# CHAPTER 4
# RESULTS

## 4.1 Mapping of Lichen diversity

### 4.1.1 Lichen diversity

Over the period of study, from May to November 2004, 234 mango trees were investigated. A total of 21 lichen species were recorded, 15 species belonging to the crustose group and 6 species belonging to the foliose group. Lists of total lichen species found are presented in Table 4.1 and the pictures of some lichen species are presented in Appendix F.

**Table 4.1** Lists of total lichen species found in study area

| | Taxa | Type |
|---|---|---|
| 1 | *Arthonia antillarum* | Crustose |
| 2 | *Arthonia* spp. | Crustose |
| 3 | *Bacidia* sp. | Crustose |
| 4 | *Buellia* sp. | Crustose |
| 5 | *Caloplaca* sp. | Crustose |
| 6 | cf. *Lecanographa* | Crustose |
| 7 | *Chrysothrix xanthina* | Crustose |
| 8 | *Cryptothecia* sp. | Crustose |
| 9 | *Dimerella* sp. | Crustose |
| 10 | *Dirinaria picta* | Foliose |
| 11 | *Graphidaceae* | Crustose |
| 12 | *Hyperphyscia adglutinata* | Foliose |
| 13 | *Hyperphyscia pandani* | Foliose |
| 14 | *Laurera* spp. | Crustose |
| 15 | *Lecanora* spp. | Crustose |
| 16 | *Parmotrema praesorediosum* | Foliose |
| 17 | *Physcia poncinsii* | Foliose |
| 18 | *Pyrenula* sp. | Crustose |
| 19 | *Pyxine cocoes* | Foliose |
| 20 | *Rinodina* sp. | Crustose |
| 21 | *Trypethelium* spp. | Crustose |

The similarity of ecological behaviour and floristic composition among lichen flora in the study area were then observed based on lichen frequencies. The hierarchical cluster analysis was performed by SPSS version 10.0, using cosine as the resemblance measure method and average linkage (between groups) as a clustering algorithm. The dendrogram is presented in Figure 4.1.

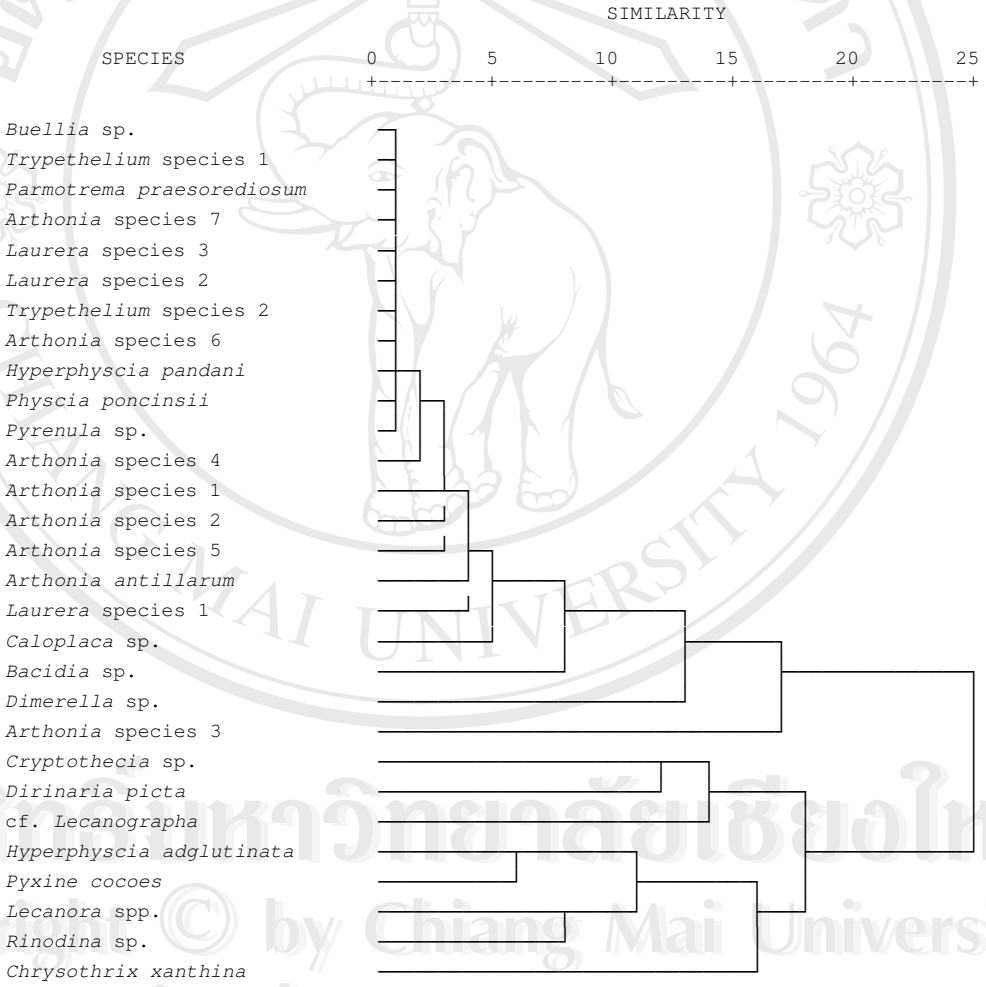


**Figure 4.1** Dendrogram of lichen species found in study area

The results from the classification of lichen species found in the study area showed that two groups of lichen species were clearly distinguished. The first group includes lichen species that were found mostly in urban areas, especially in the center of Lampang city. These lichen species are *Rinodina* sp., *Lecanora* spp., *Hyperphyscia adgultinata*, *Pyxine cocoes* and *Chrysothrix xanthina*. The other species belonging to this group are *Cryptothecia* sp., *Dirinaria picta* and cf. *Lecanographa*, which were found in the suburban area and also in the rural areas. The second group consists of the lichen species that were found in the outer zone of city and in the rural areas and include the following species; *Arthonia antillarum, Arthonia* spp., *Bacidia* sp., *Buellia* sp., *Caloplaca* sp*., Dimerella* sp., *Hyperphyscia pandani, Laurera* spp., *Parmotrema praesorediosum, Physcia poncinsii, Trypethelium* spp. and *Pyrenula* sp. Lichen species belonging to the Graphidaceae were excluded in the classification because these species are found scattered throughout the study area and are not suitable for use as indicator species.

