งค่าเฉลี่ยมวลชีวภาพเหนือพื้นดินซึ่งได้จากสมการ allometric และการสะสมคาร์บอนเหนือพื้นดิน แสดงให้เห็นว่ามวลชีวภาพและการสะสมคาร์บอนของหย่อมป่า A (101.39 ตัน/เฮกแตร์; 47.65 ตันคาร์บอน/เฮกแตร์) มีค่ามากกว่าของหย่อมป่า B (80.88 ตัน/เฮกแตร์; 38.01 ตันคาร์บอน/เฮกแตร์) และ C (81.33 ตัน/เฮกแตร์; 38.22 ตันคาร์บอน/เฮกแตร์) ดังนั้นจากผลการศึกษาทั้งด้านความหลากชนิดและปริมาณการสะสมคาร์บอน หย่อมป่า A ควรได้รับความสำคัญในลำดับแรกสุดในการอนุรักษ์

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ABSTRACT

The aims of this study were to determine and compare the species diversity and above ground carbon stock of trees among forest patches in Khon Kaen University, Nong Khai Campus which is the importance data for land management of the campus. At present, there are only 3 major forest patches in the campus. Therefore, these 3 forest patches, named forest patch A-C, were selected as the study site. Three of 25×15 m^2 were designated in each forest patch. All trees with the diameter at breast height (DBH) larger than 4.5 cm in each plot were identified to species and DBH and number of trees were also recorded. The results showed that although rarefaction curve indicated that tree diversities were not significantly different among 3 forest patches, the total number of species, Jackknite 1 richness estimator and Shannon index indicated that species diversity in forest patch A trend to be higher than in patch B and C. Moreover, cluster analysis indicated that species composition of forest patch A was covered most of species found in all 3 forest patches. Average above ground biomass from allometric equation and carbon stock indicated that the above ground biomass and carbon stock of forest patch A (101.39 ton/ha; 47.65 ton C/ha) were higher than forest patch B (80.88 ton/ha; 38.01 ton C/ha) and C (81.33 ton/ha; 38.22 ton C/ha). Therefore, based on the results from species diversity and carbon stock, the forest patch A should be the first priority to be conserved.

คำสำคัญ: ไม้ต้น ความหลากชนิด มวลชีวภาพ การสะสมคาร์บอน ป่าเต็งรัง

Keywords: Trees, Species diversity, Biomass, Carbon stock, Deciduous dipterocarp forest

Introduction

During a few decades, the anthropogenic global climate change seem to be the most important environmental issue though out the world (Cunningham and Cunningham, 2012). Many scientist pointed out that the rapid increasing of carbon dioxide (CO_2) in the atmosphere is the major cause of this problem (Wright, 2008; Cunningham and Cunningham, 2012). On the one hand CO_2 is the cause of climate change, on the other hand it have been released by most of the developmental processes. Presently, the development is progressing in everywhere and the limitation of an area is also one factor controlled the developmental process.

Khon Kaen University, Nong Khai Campus (NKC) is also dealing with this limitation. The natural forest patches in NKC have been converted to manmade constructions. Due to the fact that all forest trees can stock the carbon in its biomass, converting the forest area to the manmade construction would increase the concentration of CO_2 in the atmosphere, increasing the intensity of climate problem.

For the forest conservation, the tree diversity and carbon stock in each forest patch are the important data to support the forest conservation and land use planning. Since the difference in forest characteristic and biomass of each forest patch, removal of some forest patches may add the amount of CO_2 to the atmosphere higher than in other patches. Moreover, the difference in forest characteristics in different patches may be the cause of difference in tree diversity among the forest patches. The removing of some forest patch without the tree diversity data may has a larger impact to the biodiversity in the area. Therefore, these 2 parameters; tree diversity and carbon stock can be used as the important natural resource data to support the forest utilization planning of NKC in the future. Thus, the objectives of this study were to determine and compare the tree diversity and above ground carbon stock of the forest patches in NKC.

