# CHAPTER II
# LITERATURE REVIEW

## 2.1 Situation of greenhouse gas emissions

Since the Industrial Revolution began in 1750, the concentration of atmospheric $CO_2$ has risen from 280 ppm in the mid-18th century to 379 ppm in 2005, which are primarily from the burning of fossil fuels and cement production [2]. The current human activities increase the concentration of atmospheric greenhouse gases. It was expected that the concentration is increasing steadily. The $CO_2$ can be increased from 300 ppm to 600 ppm or up to 900 ppm during the next 100 years [9]. In 2004, the total volume of global $CO_2$ emissions from fossil fuels combustion was up to 7,910 tonnes, which broke the record of all time. It was increased from 2003 by 5.4 percent (Figure 2.1). When calculating the global $CO_2$ emissions per capita, it was found increased from 0.63 tonnes in 1950 to 1.23 tonnes in 2007, showing the average annual increasing rate of 1.14 percent (Figure 2.2) [10].

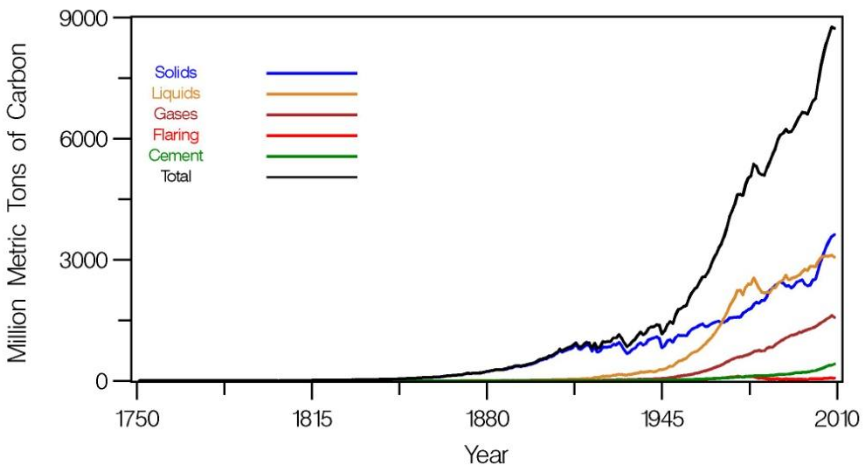


**Figure 2.1 Total volume of global $CO_2$ emissions**

**Source:** Carbon Dioxide Information Analysis Center (CDIAC), 2008

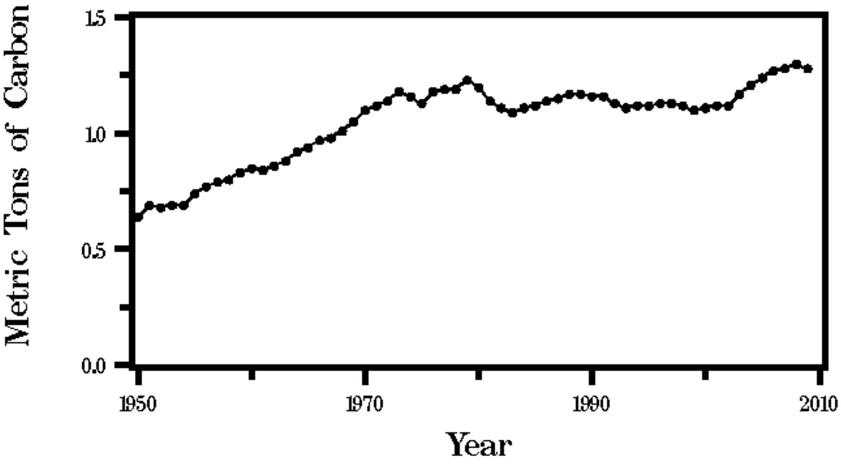


**Figure 2.2 Global $CO_2$ emission per capita**

**Source:** Carbon Dioxide Information Analysis Center (CDIAC), 2008

The national report on greenhouse gas emissions in Thailand in 2000-2010 is available from the greenhouse gases data center, greenhouse gas management organization. The total greenhouse gas emission in 2010 was 335.14 Mt $CO_2$eq in which the energy sector, the major contributor, provided 230.47 Mt $CO_2$eq. (68.80 percent of the national emission). Being minor contributors, agriculture, forestry and land use emitted 64.79 Mt $CO_2$eq (19.40 percent). The industrial processes and product use sector released 29.89 Mt $CO_2$eq (8.90 percent) and the waste sector produced the least amount of $CO_2$ (10 Mt $CO_2$eq, 3 percent). The agriculture, forestry and land use accumulates greenhouse gases as biomass in forests and agricultural plants, such as oil palm, rubber and fruit plantations, etc. Therefore, the total accumulation of greenhouse gases in 2010 was 115.23 Mt $CO_2$eq. When greenhouse gas emission was substracted agriculture, forestry and land use sectors was absorbing 50.44 79 Mt $CO_2$eq. Therefore, the net greenhouse gas emission of Thailand is equivalent to 219.91 Mt $CO_2$eq in 2010 (Figure 2.3) [11].