### 4.1.2 Calculation of lichen diversity values

According to the method by Asta *et al*. (2002), the frequencies of all lichen species found within the surveyed quadrats were expressed as the sums of frequencies (SF) (Appendix C). For each tree, four values of SF were determined, and for each cardinal point, the mean of sums of frequencies (MSF) was then calculated. Lichen diversity values (LDVs) of each sampling unit were obtained by summing MSF of each cardinal point (Table 4.2).

**Table 4.2** Mean of sum of frequencies (MSF), lichen diversity values (LDVs), standard deviation (SD) and standard error (SE)

| Sampling Unit no. | MSF | | | | LDVs | SD | | | | Mean SD | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | E | S | W | | N | E | S | W | | |
| 1 | 6.80 | 7.83 | 8.25 | 7.20 | 30.08 | 4.55 | 3.66 | 2.99 | 3.56 | 3.69 | 1.65 |
| 2 | 13.67 | 11.40 | 9.50 | 12.17 | 46.73 | 5.50 | 5.59 | 6.66 | 4.31 | 5.52 | 2.47 |
| 3 | 13.00 | 10.33 | 5.83 | 7.50 | 36.67 | 7.64 | 3.88 | 5.19 | 5.72 | 5.61 | 2.51 |
| 4 | 5.20 | 4.00 | 2.67 | 2.67 | 14.53 | 3.96 | 3.37 | 2.07 | 2.52 | 2.98 | 1.33 |
| 5 | 7.33 | 7.83 | 3.75 | 7.83 | 26.75 | 2.16 | 4.36 | 1.71 | 6.55 | 3.69 | 1.65 |
| 6 | 7.20 | 7.17 | 8.00 | 5.83 | 28.20 | 1.79 | 4.71 | 4.00 | 4.07 | 3.64 | 1.63 |
| 7 | 7.33 | 7.00 | 7.00 | 7.00 | 28.33 | 3.50 | 2.65 | 3.24 | 4.64 | 3.51 | 1.57 |
| 8 | 6.00 | 6.00 | 3.25 | 4.00 | 19.25 | 4.90 | 3.61 | 2.99 | 2.45 | 3.49 | 1.56 |
| 9 | 11.33 | 7.00 | 4.20 | 7.50 | 30.03 | 8.71 | 5.43 | 4.21 | 4.72 | 5.77 | 2.58 |
| 10 | 14.00 | 14.80 | 13.75 | 6.50 | 49.05 | 6.72 | 6.94 | 7.80 | 3.27 | 6.19 | 2.77 |
| 11 | 10.75 | 12.20 | 7.00 | 7.20 | 37.15 | 8.81 | 6.46 | 2.65 | 4.82 | 5.68 | 2.84 |
| 12 | 13.20 | 7.17 | 10.20 | 9.40 | 39.97 | 2.68 | 3.92 | 4.82 | 4.22 | 3.91 | 1.75 |
| 13 | 7.67 | 6.17 | 3.80 | 5.00 | 22.63 | 4.80 | 4.12 | 2.17 | 3.52 | 3.65 | 1.63 |
| 14 | 6.50 | 6.40 | 7.50 | 6.17 | 26.57 | 6.38 | 4.10 | 6.19 | 4.96 | 5.41 | 2.42 |
| 15 | 5.67 | 4.33 | 3.00 | 4.67 | 17.67 | 5.24 | 4.84 | 3.95 | 6.19 | 5.06 | 2.26 |
| 16 | 4.67 | 1.83 | 3.50 | 4.33 | 14.33 | 4.55 | 2.23 | 4.14 | 4.50 | 3.85 | 1.72 |
| 17 | 5.83 | 2.50 | 3.33 | 0.17 | 11.83 | 6.40 | 3.21 | 4.13 | 0.41 | 3.54 | 1.58 |
| 18 | 9.50 | 5.00 | 5.00 | 5.50 | 25.00 | 2.38 | 5.05 | 4.15 | 3.62 | 3.80 | 1.70 |
| 19 | 8.33 | 7.00 | 7.40 | 6.67 | 29.40 | 4.80 | 5.10 | 6.35 | 5.16 | 5.35 | 2.39 |
| 20 | 6.67 | 11.50 | 7.33 | 8.33 | 33.83 | 2.50 | 5.80 | 2.34 | 2.50 | 3.29 | 1.47 |

**Table 4.2** (Continued)

| Sampling Unit no. | MSF | | | | LDVs | SD | | | | Mean SD | SE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | E | S | W | | N | E | S | W | | |
| 21 | 5.00 | 3.80 | 3.25 | 4.33 | 16.38 | 3.58 | 2.28 | 1.50 | 2.80 | 2.54 | 1.14 |
| 22 | 5.33 | 4.20 | 4.25 | 4.17 | 17.95 | 2.94 | 3.49 | 1.71 | 3.60 | 2.94 | 1.31 |
| 23 | 5.50 | 4.17 | 2.60 | 1.00 | 13.27 | 3.94 | 2.79 | 2.51 | 1.73 | 2.74 | 1.23 |
| 24 | 1.80 | 4.50 | 3.40 | 3.20 | 12.90 | 2.49 | 5.01 | 6.07 | 3.70 | 4.32 | 1.93 |
| 25 | 8.50 | 6.00 | 4.33 | 6.17 | 25.00 | 7.06 | 4.47 | 3.93 | 5.98 | 5.36 | 2.40 |
| 26 | 8.80 | 7.00 | 3.75 | 6.33 | 25.88 | 5.40 | 5.23 | 4.50 | 5.28 | 5.10 | 2.28 |
| 27 | 5.50 | 5.83 | 5.33 | 5.83 | 22.50 | 3.51 | 1.94 | 3.14 | 2.99 | 2.90 | 1.30 |
| 28 | 15.40 | 10.50 | 9.60 | 8.83 | 44.33 | 7.96 | 6.38 | 6.35 | 3.19 | 5.97 | 2.67 |
| 29 | 4.17 | 4.83 | 4.17 | 4.40 | 17.57 | 1.60 | 2.56 | 2.56 | 2.61 | 2.33 | 1.04 |
| 30 | 9.60 | 8.00 | 6.83 | 7.00 | 31.43 | 6.66 | 5.76 | 5.34 | 4.12 | 5.47 | 2.45 |
| 31 | 10.17 | 8.00 | 5.50 | 4.00 | 27.67 | 6.40 | 6.20 | 3.51 | 3.92 | 5.01 | 2.24 |
| 32 | 6.00 | 4.75 | 5.50 | 6.33 | 22.58 | 3.74 | 5.91 | 3.73 | 3.50 | 4.22 | 1.89 |
| 33 | 7.33 | 5.17 | 4.67 | 6.40 | 23.57 | 3.44 | 4.26 | 4.13 | 3.05 | 3.72 | 1.66 |
| 34 | 8.50 | 5.60 | 5.17 | 6.20 | 25.47 | 3.45 | 1.95 | 2.04 | 1.79 | 2.31 | 1.03 |
| 35 | 4.67 | 6.20 | 4.80 | 2.40 | 18.07 | 2.25 | 2.17 | 4.15 | 2.70 | 2.82 | 1.26 |
| 36 | 14.50 | 9.50 | 6.50 | 8.25 | 38.75 | 6.66 | 3.94 | 4.28 | 4.57 | 4.86 | 2.17 |
| 37 | 6.17 | 6.83 | 4.17 | 4.33 | 21.50 | 1.72 | 3.97 | 3.25 | 2.73 | 2.92 | 1.31 |
| 38 | 7.83 | 10.80 | 7.00 | 6.33 | 31.97 | 5.56 | 5.07 | 4.00 | 4.08 | 4.68 | 2.09 |
| 39 | 12.33 | 13.67 | 17.00 | 10.33 | 53.33 | 5.96 | 3.20 | 5.20 | 4.46 | 4.70 | 2.10 |