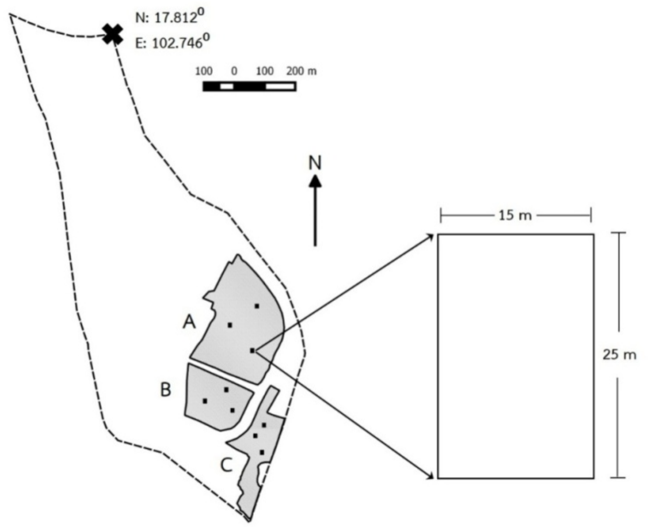

Figure 1. Boundary of Khon Kaen University, Nong Khai Cumpus (on the left) including 3 forest patches (A, B and C), 9 sampling plots (small black rectangle) and the magnified one sampling plot (on the right).

Research Methodology

At present, there are only 3 major forest patches in the NKC. Therefore, these 3 major forest patches were selected as the study sites, named forest patch A, B and C, respectively (Figure 1). Three of $25\times15\ m^2$ sampling plots were designated in each forest patch (Figure 1). Therefore, 9 sampling plots were used to sampling in 3 forest patches including forest patch A (sampling plot 1-3), forest patch B (sampling plot 4-6) and forest patch C (sampling plot 7-9). Every tree in each plot with the diameter at breast height (DBH) higher than 4.5 cm were identified to species and measured the DBH. Number of each tree species and DBH of each tree in the sampling plot were also recorded. The surveys were conducted from October 2013 to January 2014.

Data Analysis

Tree species diversity

Species and number of each species were used for tree diversity analysis while DBHs of all trees were used for the carbon stock analysis. Jacknnike 1 species richness estimator and Shannon index (H) were used to determine the tree species diversity of each forest patch. Rarefaction curve with 95% confident interval was used to compare the species richness among the forest patches. Jacknnike 1 estimator, Shannon index and rarefaction value with 95% confident interval were calculated by estimateS program (Colwell, 2013). The rarefaction values were plotted together with number of sampling tree to equivalent the sampling effort among forest patches (Magurran, 2004). Then rarefaction curves were used to determine the significant difference in species diversity among forest patches. For the species composition, the dissimilarity index was calculated according to Bray method and then the similarity in species composition among the forest patches was determined by complete linkage agglomerative clustering generated base on the dissimilarity matrix (Borcard et al., 2011). All clustering processes were generated by R program (R Core Team, 2013) with the vegan package (Oksanen et al., 2013).

Above ground biomass and carbon stock of trees

Above ground biomass of each forest patch was determined by allometric equation created base on the data from deciduous dipterocarp forest in northern Thailand (Ogawa, 1965 cited in Viriyabuncha, 2003).

$$W_s = 0.0396\ (D^2 H)^{0.9326}\ \text{kg}$$

$$W_b = 0.003487\ (D^2 H)^{1.0270}\ \text{kg}$$

$$W_l = (28.0/W_{tc}+0.025)^{-1}\ \text{kg}$$

The above ground biomass of each individual tree was the summation of W_s, W_b and W_l. W_s, W_b and W_l were the biomass of stem, branch and leaf, respectively. W_{tc} was a summation of the stem and branch biomass. D and H were DBH (cm) and height (m) of tree. Base on the high density of tree in this area, it was difficult to measure tree height directly in the field therefore, the tree height was determined by H (height) = $(121.8\ DBH^{0.638})/(38.8+3.14\ DBH^{0.638})$. The biomass of each plot was calculated by the summation of all tree biomass in the sampling plot. Then, biomass of each sampling plot was multiplied by 0.47 to determine above ground carbon stock (Aalde et al., 2006). The biomass and carbon stocks were compared among forest patches by average values with 95% confident interval.

