CHAPTER 4

RESULTS

4.1 Lichen Diversity

Over the period of study, from March to June 2011, 73 study areas were investigated. A total of 51 lichen species was collected, 38 species belonging to crustose group and 13 species belonging to foliose group. Lists of total lichen species were presented in Table 4.1 while diversity index, evenness and richness were showed in Table 4.2 too. The picture of some lichen species are presented in Appendix F.

Lichen species which mostly found in this investigation were *Hyperphyscia adglutinata, Phyllopeltula* cf. *corticola, Pyxine cocoes, Rinodina robori* and *Chrysothrix xanthina.* Lichens in following genus were found in less frequrncies; *Anisomeridium, Arthothelium, Cryptothelium, Lecania, Lecanographa, Parmotrema, Rinodina efflorescens, Trypethelium* and Unknown 2. Two samples could not be identified (unknown). Especially *Hyperphyscia adglutinata* was found with the highest frequency and found in every site except 18A, 2B, 26B and 29B. *Phyllopeltula* cf. *cortical* was mostly found in high frequency in urban areas (A site) while *Pyxine cocoes* was generally found in both areas. The lowest of lichen frequency value in this study was 1 (F= 1). There were named as following and site was in parentheses; *Anisomeridium* sp. (19A), *Arthothelium* sp. (4A), *Cryptothelium* sp. (14A),*Lecania* sp. (17B), *Lecanographa* sp. (16B),

Parmotrema gardaneri (9B),*Rinodina efflorescens* (12A), *Trypethelium* sp. (35B) and Unknown 2 (1B).

Table 4.1 List of lichen species and sum of total frequencies in study areas.

No.	Taxa	Type	Sum of total Frequency	Number of all sites
1	***Anisomeridium* sp.**	**Crustose**	**1**	**1**
2	*Arthonia* sp. 1	Crustose	2	2
3	*Arthonia* sp. 2	Crustose	288	36
4	*Arthonia* sp. 3	Crustose	3	2
5	*Arthothelium* sp.	Crustose	28	5
6	***Arthothelium* cf. *abnorme***	**Crustose**	**1**	**1**
7	*Bacidia connexula*	Crustose	43	8
8	*Bacidia medialis*	Crustose	4	1
9	*Buellia efflorescens*	Crustose	33	9
10	*Buellia punctata*	Crustose	3	1
11	*Candelaria concolor*	Foliose	2	1
12	*Chrysothrix xanthina*	Crustose	347	52
13	***Cryptothelium* sp.**	**Crustose**	**1**	**1**
14	*Dimerella* sp.	Crustose	4	4
15	*Dirinaria applanta*	Foliose	3	2
16	*Dirinaria picta*	Foliose	76	14
17	*Glyphis* sp.	Crustose	128	17
18	*Graphis* sp. 1	Crustose	14	6
19	*Graphis* sp.2	Crustose	55	7
20	***Hyperphyscia adglutinata***	**Foliose**	**1300**	**69**
21	*Hyperphyscia pruinosa*	Foliose	195	26
22	*Hyperphyscia tuckermanii*	Foliose	38	9
23	*Laurera* sp.	Crustose	9	1
24	***Lecania* sp.**	**Crustose**	**1**	**1**
25	***Lecanographa* sp.**	**Crustose**	**1**	**1**
26	*Lecanora* sp.1	Crustose	203	20
27	*Lecanora* sp.2	Crustose	333	40
28	*Lecanora* sp.3	Crustose	41	9
29	*Lecanora* sp.4	Crustose	10	1
30	*Lepraria* sp. 1	Crustose	49	11
31	*Lepraria* sp. 2	Crustose	11	2
32	*Lepraria* sp. 3	Crustose	27	4
33	*Opegrapha* sp. 1	Crustose	31	8
34	*Opegrapha* sp. 2	Crustose	154	19

Table 4.1 (continued)

No.	Taxa	Type	Sum of total Frequency	Number of all sites
35	*Opegrapha* sp. 3	Crustose	22	3
36	*Opegrapha* sp. 4	Crustose	6	1
37	***Parmotrema gardaneri***	**Foliose**	**1**	**1**
38	*Phyllopeltula* cf. *corticola*	Foliose	1036	55
39	*Physcia* sp.1	Foliose	28	7
40	*Physcia* sp.2	Foliose	7	1
41	*Porina borreri*	Foliose	10	1
42	*Porina distans*	Foliose	12	6
43	*Pyxine cocoes*	Foliose	865	63
44	***Rinodina efflorescens***	**Crustose**	**1**	**1**
45	*Rinodina pyrena*	Crustose	34	6
46	*Rinodina roboris*	Crustose	554	49
47	*Rinodina teichophila*	Crustose	4	2
48	*Sarcographa* sp.	Crustose	8	1
49	***Trypethelium* sp.**	**Crustose**	**1**	**1**
50	Unknown 1	Crustose	8	1
51	**Unknown 2**	**Crustose**	**1**	**1**

Table 4.2 List of diversity index, evenness and richness in study areas.

Sites	Diversity Index	Evenness	Richness
1A	0.735	0.814	8
2A	0.551	0.916	4
3A	0.496	0.824	4
4A	0.778	0.778	10
5A	0.867	0.804	12
6A	0.847	0.847	10
7A	0.43	0.615	5
8A	0.233	0.488	3
9A	0.395	0.565	5
10A	0.416	0.691	4
11A	0.698	0.773	8
12A	0.819	0.858	9
13A	0.933	0.864	12
14A	0.808	0.776	11
15A	0.662	0.783	7
16A	0.631	0.811	6
17A	0.545	0.7	6
18A	**0**	**0**	**1**
19A	0.854	0.792	12
20A	0.809	0.848	9
21A	0.454	0.65	5
22A	0.515	0.662	6
23A	0.5	0.83	4
24A	0.344	0.721	3
25A	0.94	0.82	14
26A	0.843	0.883	9
27A	0.436	0.516	7
28A	0.612	0.787	6
29A	0.713	0.747	9
30A	0.241	0.505	3
31A	0.508	0.726	5
32A	0.604	0.668	8
33A	0.916	0.779	**15**
34A	0.653	0.84	6
35A	-	-	-
36A	0.209	0.439	3
1B	0.993	0.867	14

Note: Suitable tree was not found in 35A.

Table 4.2 (continued)

Sites	Diversity Index	Evenness	Richness
2B	**0.997**	0.895	13
3B	1.017	0.865	**15**
4B	0.765	0.765	10
5B	0.904	0.838	12
6B	0.619	0.686	8
7B	0.892	0.827	12
8B	0.997	0.895	13
9B	0.999	0.897	13
10B	0.527	0.754	5
11B	0.661	0.782	7
12B	0.608	0.87	5
13B	0.366	0.767	3
14B	0.877	0.813	12
15B	0.766	0.907	7
16B	0.851	0.817	11
17B	0.897	0.897	10
18B	0.596	0.766	6
19B	0.782	0.866	8
20B	0.812	0.9	8
21B	0.626	0.805	6
22B	0.787	0.825	9
23B	0.606	0.867	5
24B	0.644	0.762	7
25B	0.764	0.904	7
26B	0.683	0.878	6
27B	0.688	0.762	8
28B	0.838	**0.928**	8
29B	0.699	0.733	9
30B	0.923	0.923	10
31B	0.488	0.577	7
32B	0.747	0.827	8
33B	0.873	0.915	9
34B	0.789	0.873	8
35B	0.963	0.865	13
36B	0.822	0.861	9
37B	0.825	0.825	10
38B	0.836	0.802	11

The highest diversity index and evenness was found in 2B and 28B, respectively. The highest of richness was found in two sites; 33A and 3B. The lowest of diversity index, evenness and richness also were found in the same site, 18A which only one species was found.

The similarity of environmental factors and human activities among lichen flora in the study areas were then observed based on lichen frequencies. The cluster analysis was performed by using MVSP program. The dendrogram was presented in Figure 4.1.

Dendograme base on lichen species and their frequency in all site study area showed six groups of study sites. Four groups were clearly distinguished. The first group was 7B where a temple in quite rural area was located and in this area one of lichen species which did not exist in other areas was found. The second group was 6A where Scorpion Tailed boats harbor. The third group was 26B was in military areas. The fourth group was 2B that was suburban area. *Phyllopeltula* cf. *corticola* was not found in group 2,3 and 4. As same as *Hyperphyscia adglutinata* was not found in group 3 and 4. The fifth group was found in the area which less human activities such as privacy car park and university areas. All of study sites found in this group was suburban area (17B, 5B, 3B, 9B and 1B). The sixth group was the largest group in this classification. The number of site in this group were 64 sites. These were found scattered in urban and developed areas where high human activities and human disturbance occur. The human activities such as driving a car, building construction, biomass combustion and housing development could cause of high pollutions.

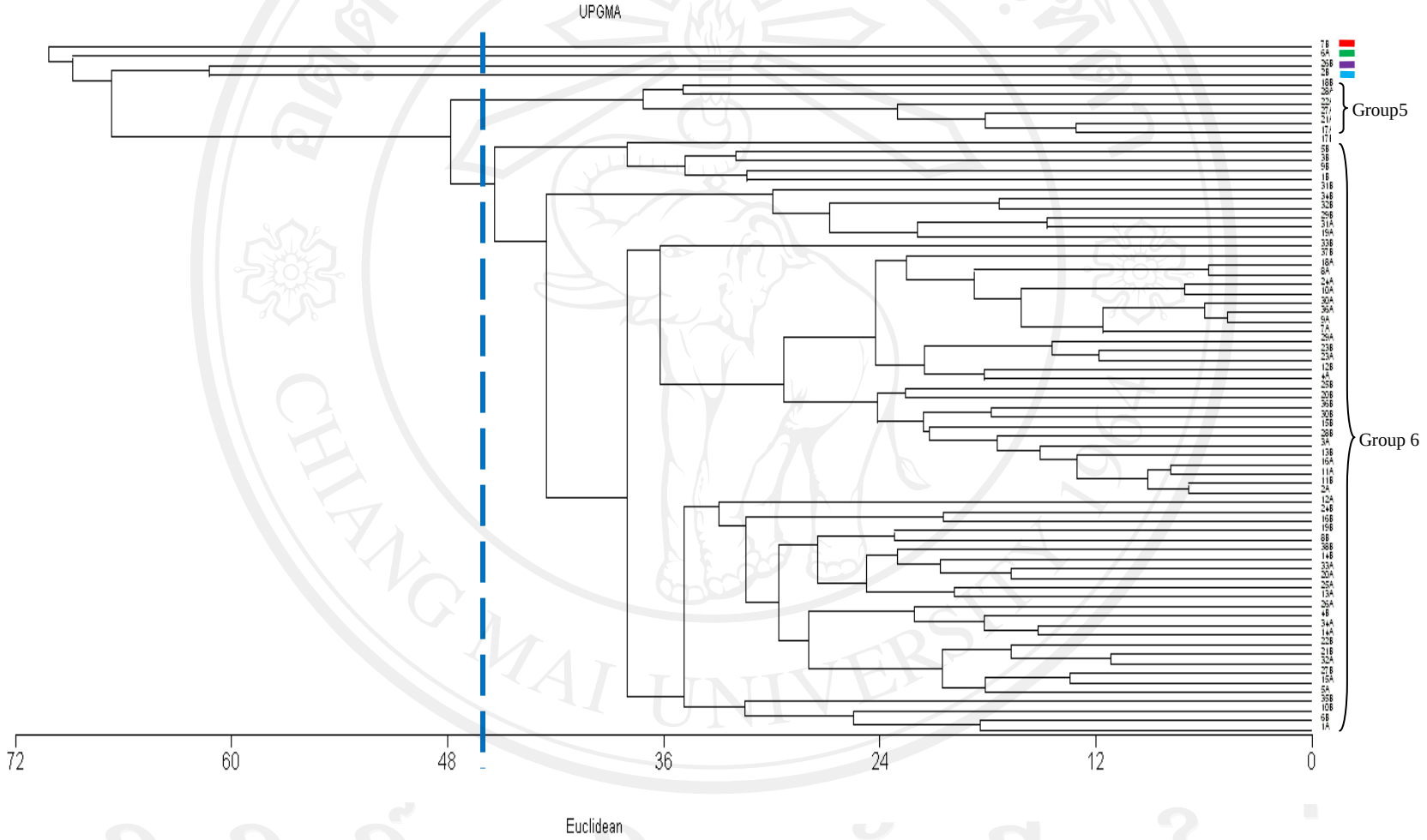


Figure 4.1 Dendrogram of lichen species and average frequency was found in study area (different colors line means different group; red line mean group 1, green line mean group 2, purple line mean group 3 and blue line mean group 4)

4.2 Lichen mapping for define the zones of different air quality in Chiang Mai

According to the method by VDI (1995), the frequencies of all lichen species found within and out of grid frame were used as lichen index to produce air quality map. Sums of frequency of lichens on individual mango trees or bullet wood trees of each square were presented in Table 4.3. The air quality indices and standard deviation were calculated based on such data, are also presented in Table 4.3.