### 4.1.3 Determination of lichen diversity classes

The width of lichen diversity class of 5.16 was obtained by multiplying the median value of standard error (SE) by three (Table 4.3). Standard deviation and standard error of each cardinal point are presented in Table 4.2.

**Table 4.3** The median of standard error and the width of lichen diversity class

| | Value |
|---|---|
| Median of SE of all sampling units | 1.72 |
| Width of lichen diversity class | 5.16 |

### 4.1.4 Scales to interpret lichen diversity

The exposure scale for the study area was obtained by comparing the width of lichen diversity class with the VDI standard scale (Figure 4.2). The suitable color code for exposure scale was indicated according to the color code of VDI standard scale.

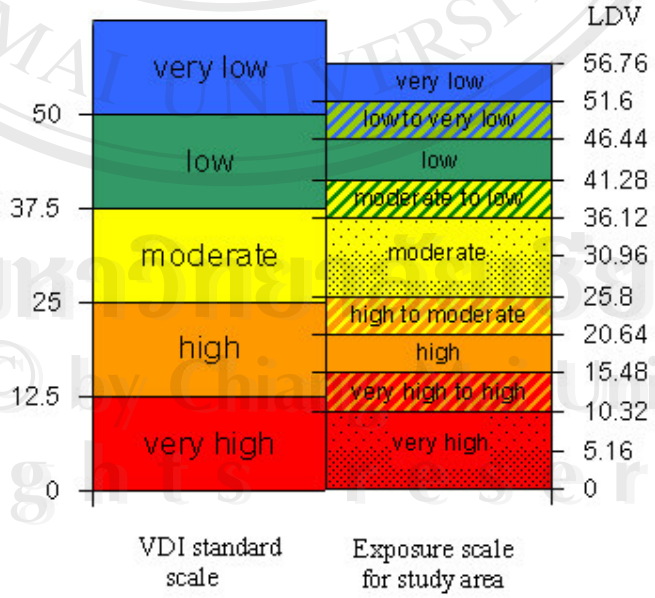


**Figure 4.2** Exposure scale of study area

The color code of air quality classes 2, class 4, class 6 and class 8 in this study are indicated by the combined color code of the two classes because their ranges overlapped low air quality classes according to the VDI standard scale. Air quality class 1 and class 5 each had two sub classes, and are indicated by black dots. The density of black dots, which was used for separating two subclasses, decreased towards the range of better air quality (Figure 4.2).

### 4.1.5 Lichen mapping

LDVs of all sampling units, which varied from 11.83 to 53.33, were assigned to lichen diversity classes (Table 4.4). Eight air quality classes were classified, and their color codes were indicated according to the exposure scale (Figure 4.2). The air quality results in Lampang city using lichen mapping are demonstrated in two figures. The first air quality map, (Figure 4.3) presents each sampling unit colored according to the air quality class. Another lichen map (Figure 4.4) presents the isoline indicating the air pollution zone.

For air quality class 1, LDVs varied from 10.32 to 15.48, which represent very high-to-high air pollution. This classification accounts for 12.82% of study area sampling units and was characteristic of urban area and densely developed areas with the highest density population. This class was located in the central part of Lampang city, which had a high volume of traffic.

For air quality class 2, LDVs varied from 15.48 to 20.64, which represent high air pollution. This category accounts for 15.38% of the study area sampling units and was characteristic of urban areas located along highway and main roads. This zone was also in a densely developed area, but the population density was lower than that of air quality class1.

For air quality class 3, LDVs varied from 20.64 to 25.80, which represent moderate to high air pollution. This range account for 20.51 % of study area sampling units and was characteristic of the suburban areas located south east of Lampang city. The area was a moderately developed area, which included residential and the university. The population density was at the same level of air quality class 2.

For air quality class 4, LDVs varied from 25.80 to 36.12, which represent moderate air pollution. This range of values accounts for 33.33% of study area sampling units, which included most of the study area. These values were found scattered throughout the outer part of Lampang city.

For air quality class 5, LDVs varied from 36.12 to 41.28, which represent moderate to low air pollution. This category accounts for 7.69% of study area sampling units and was found in the moderately developed area, such as villages and rice paddies.

For air quality class 6, LDVs varied from 41.28 to 46.44, which represent low air pollution. This class account for 2.56% of study area sampling units and was found in village areas with the lowest population density relative to the other areas in the study area.

For air quality class 7, LDVs varied from 46.44 to 51.60, which represent low to very low air pollution. This class account for 5.13% of study area sampling units and was found in the old city and in residential areas with a low population density.

For air quality class 8, LDVs varied from 51.60 to 56.76, which represent very low air pollution. This category accounts for 2.56% of study area sampling units and was found south of city in small rural villages and agricultural areas.