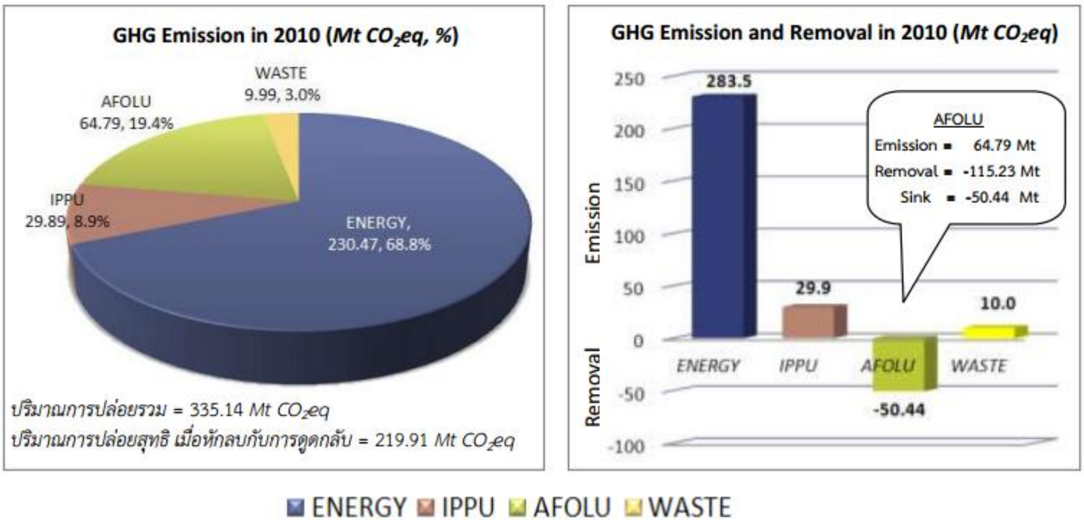


**Figure 2.3 Amount and ratio of Thailand's categoried national greenhouse gas emission in 2010**

**Source:** Thailand Greenhouse Gas Management Organization (TGO, 2015)

The trend in greenhouse gas emission in 2000-2010 shows that the release and uptake are the cause of the total amount of the emission. The net emission was between 152.2-219.9 Mt $CO_2$eq. Considering last decade's amount of greenhouse gas emission in which the amount of sequestration in forestry and land use were excluded, the national emission was between 240.0-335.1 Mt $CO_2$eq (Figure 2.4). The energy sector remained the major contributor, followed by agriculture, forestry and land use sectors, industrial processes and product use sector and waste sector, respectively. The national development results in the emission of greenhouse gases over the last decade as the annual release amount increased by 3.44 percent. When agriculture, forestry and land use sectors were substracted, the trend of greenhouse gas emissions was reduced to 3.28 percent per year, which coincided with the trend during 2000-2004 of 3.8 percent per year. It is possibly due to the increased number of natinoal measures to reduce greenhouse gases, together with the increased amount by 1.13 percent of the gases being captured and stored in the forestry and land use sectors. As the result, the sector has been aware of how to increase the uptake and reduce the national emissions of greenhouse gases [11].

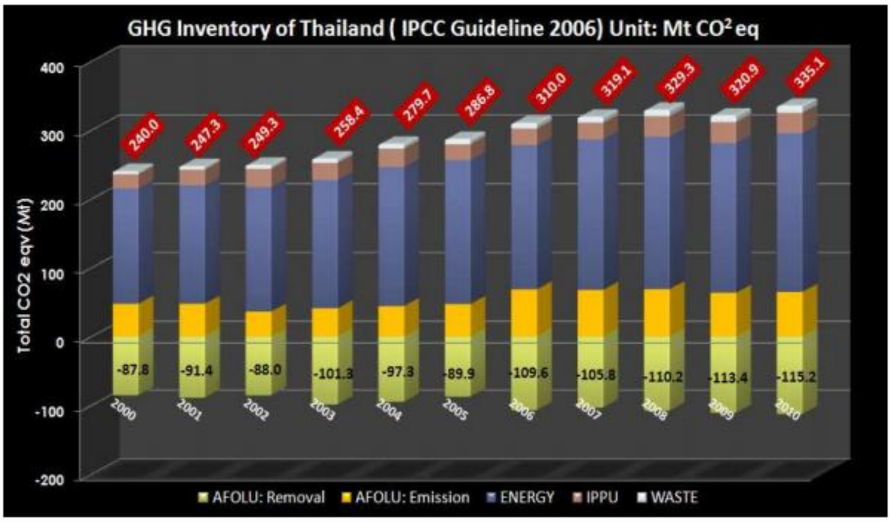


**Figure 2.4 Amount of the greenhouse gases being emitted and stored in 2000-2010**
**Source:** Thailand Greenhouse Gas Management Organization (TGO, 2015)