Table 4.3 Air quality indices (AQI) of study sites

Examined unit	Sums of lichen frequencies on individual tree						Sum	AQI
j	T1	T2	T3	T4	T5	T6		
1A	16	29	19	2	17	18	101	16.83
2A	8	15	5	3	11	-	42	8.40
3A	4	6	7	13	-	-	30	7.50
4A	10	5	10	10	22	22	79	13.17
5A	40	17	18	27	14	8	124	20.67
6A	39	35	49	17	10	48	198	33.00
7A	10	10	2	3	16	14	55	9.17
8A	4	3	10	3	6	3	29	4.83
9A	4	8	11	11	12	13	59	9.83
10A	13	12	2	6	13	12	58	9.67
11A	2	2	6	13	7	4	34	5.67
12A	24	23	23	20	14	22	126	21.00
13A	10	6	22	22	13	41	114	19.00
14A	19	23	19	8	4	9	82	13.67
15A	22	15	5	15	14	18	89	14.83
16A	3	5	2	8	3	5	26	4.33
17A	10	18	8	20	19	12	87	14.50
18A	10	5	1	2	1	8	27	4.50
19A	20	20	9	16	13	22	100	16.67
20A	6	12	27	19	11	33	108	18.00
21A	12	21	13	16	10	10	82	13.67
22A	15	19	17	11	12	13	87	14.50
23A	33	20	14	-	-	-	67	22.33
24A	6	16	3	10	11	2	48	8.00
25A	22	11	6	21	37	42	139	23.17

Note: - means suitable tree was not found

Table 4.3 (continued)

Examined unit	Sums of lichen frequencies on individual tree						Sum	AQI
j	T1	T2	T3	T4	T5	T6		
26A	32	13	9	37	7	23	121	20.17
27A	13	13	16	19	10	14	85	14.17
28A	21	10	23	16	10	10	90	15.00
29A	21	25	10	2	6	10	74	12.33
30A	10	15	10	10	11	-	56	11.20
31A	6	12	5	6	6	10	45	7.50
32A	13	14	9	15	5	10	66	11.00
33A	23	25	20	14	18	9	109	18.17
34A	15	10	7	9	11	10	62	10.33
35A	-	-	-	-	-	-	-	-
36A	4	10	11	10	8	11	54	9.00
1B	18	30	24	5	46	15	138	23.00
2B	40	66	20	60	25	34	245	40.83
3B	38	43	55	14	12	8	170	28.33
4B	17	12	11	28	14	12	94	15.67
5B	23	26	10	26	29	31	145	24.17
6B	11	12	11	28	10	25	97	16.17
7B	30	42	25	32	35	42	206	34.33
8B	20	11	2	51	12	34	130	21.67
9B	11	32	16	24	23	16	122	20.33
10B	11	12	13	22	14	35	107	17.83
11B	4	10	4	5	3	11	37	6.17
12B	13	11	27	7	10	10	78	13.00
13B	5	9	10	8	10	9	51	8.50
14B	8	23	24	6	43	5	109	18.17
15B	5	10	13	8	17	17	70	11.67
16B	5	35	28	29	20	21	138	23.00
17B	30	22	12	18	23	37	142	23.67
18B	11	10	20	26	28	15	110	18.33
19B	10	30	4	15	10	16	85	14.17
20B	23	10	30	5	2	6	76	12.67
21B	12	2	18	18	10	17	77	12.83
22B	11	19	18	20	10	33	111	18.50
23B	12	3	7	15	11	2	50	8.33
24B	15	9	24	1	5	5	59	9.83
25B	23	14	7	31	-	-	75	18.75
26B	24	33	44	24	26	18	169	28.17
27B	22	1	15	20	10	22	90	15.00

Note: - means suitable tree was not found

Table 4.3 (continued)

Examined unit	Sums of lichen frequencies on individual tree						Sum	AQI
j	T1	T2	T3	T4	T5	T6		
28B	10	19	16	6	3	23	77	12.83
29B	11	22	5	5	11	10	64	10.67
30B	10	4	5	16	6	29	70	11.67
31B	2	23	14	12	11	7	69	11.50
32B	28	20	28	14	25	15	130	21.67
33B	10	6	11	17	19	31	94	15.67
34B	20	18	6	6	21	44	115	19.17
35B	43	46	16	15	22	41	183	30.50
36B	21	2	1	29	5	6	64	10.67
37B	10	2	20	20	10	15	77	12.83
38B	19	38	1	13	22	17	110	18.33

Note: - means suitable tree was not found

After calculation for AQI values and SD above, the width of air quality classes was calculated based on the following values;

Sum of all squared deviations; 27,867.42

Mean number of trees per grid squared (np); 6

Mean standard deviation of all examined grid squared (Sp); 8.7

Width of air quality classes; 9.1

The exposure scale for the study area was obtained by comparing with the width of VDI standard scale (Figure 4.2). The suitable color code for exposure scale was in accordance with the VDI standard scale and some classes in this study are indicated by both combined the categories. Because their range was overlapped with another class, so these classes have two color codes (e.g. very high to high; orange hatching and red background). The exposure scale of the study area divided the

investigated area into difference zones by air quality width of 9.1, 18.2, 27.3, 36.4 and 45.5.

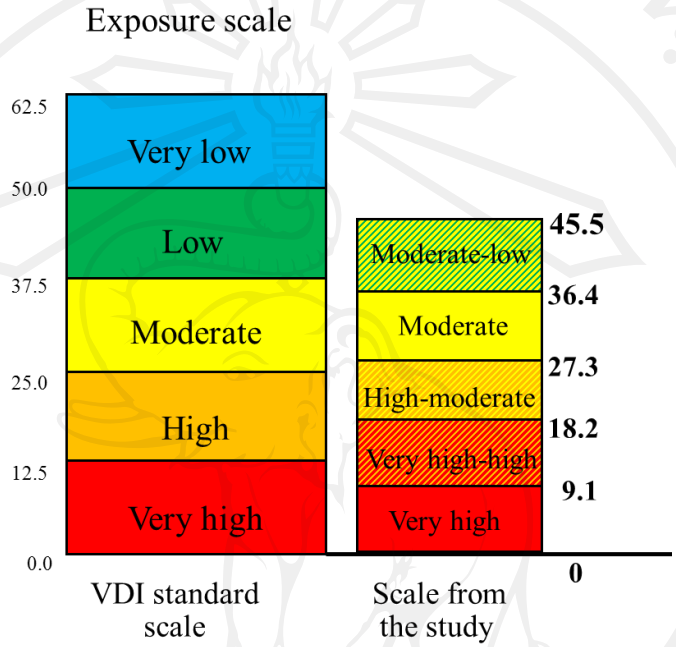


Figure 4.2 Exposure scale of the study area

The air quality values of each grid square were classified according to air quality classes (AQC) which were presented in Table 4.4. AQI ranged from 4.33 to 9.00 indicated very high pollution (class 1: red). AQI ranged from 9.17 to 18.17 indicated very high to high pollution (class 2: red and orange). AQI ranged from 18.33 to 24.17 indicated high to moderate pollution (class 3: orange and yellow). AQI ranged from 28.17 to 34.33 indicated moderate pollution (Class 4: yellow). AQI value of 40.83 indicated moderate to low pollution (Class 5: yellow and green). The AQC of each grid square were presented in Table 4.5.

Table 4.4 Air Quality Classes (AQC) in this study

AQC	AQI	Color
1	$0.00 < AQI \leq 9.1$	red
2	$9.1 < AQI \leq 18.2$	red and orange
3	$18.2 < AQI \leq 27.3$	orange and yellow
4	$27.3 < AQI \leq 36.4$	yellow
5	$36.4 < AQI \leq 45.5$	yellow and green

Table 4.5 Air Quality Classes (AQC) of each grid square and interpretation in Chiang Mai

Grid square no.	**AQI**	**Range of AQC**	**Level of air pollution**	**AQC**
16A	4.33	$0.00 < AQI \leq 9.1$	very high	1
18A	4.50			
8A	4.83			
11A	5.67			
11B	6.17			
3A	7.50			
31A	7.50			
24A	8.00			
23B	8.33			
2A	8.40			
13B	8.50			
36A	9.00			
7A	9.17	$9.1 < AQI \leq 18.2$	very high to high	2
10A	9.67			
9A	9.83			
24B	9.83			
34A	10.33			
29B	10.67			
36B	10.67			
32A	11.00			
30A	11.20			
31B	11.50			
15B	11.67			
30B	11.67			

Table 4.5 (Continued)

Grid square no.	AQI	Range of AQC	Level of air pollution	AQC
29A	12.33			
20B	12.67			
21B	12.83			
28B	12.83			
37B	12.83			
12B	13.00			
4A	13.17			
14A	13.67			
21A	13.67			
27A	14.17			
19B	14.17			
17A	14.50			
22A	14.50	$9.1 < AQI \leq 18.2$	very high to high	2
15A	14.83			
28A	15.00			
27B	15.00			
4B	15.67			
33B	15.67			
6B	16.17			
19A	16.67			
1A	16.83			
10B	17.83			
20A	18.00			
33A	18.17			
14B	18.17			
18B	18.33			
38B	18.33			
22B	18.50			
25B	18.75			
13A	19.00			
34B	19.17			
26A	20.17	$18.2 < AQI \leq 27.3$	high to moderate	3
9B	20.33			
5A	20.67			
12A	21.00			
8B	21.67			
32B	21.67			
23A	22.33			

Table 4.5 (Continued)

Grid square no.	AQI	Range of AQC	Level of air pollution	AQC
1B	23.00			
16B	23.00			
25A	23.17	18.2 < AQI ≤ 27.3	high to moderate	3
17B	23.67			
5B	24.17			
26B	28.17			
3B	28.33			
35B	30.50	27.3 < AQI ≤ 36.4	moderate	4
6A	33.00			
7B	34.33			
2B	40.83	36.4 < AQI ≤ 45.5	moderate to low	5

AQI of all grid squares, which varied from 4.33 to 40.83, were assigned to lichen frequencies (Table 4.3). The air quality results in Chiang Mai province using lichens as indicators are demonstrated in two figures. The first air quality map presented each grid square colored according to the AQC (Figure 4.3). The other lichen map presented the isoline indicating the air pollution zone (Figure 4.4).

Grid squares which their AQI varied from 4.33 to 9.1 belonged to class 1. This class accounted for 16.4% of study area and it was open area in urban and suburban where there were densely developed areas with high human activities occurred. This class was located in the center of Chiang Mai City and in high volume of traffic or construction areas.

Grid squares which their AQI varied from 9.17 to 18.17 belonged to class 2. The range of values accounted for 50.7% of study area, which covered most of the study area. The characteristic of these area was urban areas near the main roads and crowded residential areas. This zone is also in densely developed areas like class 1.

Grid squares which their AQI varied from 18.33 to 24.17 belonged to class 3. This class accounted for 24.7% of study area and was a characteristic of the suburban areas located in the northwest, the west, the southwest, the south and dispersed in urban. This area including residential and university area was moderately developed, which included residential and university area.

For air quality class 4, AQI of grid square varied from 28.17 to 34.33. This class accounted for 6.9% of study area and was a characteristic of suburban military area, the village was not as crowded as urban area.

Finally, the square with AQI of 40.83 belonged to class 5. This class accounted for 1.4% of study area. There were less human disturbance and activities in the village. These areas were residential areas in the northwest of Chiang Mai city.