Results

Tree species diversity

From 9 sampling plots, the total of 37 species of trees were found including 3 unknown species (appendix 1). The leaf shedding of tree in the study area was found during the late of study period (December to January). Among 34 identified tree species, they belonged to 16 families. Dipterocarpaceae and Rubiaceae were the highest diverse families in this study which were included 6 tree species for each family (Table 1). The highest abundant tree in the area was *Shorea obtusa* Wall. ex Blume (Shob) followed by *S. siamensis* Miq (Shsi) (Figure 2) (Appendix 1). Small trees (DBH: 4.5-9.99 cm) were major proportion of trees in the area (Figure 3).

Table 1. Number of species found in each family from all sampling plots.

Family	No. of species
Dipterocarpaceae	6
Rubiaceae	6
Leguminosae	5
Ebenaceae	3
Anacardiaceae	2
Labiatae	2
Other 10 families	1

Total number of species found from the survey, Shannon index and Jackknite 1 species richness estimator showed the similar trend and indicated that among 3 forest patches, the tree species diversity was highest at the forest patch A (Table 2). Although, Shannon index indicated that the diversity was highest at forest patch A followed by patch B and C, respectively, total number of species and Jackknite 1 estimator indicated that patch A had the highest diversity followed by patch B and C with the similar level of diversity (Table 2). However, rarefaction curve indicated that there were no significant difference in species diversities among these 3 forest patches (Figure 4).

Rarefaction curve showed that species richness in the forest patch A had only trended to be higher than in other 2 patches but it was not significantly different. It also showed that the species richness of tree were similar between forest patch B and C (Figure 4).

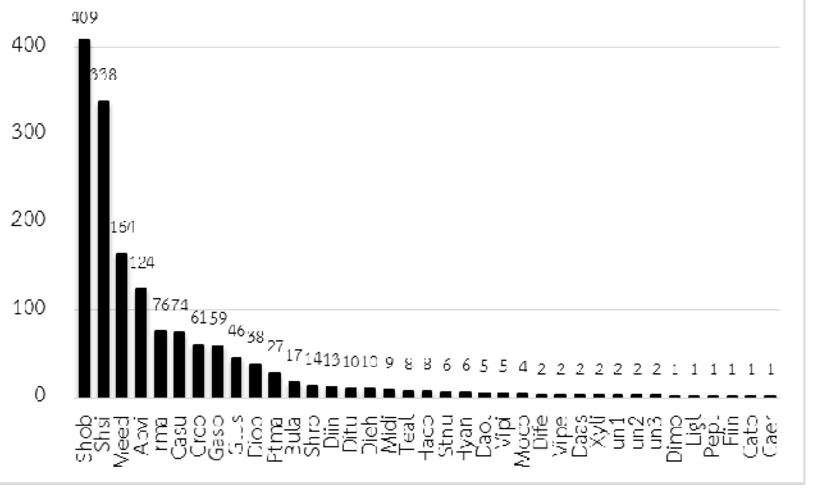

Figure 2. The total abundance of each tree species found from 9 study plots.

Remark: X label is the initial of scientific name of tree from Appendix 1.