Bangkok, the capital of Thailand, is the transportation hub, the core of government's administration and the business center. It is the major source of $CO_2$ emission. In 2005, up to 43 million tones of gases has been freed up. The amount is higher than the emission from the city of Toronto (24 million tonnes). Although the number is less than New York City's (58 million tonnes) and equivalent to the emission from London (44 million tonnes), the amount of greenhouse gas emitted in Bangkok per capital in 2005 was found up to 7.1 tonnes annually which is equal to New York City's and more than London's (5.9 tonnes) but less than Toronto's (9.6 tonnes) (Table 2.1) [12].

**Table 2.1 The emitted amount of $CO_2$ in major cities in 2005**

| Cities | $CO_2$ emission (million tonnes) | $CO_2$ emission per capita (tones per capita) |
|---|---|---|
| Bangkok | 43 | 7.1 |
| Toronto | 24 | 9.6 |
| New York | 58 | 7.1 |
| London | 44 | 5.9 |

**Source:** Bangkok Metropolitan Administration, 2007

The source of the greenhouse gases in Bangkok is the transportation sector (37.68 percent) and electricity production (33.37 percent). In 2007, the former released $CO_2$ of up to 23.07 million tonnes from the use of gasoline and diesel of 8,948,683 million liters in total combined with electricity used up of 29,180 GWh, causing 20.43 million tonnes $CO_2$ equivalent emissions. Garbage and sewage released $CO_2$ of 12.16 million tonnes $CO_2$ equivalent emissions (19.86 percent) and 9.09 percent from other source such as agriculture [12].

**Table 2.2 Greenhouse gas emission in production section**

| **Production Section** | **Annual $CO_2$ emission (million tonnes)** | **Percent** |
|---|---|---|
| Transportation | 20.43 | 33.37 |
| Electricity generation | 23.07 | 37.68 |
| Garbage and sewage | 12.16 | 19.86 |
| Other (Agriculture) | 5.57 | 9.09 |
| **Total** | **61.23** | **100** |

**Source:** Bangkok Metropolitan Administration, 2007

## 2.2 Carbon sequestration

Carbon sequestration refers to the process that transforms atmospheric $CO_2$ to store in long-term reservoirs including the oceans, vegetation, soil and rock layers, in order to reduce the increase rate of atmospheric carbon dioxide using engineering methods to compress the gas into the reservoir rock in the ocean, old coal mines and oil wells. Even these approaches are potential, they require high investment budget and take risk of gas leakage [13]. However, there is another safe and effective way in reducing the amount of $CO_2$ in the atmosphere via photosynthesis process of plants in which atmospheric $CO_2$ was accumulated in plants and soil [14].

Nathsuda Phoommijamnong said that carbon sequestration in trees and long-lasting wooden products is the best way to store $CO_2$. The trees and forests are important carbon reservoirs. About half of organic carbon was stored in the biomass of trees as the dry weight of the plant, including stems, branches, leaves and roots [15].

In addition, carbon sequestration in the soil is another method that has been gaining attention since it is natural, low-cost and environmentally friendly [16]. Not only being a way to help reduce the amount of $CO_2$ in the atmosphere, it improves the quality of the soil, increases agricultural productivity and reduces the impacts of climate change as well. [17]

### 2.2.1 Terrestrial carbon sequestration

Carbon sequestration in terrestrial ecosystems takes place in plants and soil. Through the process of photosynthesis, which plants convert atmospheric $CO_2$ and store it in plant tissues, so-called biomass in both all above-ground form i.e. stem, branch and leaf and below-ground biomass form i.e. roots and plant debris after the fallen off or dead parts of tree was decomposed by soil microbial activity. There are some non-degradable organic carbons due to its structural complexity which microorganism secreted enzyme cannot digest. For example, humus, non-degradable compounds is the term for stable organic carbon compounds commonly found form of carbon that has accumulated as soil organic carbon (SOC) [6].

The major carbon pool in the terrestrial ecosystems is forest ecosystem. It consists of over 2,300 billion tonnes (Gt) sinks in vegetation and soil [18]. The agreement in the Meeting of States Parties to the Kyoto Protocol (COP / MOP) of the United Nations Framework Convention on Climate Change (UNFCCC) has determined 5 main areas of the carbon sequestration in forests, also known as forest carbon pool.