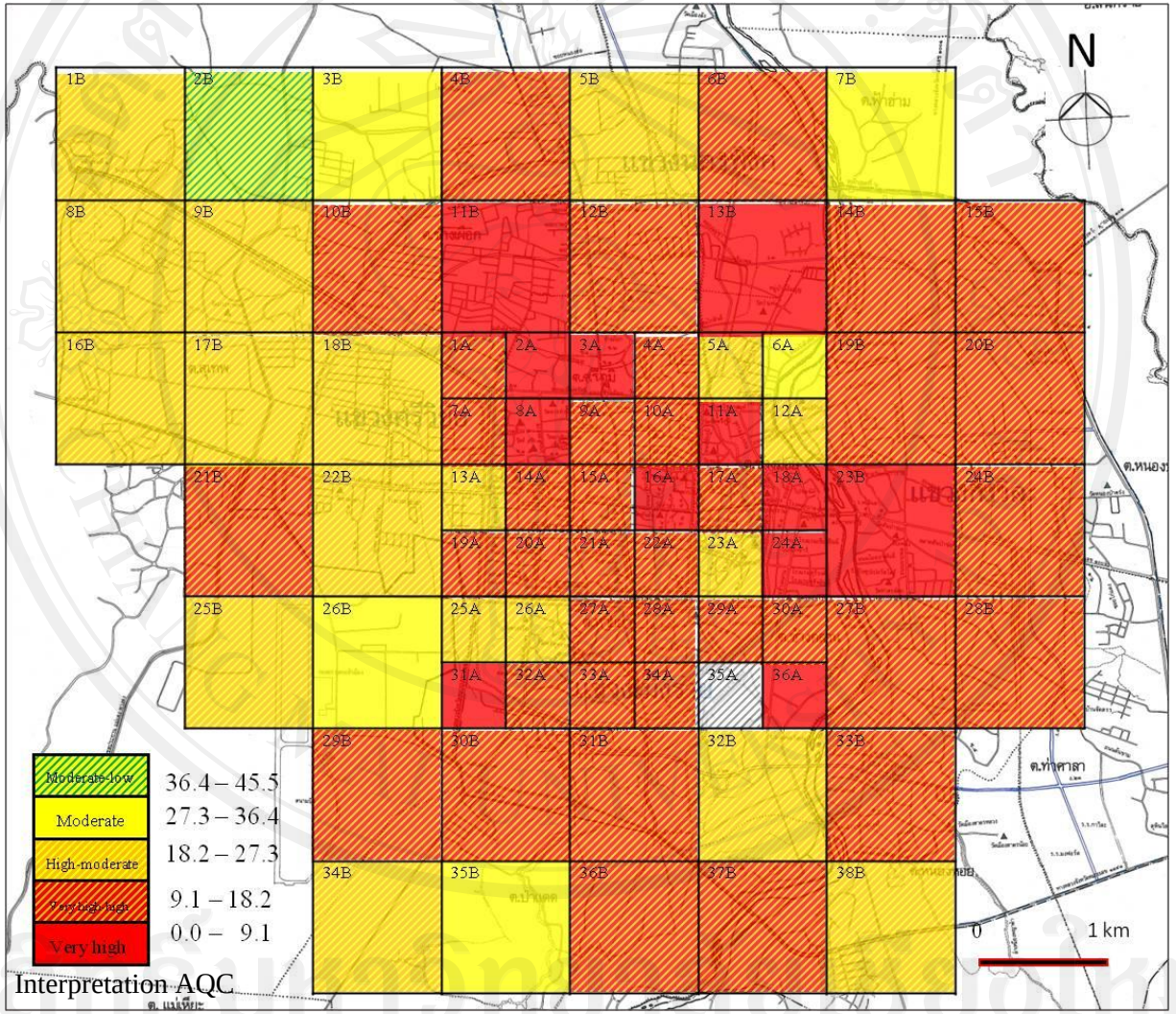


Figure 4.3 Air quality map presented each grid square colored according to the AQC (Note: 35A: No suitable tree was found)

The lichen investigation could provide study areas into different zone of air quality by isoline which air quality indices 9.1, 18.2, 27.3, 36.4 and 45.5 (Table 4.6; See the calculated method in Appendix A). The isoline map was shown in Figure 4.4.

Table 4.6 Confine of study areas with different air qualities

Zone	Confine of isoline	Rating of air qualities	colored
1	9.1	Very high	Red
2	18.2	Very high- High	Red- Orange
3	27.3	High- Moderate	Orange- Yellow
4	36.4	Moderate	Yellow
5	45.5	Moderate- low	Yellow- Green

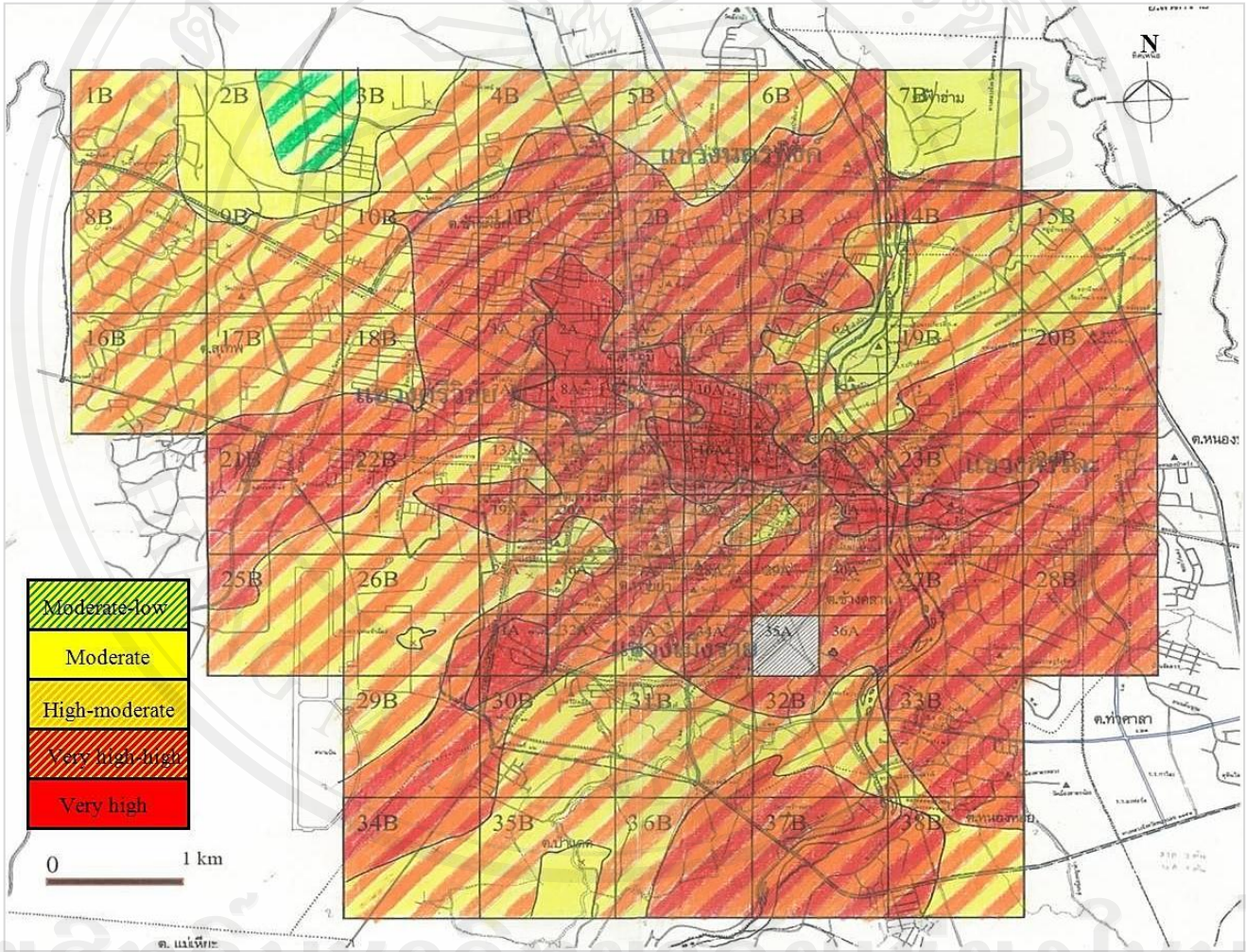
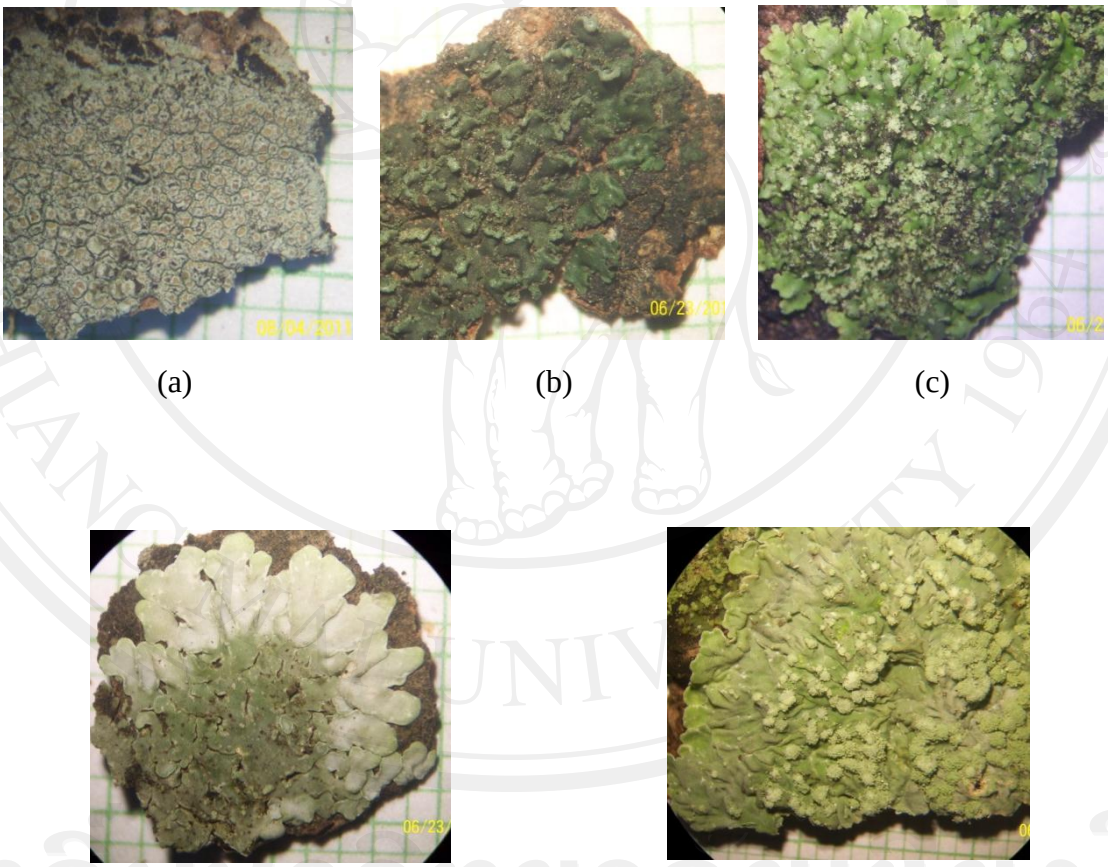


Figure 4.4 Isoline of air quality map presented different zone of air quality in Chiang Mai City (Note: 35A: No suitable tree was found)

4.3 Distribution map of some selected lichens

From lichen investigation, five lichen species were selected to produce lichens distribution map. One species was crustose (*Lecanora* spp.) and four species were foliose (*Phyllopeltula* cf. *corticola, Hyperphyscia adglutinata, Pyxine cocoes,* and *Dirinaria picta*). Five species of lichens are shown in Figure 4.5. Their average frequencies were presented in Table 4.7.



(a) (b) (c)

(d) (d)

Figure 4.5 (a) *Lecanora* spp. (b) *Phyllopeltula* cf. *corticola* (c) *Hyperphyscia adglutinata* (d) *Pyxine cocoes* and (e) *Dirinaria picta*

Phyllopeltula cf. *corticola* mostly found in main road areas (or used for shortcut road, 36A) especially Chiang Mai canal road (9A, 22A and 27A) and highly of human activities areas liked Waroros Market (17A), Chiang Mai Night bazaar (23A) and a School near Chedi Luang Temple (21A) and Sri Don Chai Temple (30A Temple, school and car park). The distribution of *P.* cf. *corticola* was mostly high in urban areas and some suburban areas where high human activities presented (Figure 4.6). The highest frequency in this study was 10 and the lowest frequency was 0.

Hyperphyscia adglutinata was mostly found around the study areas especially occured in higher frequency in the main road areas. Except in 2B, 26B and 29B where were private road, house with less human activities, military area and privately official residence, respectively. High distribution of *H. adglutinata* was found in suburban areas which higher human activities (Figure 4.7). The highest frequency of *H. adglutinata* in this study is 10 and the lowest frequency is 0.

Pyxine cocoes was widely distributed around Chiang Mai city, similar to *H. adglutinata,* but with less frequency than *H. adglutinata*. *P. cocoes* was found with high frequency in only 2 sites (6A; Scorpion Tailed Harbor and 7B; Lankga Temple, Figure 4.8). The highest frequency is 10 and the lowest frequency is 0.

Lecanora spp. was found around the study areas, like *H. adglutinata* and *P. cocoes,* but with less average frequency than both species in urban and suburban areas. But it was widely distributed in suburban areas with higher average frequency than urban area (Figure 4.9). The highest frequency in this study was 10.67 and the lowest frequency was 0.

Dirinaria picta, the later specie was also distributed widely but with less frequency in the city. *D. picta* was found only in some areas (five sites for urban areas and nine sites for suburban areas) and showed much lower frequency than other lichens. Their high average frequency value was 2.17 (Figure 4.10).