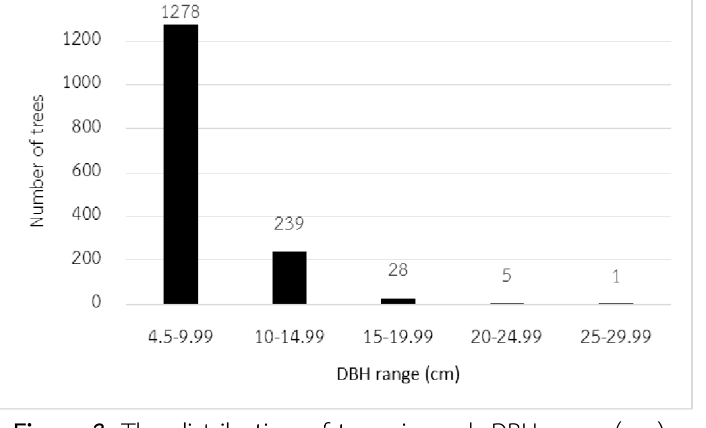

Figure 3. The distribution of trees in each DBH range (cm).

Table 2. Total number of species, Shannon index and Jackknite 1 estimator of each forest patch.

Patch	Total number of species	Shannon index	Jackknite 1 estimator
A	29	2.46	41
B	23	2.33	29
C	23	2.05	29

Table 3. Tree density, biomass and above ground carbon stock in each forest patch.

Forest patch	Tree density (tree/ha)	Biomass (ton/ha)				Above ground carbon (ton C/ha)
		Stem	Branch	Leaf	Above ground	
A	4,435.56	83.64	14.40	3.36	101.39	47.65
B	4,684.44	67.03	11.14	2.71	80.88	38.01
C	4,666.67	67.40	11.20	2.73	81.33	38.22

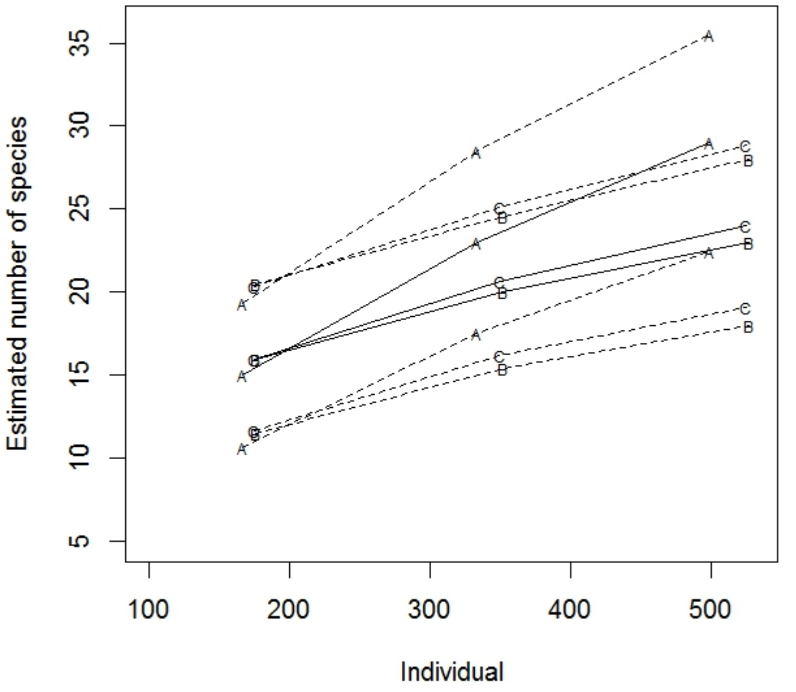

Figure 4. Rarefaction curve with 95% confident interval of tree species found from 3 forest patches.

Remark: A, B and C labeled the forest patch A, B and C, respectively. Solid line indicated the rarefaction value and dash line indicated 95% confident interval.