**Table 4.4** Air pollution level of sampling units according to lichen air quality classes

| Sampling unit no. | LDV | Range of lichen diversity class | Level of air pollution | Lichen air quality class |
|---|---|---|---|---|
| 17 | 11.83 | | | |
| 24 | 12.90 | | | |
| 23 | 13.27 | 10.32 < LDV ≤ 15.48 | very high to high | 1 |
| 16 | 14.33 | | | |
| 4 | 14.53 | | | |
| 21 | 16.38 | | | |
| 29 | 17.57 | | | |
| 15 | 17.67 | 15.48 < LDV ≤ 20.64 | high | 2 |
| 22 | 17.95 | | | |
| 35 | 18.07 | | | |
| 8 | 19.25 | | | |

**Table 4.4** (Continued)

| Sampling unit no. | LDV | Ranges of lichen diversity class | Level of air pollution | Lichen air quality class |
|---|---|---|---|---|
| 37 | 21.50 | | | |
| 27 | 22.50 | | | |
| 32 | 22.58 | | | |
| 13 | 22.63 | | | |
| 33 | 23.57 | 20.64 < LDV ≤ 25.80 | moderate to high | 3 |
| 25 | 25.00 | | | |
| 18 | 25.00 | | | |
| 34 | 25.47 | | | |
| 26 | 25.88 | | | |
| 14 | 26.57 | | | |
| 5 | 26.75 | | | |
| 31 | 27.67 | | | |
| 6 | 28.20 | 25.80 < LDV ≤ 30.96 | | |
| 7 | 28.33 | | | |
| 19 | 29.40 | | moderate | 4 |
| 11 | 30.02 | | | |
| 9 | 30.03 | | | |
| 1 | 30.08 | | | |
| 30 | 31.43 | | | |
| 38 | 31.97 | 30.96 < LDV ≤ 36.12 | | |
| 20 | 33.83 | | | |
| 3 | 36.67 | | | |
| 36 | 38.75 | 36.12 < LDV ≤ 41.28 | moderate to low | 5 |
| 12 | 39.97 | | | |
| 28 | 44.33 | 41.28 < LDV ≤ 46.44 | low | 6 |
| 2 | 46.73 | 46.44 < LDV ≤ 51.60 | low to very low | 7 |
| 10 | 49.05 | | | |
| 39 | 53.33 | 51.60 < LDV ≤ 56.76 | very low | 8 |