Table 4.7 Average frequency of *Phyllopeltula* cf. *corticola*, *Hyperphyscia adglutinata, Pyxine cocoes, Lecanora* spp. and *Dirinaria picta* in study areas

Grid	*Phyllopetula* cf. *corticola*	*Hyperphyscia adglutinata*	*Pyxine cocoes*	*Lecanora* spp.	*Dirinaria pic*ta
1A	0.17	0.58	3.33	3.33	0.00
2A	2.20	3.00	1.20	0.00	0.00
3A	3.25	1.25	0.00	0.00	0.00
4A	3.83	1.00	0.83	0.17	0.00
5A	2.67	6.17	1.50	1.00	0.00
6A	0.00	5.67	7.00	8.00	0.00
7A	6.00	0.50	1.17	0.00	0.00
8A	3.67	0.33	0.00	0.00	0.00
9A	7.00	1.17	0.33	0.00	0.00
10A	5.67	3.00	0.00	0.00	0.00
11A	0.67	2.17	0.17	0.33	0.00
12A	3.50	5.17	3.83	2.00	0.00
13A	0.83	3.83	3.17	2.50	0.67
14A	1.33	3.33	1.50	0.33	0.83
15A	2.50	6.17	2.50	0.33	0.00
16A	1.33	1.33	0.17	0.00	0.00
17A	8.17	2.50	1.33	0.00	0.00
18A	4.50	0.00	0.00	0.00	0.00
19A	0.67	0.67	0.33	3.50	0.00
20A	2.00	4.17	4.50	0.50	0.00
21A	8.83	0.67	2.00	0.00	0.00
22A	8.50	2.00	0.17	0.00	0.00
23A	10.00	8.00	0.00	0.00	0.00
24A	5.00	2.67	0.00	0.00	0.00
25A	1.00	4.17	3.83	1.17	0.17
26A	2.17	4.67	3.33	0.00	0.50
27A	10.00	2.33	0.33	0.00	0.00
28A	5.50	2.17	5.33	0.67	0.00
29A	3.83	2.67	0.33	0.33	0.00
30A	9.00	2.00	0.00	0.00	0.00

Table 4.7 (continued)

Grid	*Phyllopetula* cf. *corticola*	*Hyperphyscia adglutinata*	*Pyxine cocoes*	*Lecanora* spp.	*Dirinaria picta*
31A	0.50	0.17	0.67	0.83	0.00
32A	2.17	6.17	0.83	0.00	0.17
33A	1.33	8.50	3.67	0.50	0.00
34A	1.33	2.83	0.33	0.33	0.00
35A	-	-	-	-	-
36A	7.33	0.83	0.00	0.00	0.00
1B	0.67	2.00	5.83	3.50	1.00
2B	0.00	0.00	0.00	9.00	0.67
3B	0.00	2.50	3.00	2.50	0.00
4B	0.33	5.00	1.83	1.83	0.00
5B	0.00	2.00	3.83	4.17	0.00
6B	0.00	6.67	5.50	0.67	0.00
7B	1.67	5.00	10.00	1.50	2.17
8B	0.00	3.17	2.83	2.67	1.50
9B	0.00	0.50	3.50	1.33	2.17
10B	0.00	8.33	3.67	1.83	0.17
11B	1.50	2.83	0.33	0.50	0.00
12B	3.33	3.67	1.67	0.00	0.00
13B	2.50	3.67	0.00	0.00	0.00
14B	1.67	4.17	4.83	1.67	0.33
15B	3.33	2.00	2.00	0.00	0.00
16B	0.00	5.33	1.50	0.83	0.00
17B	0.00	2.33	0.83	4.33	0.00
18B	6.67	6.83	2.67	0.17	0.00
19B	0.00	4.00	3.00	0.17	0.00
20B	0.83	1.67	2.83	0.17	0.00
21B	1.67	5.83	0.17	0.00	0.00
22B	1.67	5.67	0.83	0.00	0.00
23B	3.50	3.33	0.50	0.83	0.00
24B	0.67	3.83	1.00	0.00	0.00
25B	0.00	0.50	0.50	0.00	0.00
26B	0.00	0.00	5.83	10.67	2.00
27B	4.17	5.17	2.67	0.00	0.00
28B	1.67	2.83	1.17	0.33	0.00
29B	0.00	0.00	0.33	1.33	0.00
30B	0.67	0.50	1.83	0.33	0.00
31B	0.50	1.83	0.17	0.00	0.00
32B	0.00	1.83	1.17	6.50	0.00
33B	0.00	1.83	0.67	4.17	0.00
34B	0.00	1.67	1.33	3.67	0.00

Table 4.6 (continued)

Grid	*Phyllopetula* cf. *corticola*	*Hyperphyscia adglutinata*	*Pyxine cocoes*	*Lecanora* spp.	*Dirinaria picta*
35B	0.00	5.67	4.00	1.67	0.33
36B	1.83	0.83	1.83	0.17	0.00
37B	5.00	2.00	0.50	0.17	0.00
38B	0.00	3.33	4.50	2.17	0.00

Note: Suitable tree was not found in 35A.

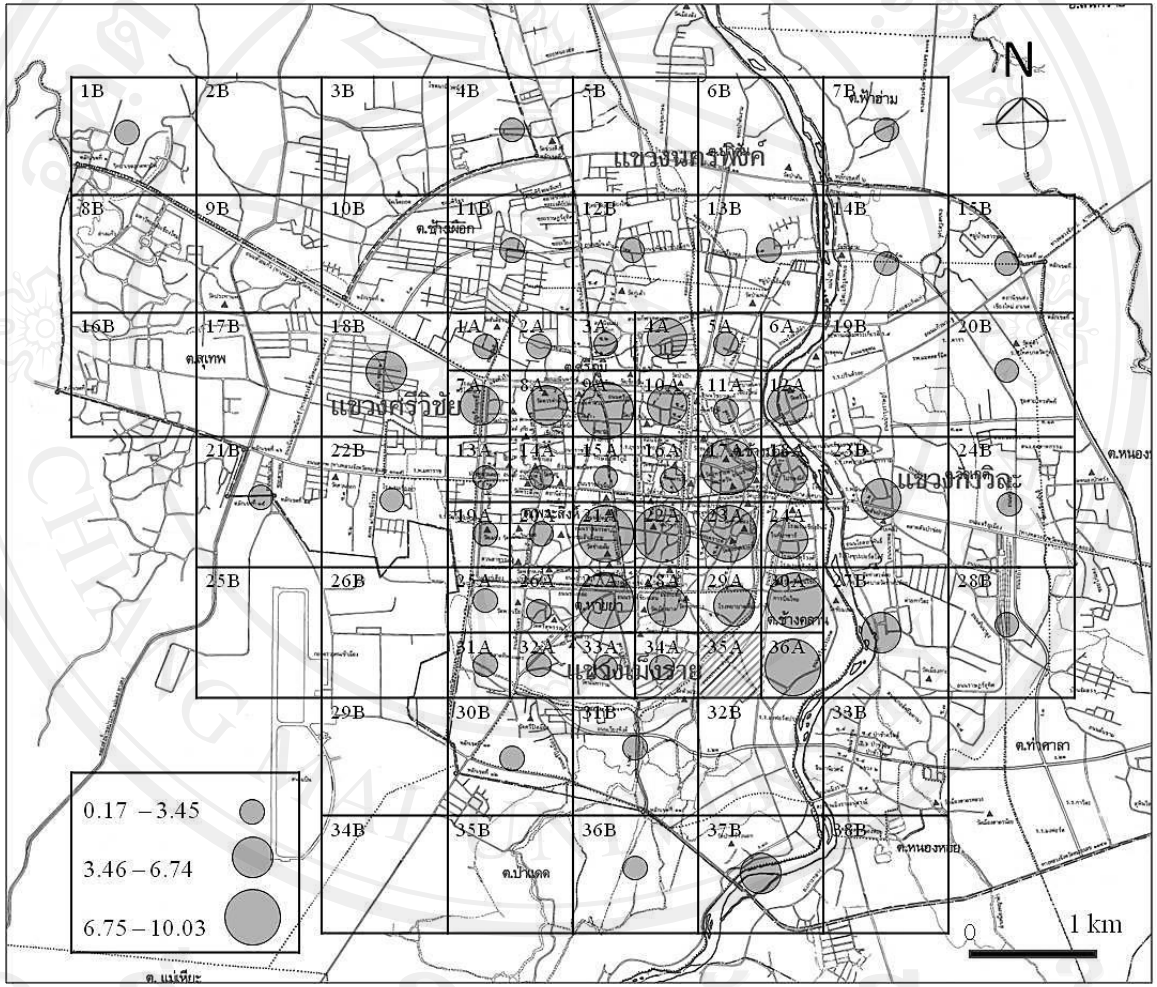


Figure 4.6 Distribution and average frequency of *Phyllopeltula* cf. *corticola* in urban and suburban areas, Chiang Mai (map from Chiang Mai municipality) (* 35A: No suitable trees for investigation)

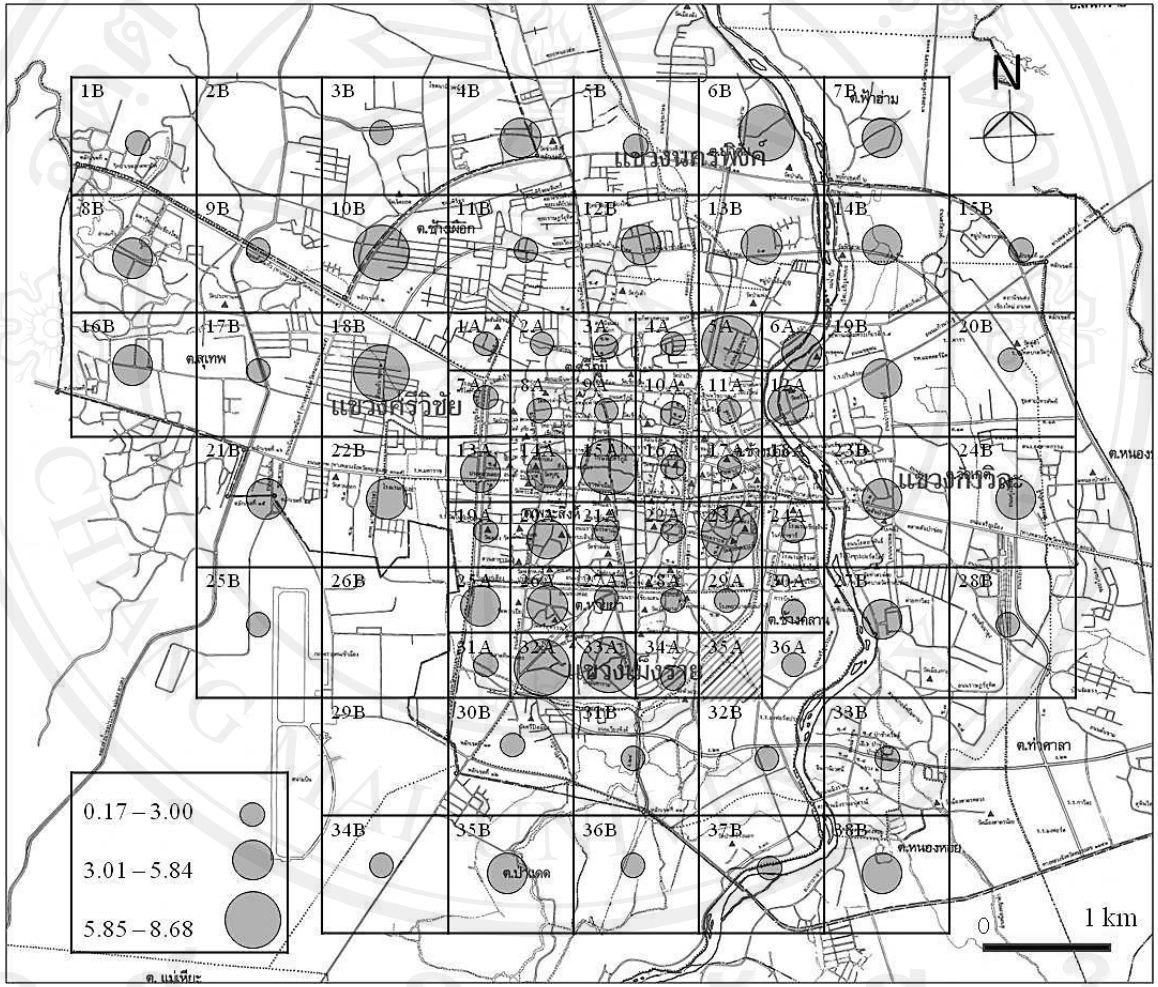


Figure 4.7 Distribution and average frequency of *Hyperphyscia adglutinata* in urban and suburban areas, Chiang Mai (Note: No suitable trees for investigation in grid 35A, map from Chiang Mai municipality)