1) Above-ground biomass: stems, branches, leaves, flowers and fruits
2) Below-ground biomass: roots
3) Dead organic matter in wood: fallen parts of plant, dead plants
4) Dead organic matter in litter
5) Soil organic matter

There is also a source of carbon sequestration in long-lasting harvested wood products such as houses, furniture, etc. [19].

**2.2.2 Carbon sequestration in urban ecosystem**

Urban ecosystem can be a large carbon sink with man-made (rather than natural) proper management to conduct the protection and restoration. Therefore, man plays a vital role in this kind of sequestration. The reservoirs in urban ecosystem are above-ground biomass (biotic pool) and soil (pedologic pool) [20, 21, 22]. Four carbon sinks in urban ecosystem [23] are:

1) Urban forest

2) Grassland: turfs, lawns and recreational grounds

3) Soil carbon pool

4) Urban agriculture

2.2.2.1 Vegetation carbon pool is composed of carbon in above-ground and below-ground biomass, dead organic matter in wood i.e. fallen parts of plant and dead plants. The global amount of carbon stored in vegetation is about 560 Pg (1 Pg = 1015 g) [13]. Trees and shrubs in the city can transform $CO_2$ to above-ground and below-ground biomass via photosynthesis. Trees are most studied because only small amount of carbon can be stored other kinds of plant stores when comparing to trees i.e. 3 percent in undergrowth plants, 5-40 percent in dead plants and 5 percent in plant debris [19]. Above-ground biomass was more focused in research because of its less variation comparing to below-ground biomass [24].

Liu and Li studied the carbon storage in an urban forest in Shenyang, China. In the urban forests in the third ring road in Shenyang, it was found that 337,000 tonnes of carbon was stored at the annual sequestration rate of 29,000 tonnes. 3.02 percent of the annual carbon emissions was from burning fossil fuels. The carbon sequestration could offset the carbon emissions annually in the city of Shenyang by 0.26 percent. It was also revealed that the rate of carbon sequestration and its rate were proportionally varied on the type of urban forests, structure, age and composition of plant species [25].

Nowak and colleagues conducted a study on carbon sequestration in urban trees in the United State. The average carbon storage in the trees was found 7.69 kg C $m^{-2}$ of the tree cover. The rate of average carbon retention was 0.28 kg C $m^{-2}$ per year. The sequestration was about 643 million tonnes. The rate of annual carbon sequestration was approximately 25.6 million tonnes per year [26].

Strohbach and Haese studied the above-ground carbon sequestration in Leipzig. They found that the total amount of carbon stored above-ground of 316,000 Mg C and the consequent sequestration per area was 11 Mg C $ha^{-1}$. The highest distribution was considered as the intermediate urbanization levels. However, the sequestration in the city was a lower than other cities in Europe, Asia and America [27].

2.2.2.2 Soil carbon pool is a large and important carbon sink. The amount of carbon stored in soils throughout the world is about 2,500 Pg in which about 1,550 Pg of them is in the organic carbon form and about 950 Pg of them is in soil inorganic carbon (SIC) form. The carbon in the soil is 4 times of the amount of biomass carbon (560 Pg) and 3 times of the amount of atmospheric carbon (760 Pg) [13]. In Thailand, organic carbon was about 6 million Gg (1 Gg = 109g) representing 0.046 percent of the world's organic carbon. Thailand's carbon content of inorganic was approximately 184,049 Gg percent which is equal to 0.019 percent of the world's inorganic carbon (carbonate form) [28]. The sequestration of organic carbon in the soil depends on the type of land cover and land use change. A significant lost is possible via interference with disturbance and cultivation [16].

The soil in the urban park acts as a carbon sink in the city. It also retains a large amount of organic carbon before being freed into the atmosphere again. The trees play an important role in carbon sequestration in the soil. By increasing the number or the density of trees, total biomass product per unit area will improve, resulting in the higher carbon sequestration in the soil [13].

Edmondson and coworkers studied the carbon storage in the soil and the urban agricultural areas. They found that the average sequestration of organic carbon in the soil of the urban green space of Leicester was equal to 9.9 kg $m^{-2}$ at the depth of 21 cm. The storage under the cover of trees and shrubs in the domestic garden was 13.5 kg $m^{-2}$ which was higher than other types of land cover in domestic and non-domestic garden (more than 3 kg $m^{-2}$) and cropland (5 kg $m^{-2}$). In addition, it was found that the land cover does not significantly impact on the soil capacity in non-domestic garden. The organic carbon sequestration under the trees is higher than both the pasture and cropland. The sequestration under shrubs and herbaceous plants are also higher than agricultural areas [29].