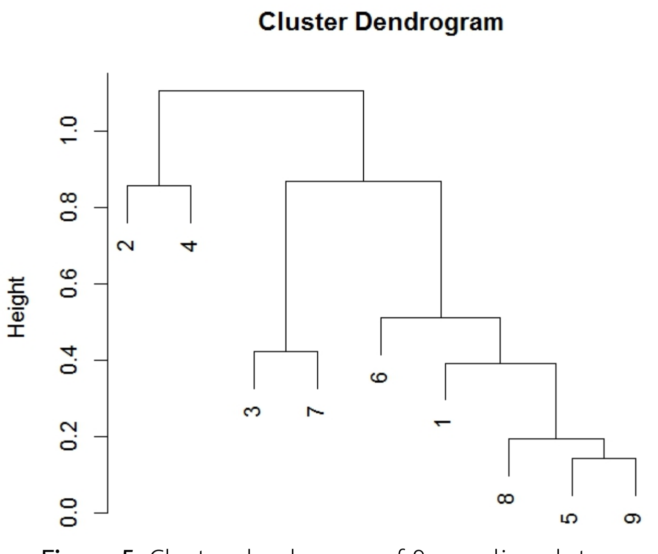

Figure 5. Cluster dendrogram of 9 sampling plots.

The complete linkage agglomerative clustering indicated that among 9 plots in this study, they were divided into 2 major groups (Figure 5). The first major group included plot 2 from forest patch A and plot 4 from forest patch B. The second major group had many more members. Therefore, the second major group was sub-divided in to 2 minor groups. The first minor-group was composed of plot 3 from forest patch A and plot 7 from forest patch C and the second minor-group was composed of plot 1 from forest patch A, plot 5 and 6 from forest patch B and plot 8 and 9 from forest patch C. The cluster result indicated that among these 3 clustering groups, forest patch A was the only one patch that had the members placed in each of 3 clustering groups.

Above ground biomass and carbon stock of trees

From the overall 9 sampling plots, the forest patch B had the highest density of tree (4,684 tree/ha) followed by patch C and A, respectively (Table 3). Among each parts of trees (stem, branch and leaf), most of biomass was in the stem part. The allometric equation indicated that the biomass of forest patch A, B and C were 101.39, 80.88 and 81.33 ton/ha, respectively. The above ground carbon stock was highest in the forest patch A (47.65 ton C/ha) followed by forest patch C and B with the values of 38.22 and 38.01, respectively. The 95% confident interval indicated that both biomass and carbon stock in forest patch A were higher than other 2 patches while, the biomass and carbon stock between patch B and C were not different (Figure 6 and 7).

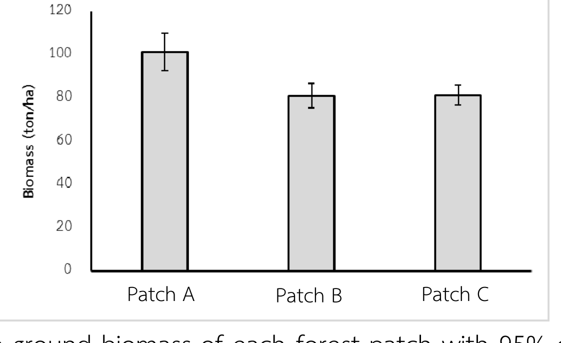

Figure 6. Average above ground biomass of each forest patch with 95% confident interval error bar.

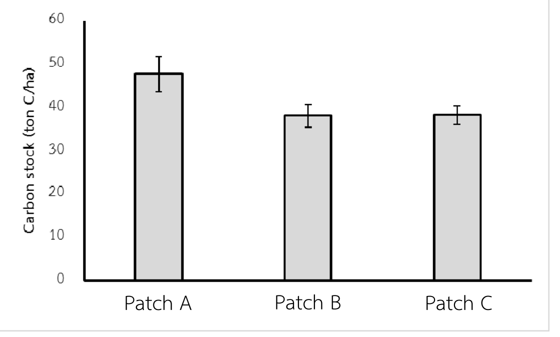

Figure 7. Average above ground carbon stock of each forest patch with 95% confident interval error bar.