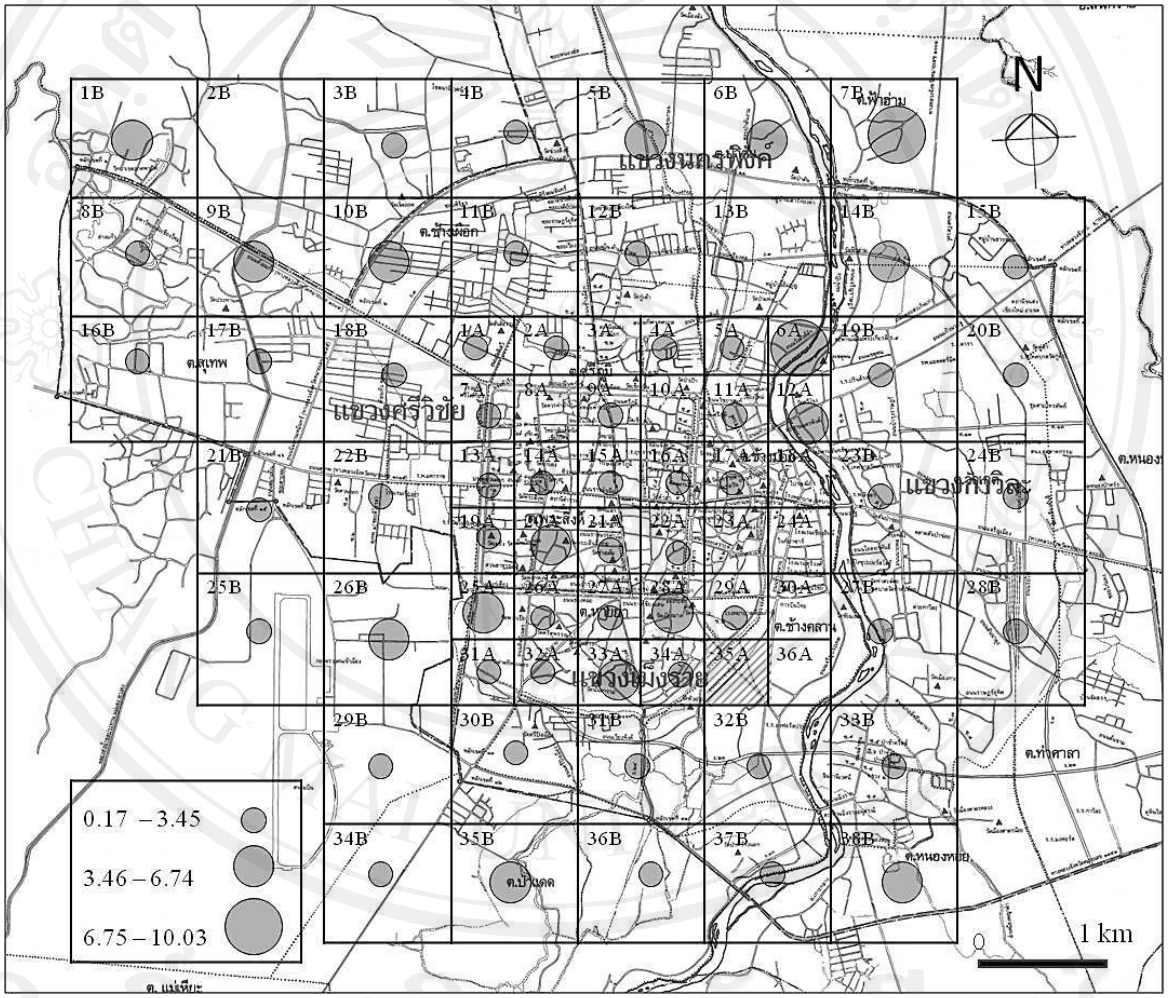


Figure 4.8 Distribution and average frequency of *Pyxine cocoes* in urban and suburban areas, Chiang Mai (Note: No suitable trees for investigation in grid 35A, map from Chiang Mai municipality)

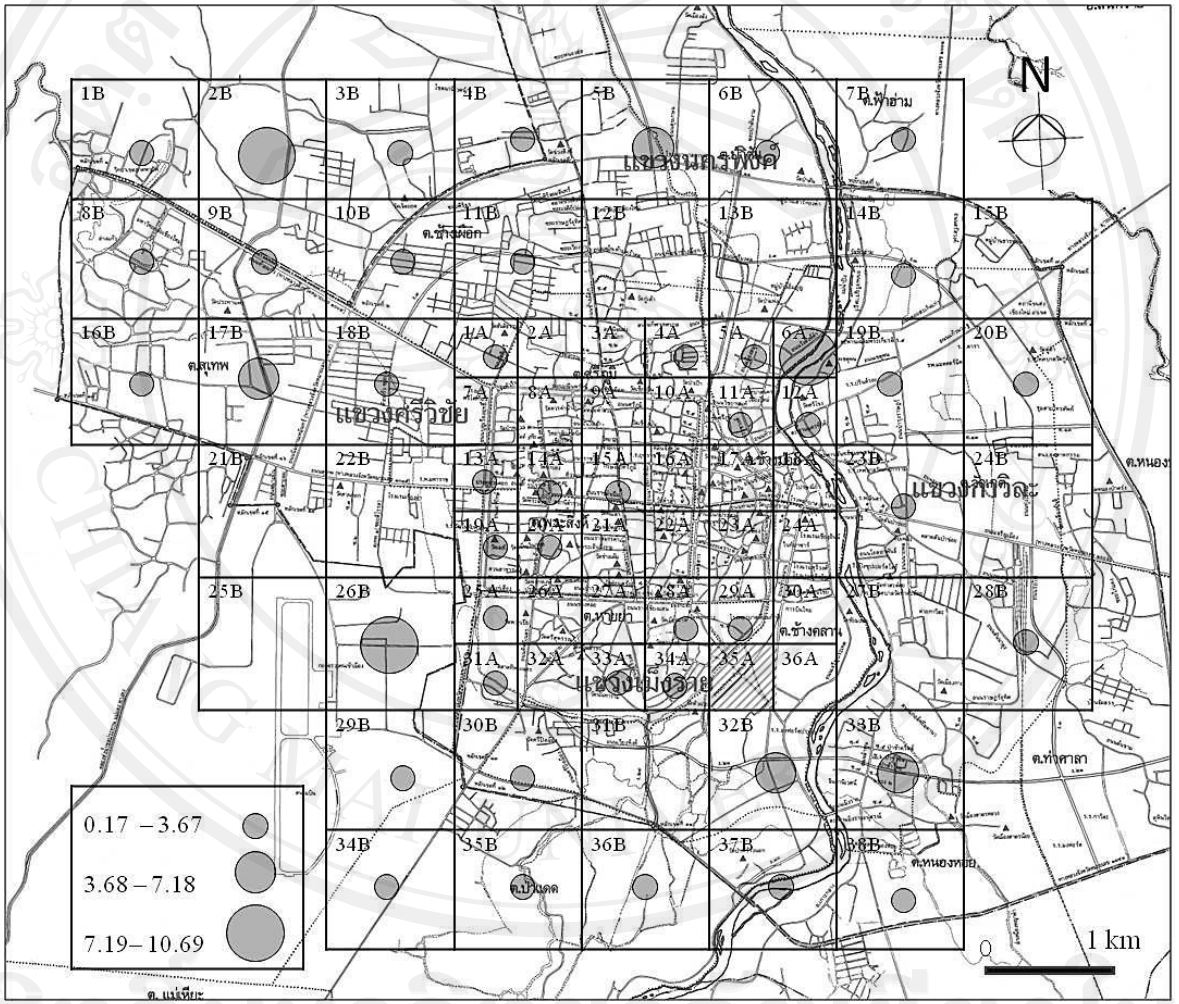


Figure 4.9 Distribution and average frequency of *Lecanora* spp. in urban and suburban areas, Chiang Mai (Note: No suitable trees for investigation in grid 35A, map from Chiang Mai municipality)

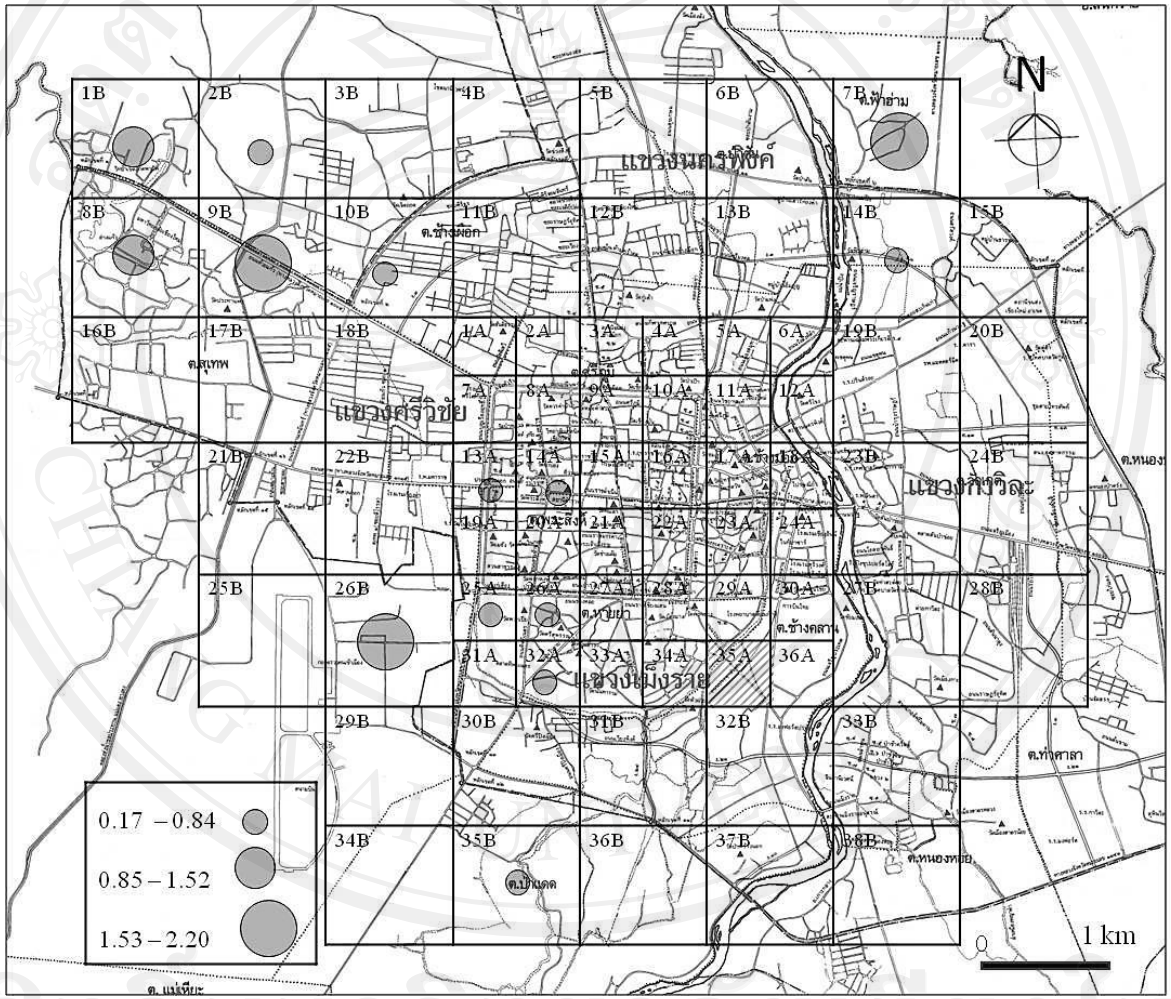


Figure 4.10 Distribution and average frequency of *Dirinaria picta* in urban and suburban areas, Chiang Mai (Note: No suitable trees for investigation in grid 35A, map from Chiang Mai municipality)

4.4 Analysis of pH Bark

Four hundred and twenty nine mango trees and bullet wood tree were measured for pH values. The pH of bark varied from 4.36 to 5.97. The lowest pH value was found in class 4 (4.36), representing moderate air pollution zone (7B). The highest pH value was found in class 3 (5.97), representing high to moderate air pollution zone (23A) (Figure 4.11). The average pH of bark which collected from urban and suburban areas was compared with the lichen air quality classes (Table 4.8).

The statistical test from One-way analysis of variance (ANOVA) implied that there was significant difference between mean bark pH and air quality classes ($F = 3.551$, $p < 0.05$). The statistical analysis tables are showed in Appendix B.

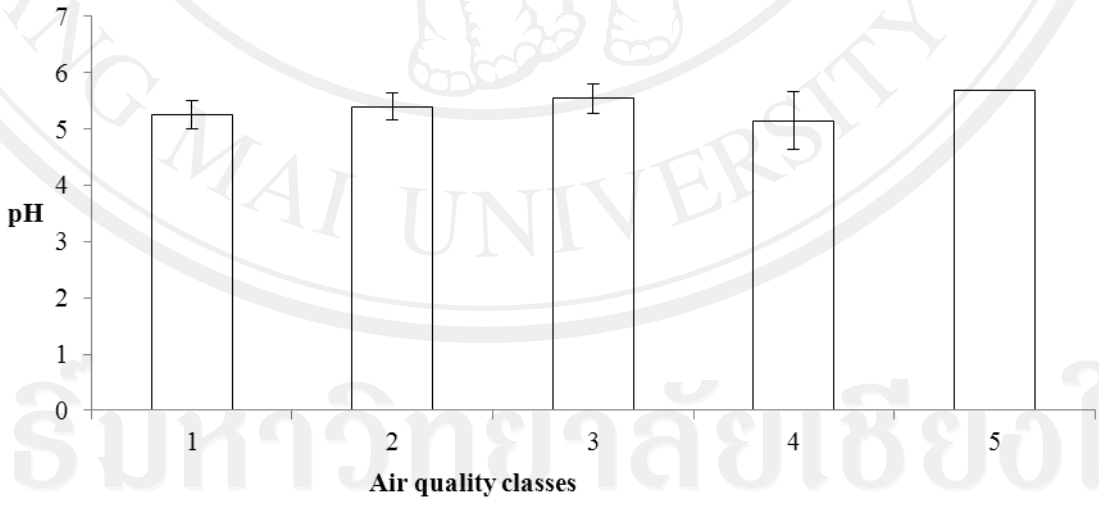


Figure 4.11 Average of bark pH in each air quality classes

Table 4.8 Comparison of bark pH and air quality classes

air quality classes	Level of air pollution	No. of Sampling unit	Mean pH ± SD
1	very high	12	5.25 ± 0.25^{a}
2	very high to high	37	5.40 ± 0.24^{b}
3	high to moderate	18	5.54 ± 0.26^{bc}
4	moderate	5	5.15 ± 0.51^{a}
5	moderate to low	1	5.69^{a}
Total		73	5.40 ± 0.24

Note: Same superscript letter indicates no significantly difference results of ANOVA test as 0.05 reliability level between five air quality classes for bark pH while a different superscript letter indicates significantly difference as 0.05 reliabilities.