Takahashi and colleagues conducted a study of carbon sequestration in different land use. It was found that carbon sequestration in lawns, managed tree-planting area and non-managed tree-planting area are 82, 79 and 120 Mg C $ha^{-1}$, respectively. The amount was higher than the carbon storage in trees in urban park. The carbon (organic matter) cannot be accumulated in the soil of the urban park because the litter, which is the source of carbon in the soil, can be removed. The differences of the carbon amount in each area also depends on the history of the land use [30].

From the carbon sequestration study in cities in China by Zhao and coworkers, the amount was revealed to be 577 ± 60 Tg C (1 Tg = $10^{12}$) in 2006. Soil has played the most dominant role in carbon sequestration (56 percent), followed by carbon in buildings (36 percent) and plants (7 percent), while carbon sequestration in humans was very small (1 percent). The density of carbon in China's urban areas was equal to 17.1 ± 1.8 kg C $m^{-2}$, which was approximately two times of the national average of the total area. [31]

Saha and colleagues studied the influence of the density of trees and the appearance of vegetation in the homegarden on carbon sequestration in soil. The capacity has a direct relationship with the diversity of plant species. The more various and the denser homegarden is, the more organic carbon stored especially the soil at the depth of 50 cm. At 1 m deep, the carbon content in the soil was in the range of 101.5 to 127.4 Mg $ha^{-1}$. Small homegarden (<0.4 ha) with a high tree density and species rishness, it will be much soil carbon per hectare (119.3 Mg $ha^{-1}$) than large homegarden (> 0.4 ha) (108.2 Mg $ha^{-1}$) [32].

Zhe and his team investigated the carbon sequestration in the soil in different areas in Shanghai, China. It was found that carbon sequestration in soils ranged from 13.8 (flooded rice field) to 38.6 t $ha^{-1}$ (agricultural area). The average carbon sequestration of soil in urban forests (31.5 t $ha^{-1}$) was lower than in the agricultural area (38.6 t $ha^{-1}$), but higher than lawn (26.5 t $ha^{-1}$) and in the urban park (21.3 t $ha^{-1}$). The carbon sequestration in the soil in the urban park of the newly founded city is less than the old city. The soil organic carbon density in the green space in the northern and southeastern suburbs was greater than the urban business of the city and recently developed districts [33].

## 2.3 Factors effecting on carbon sequestration

### 2.3.1 Factors effecting on carbon sequestration in vegetation

2.3.1.1 Species diversity

Species diversity effect on carbon sequestration in vegetation. Cardinale and colleagues studied impacts of plant diversity on biomass production increase. It was found that mixtures of species produce an average of 1.7 times more biomass than species monocultures and are more productive than the average monoculture in 79 percent of all experiments. However, in only 12 percent of all experiments do diverse polycultures achieve greater biomass than their single most productive species [34]. Wacker and coworkers studied effects of plant species richness on stand structure and productivity. It was found that above-ground biomass production commonly increases with species richness in plant biodiversity experiments [35].

2.3.1.2 Spacing or tree density

Spacing or tree density effect on the carbon sequestration in vegetation. The study of the effect of spacing on the biomass product from 3 years old *Canocarpus erectus*, it was revealed that the spacing of 0.7, 1.4 and 2.1 meters gives the above-ground biomass of 4.57, 11.93 and 20.80 kg tree$^{-1}$ [36]. From the study of mulberry biomass production whose age were 14 and 16 months in 5 spacings i.e. 1x1, 1x2, 2x2, 2x4 and 4x4 meters, the highest average biomass per tree was obtained in the spacing of 4x4 meters from both the age of 14 months (1,917 g tree$^{-1}$) and the age of 16 months (2,276 g tree$^{-1}$). The maximum average biomass yield was obtained in the spacing of 1x1 meters from both the age of 14 months (805 kg Rai$^{-1}$) and the age of 16 months (1,035 kg Rai$^{-1}$) [37]. Due to narrow spacing, the number of trees per unit area and consequent biomass and carbon sequestration per unit area are high. On the other hand, the wider spacing leads to the higher biomass and carbon sequestration per plant because the trees are in less natural competition [38].

2.3.1.3 Total basal area

Total basal area is the sum of the cross-sectional area, in square meters per hectare, which was measured at the breast level (a height of 1.30 meters) of every tree. It is the indicator of biomass and carbon because it has included the tree size which involves biomass and the basal area relates to the diameter of the trunk [39]. From the above-ground biomass and carbon sequestration study of the deciduous forests in the tropical area in the State of Madhya Pradesh, India, it was found that the above-ground biomass is positively correlated with the basal area. In the mature trees plot, the diameter of trees is larger, leading to more above-ground biomass than the plot with denser trees because of the high correlation between basal area, above-ground biomass and tree architecture [40].

