CHAPTER I

INTRODUCTION

1. Statement and significance of the problem

The house fly, Musca domestica Linn (Diptera: Muscidae), and blow fly, Chrysomya megacephala Fabricius (Diptera: Calliphoridae), are medically important flies distributed worldwide including Thailand. According to previous surveys, both are the most prevalent fly species (≈90%) in the central and northern part of Thailand, (Sucharit et al. 1976, Tumrasvin et al. 1976, 1978, 1979, Tumrasvin and Shinonaga 1978, Sucharit and Tumrasvin 1981, Lertthamnongtham et al. 2003). Since their breeding grounds and adult habitat are shared with the human environment, both fly species can have an unpleasant impact on humans. Adult flies are not only pest, but they also serve as mechanical carriers of several pathogens that may cause diseases from unsanitary places to human food (Greenberg 1973, Monzon et al. 1991, Nazni et al. 2005, Thaddeus et al. 2005, Sukontason et al. 2007). These pathogens include numerous bacterial species, viruses and helminth eggs (Hewitt 1910, 1912). In addition, the larval stage of both fly species can produce myiasis in humans and animals, particularly agronomic livestock with economic importance (Zumpt 1965, Parker and Welch 1991, Jelinek et al. 1995, Amin et al. 1997, Sehgal et al. 2002, Sukontason et al. 2005).

On a global scale, environmental conditions constitute the major factors that provide conditions for insect dynamics. Various factors such as temperature,
relative humidity, solar radiation, wind velocity and rainfall have been recorded for regulating the population density of many fly species; *Bactrocera dorsalis*, *Glossina morsitans morsitans*, *Lutzomyia longipalpis*, and *Stomoxys calcitrans* (van den Bossche and de Deken 2002, Cruz-Vezquez et al. 2004, Ximenes Mde et al. 2006, Peng and Hui 2007). For *M. domestica* and *C. megacephala*, temperature is an important factor in their population growth, particularly in equatorial and tropical zones, where there is a high density of these species (West 1951, Greenberg 1973, Keiding 1986, Noorman and den Otter 2002). Although some studies have been designed to investigate population behavior in response to temperature (Buchan and Sohal 1981, Fletcher et al. 1990, Tardelli et al. 2004, Reigada and Godoy 2006), none focused specifically on the influence of temperature, relative humidity, light intensity, and land use types on the field population trend of these fly species.

Chiang Mai is the second largest city in Thailand and the business center and tourist attraction of the North, with a population of approximately 1.6 million people. Twenty six percent of the people live in the municipality. In recent times, the urban area of Chiang Mai city has increased progressively due to the rapid rise in the human population (http://www.chiangmai.go.th/). Although expansion and development of urban environment can signal rising tourism and economic growth in the region, environmental degradation is just as likely to be found alongside prosperity. Large quantities of rubbish from households, businesses and agricultural sectors cannot be managed totally by local government (http://www.chiangmai-mail.com/014/news.shtml) and together with its temperate climate this area is suitable for increasing of fly populations. The control of fly populations, especially in particular areas is needed urgently. However, prior to implementation of the control
measures in the community, fly distribution and factors that influence fly populations should be clarified. Field survey is the proper method for discovering fly species and fly density in particular areas. Nevertheless, this method cannot predict these parameters in other areas, which have not been surveyed. Proper prediction methods for fly species and fly density in urban and suburban areas of Chiang Mai are considered necessary.

The Geographic Information System (GIS) has been used for nearly half a century for finding the relationship among different spatial data and drawing conclusions concerning interaction. Maps have played an important role in orienting investigators to local conditions and guiding epidemiological activities within study areas. With this information, spatial relationships associated with many parameters and environments can be compared in order to learn more about the complex nature of these interactions (William 2004). So far, developments in GIS and satellite derived meteorological information offer the most useful tools for precise and timely epidemic forecasting (Najera 1999). Recently, some insects, particularly those of medical importance, have been investigated for their biology using GIS methodology; for instance, the range and potential distribution of the sand fly, Lutzomyia (Heleocyrtomyia) apache and Chrysomya bezziana (old world screwworm), were found by this technique in southwestern USA and the Mesopotamia valley in Iraq, respectively (Herrero et al. 2004, Siddig et al. 2005). Furthermore, many investigations have used GIS methodology for studying many vector-borne diseases such as malaria, dengue fever, lymphatic filariasis, trypanosomiasis, leishmaniasis and myiasis in both humans and livestock (Sabesan et al. 2000, Elnaiem et al. 2003,