4.5 The Direction of Lichens on Trees Trunk

From lichen investigation, grid frame was put on tree trunk where high diversity occurred. It was found that most of lichen was found in north direction. Next were north east, northwest, west and east direction. For southeast, southwest and south were direction which less lichens was found (Figure 4.12). However, if consider the direction in urban areas (A sites) and suburban areas (B sites) as showed in Figure 4.13. In A sites, the highest lichen frequency was found in north direction while less lichen was found in south direction. For B sites, the highest lichen frequency was found in north direction and less lichens was found in southeast direction.

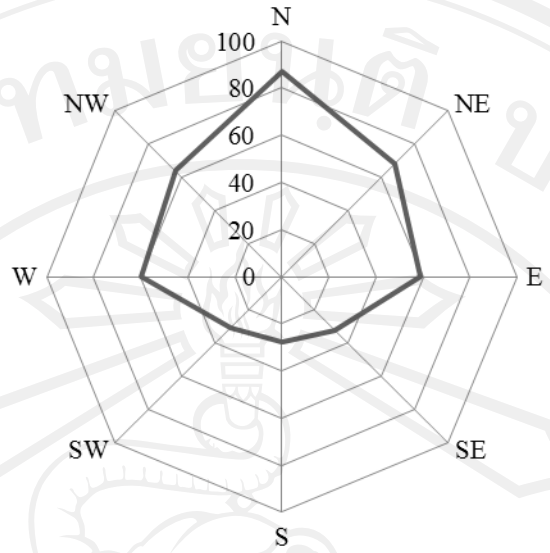


Figure 4.12 The direction which the lichens were found in the study sites

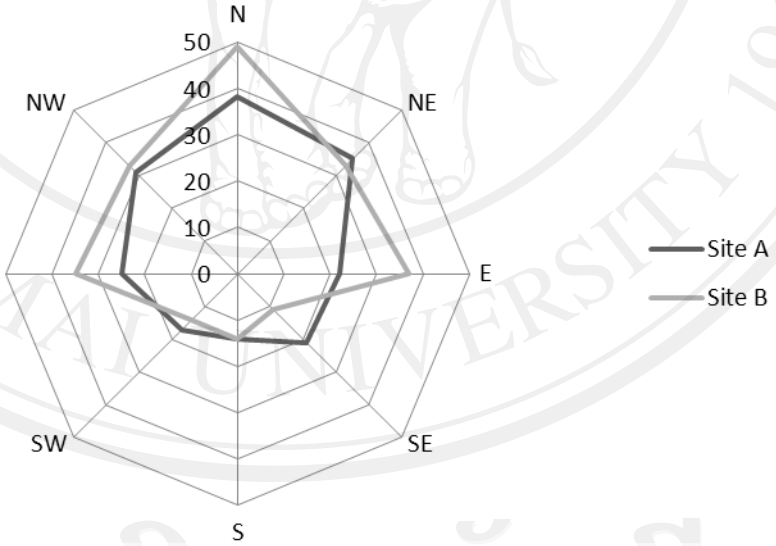


Figure 4.13 The direction which the lichens were found in the A and B site

4.6 Determination of NO_2 by Passive Sampling Technique

4.6.1 Sampling site

To determine the NO_2 concentration of each air quality classes in the study areas, diffusion tubes for passive sampling technique were installed for 19 sites. In each site, the passive sampling position was based on the center location with six trees (Figure 4.14). The sampling sites were selected from each direction in suburban areas by random in each class and in urban area in Chiang Mai province. Sites, which were in AQI class 4 and class 5, were selected for passive sampling. There were 19 sites in total and could be divided into three urban sites, 10 suburban sites, five sites in AQI class 4 and one site in AQI class 5. The location was described in Table 4.9 and the picture of each location was showed in Appendix B. The sampling duration was seven days per month. Sampling had been done in dry season during January 2012 to April 2012.

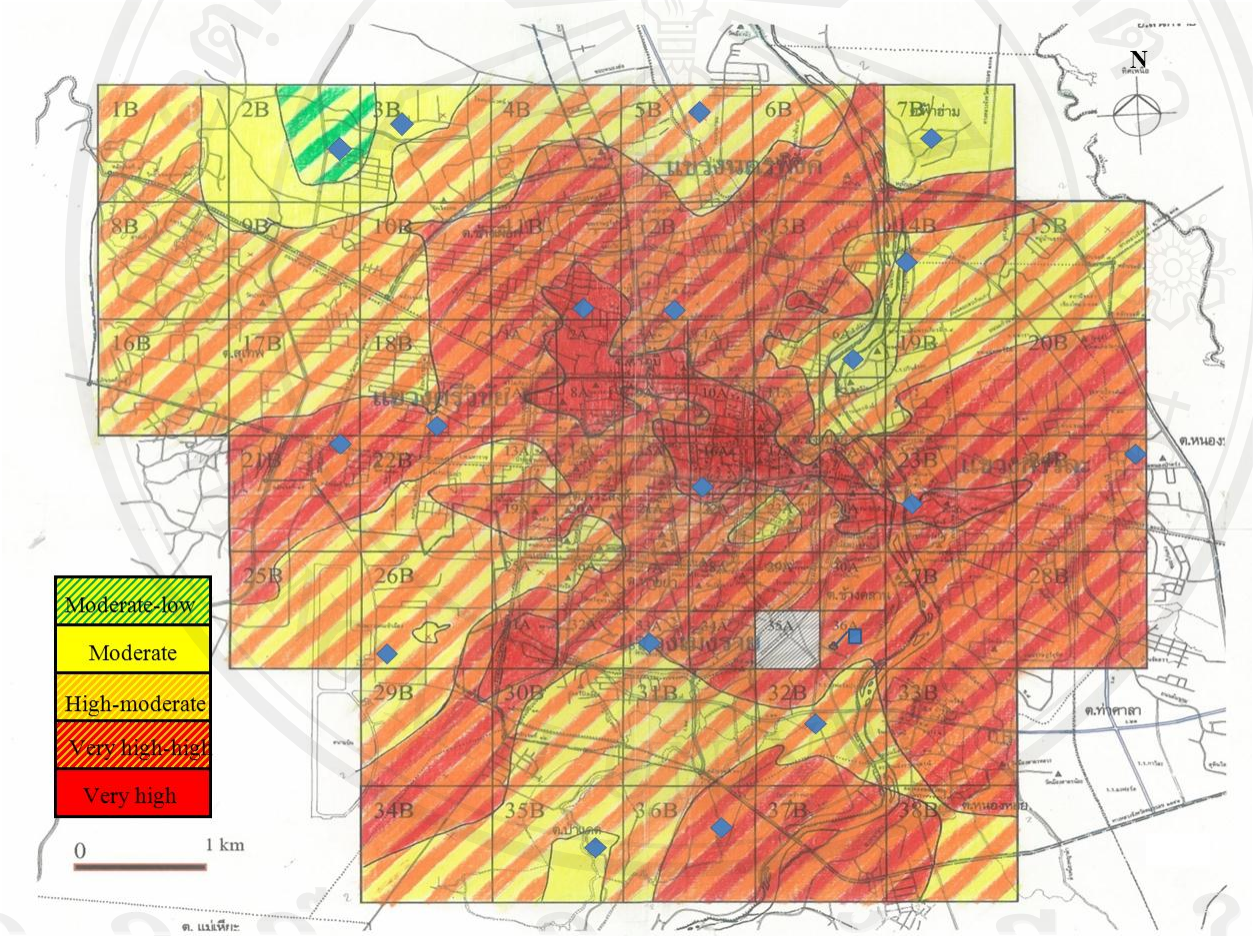


Figure 4.14 passive sampling positions in the study areas. (map from Chiang Mai municipality)
(* 35A: No suitable trees for investigation, 36A; ▰ : position is in the red area)

Table 4.9 The location of sampling sites in Chiang Mai Province.

Sampling sites	site	Location	Latitude-Longtitude
Urban area	16A	Phan-ohn Temple (วัดพันอ้น)	18°47'15.05" N 98°59'27.54" E
	33A	Nuntaram Temple (วัดนันทาราม)	18°47'15.05" N 98°59'13.53" E
	36A	Charoen Prathet alley 12 (ริมถนนเจริญประเทศ ซอย 12)	18°46'28.56" N 98°59'59.29" E
Suburban (North)	5B	Lanna Polytechnic Technology College Chiang Mai car park (ที่จอดรถวิทยาลัยเทคโนโลยีโปลิเทคนิคลานนา เชียงใหม่)	18°48'51.21" N 98°59'30.80" E
	11B*	Changpuak crematory (สุสานช้างเผือก)	18°48'03.58" N 98°58'53.89" E
	12B*	Institute of physical education (สถาบันการพลศึกษา เชียงใหม่)	18°47'56.85" N 98°59'21.44" E
Suburban (East)	14B	Brownie Steak & Bakery (ร้าน บราวนี่บุฟเฟ่ต์สเต็ก)	18°48'51.21" N 98°59'30.80" E
	23B	Chiang Mai- Lamphun Roadside (ริมถนนเชียงใหม่ ลำพูน)	18°47'10.41" N 99°00'19.23" E
	24B	Industrial Promotion Centre Region 1 Department of Industrial Promotion (ศูนย์ส่งเสริมอุตสาหกรรมภาคที่ 1 กรมส่งเสริมอุตสาหกรรม)	18°47'30.14" N 99°01'08.91" E
Suburban (South)	32B	Chiang Mai Land Village (หมู่บ้านเชียงใหม่แลนด์)	18°46'08.53" N 98°59'50.80" E
	36B	Wang Tan Villa 2nd Exit, Padad (หน้าทางเข้าออกที่ 2หมู่บ้านวังตาล ป่าแดด)	18°45'28.41" N 98°59'44.98" E
Suburban (West)	18B	Maharaj Nakorn Chiang Mai Hospital (โรงพยาบาลมหาราช เชียงใหม่)	18°47'34.12" N 98°58'16.73" E
	21B	Chiang Mai Provincial Public Health Office (สำนักงานสาธารณสุข จังหวัดเชียงใหม่)	18°47'26.32" N 98°57'50.61" E

Table 4.9 (continued)

Sampling sites	site	Location	Latitude-Longtitude
class 4	6A	Scopian tailed pier (ท่าเรือหางแมงป่อง)	18°47'44.93" N 99°00'01.07" E
	3B	Trees Market for Welfare, 33rd Military circle (ตลาดต้นไม้เพื่อสวัสดิการ มณฑลทหารบกที่ 33)	18°49'12.95" N 98°58'19.83" E
	7B	Lankga Temple (วัดลังกา)	18°48'41.09" N 99°00'22.58" E
	26B	Wing 41 (กองบิน 41)	18°46'29.39" N 98°58'05.99" E
	35B	Ban North Padad alley 5 (บ้านป่าแดดเหนือ ซอย 5)	18°45'09.69" N 98°59'14.93" E
class 5	2B	700 years Roadside (ริมถนนสมโภช 700 ปี)	18°48'47.99" N 98°57'49.37" E

Note: * means in those sites may be not the center from six trees because shelter was lost.

4.6.2 Analytical characteristics of Spectrophotometer

4.6.2.1 Linear range

One ml of nitrite standard was mixed with 2 ml of Saltzmann reagent and stood for 10 minutes. Absorbance of nitrite standard solution (0.01- 10.0 mg/l) was measured at 540 nm. Concentrations and their absorbance were plotted and showed in table 4.10 and Figure 4.15.