### 2.3.2 Factors effecting on carbon sequestration in the soil

2.3.2.1 Soil texture

Soil texture is the general physical properties of the soil influenced by parent materials which directs on carbon sequestration in the soil. Because of its small particles and subsequent higher surface area, the fine texture is more capable for carbon than coarse texture where the decomposition of carbon is faster. Clay stores more carbon than sand [41, 42]. The carbon sequestration rises when there is more amount of clay in the soil [43]. The study of Don and colleagues found that soils containing much clay have two-fold (86 t $ha^{-1}$) carbon sequestration more than sandy soil (48 t $ha^{-1}$) at the depth of 0-60 cm [44]. Kong and colleagues found that soil with very fine particles has the potential in retention and the accumulation rate of organic carbon. The study was also found that the concentration of organic carbon in soil is maximum in the middle loam soil while fine sand has the least concentration (fine sand <sand loam <light loam <middle loam). The middle loam and light loam has the high ability to absorb water and nutrients leading to the high production of biomass. When the dead part of plants falls to the ground, the organic carbon sequestration in middle loam and light loam soils is in a larger amount than those in fine sand and sand loam [45].

2.3.2.2 Soil reaction

Soil pH effects the soil's physical, chemical and biological properties and processes, as well as plant growth. The nutrition, growth and yields of most crops decrease where pH is low and increase as pH rises to an optimum level. At very acid or alkaline ph levels, organic matter mineralization is slowed down or stopped because poor microbial activity linked to bacteria. Nitrification and nitrogen fixation are also inhibited by low pH [46]. Soil pH have a negative effect on soil organic carbon sequestration in the soil. A study by Kemmitt and colleagues shows that increasing acidity in the soil and the low soil reactions inhibit the activity of soil microorganisms and reduce the decomposition of organic carbon in the soil which leads to more carbon sequestration in the soil. The soil whose reactions are neutral or weak alkaline leads to the faster rate of decomposition of organic matter over the soil whose reactions are acidic or alkaline [47].

2.3.2.3 Soil organic matter

Soil organic matter is derived from organic materials that are added to the soil and the majority of soil organic matter derived from the breakdown of residues remaining after plants have died. These residues can take the form of root residues located in the soil matrix or leaves, stems and stubble existing as litter on the soil surface. Animals also provide a proportion of the soil organic matter to varying degrees depending on management and the ecosystem. Soil organic matter includes plant debris, root exudates and animal materials; their degradation products; and products synthesized by soil microorganisms and other soil biota. [48]. The amount of organic matter in the soil is positively correlated to the organic carbon in the soil because the organic matter, which is abundant in upper soil where humus are accumulated, contains up to 58 per cent of carbon [49]. It is generally accepted that the carbon (organic matter) is not accumulated in the soil in the urban gardens because plant residues, which is the source of carbon in the soil, has been removed from the area. [30, 50]. The amount of carbon in the soil has consistently increased with growing amount of plant residues dropped or fell to the soil or adding organic fertilizer [51].

2.3.2.4 Nitrogen in soil

All of the essential nutrients, nitrogen is required by plants in the large quantity and is most frequently the limiting factor in crop productivity [52]. The nitrogen content in the soil has a positive effect on soil organic carbon sequestration because nitrogen serves as the growth stimulating nutrient which consequently increases biomass production with the increased amount of organic carbon from the fallen plant residues. The study by Jung and Lal found that adding nitrogen fertilizer increases the organic carbon in the soil by enhancing biomass productivity which then becomes the plant residues fallen to the ground. After the decomposition, they are retained as the organic carbon [53].

2.3.2.5 Carbon to nitrogen ratios

Carbon to nitrogen ratios (C:N ratios) indicates the difficulty or ease of the decomposition of organic matter in the soil in carbon to 1 part of nitrogen unit. It effects carbon sequestration in the soil. When the C:N ratio is high, the decomposition rate of organic matter in the soil slows. The high C:N ratio points out that the soil contains less nitrogen, which is not sufficient to meet the needs of the soil microorganisms to decompose organic matter in the soil [41]. As a result, carbon sequestration in the soil is high. Hoorman and Islam found that young legumes (Alfalfa) a contains a large amount of protein, amino acids and sugar in the trunk. It is then easily decomposed by soil microorganisms. The soil in the area therefore has high nitrogen content (low C:N ratio) and the high degradation rate which leads to the low carbon sequestration in soil. However, old oak and wheat straw contains only small amount level of protein and sugar in a trunk but much lignin which is resistant to the degradation by soil microorganisms. As a result, the C:N ratios is high. The difficulty of microbial degradation retains high level of carbon sequestration in the soil (approximately 10:1) [54]. The study of Jagadamma and colleagues shows that the land with the addition of nitrogen fertilizer (280 kg N $ha^{-1}$) contains 75.8 Mg $ha^{-1}$ of carbon, comparing to than areas without fertilizer (68.4 Mg $ha^{-1}$). The increase of the nitrogen amount reduces the C:N ratios at the depth of 0-10 cm resulting in more organic carbon in the soil [55].