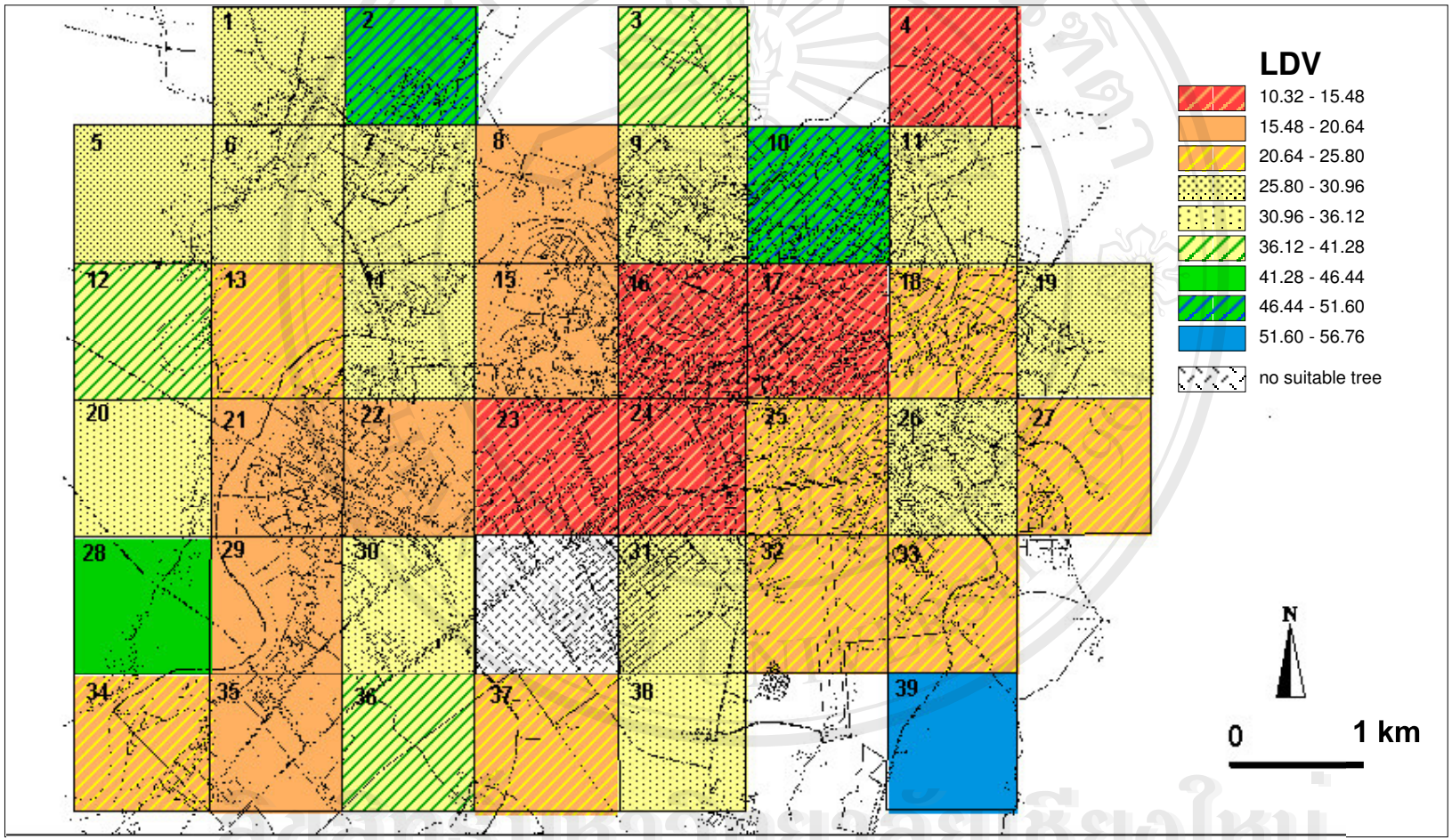


**Figure 4.3** Map of lichens indicating air quality in Amphoe Mueang Lampang

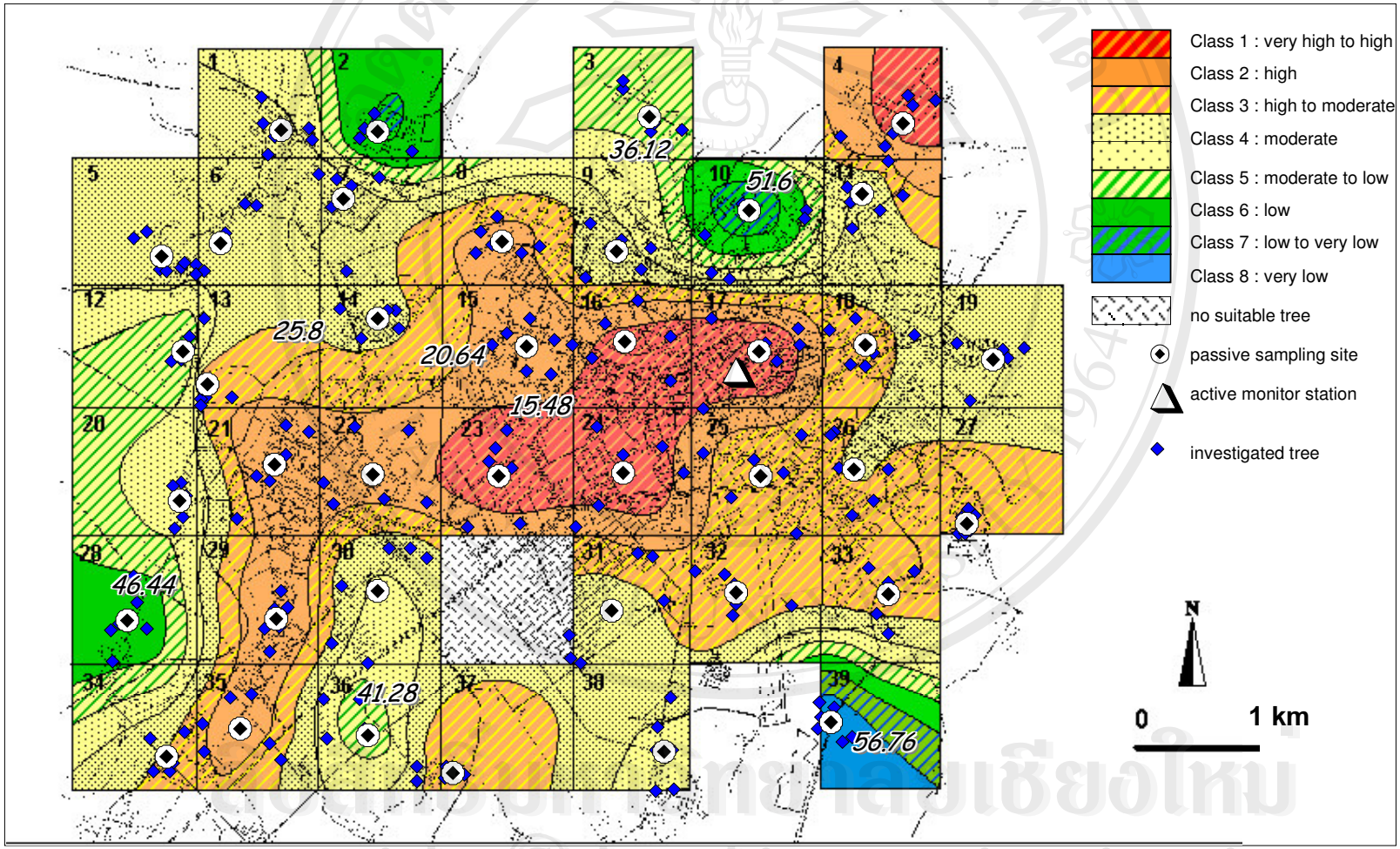


**Figure 4.4** Map of lichens indicating air quality zone in Amphoe Mueang Lampang and location of passive sampling site

### 4.2 Analysis of bark pH

The average pH of the Mango tree bark samples collected from Lampang city when compared with lichen air quality classes are presented in Table 4.5.

The statistical test from one-way analysis of variance (ANOVA) implied that there was no significant difference in mean bark pH between lichen air quality classes ($F^{NS}$ = 0.587, p< 0.05). The statistical analysis tables are shown in Appendix E. However, the average bark pH decreased toward the better range of air quality. The pH of bark varied from 5.22 to 5.74. The highest pH value was found in lichen air quality class one, representing the very high-to-high air pollution zone. High pH values were also found in lichen air quality class two, which represents a high pollution zone, but the same high pH value was found in lichen air quality class seven, which represents a very low-to-low air pollution zone. The lowest pH was found in the very low air pollution area.

**Table 4.5** Comparison of bark pH with lichen air quality classes

| Lichen air quality class | Level of air pollution | No. of Sampling unit | Mean pH ± SE |
|---|---|---|---|
| 1 | Very high to high | 5 | 5.74 ± 0.19[a] |
| 2 | High | 6 | 5.68 ± 0.20[a] |
| 3 | Moderate to high | 8 | 5.51 ± 0.13[a] |
| 4 | Moderate | 13 | 5.47 ± 0.09[a] |
| 5 | Moderate to low | 3 | 5.41 ± 0.18[a] |
| 6 | Low | 1 | 5.35 [a] |
| 7 | Very low to low | 2 | 5.68 ± 0.44[a] |
| 8 | Very low | 1 | 5.22 [a] |
| **Total** | | 39 | 5.54 ± 0.06 |

Note: same superscript letter indicate no significantly different results of ANOVA test at 0.05 probability level between eight lichen air quality classes for bark pH

### 4.3 Determination of $NO_2$ and $SO_2$ by passive sampling technique

#### 4.3.1 Sampling site

To determine the $NO_2$ and $SO_2$ concentration of each air pollution zone in the study area, diffusion tubes for passive sampling were installed within each sampling

unit of the study are at thirty-nine sites. In each sampling unit, the sampling site of installed diffusion tube was based on the center location within the six sampled Mango trees (Figure 4.4).

### 4.3.2 Determination of nitrite ($NO_2^-$) and sulfate ($SO_4^{2-}$) by ion chromatography

After two weeks of exposure, the diffusion tubes were collected. The extracted solution was filtered and prepared for injection into the ion chromatograph to determine $NO_2^-$ and $SO_4^{2-}$. The concentrations of $NO_2^-$ and $SO_4^{2-}$ in the diffusion tubes were calculated with the help of a calibration curve. Two examples of calibration curves are shown in Figure 4.5 and 4.6. Blank and exposed tubes were measured subsequently, under optimized ion chromatograph conditions.

The concentrations of $NO_2$ and $SO_2$ in the exposed tube were subtracted from the laboratory blank. Then, this concentration value was used in equation 2.5 to calculate the concentration of $NO_2$ ($\mu g/m^3$) and $SO_2$ ($\mu g/m^3$) in ambient air. The details of calculation are shown in Appendix B. The results of average $NO_2$ ($\mu g/m^3$) and $SO_2$ ($\mu g/m^3$) of each lichen air quality class are shown in Table 4.6 and Table 4.7, respectively.