By using the field survey and the GIS methodology, the spatial and temporal distribution on *M. domestica* and *C. megacephala* in urban and suburban areas of Chiang Mai were determined. The information obtained in this study is useful in understanding the biology and distribution, including influencing factors, in the population of both fly species. The area and period of time in which these flies should be present may be predictable.
2. Literature review

In Thailand, the muscid and calliphorid flies have been collected to investigate their medical importance as well as making a zoogeographical study. Fifteen genera of family Calliphoridae (Bengalia, Calliphora, Catapicephala, Chrysomya, Hemipyrellia, Hypopygiopsis, Lucilia, Melinda, Onesia, Phumosia, Pollenia, Polleniopsis, Tainanina, Tricycleopsis and Verticia) and 11 genera of family Muscidae (Haematobia, Haematobosca, Haematostoma, Orthellia, Mitroplatia, Morellia, Musca, Pyrellia, Rypellia, Stomoxys and Stygeromyia) were also identified in the country (Tumrasvin et al. 1976, 1978, 1979, Tumrasvin and Shinonaga 1977, 1978). Musca and Chrysomya, particularly Musca domestica and Chrysomya megacephala are the two most abundant fly species collected, occupying ≥90% of all specimens captured, and widespread throughout the country (Sucharit et al. 1976, Tumrasvin et al. 1976, 1978, 1979, Lertthamnongtham et al. 2003, Sukontason et al. 2003, Masmeatathip et al. 2006).

2.1 General consideration and medical importance of M. domestica

The house fly, M. domestica, is a well-known cosmopolitan pest of both farm and home. This species is always found in association with humans or activities of human and is able to complete its entire life cycle within the residence of humans and their domestic animals. It originated on the steppes of central Asia, but now occurs on all inhabited continent, in all climates from tropical to temperate, and in a variety of environments ranging from rural to urban, so it is abundant almost anywhere people live (West 1951).
Life cycle and description

House fly has complete metamorphosis life cycle with 4 distinct stages (egg, larva or maggot, pupa and adult stages). During the larval stage, the fly passes through 3 different instars (the first, second and third instars) by molting. Development is temperate dependent. Warm summer conditions are generally optimum for development of the house fly and it can complete its life cycle in 7-10 days. As many as 10-12 generations may occur in one summer. In colder climates, the life cycle is complete in 10-20 days (Hewitt 1910, 1912, West 1951, Barnard et al. 1993).

**Egg:** The house fly egg is creamy-white, cylindrical and narrow in shape, measuring about 1.20×0.25 mm. It resembles minute pine kernels or rice grains. A female house fly may lay four to six batches of eggs consisting of 75-150 eggs each. The eggs are deposited in clumps in cracks and crevices of a moist medium to protect them from desiccation. Manure and spilled food are known to be the principle breeding media for the houseflies (Hewitt 1910, West 1951, Skoda et al. 1993). In warm weather, hatching occur within 8-20 hours, and they immediately feed on and develop in the material where the eggs were laid.

**Larva:** The larva is cone-shaped, white and legless and about 10 mm long when fully grown. The body surface is smooth with 10 visible segments (one head, three thoracic and eight abdominal segments). On the ventral side of the first segment, there are two oral lobes crossed by parallel tubes, which converge on the mouth. The head is retracted into the thorax and its dark cephalopharyngeal skeleton can be seen through the translucent body. Respiration is amphineustic with fan-shaped anterior spiracles on the second segment being undeveloped in the first stage larvae. Larvae
also have dark, flat, plate-like spiracles on the posterior end of their bodies which are present throughout development. The posterior spiracle has one simple opening (slit) in the first stage, and two nearly straight slits in the second stage. In the third instar, the fan-shaped anterior spiracle consists of 5-7 openings, and the posterior spiracle looks like letter “D”, with three M-shape sinuous slits and button in the middle of the straight side of the D-shaped plate (Hewitt 1910, 1912, 1914). When the maggot is full-grown, they crawl up to 15 m to a dried, cool place near breeding material and transform to the pupal stage.