## 2.4 Public park

### 2.4.1 Definition

Public park refers to the recreation area for public and leisure activities such as walking, physical activity held by the state and etc. The parks are landscaped beautifully with trees and flowers, lawn, pool, and various facilities. It is open free of charge to public every day including weekends and public holidays [56, 57, 58]. The park is the green area and urban forests. It is also considered as a human-dominate restoration ecosystem [59].

### 2.4.2 Types of public park

Criteria involving the area characteristics, purpose and order to classify the park into 7 categories were defined by the Environment Agency [60] are listed as follow:

1) Pocket park or mini tot park occupies an area of not more than 2 rais with a service radius of about 1 kilometers and in the 5-10 minutes walking distance. It can be located in between the buildings for the neighbourhood. Playgrounds, physical exercise spaces and facilities are available for citizen of all ages.

2) Neighbourhood park has area of 2-25 rais with a service radius of about 1-3 kilometers. The park is for the residents of the neighborhood. More facilities in the park are more accessible than the parks in the previous topic.

3) Community park has area of 25-125 rais with a service radius of about 3-8 kilometers. More facilities in the park are more accessible than the parks in the 2 previous topics, including sport field and beautiful natural leisure area.

4) District park has area of 125-500 rais with a service radius of over 8 kilometers, serving both local pedestrian and people from remote area. It can be accessible by public transport or by car. There are more facilities than the parks in level 1, 2 and 3, such as picnic areas, multi-purpose space and specific area such as lagoons, streams, large garden.

5) Metro park or city park occupies an area of over 500 rais, with a service for throughout the whole city and the adjacent areas surrounding the city. There are courtyards for events. Customers come from all over Bangkok and spend more than

half a day's rest. There is a variety of activities to attract more attention apart from the basic garden.

6) Street park has a width of not less than 3 metres, the length is not limited, divided into 3 types: street side garden, island garden and fork garden.

7) Special purpose park with unlimited space such as historical garden, cultural park, sport space and roof garden.

Currently, the public park office in the environment agency of Bangkok metropolitan administration has taken care of 32 parks with approximately 4.462 $km^2$ or 2,787,562 rais. Compared to 1,568,737 $km^2$ of the whole Bangkok, the park has taken up 0.28 percent of the whole area (Table. 2.3).

**Table 2.3 The main parks in the responsibility of Environment Department, Bangkok**

| **Location** | **Park name** | **Area** | |
|---|---|---|---|
| | | **$km^2$** | **(rai-ngan-wa$^2$)** |
| **Inner city** | | | |
| Phra Nakon | Saranrom Park | 0.037 | 23-0-0 |
| | Rommaninart Park | 0.048 | 29-3-72 |
| | Santichaiprakan Public Park | 0.014 | 8-2-0 |
| | Nakharaphirom Park | 0.006 | 3-3-70 |
| Pathumwan | Lumpini Park | 0.576 | 360-0-0 |
| | The twin tower hotel green space | 0.002 | 1-0-20 |
| Bangkholaem | Public Park in Commemoration of H.M. the King’s 6$^{th}$ Cycle Birthday | 0.046 | 29-0-0 |
| Dusit | Chaloem Phrakiat Kiakkai Public park | 0.016 | 10-0-0 |
| Ratchathewi | Santiphap Park | 0.032 | 20-0-80 |
| Huaikhwang | Phanphirom Park | 0.022 | 14-0-0 |
| Khlongtoei | Benchasiri Park | 0.046 | 29-0-0 |
| | Benchakitti Park | 0.208 | 130-0-0 |