Table 4.10 Linear dynamic ranges of nitrite standard

Concentration of NO_2^- standard solution (mg/L)	Mean Absorbance
0.01	0.00
0.02	0.01
0.04	0.02
0.10	0.04
0.20	0.07
0.40	0.15
0.60	0.22
0.80	0.30
1.00	0.37
2.00	0.71
4.00	1.41
6.00	2.06
8.00	2.77
10.00	3.34

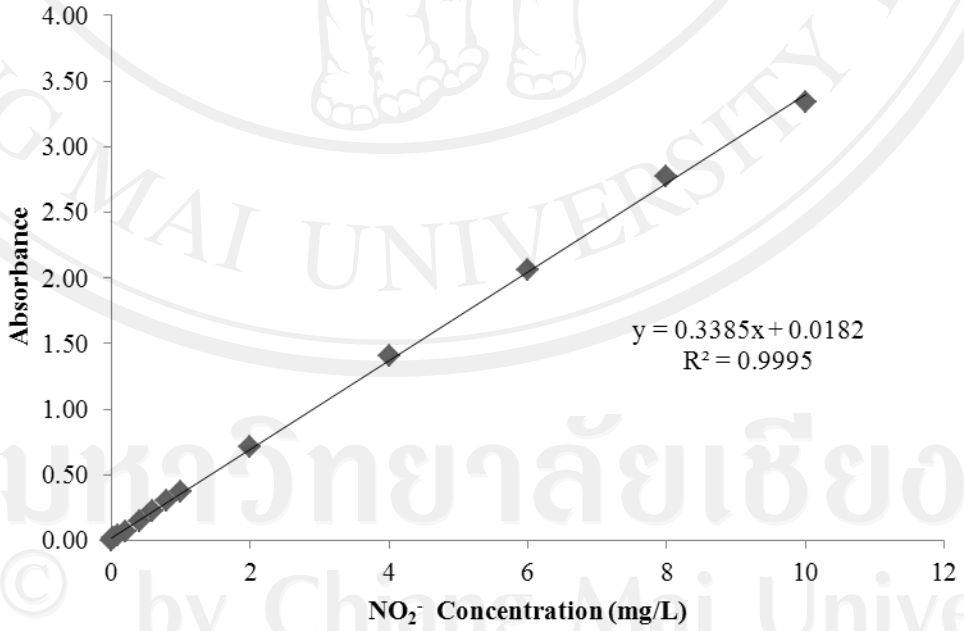


Figure 4.15 Linear dynamic range of nitrite standard

4.6.2.2 Calibration curve of nitrogen dioxide

Nitrogen dioxide trapped in diffusion tube was presented in form of nitrite (NO_2^-). The NO_2^- concentration was determined using the linear regression equation of the calibration curve prepared from different concentration of nitrite standard solution in range of 0.01- 1.00 mg/L as showed in Table 4.11 and Figure 4.16. Linear regression analysis of nitrogen dioxide as absorbance unit (Y) versus nitrite concentration in mg/L (X) yielded an equation: $Y = 0.2366x - 0.0056$ ($r^2 = 0.9992$)

Table 4.11 Absorbance of nitrite standard solution

Nitrite (mg/L)	Absorbance
0.01	0.0000
0.02	0.0004
0.04	0.0018
0.10	0.0146
0.20	0.0394
0.40	0.0912
0.60	0.1388
0.80	0.1845
1.00	0.2288

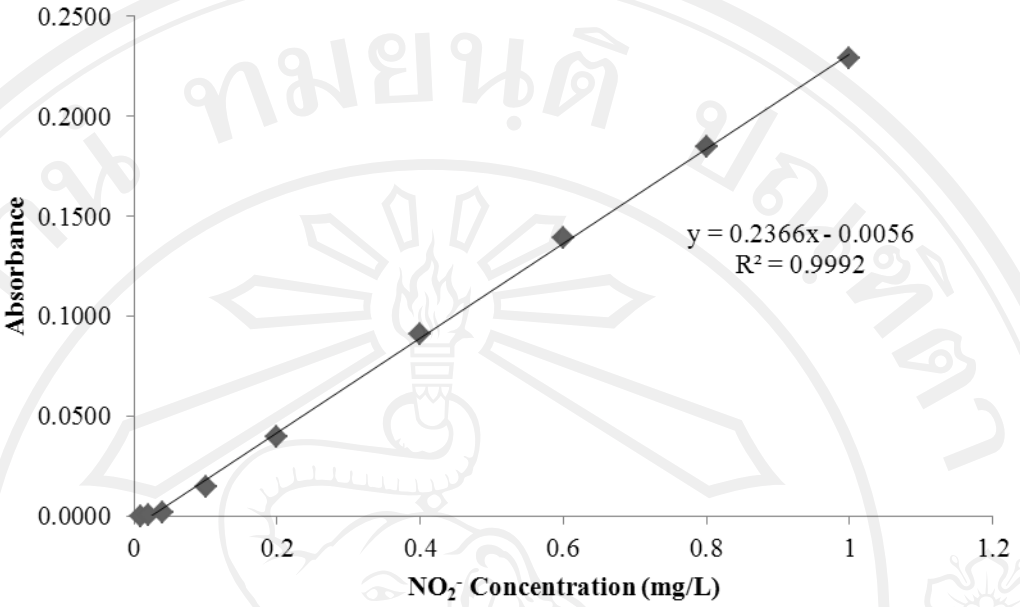


Figure 4.16 Calibration curve of nitrite standard solution

4.6.2.3 Limit of detection and limit of quantification

The limit of detection (LOD) was obtained by using linearity curve of nitrite standard concentration with high correlation (r^2> 0.99). LOD was calculated using equation in topic 3.5.4.3 and the result of ten measurements of 0.01 mg/L of nitrite standard solution is showed in Table 4.12. LOD and limit of quantification (LOQ) were calculated by 3 times and 10 times of standard deviation (SD) obtained from those ten measurement. LOD and LOQ of spectrophotometer for nitrite measurement were 0.011 and 0.036 mg/L, respectively.

Table 4.12 Limit of detection and limit of quantification of spectrophotometer for nitrite measurement

Number of measurement	Absorbance	Nitrite (mg/L)
1	0.0096	0.020
2	0.0068	0.012
3	0.0065	0.012
4	0.0063	0.011
5	0.0060	0.010
6	0.0058	0.010
7	0.0060	0.010
8	0.0052	0.008
9	0.0053	0.008
10	0.0050	0.008
Average		0.011
Standard		0.004
LOD (3 × SD)		0.011
LOQ (10 × SD)		0.036

4.6.2.4 Repeatability and reproducibility

The repeatability of the system was determined by repeating measurements of 0.2 mg/L nitrite solution for 10 times. The reproducibility of the system was find out by preparing 10 solution of 0.2 mg/L nitrite solution and analysis by the same manner. The result was showed in Table 4.13. The repeatability and reproducibility of the method were reported in term of % relative standard deviation (RSD), which were 0.5796 and 3.8311%, respectively.

Table 4.13 Repeatability and reproducibility of spectrophotometer

No. of measurement	Repeatability (mg/L)	Reproducibility (mg/L)
1	0.0426	0.0449
2	0.0426	0.0444
3	0.0429	0.0461
4	0.0425	0.0425
5	0.0425	0.0443
6	0.0423	0.0447
7	0.0423	0.0432
8	0.0422	0.0478
9	0.0422	0.0444
10	0.0421	0.0419
Average	0.0424	0.0444
Standard	0.0002	0.0017
%RSD	0.5796	3.8311

4.6.3 Determination of nitrite (NO_2^-) by Spectrophotometer

After seven days of exposure, the diffusion tubes were collected. The filtrate solution was prepared for measurement by spectrophotometer to determine NO_2^-. The concentration of NO_2^- in the diffusion tubes were calculated with the equation from calibration curve. The concentration of NO_2^- in the exposed tubes were subtracted from blank tube. Then, this concentration values was calculated by equation 3.5.8-1 to calculate the concentration of NO_2 (ppbv) in ambient air. The concentration of NO_2 (ppbv) in each month was showed in Table 4.14. The average of NO_2 (ppbv) in each month and average of NO_2 (ppbv) in order by Air Quality class were showed in Figure 4.17 and 4.18, respectively.

Table 4.14 The concentration of NO_2 (ppbv) in each month 2012 in Chiang Mai City

Direction	Sites Study	21- 28 Jan 2012		17- 24 Feb 2012		13- 20 March 2012		18- 25 Apr 2012	
		Sample	±SD	Sample	±SD	Sample	±SD	Sample	±SD
Center	16AB	2.38	1.40	4.44	0.74	3.61	0.66	0.70	0.34
	33A	1.95	0.47	3.03	0.47	2.91	0.90	0.33	0.17
	36A	6.11	1.49	13.09	1.25	9.41	1.65	2.97	1.46
North	5B	0.87	0.15	3.51	0.61	2.86	0.71	0.84	0.26
	11B	-	-	4.56	0.91	3.67	0.40	1.06	0.50
	12B	-	-	4.19	0.86	5.79	1.74	2.96	2.07
East	14B	2.36	0.55	4.29	1.11	5.61	0.93	1.83	1.04
	23B	3.89	0.28	5.71	0.63	5.11	0.79	2.71	1.34
	24B	1.27	0.19	1.70	0.75	2.14	0.50	0.24	0.08
South	32B	1.19	0.09	2.82	0.81	2.58	0.62	0.50	0.47
	36B	3.34	0.44	8.63	1.52	5.73	1.25	4.08	1.61
West	18B	2.27	0.44	6.78	1.62	2.87	1.84	2.44	0.44
	21B	3.96	0.63	7.98	1.31	4.52	1.46	3.39	1.21
Class 4	6A	1.43	0.41	4.31	0.88	3.08	0.67	-	-
	3B	0.21	0.13	2.97	1.80	1.67	0.36	0.81	0.24
	7B	0.33	0.14	2.80	0.31	2.29	0.64	2.03	0.32
	26B	0.36	0.26	2.51	0.10	2.31	0.49	1.19	0.41
	35B	1.16	0.19	3.23	0.29	2.39	0.48	0.65	0.25
Class 5	2B	1.26	0.26	5.55	0.94	3.65	0.97	1.92	1.26

Note: - means no result because of shelter was lost.

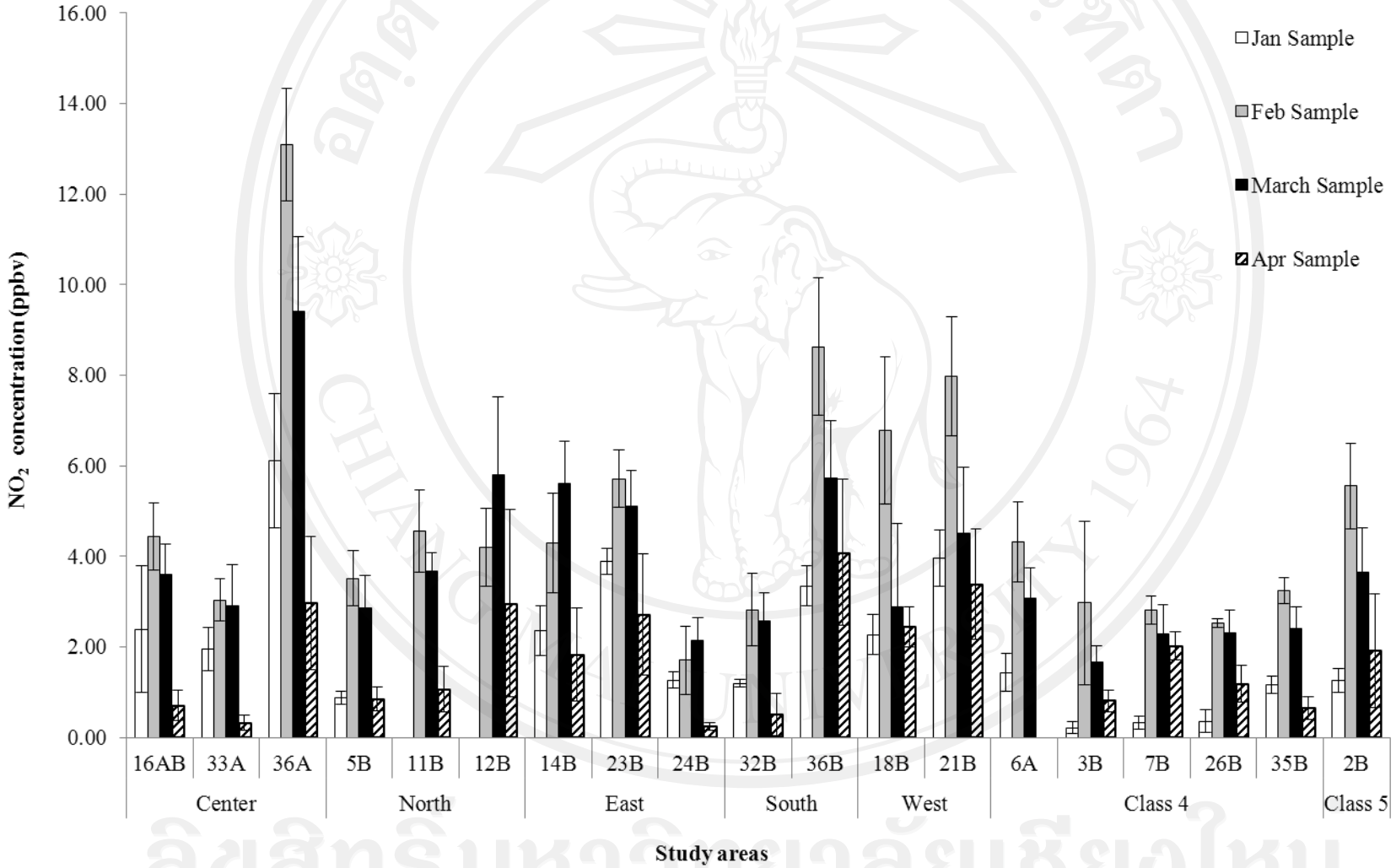


Figure 4.17 The average of NO_2 (ppbv) in each month with study site by direction