**Pupa:** The pupa is dark brown in color and 8 mm in length. The pupal stage is passed in a pupal case formed from the last larval skin which varies in color from yellow, red, brown, to black as the pupa ages. After approximately 5 days, the emerging fly escape from the pupal case through the use of an alternately swelling and shrinking sac, called the ptilinum, on the front of its head which it uses like a pneumatic hammer.

**Adult:** The adult fly is medium in size and non metallic, about 6-9 mm in length with a 13 to 15 mm wingspan, depending on the conditions which the larva grows up. The female is usually bigger than the male. The body of the adult fly is composed of three parts; head, thorax, and abdomen. The thorax is marked with four longitudinal black stripes on its dorsal side and bears three pairs of legs, two halteres or balancing organs, and one pair of wings. As is characteristic of the subfamily Muscinae, the fourth longitudinal wing vein is strongly bent upwards towards the third longitudinal vein when approaching the margin of the wing. The head is dominated by a pair of compound eyes on its lateral sides. The sexes can easily be distinguished by the dorsal space between the eyes which is wider in the female. On
the dorsal side of the head, three ocelli or simple eyes are situated. The mouthparts are configured to a suctorial organ, the proboscis, located ventrally on the head. The proboscis can be folded into a subcranial cavity. Rostrally between the eyes, the head bears two aristate type antennae. The funiculi are covered with olfactory hairs which enable the fly to smell (Hewitt 1910, 1912, West 1951).

Adult flies feed on all kinds of human food, garbage, excreta and animal dung. During the day, female flies are more predominant than male in or around feeding and breeding places, where mating and resting also take place. Adults become sexually mature within 2-3 days after emergence; and four days after copulation, females deposit their first batch of eggs. The preferred temperature for resting is between 35 °C and 40°C. Oviposition, mating, feeding and flying all stop at temperatures below 15°C. At high temperatures (above 20 °C), most houseflies spend the time outdoors or in covered areas near the open air (West 1951).

House fly densities are highest at mean temperatures of 20–25 °C; they decrease at temperatures above and below this range and become undetectable at temperatures above 45 °C and below 10°C. (Keiding 1986). Its distribution is greatly influenced by their reactions to light, temperature, humidity, season and surface color and texture but not with rainfall. In Thailand, the highest density of house fly is found during July to October. When the relative humidity is high, the density of flies increases (Sucharit et al. 1976).

Furthermore, temperature and humidity have affect on the production of cuticular hydrocarbon by insect. Generally, the cuticular hydrocarbon of insect provides a barrier to water diffusion, thus preventing desiccation of the animals. However, some of these substances may also act as semiochemicals and may play a
role in mating behavior. In *M. domestica*, several hydrocarbons on the body of females which is considered to be sex pheromone called muscalure induce sexual behavior in males. Under very wet conditions (90% relative humidity), newly emerged adults of *M. domestica* delayed the production of cuticular hydrocarbons up to at least 3 days when compared to the production at 50 and 20% relative humidity. Male and Female flies produce more hydrocarbons at 35 °C than at 20 °C. On females, temperature has a prominent effect on the production of muscalure. It is suggested that, temperature has been considered essential since it can directly influence the population behavior of *M. domestica* (Noorman and Den Otter 2002).

**Medical importance**

The house fly is one of the most important hygiene pests world-wide. Adult files can cause annoyance in slaughterhouses and on meat, fish, sweet, fruit, and other foodstuffs in market places (Greenberg 1971, 1973). For humans, flies can disturb human work and be a direct annoyance.