Discussion

Tree species diversity

This study found that the forest in this area started to shed the leaves during late of the December to the early of the January. The overall result also indicated that base on the abundance data, *S. obtusa* and *S. siamensis* were the dominance species. Moreover, forest trees in this area were composed of other deciduous Dipterocarpaceae. Therefore, based on the characteristic for forest type identification by Marod and Kutintara (2009), the forest type in the campus should be the deciduous dipterocarp forest.

For this study, number of species found in each patch was around 23-29 species (H=2.05-2.46) and the total number of species found in the area was 37 species. This number is relatively low when compared with the assessment on biodiversity of tree at Sakaerat biosphere reserves (Sampanpanish, 2000). Sampanpanish (2000) reported that there were 88 tree species found in the Sakaerat area and the Shannon index (H) was 5.32. This major difference may be because the Sakaerat had much larger area (7,808 ha) than the total area of all major forest patches in NKC (14.77 ha). However, the species diversity in this study was similar to the diversity of tree in the deciduous dipterocarp-oak forest of Doi Suthep-Pui national park which had the total number of species of 21-22 and H = 2.18-2.24 (Kafle, 2008). This indicated that although species diversity in this study was much lower than tree diversity of Sakaerat area, the diversity in this area was similar to the diversity of tree sampling from dipterocarp-oak forest of Doi Suthep-Pui national park which was the protected area for more than 30 years.

For the similarity in species composition among 3 forest patches, the cluster analysis divided 9 sampling plots in to 3 groups and only the sampling plots from forest patch A were placed in each of 3 clustering groups. This indicated that species composition of forest patch A covered most of species found in all of the NKC forest patches.

Above ground biomass and carbon stock of trees

The tree density in this study was very high (4,436-4,684 tree/ha) comparing with the previous results (Table 4) and most of trees in this area had DBH only 4.5 to 9.99 cm (Figure 3). It can be assumed base on this result that the forest in NKC may be disturbed and now, it may be at the early stage of succession, therefore the trees are high density and there are a lot of small trees. Although the tree density in this study was different from those of the previous researches while the biomass and carbon stock was slightly lower than those of deciduous dipterocarp forest studied by Senpaseuth et al. (2009) and mixed deciduous forest studies by Petsri et al. (2007) and Terakunpisut et al. (2007). However, the carbon stock of this study was higher than the carbon stock of deciduous dipterocarp forest located near Mancha Khiri plantation in the Khon Kaen province (Jundang et al., 2010). This indicated that although forest patches in NKC were at the early stage of succession, their carbon storage abilities were almost similar to the carbon storage ability of deciduous forest in other places. The study of carbon storage by Piyaphongkul et al. (2011) indicated that in the same forest type, the forest at late stage of succession (primary forest) stocked the amount of carbon more than at early stage (secondary forest) (Table 4). It can be assumed based on this indication that if the forest patches in NKC are well protected, the amount of carbon storage by forest patches can increase in the future.

Table 4. Density, above ground biomass and above ground carbon stock of trees in this study and previous researches.

Forest types	Density (tree/ha)	Above ground biomass (ton/ha)	Above ground carbon stock (ton C/ha)	Sources
Deciduous dipterocarp	4,436-4,684	80.88-101.39	38.01-47.65	This study
	-	-	59.41	Senpaseuth et al. (2009)
	783	38.11	19.27	Jundang et al. (2010)
Mixed deciduous	544±68.9	96.28	48.14	Terakunpisut et al. (2007)
	644.72	-	60.06	Petsri et al. (2007)
Primary forest	919	684.76	342	Piyaphongkul et al. (2011)
Secondary forest	1,464	198.20	99.10	Piyaphongkul et al. (2011)

Implication to conserve the forest in NKC

Although the rarefaction result indicated that species diversities of trees were not significantly different among 3 forest patches, the overall species found, Jackknife 1 richness estimator and Shannon index indicated that species diversity of forest patch A trended to be higher than in the other 2 patches. Moreover, the cluster analysis result also indicated that only the species composition of forest patch A covered almost of compositions of all 3 forest patches in NKC. Therefore, based on the tree species diversity and composition, the forest patch A should be the first priority for forest conservation among all forest patches in NKC.