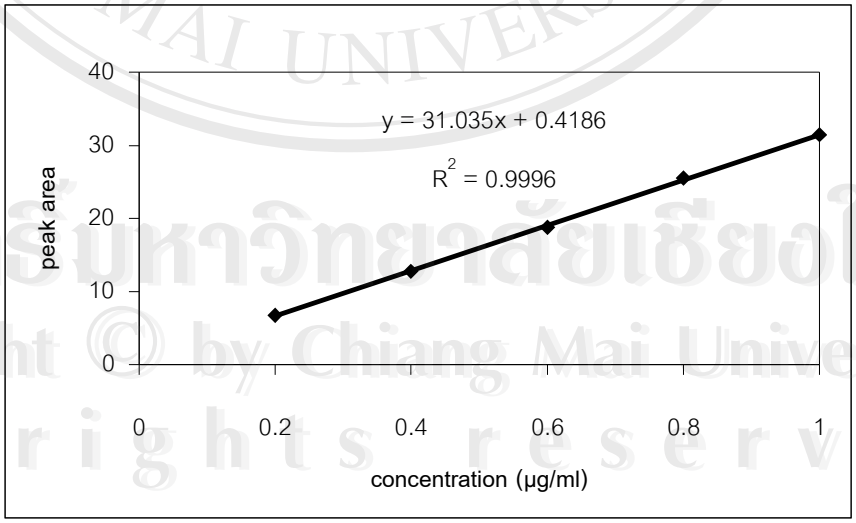


**Figure 4.5** Calibration curve of $NO_2^-$ (0.2 µg/ml – 1 µg/ml)

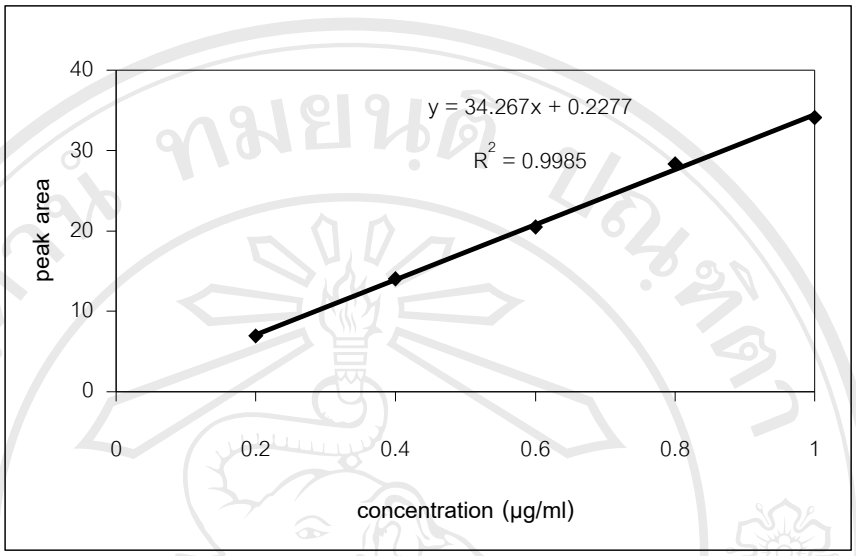


**Figure 4.6** Calibration curve of $SO_4^{2-}$ (0.2 µg/ml – 1 µg/ml)

**Table 4.6** Comparison of average concentration of $NO_2$ (µg/$m^3$) in ambient air with lichen air quality classes

| Lichen air Quality class | Level of air pollution | no. of sampling site | Mean $NO_2$ (µg / $m^3$) ± SD |
|---|---|---|---|
| 1 | Very high to high | 5 | $35.84 \pm 14.15^{c}$ |
| 2 | High | 6 | $29.59 \pm 4.89^{bc}$ |
| 3 | Moderate to high | 8 | $23.46 \pm 5.56^{abc}$ |
| 4 | Moderate | 13 | $24.21 \pm 7.90^{bc}$ |
| 5 | Moderate to low | 3 | $19.60 \pm 5.43^{ab}$ |
| 6 | Low | 1 | $19.99^{ab}$ |
| 7 | Very low to low | 2 | $10.39 \pm 8.80^{a}$ |
| 8 | Very low | 1 | $12.95^{a}$ |
| Total | | 39 | $24.91 \pm 9.52$ |

Note: superscript letters indicate significantly different results of ANOVA test at 0.05 probability level between eight lichen air quality classes for $NO_2$

**Table 4.7** Comparison of average concentration of $SO_2$ ($\mu g/m^3$) in ambient air with lichen air quality classes

| Lichen air quality class | Level of air pollution | no. of sampling site | Mean $SO_2$ ($\mu g / m^3$) ± SE |
|---|---|---|---|
| 1 | Very high to high | 5 | 9.80 ± 6.13[a] |
| 2 | High | 6 | 23.60 ± 20.60[a] |
| 3 | Moderate to high | 8 | 19.77 ± 9.78[a] |
| 4 | Moderate | 13 | 16.93 ± 7.34[a] |
| 5 | Moderate to low | 3 | 17.27 ± 10.45[a] |
| 6 | Low | 1 | 52.57[a] |
| 7 | Very low to low | 2 | 7.88 ± 7.46[a] |
| 8 | Very low | 1 | 11.02[a] |
| Total | | 39 | 17.95 ± 12.43 |

Note: same superscript letter indicate no significantly different results of ANOVA test at 0.05 probability level between eight lichen air quality classes for $SO_2$

The one-way analysis of variance (ANOVA) with Least significant difference (LSD) was used to determine the difference of mean $SO_2$ and $NO_2$ concentration between each lichen air quality class. The results showed that the mean $SO_2$ concentration of each lichen air quality class were not significantly different ($F^{NS}$ = 1.599, $p < 0.05$). However, the results showed there was a significant difference in mean $NO_2$ concentrations between lichen air quality classes ($F^{*}$ = 5.455, $p < 0.05$). The statistical analysis tables are presented in Appendix E.

The scatter plot diagram was drawn between LDVs and $NO_2$ concentrations (Figure 4.7) and between LDVs and $SO_2$ concentrations of the sampling units (Figure 4.8). The correlation test was carried out by Pearson's correlation. The results showed a significant moderate correlation ($r^{**}$ = -0.614, $p < 0.01$) between $NO_2$ and LDVs, but no significant correlation between $SO_2$ and LDVs ($r$ = -0.119, $p < 0.01$).