In addition to a nuisance, irritating people and animals, adult flies are extremely important as disease carriers. They fulfill all the conditions required of a human disease vector namely: (1) being eusyanthropic, i.e., they maintain a close existence with human, sharing an artificial biocoenosis (anthropobioconeosis) created by humans; (2) consuming both contaminated and non-contaminated food; (3) demonstrating great flight activity and dispersal and (4) constantly alternating between feces and food in their feeding behavior (Greenberg 1971). About a hundred different pathogens have been found in and on houseflies. There are three different ways in which houseflies may transmit pathogens. The surface of their body,
particularly the legs and proboscis, may be contaminated; and because a house fly sucks food after it has been liquefied in regurgitated saliva, the pathogen may be deposited onto food with the vomit drop. Thirdly, pathogens may pass through the gut of fly and be deposited with its feces (Sasaki et al. 2000, De Jesus et al. 2004, Nazni et al. 2005).

Pathogens that may be transmitted by houseflies include viruses [e.g., poliomyelitis, rotavirus (Otake et al. 2003)]; bacteria [e.g., Escherichia coli, Shigella spp. non-01 Vibrio cholerae, Vibrio fluvalis Shigella, Vibrio fluvalis, Bacillus sp., Coccobacillus sp., Staphylococcus sp., Micrococcus sp., Streptococcus sp., Acinetobacter sp., Enterobacter sp. and Proteus sp. (Echeverria et al. 1983, Nazni et al. 2005)]; protozoan [e.g., Sarcocystis spp., Toxoplasma gondii, Isospora spp., Giardia spp., Entamoeba coli, Entamoeba histolytica/Entamoeba dispar, Endolimax nana and Cryptosporidium parvum (Khan and Huq 1978, Markus 1980, Kasprzak and Majewska 1981, Graczyk et al. 1999)] and helminth egg [e.g., Ascaris spp., Trichuris trichiura, hookworm, Taenia spp., Toxocara spp. and Capillaria hepatica (Mzon et al. 1991)]. Further medical importance of *M. domestica* is its cause of myiasis, the pathology from the occurrence of fly larvae in living tissue (Zumpt 1965). Report of house fly caused myiasis included intestinal, urino-genital, traumatic, aural and nasopharyngeal myiasis (Burgess and Davies 1991, Sehgal et al. 2002).

### 2.2 General consideration and medical importance of *C. megacephala*

*C. megacephala* is widely distributed, ranging from Asian, Australia, the pacific region, South Africa and North America (Zumpt 1965, Wells 1991, Wells and Kurahashi 1994, Kurahashi and Chowanadisai 2001). In Thailand, it is the second
most abundant fly species collected, but ranked top among the blow fly species (Sucharit et al. 1976, Tumrasvin et al. 1978, Sucharit and Tumrasvin 1981).

**Life cycle and description**

The life cycle of *C. megacephala* is holometabolous, the same as that of *M. domestica*. Wells and Kurahashi (1994) reported the development of *C. megacephala* completed by all larvae (27 °C) occurred in the following ages: egg hatch, 18 hr; first molt, 30 hr; second molt, 72 hr; pupation, 144 hr; and adult emergence, 234 hr.

**Egg:** Adult *C. megacephala* females deposit their eggs on suitable oviposition sites (breeding sites) such as in garbage, high humid areas, meat, carrion, urine, excrement, and decaying animals or corpses. This species seldom oviposits in isolated human feces but fresh, rather than old, carrion is preferred (Bohart and Gressitt 1951). They lay their eggs in batches of 150-300 eggs each. The blow fly egg is larger than that of the house fly, measuring about 1.40×0.40 mm.

**Larva:** The larva is creamy and muscoid-shaped. It looks roughly similar to the house fly larva, but larger in size. The mature larva is up to 16 mm in length. The posterior spiracles of the third-instar of *C. megacephala* have three straight slits, which is definitely different from those of the house fly larva. The anterior spiracle shows 11-13 branches. The larva is primarily a carrion feeder and needs high temperature and high humidity for good development. The maggot is very active and ravenous, and it crowds out competitors. The pre-pupa migrates from the breeding site to reach a dry area to pupate (Greenberg 1973).

**Pupa:** The pupa of *C. megacephala* looks like that of the house fly, but is bigger in size. Mature puparium is mahogany brown in color, and the anterior
projecting spiracles are yellow and fan-shaped. The pupal stage lasts \(\approx 100\) hr after which newly emerged flies break out from the pupal case.