Comparing among 3 forest patches in NKC, the biomass and carbon stock per unit area in forest patch A were higher than in other 2 patches while the biomass and carbon stock of forest patch B and C were at the similar level (Figure 5 and 6). This indicated that the converting of forest patch A into another land use type should have the highest CO_2 emission in to the atmosphere. Therefore, based on the biomass and carbon stock result, the forest patch A was also the first priority for forest conservation in NKC.

The results from tree diversity and carbon stock indicated the same direction. The forest patch A is the most suitable forest patch to be conserved based on these 2 data aspects. However, the total of only 29 species were found from 3 sampling plots in the forest path A, whereas the overall species found from this study was 37 species. This indicated that status of 8 species, which were not found in 3 sampling plots from forest patch A, should be concerned for conservation propose of biodiversity in this area. Thus, before NKC decides to protect only patch A and converts patch B and C into other land use types, the intensive survey should be conducted to confirm the status of these 8 species in the forest patch A. If the intensive surveys of these species were conducted, the conservation planning of these 8 species would be created in the appropriated direction. Moreover, the study of the rate of carbon storage by the forest per year and the CO_2 release by the human activity in NKC of each year are still need to be conducted because these data are important for balancing between carbon absorption and emission of the campus. If the carbon absorption by forest and the CO_2 emission by human activity in this campus are determined, the planning to be the zero CO_2 emission organization can be created in the appropriated way.

Conclusions

Based on the result from this study, the diversity of trees in forest patch A trended to be higher than in other 2 forest patches. The cluster analysis also indicated that species composition of forest patch A covered most of the species found from all 3 forest patches. Moreover, the above ground biomass and carbon stock were highest at the forest patch A. These results indicated that in both biodiversity and carbon stock aspects, the forest patch A was the most suitable forest patch in the campus to be protected.

Appendix 1. Family name, Thai name, scientific name, initial name, total abundance and average DBH of all tree species in all study plots.