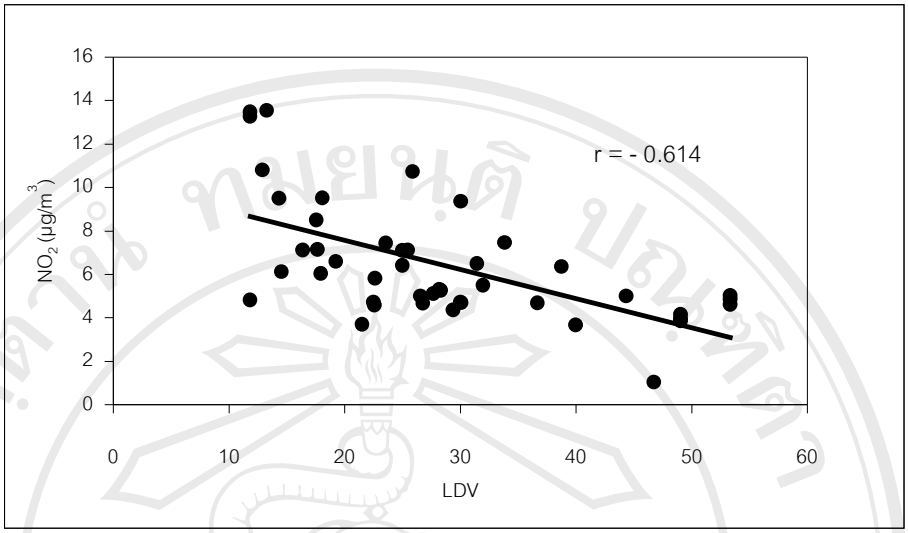


**Figure 4.7** Correlation between LDVs and $NO_2$ (µg/$m^3$) of all sampling site

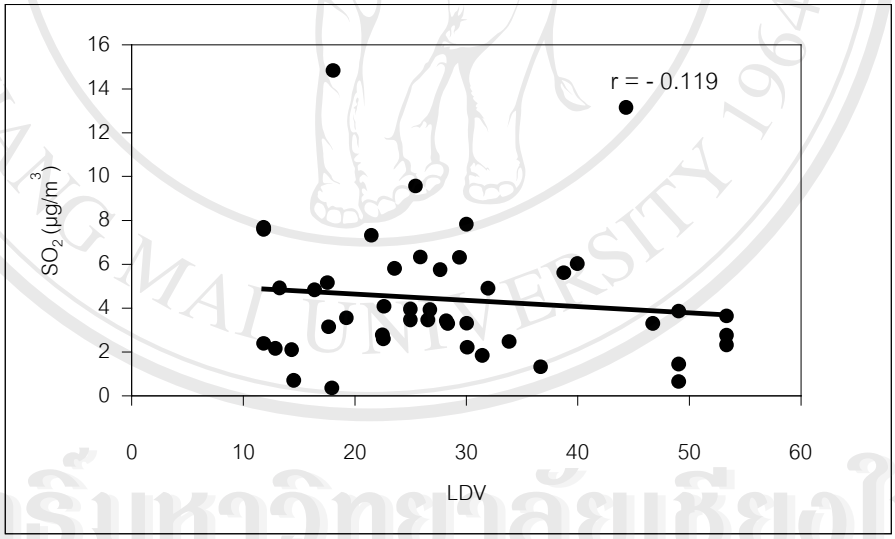


**Figure 4.8** Correlation between LDVs and $SO_2$ (µg/$m^3$) of all sampling site

### 4.3.3 Comparison with active sampling measurement

The active sampling data, which was measured by a chemiluminescence monitor for $NO_2$ and a fluorescent analyzer for $SO_2$, was obtained from the Pollution Control Department of Thailand (2005).

The concentrations of $NO_2$ and $SO_2$ obtained by active sampling were compared with average concentrations obtained by passive sampling during the two weeks of exposure at sampling unit no. 16, 17, 23 and 24 (Figure 4.9). Theses area were chosen due to the highest air pollution zone as well as located in the central of city where the active monitor station is established. The results from the comparison of the average concentration of $NO_2$ by passive sampling from four sampling units and active sampling showed that, the underestimation of average $NO_2$ concentration from passive sampling was within 11.56 % error of the value obtained from active sampling. While, the average $SO_2$ concentrations obtained from passive sampling was higher than the concentration measured by active sampling (Figure 4.10).

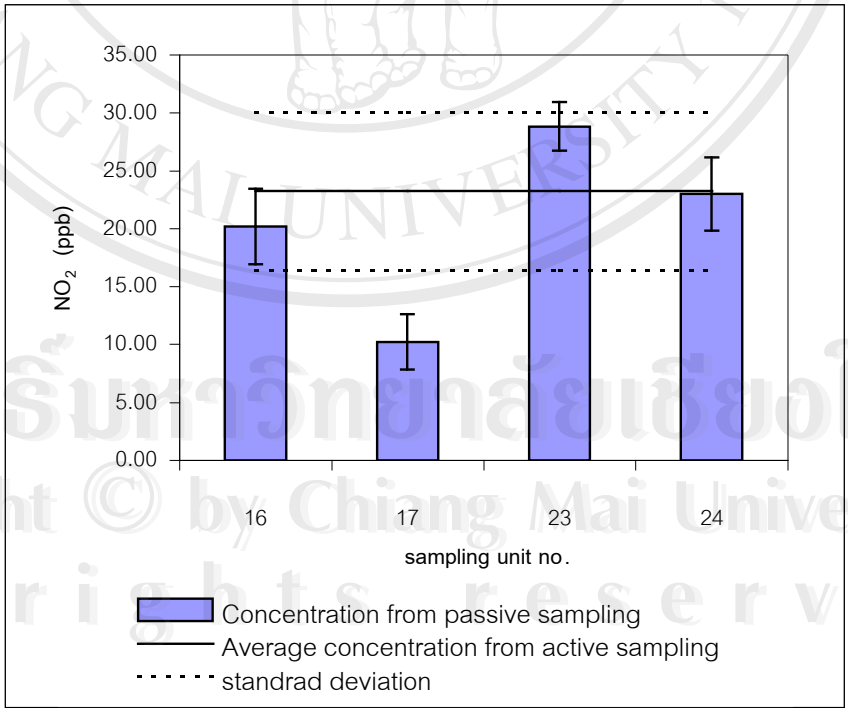


**Figure 4.9** Comparison of average $NO_2$ concentration measured by passive with active sampling during the two weeks period of exposure