**Table 2.3 The main parks in the respondsibility of Environment Department, Bangkok (cont.)**

| Location | Park name | Area | |
|---|---|---|---|
| | | km$^2$ | (rai-ngan-wa$^2$) |
| **Inner city** | | | |
| Chatuchak | Chatuchak Park | 0.248 | 155-0-57 |
| | Queen Sirikit Park | 0.315 | 196-3-65 |
| | Wachirabenchatat Park | 0.600 | 375-0-0 |
| Bangkoknoi | Sirindhra Preuksaphan Park | 0.005 | 3-0-16 |
| | The 80$^{th}$ Anniversary Commemoration | 0.034 | 21-0-0 |
| Sathorn | The 80$^{th}$ Anniversary Commemoration of King Rama IX Park | 0.028 | 17-2-58 |
| **Urban fringe** | | | |
| Prawet | Suan Luang Rama IX Park | 0.800 | 500-0-0 |
| | Wanadharm Park | 0.069 | 43-0-0 |
| | Maha Chakri Sirindhorn's 50$^{th}$ Birthday Park | 0.032 | 20-0-49 |
| Bangkhen | Ram Indra Sports Park | 0.094 | 59-0-36 |
| Buengkum | Seri Thai Park | 0.560 | 350-0-0 |
| | Nawaminphirom Park | 0.122 | 76-0-39 |
| Bangphlat | Suan Luang Rama VIII Park | 0.038 | 24-0-0 |
| Thungkhru | Thonburirom Park | 0.101 | 63-1-20 |
| Ladprao | Bueng Nam Latphrao 71 Park | 0.034 | 21-0-0 |
| **Suburb** | | | |
| Donmueang | Rommani Thungsikan Park | 0.025 | 15-2-74 |
| Nongchok | Nong Chok Park | 0.057 | 35-2-0 |

**Table 2.3 The main parks in the respondsibility of Environment Department, Bangkok (cont.)**

| Location | Park name | Area | |
|---|---|---|---|
| | | $km^2$ | (rai-ngan-$wa^2$) |
| **Suburb** | | | |
| Ladkrabang | Phra Nakhon Park | 0.080 | 50-0-0 |
| | Her Majesty the Queen's $60^{th}$ Birthday Park | 0.084 | 52-1-69 |
| Thawiwattana | Thawiwanarom Park | 0.086 | 54-0-0 |
| | **Total** | **4.462** | **2,787-2-24.80** |

## 2.5 Study area

### 2.5.1 Lumpini park

2.5.1.1 Background

Lumpini park is the first public park of Bangkok Metropolitan Administration (BMA) and the royal heritage given by King Rama VI for Phra Nakhon people on the Fifteenth Anniversary Celebrations of His Majesty's Accession to the Throne. In year 1925, after King Rama VI ordered to contact the exhibition of products and natural resources museum, this park should be created as botanical garden for people's recreation and education. Besides, His Majesty had given the name of this park as "Lumpini Park", that means Buddha's place for birth. Unfortunately, His Majesty died before the expected time, so opening of the park was cancelled. Later on in the reign of Rama VII, the project was revised; King Rama VII kindly rent the 14.4 hectares lands, located in the south of the former Lumpini park, out to be an amusement park named Wanaruengrom; and the rental was used for the development of the rest area to be public park.

Since then Lumpini park become a pleasure place for people. The entertainment contains kiting, cow races, ferris wheel, and merry-go-round. King Rama VII donated this land to be under the cabinet's administration and commanded to use this site only for public park purpose. During the World War II, Lumpini park was changed into Japanese military camp location. The park was no longer important as before. Until the war finished in year 1952-1954, Lumpini Park was used as the site for constitution celebration and Siamese beauty Pageant.

2.5.1.2 Park components

Lumpini Park is multipurpose park which provides variety of facilities and services surrounding which green and beautiful trees all over the place. There are Bangkok Senior Citizens Club, Lumpini Public Library, Lumpini Youth Center, food court. Furthermore there are also many clubs for people to meet and exchange their idea. Besides, row boats and pedal boats for rent are available at island in the Pond and Clock Tower [61].

### 2.5.2 Vachirabenjatas park

2.5.2.1 Background

Vachirabenjatas park is previously known as Rot-fai park which was constructed following the cabinet's resolutions on 2 and 29 January, 1991 to build a public park on the land owned by the State Railway of Thailand (SRT). Bangkok Metropolitan Administration (BMA) accordingly received the land of 60 hectares from Ministry of Transport on 5 November, 1998; and compensated SRT for that land at the amount of 555 million baht. The land development was begun in 23 April, 1999. Later on, the park name was changed to be "Vachirabenjatas park", the new name which was kindly conferred by His Royal Highness Crown Prince Maha Vajiralongkorn in commemoration of H.R.H. the Prince's 50$^{th}$ Birthday on 28 July, 2002.

2.5.2.2 Park Components

This park was built with family park concept providing various recreational activities to attract all family members around the park area. The exercising equipments are distributed on the green open space under the shady trees, accompanied with hilly lawns and flat plains, bring relaxing atmosphere for the visitors. The cycling track is also provided for cyclists, and other people can exercise at Sports Ground and Community Recreational Center or party and enjoy at Picnic Garden. Moreover, there is, Bangkok Butterfly Garden and insectarium, the outdoor natural discovery classroom as the self-learning platform for children. Traffic Model Garden and playground are also as the other elements as learning and practice sites for kids [61].