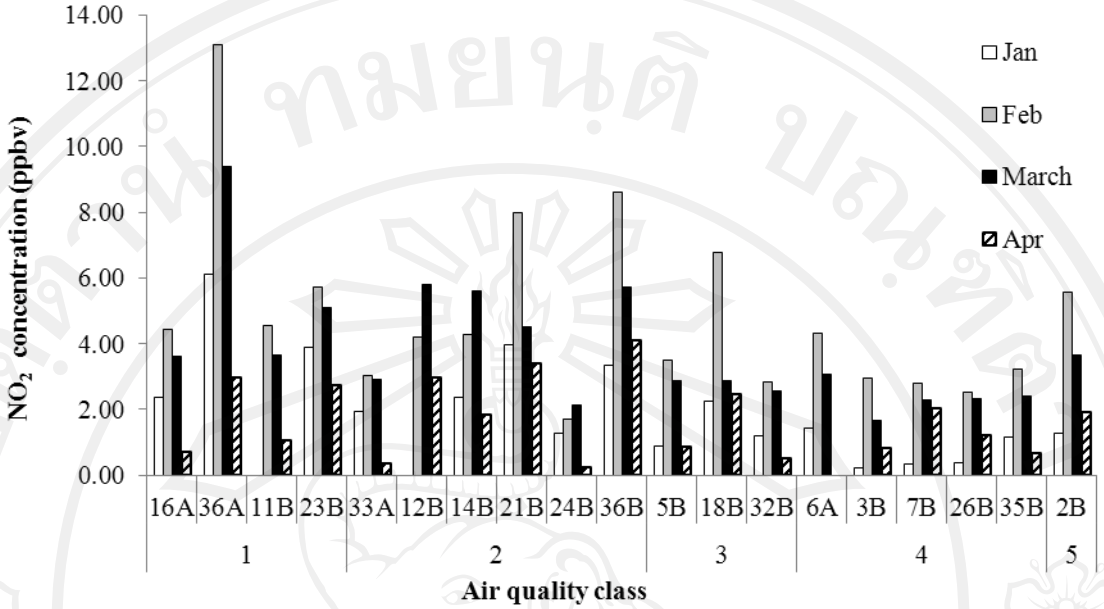


Figure 4.18 The average of NO_2 (ppbv) each month in each Air Quality Class

The average concentration of NO_2 in each site during January to April was ranged between 0.208- 13.087 ppbv. The lowest value was found in 3B (January) and the highest value was found in 36A (February). Figure 4.17(b) and 4.18(b) showed the highest NO_2 values in February and the lowest NO_2 values found in April. Consideration the average of NO_2 in each month it was found that in January the lowest value was found in 3B (0.208) and the highest value was found in 36A (6.107). In 11B and 12B had no value because shelters were stolen. The lowest value was found in 24B in February (1.700) and the highest value was found in 36A (13.087). In March the lowest value was found in 3B (1.673) as same as in January and the highest value was found in 36A (9.407). In the last month, April, the lowest value was found in 24B (0.243) similar to those of February and the highest value was found in

36B (4.082). The highest value of NO_2 found in 36A except in April which found in 36B while the lowest values of NO_2 were alternated with 3B and 24B.

The statistical test from Pearson correlation test implied that there was significant correlation between mean NO_2 and air quality classes ($r = -0.525$, $p < 0.05$) (Table 4.15). The statistical analysis tables were showed in Appendix C. The result was showed non significantly different between NO_2 in each class.

The results of average NO_2 (ppbv) of each lichen air quality class and average AQI was showed in Table 4.16 and Figure 4.19.

Table 4.15 Comparison of average concentration of NO_2 (ppbv) in ambient air with lichen air quality class

Lichen air quality class	level of air pollution	No. of sampling site	Mean NO_2 (ppbv) ± SD
1	very high	12	4.53± 2.34 [a]
2	very high to high	37	3.61 ± 1.63 [a]
3	high to moderate	18	2.46 ± 0.99 [a]
4	moderate	5	1.93 ± 0.59 [a]
5	moderate to low	1	3.09 [a]
Total		73	

Note: Same superscript letter indicated non significantly different results of Pearson correlation test as 0.05 probability level between five air quality classes and average concentration of NO_2

Table 4.16 The average frequency of lichen, average NO_2 in each class and AQI values

AQC	Site by Class	Average Frequency of Lichen	Average NO_2 (ppbv)	Mean NO_2 ± SD	AQI	Mean AQI
1	16A	3.67	2.78	4.53 ± 2.34	4.33	6.96
	36A	8.50	7.89		9.00	
	11B	6.17	3.10		6.17	
	23B	9.83	4.36		8.33	
2	33A	17.50	2.06	3.61 ± 1.63	18.17	13.78
	12B	11.17	4.31		13.00	
	14B	17.00	3.52		18.17	
	21B	12.00	4.96		12.83	
	24B	8.83	1.34		9.83	
	36B	12.17	5.45		10.67	
3	5B	21.50	2.02	2.46 ± 0.99	24.17	21.39
	18B	18.50	3.59		18.33	
	32B	15.00	1.77		21.67	
4	6A	32.33	2.94	1.93 ± 0.59	33.00	30.87
	3B	21.17	1.42		28.33	
	7B	32.33	1.86		34.33	
	26B	21.83	1.59		28.17	
	35B	24.67	1.86		30.50	
5	2B	31.17	3.09	3.09	40.83	40.83

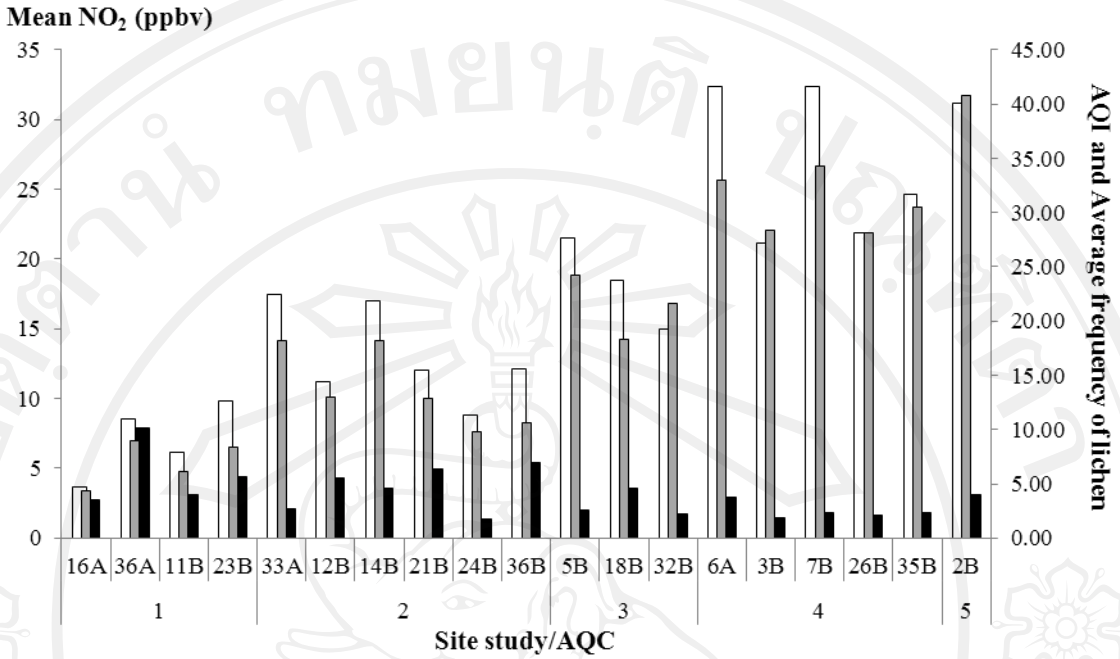


Figure 4.19 The average frequency of lichen, average NO_2 in each class and AQI values (White bar = Average frequency of lichen, Gray bar = AQI, Black bar = Average NO_2)

Table 4.14 and Figure 4.19 showed the average frequency of lichen value in selected study sites, it was found that concentration of NO_2 was between 3.67- 32.33. The less value was found in site 16A; class 1. The high value was found in site 6A and 7B. Both of them were in class 4. AQI values were range between 4.33- 40.83. The lowest AQI value was found in site 16A (4.33) while the highest value found in site 2B (40.83). The average concentration of NO_2 had range between 1.34- 7.89. The less concentration of NO_2 was found in 24B (class 2) and the highest was found in 36A (class 1).

Comparison between the average concentration of NO_2 in AQC and AQI values found that AQI values in each site was direct variation with AQC. Average concentration of NO_2 was inversely values with AQI and AQC except in class 5. It

had the highest of AQI value but average concentration of NO_2 value was same period with class 2. The average frequency of lichen also had a direct variation with AQI values while average concentration of NO_2 values had an inversely result. (Table4.16).

Correlation between concentration of NO_2 and Air Quality Index (AQI) was analyzed by using Pearson correlation. The result found that NO_2 and AQI was significant with 0.05 reliability ($r= -0.473$, $p< 0.05$). Low value of average NO_2 concentration had moderate to high of AQI values (10.00- 40.83) while high value of average NO_2 concentration had low of AQI values (4.33- 13.00) (Figure 4.20).

Correlation between concentration of NO_2 and pH bark values was analyzed by using Pearson correlation. The result found that NO_2 and pH bark values was no significant with 0.05 reliability ($r= -0.022$, $p< 0.05$) (Figure 4.21).

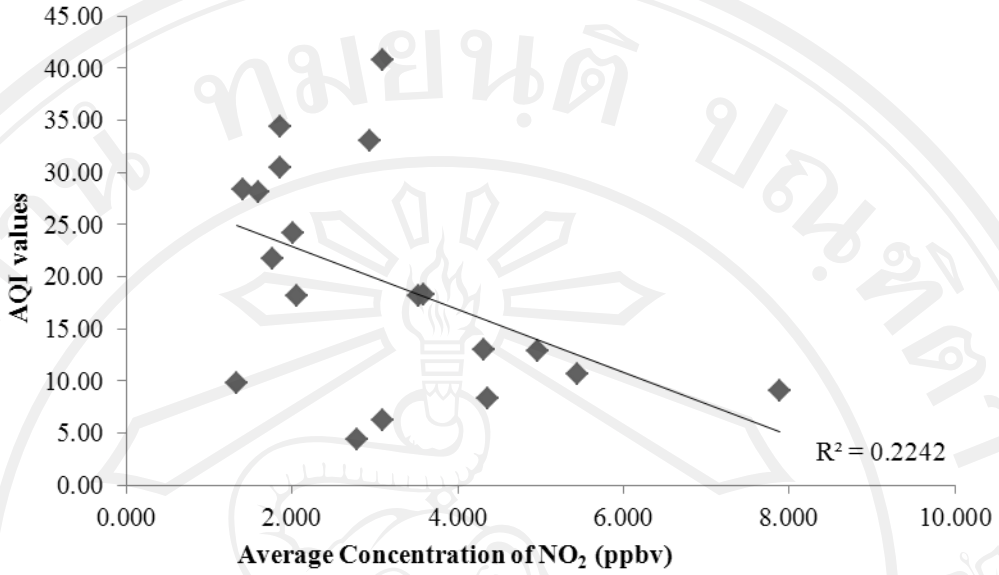


Figure 4.20 The correlation between NO_2 and AQI

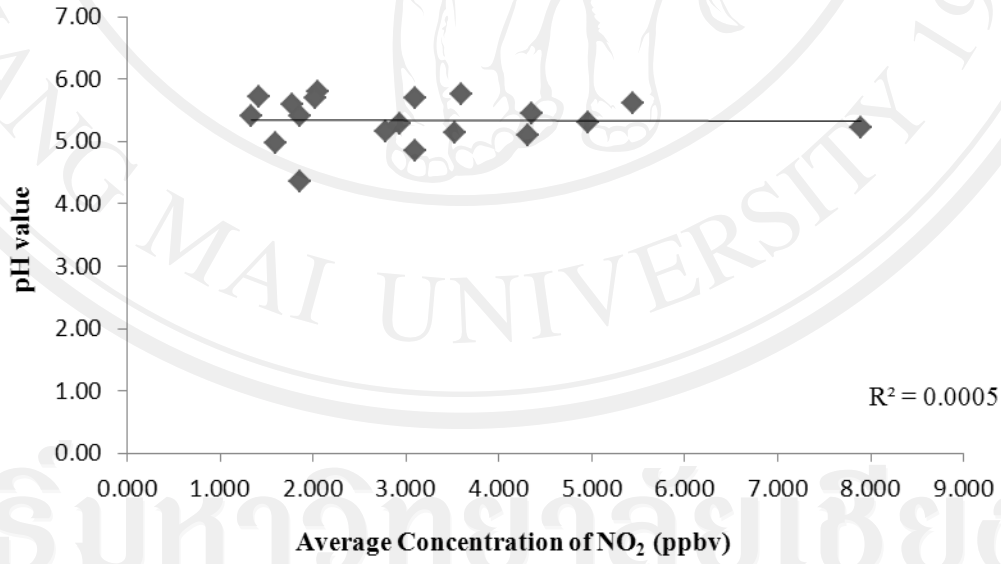


Figure 4.21 The correlation between NO_2 and pH value