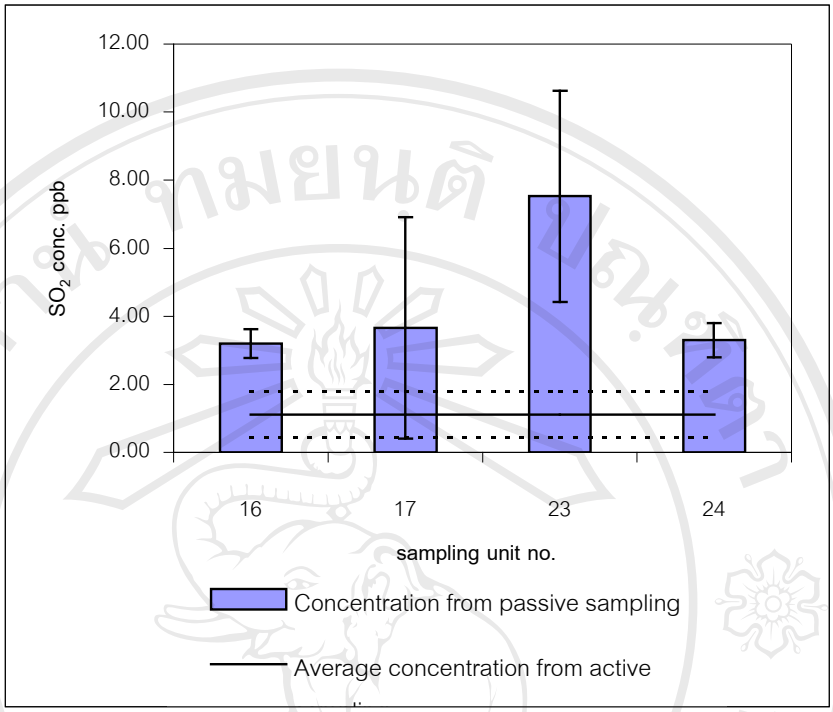


**Figure 4.10** Comparison of average $SO_2$ concentration measured by passive with active sampling during the two weeks period of exposure

### 4.4 Correlation between the four parameters

The correlation tests between four parameters; LDVs, $NO_2$, $SO_2$ and bark pH were performed using Pearson's correlation test. The results are shown in Table 4.8. A significant correlation between $NO_2$ and LDVs ($r^{**} = -0.614$, $p < 0.01$) and a slightly significant correlation between bark pH and $NO_2$ ($r^{*} = 0.368$, $p < 0.05$) were found.

**Table 4.8** Correlation between four parameters with the results of the Pearson test

| **Pearson correlation test** | LDVs | $NO_2$ | $SO_2$ |
|---|---|---|---|
| $NO_2$ | r = -0.614** | - | - |
| $SO_2$ | r = - 0.119 | r = 0.151 | - |
| Bark pH | r = -0.205 | r = 0.368* | r = -0.204 |

* significant at $p < 0.05$, ** significant at $p < 0.01$

**Table 4.9** Comparison between LDV, concentration of $NO_2$, $SO_2$ and type of land use of eight lichen air quality classes

| Lichen air quality class | Level of air pollution | Sampling unit no. | LDV | Median $NO_2$ ($ug/m^3$) | Median $SO_2$ ($ug/m^3$) | Land use type |
|---|---|---|---|---|---|---|
| 1 | very high to high | 17 | 11.83 | 19.26 | 9.56 | Urban area |
| | | 24 | 12.90 | 43.25 | 8.63 | |
| | | 23 | 13.27 | 54.21 | 19.67 | |
| | | 16 | 14.33 | 37.98 | 8.38 | |
| | | 4 | 14.53 | 24.48 | 2.77 | |
| 2 | high | 21 | 16.38 | 28.46 | 19.31 | Urban area |
| | | 29 | 17.57 | 31.87 | 34.73 | |
| | | 15 | 17.67 | 28.60 | 12.57 | |
| | | 22 | 17.95 | 24.17 | 1.43 | |
| | | 35 | 18.07 | 38.09 | 59.35 | |
| | | 8 | 19.25 | 26.36 | 14.23 | |
| 3 | moderate to high | 37 | 21.50 | 14.80 | 29.26 | Suburban area |
| | | 27 | 22.50 | 18.92 | 11.07 | |
| | | 32 | 22.58 | 18.36 | 10.37 | |
| | | 13 | 22.63 | 23.25 | 16.31 | |
| | | 33 | 23.57 | 29.76 | 23.20 | |
| | | 25 | 25.00 | 28.42 | 13.85 | |
| | | 18 | 25.00 | 25.66 | 15.83 | |
| | | 34 | 25.47 | 28.49 | 38.25 | |

**Table 4.9** (continued)

| Lichen air quality class | Level of air pollution | Sampling unit no. | LDV | Median $NO_2$ ($ug/m^3$) | Median $SO_2$ ($ug/m^3$) | Land use type |
|---|---|---|---|---|---|---|
| 4 | moderate | 26 | 25.88 | 42.92 | 25.30 | Suburban and agricultural area |
| | | 14 | 26.57 | 20.00 | 13.84 | |
| | | 5 | 26.75 | 18.69 | 15.72 | |
| | | 31 | 27.67 | 20.43 | 23.01 | |
| | | 6 | 28.20 | 21.24 | 13.65 | |
| | | 7 | 28.33 | 21.06 | 13.16 | |
| | | 19 | 29.40 | 17.44 | 25.27 | |
| | | 11 | 30.02 | 18.88 | 31.27 | |
| | | 9 | 30.03 | 37.43 | 13.24 | |
| | | 1 | 30.08 | 18.81 | 8.82 | |
| | | 30 | 31.43 | 25.97 | 7.37 | |
| | | 38 | 31.97 | 22.01 | 19.61 | |
| | | 20 | 33.83 | 29.88 | 9.88 | |
| 5 | moderate to low | 3 | 36.67 | 18.70 | 5.24 | Suburban and agricultural area |
| | | 36 | 38.75 | 25.42 | 22.44 | |
| | | 12 | 39.97 | 14.68 | 24.11 | |
| 6 | low | 28 | 44.33 | 19.99 | 52.57 | Suburban and agricultural area |
| 7 | low to very low | 2 | 46.73 | 4.17 | 13.16 | Suburban and agricultural area |
| | | 10 | 49.05 | 16.61 | 2.60 | |
| 8 | very low | 39 | 53.33 | 12.95 | 11.02 | Rural area |