No.	Family	Thai name	Scientific name	Initial name	Total abundance	Average DBH (cm)
1	ANACARDIACEAE	ต้นรักใหญ่	*Gluta usitata* (Wall.) Ding Hou	Glus	46	8.08
2	ANACARDIACEAE	ต้นมะม่วงหัวแมงวัน	*Buchanania lanzan* Spreng.	Bula	17	7.64
3	BURSERACEAE	ต้นมะกอกเกลื้อน	*Canarium subulatum* Guillaumin	Casu	74	9.12
4	COMBRETACEAE	ต้นรกฟ้า	*Terminalia alata* Heyne ex Roth	Teal	7	6.02
5	DIPTEROCARPACEAE	ต้นเต็ง	*Shorea obtusa* Wall. ex Blume	Shob	409	7.42
6	DIPTEROCARPACEAE	ต้นรัง	*Shorea siamensis* Miq.	Shsi	338	8.24
7	DIPTEROCARPACEAE	ต้นเหียง	*Dipterocarpus obtusifolius* Teijsm. ex Miq.	Diob	38	9.21
8	DIPTEROCARPACEAE	ต้นพะยอม	*Shorea roxburghii* G.Don	Shro	14	7.50
9	DIPTEROCARPACEAE	ต้นยางกราด	*Dipterocarpus intricatus* Dyer	Diin	13	8.00
10	DIPTEROCARPACEAE	ต้นพลวง	*Dipterocarpus tuberculatus* Roxb.	Ditu	10	9.57
11	EBENACEAE	ต้นตับเต่าต้น	*Diospyros ehretioides* Wall. ex G.Don	Dieh	10	6.89
12	EBENACEAE	ต้นขี้หนู	*Diospyros ferrea* (Willd.) Bakh.	Dife	2	5.01
13	EBENACEAE	ต้นมะเกลือ	*Diospyros mollis* Griff.	Dimo	1	14.64
14	EUPHORBIACEAE	ต้นเหมือดโลด	*Aporosa villosa* (Wall. ex Lindl.) Baill.	Apvi	124	6.21
15	FLACOURTIACEAE	ต้นกระเบา	*Hydnocarpus anhelminthicus* Pierre ex Laness.	Hyan	6	7.05
16	GUTTIFERAE	ต้นติ้วเกลี้ยง	*Cratoxylum cochinchinense* (Lour.) Blume	Crco	61	6.10
17	IRVINGIACEAE	ต้นกระบก	*Irvingia malayana* Oliv. ex A.W.Benn.	Irma	76	7.51
18	LABIATAE	ต้นตีนนก	*Vitex pinnata* L.	Vipi	5	6.62
19	LABIATAE	ต้นกาสามปีก	*Vitex peduncularis* Wall. ex Schauer	Vipe	2	10.42
20	LAURACEAE	ต้นหมีเหม็น	*Litsea glutinosa* (Lour.) C.B.Rob.	Ligl	1	7.32
21	LEGUMINOSAE	ต้นนนทรี	*Peltophorum pterocarpum* (DC.) Backer ex K.Heyne	Pept	1	23.55
22	LEGUMINOSAE	ต้นแดง	*Xylia xylocarpa* (Roxb.) Taub.	Xyli	2	10.98
23	LEGUMINOSAE	ต้นประดู่	*Pterocarpus macrocarpus* Kurz	Ptma	27	11.17
24	LEGUMINOSAE	ต้นชิงชัน	*Dalbergia oliveri* Gamble	Daol	5	7.32
25	LEGUMINOSAE	ต้นเก็ดดำ	*Dalbergia assamica* Benth.	Daas	2	7.24
26	MELASTOMATACEAE	ต้นพลองเหมือด	*Memecylon edule* Roxb.	Meed	164	5.61
27	MORACEAE	ต้นเลียบ	*Ficus infectoria* Roxb.	Fiin	1	6.05
28	RUBIACEAE	ต้นคำมอกหลวง	*Gardenia sootepensis* Hutch.	Gaso	59	7.21
29	RUBIACEAE	ต้นกระทุ่มนา	*Mitragyna diversifolia* (Wall. ex G. Don) Havil.	Midi	9	6.69
30	RUBIACEAE	ต้นขว้าว	*Haldina cordifolia* (Roxb.) Ridsdale	Haco	8	8.20
31	RUBIACEAE	ต้นยอป่า	*Morinda coreia* Ham.	Moco	4	12.69
32	RUBIACEAE	ต้นหนามแท่ง	*Catunaregam tomentosa* (Blume ex DC.) Tirveng.	Cato	1	4.77
33	RUBIACEAE	ต้นมะคังแดง	*Dioecrescis erythroclada* (Kurz) Tirveng.	Gaer	1	4.77
34	STRYCHNACEAE	ต้นแสลงใจ	*Strychnos nux-vomica* L.	Stnu	6	7.15
35	-	-	unknown 01	un1	2	9.87
36	-	-	unknown 02	un2	2	11.14
37	-	-	unknown 03	un3	2	11.38

Acknowledgements

I would like to gratefully thank to Nattawan Jaiboon and Krittiya Ukham for their large contribution in the field data collecting and also express my gratitude to Prof. Dr. Pranom Chantaranothai, Dr. Piyarat Itharat and Thawee Insura for their kindness in the tree species identifications. The facility for manuscript writing was supported by Faculty of Applied Science and Engineering, Khon Kaen University, Nong Khai Campus.

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