**Adult:** The adult of *C. megacephala* is metallic greenish blue in color with purple reflections. It has a short stout body with a noticeably large head. The body length is 8-11 mm. The eyes are usually large and a very prominent shade of red. The upper facets of the male eye are strongly enlarged sharply demarcated from the small ones in the lower third. In the female, the eyes are separated by broad frons, and the upper facets are neither strikingly enlarged nor demarcated from the lower ones. The face including buccae in both sexes is bright orange, but the frons is predominantly black. The adult *C. megacephala* is a hemisyanthropic to eusynanthropic exophilic species and commonly is found near human dwellings.

*C. megacephala* is one of the first species to become active in the early morning hours and is one of the last species to depart carrion at nightfall. They normally rest at night, although they adapt to some extent to artificial light (Byrd and Castener 2000). The adult has a pronounced activity peak during the afternoon (Sucharit et al. 1976). Though there is no apparent explanation for this evidence but it can be assumed that the heat of the afternoon influence the adults fly body temperature and encourage the rates of physical processes; body size and potential fecundity (Reigada and Godoy 2006). Adult longevity is shown depending on temperature and humidity. At temperature of 25-29°C and 75% relative humidity, flies live for an average of 54 days (90 days maximum); at lower humidity they appear to live longer (Greenberg 1973). The food and feeding behavior of *C. megacephala* resemble those of *M. domestica*. The adult shows a preference for the fresh remains of corpse and/or other carrion (Bohart and Gressitt 1951).
Medical importance

The greatest medical importance of *C. megacephala* is its mechanical transmission of various pathogens including bacteria [e.g., *Aeromonas hydrophila*, *Edwardsiella tarda*, *Vibrio cholerae* non-01, *Aeromonas sobria*, *Citrobacter freundii*, *Escherichia coli*, *Providencia alcalifaciens* and *Pseudomonas aeruginosa* (Greenberg 1971, Sukontason et al. 2000)], protozoa [e.g., *Chilomastix mesnili*, *Endolimax nana*, *Entamoeba histolytica*, *Iodamoeba butschlii*, and *Trichomonas hominis* (Greenberg 1971), helminth [e.g., *Ascaris* spp., *Hymenolepis diminuta*, *Toxocara* spp. and *Trichuris trichiura* (Greenberg 1971, Sulaiman et al. 1988, Monzon et al. 1991)] that cause disease in human. Previously reports established that this fly species appeared to represent a stronger potential for pathogen transmission than the house fly (Sukontason et al. 2007, Maldonado and Centeno 2003). Furthermore, the medically important aspects such as annoyance and/or myiasis production have been recorded (Zumpt 1965, Sukontason et al. 2005). In contrast, *C. megacephala* plays a much more important role than *M. domestica* in forensic entomology. The idea behind forensic entomology is that different insects colonize carcasses at different stages of decomposition. By identifying species and stages of the insects in and on a carcass, it is possible to predict the time of death with a certain degree of accuracy (Smith 1986). Larva of *C. megacephala* have been used as entomological evidence for estimating the postmortem interval of a corpse (Smith 1986, Goff and Flynn 1991, Catts 1992).
2.3 Conception of what Geographic Information Systems (GIS) mean

The first Geographic Information Systems (GIS) was developed in the mid 1960s by governmental agencies as a response to a new awareness and urgency in dealing with complex environmental and natural resource issues (Mark et al. 2008). The first GIS emphasized the accumulation and use of data sets of local, regional and occasionally, national scope (Peuquet and Marble 1990). Today, GIS is one of the fastest growing technologies; it has applications in public safety, natural resource management, environmental analysis, utilities, and government, and is moving quickly into many other areas; for example, asset management. Environmental Impact Assessment, urban planning, cartography, route planning, banking, retail and manufacturing planning and demographic analysis, ecology, and environmental engineering.

There are many attempts to define GIS and it is difficult to select one definitive description. Some authors consider that GIS is a computer system that can hold and use data describing places on the earth’s surface or a set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real word for a particular set of purposes or a system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data which are spatially referenced on the Earth (Burrough 1986). In the broadest possible terms, GIS is a combination of computer technologies that integrate graphic elements with database or geographically referenced information and empower the computation of spatial relationship. On the other hand, the power of a GIS comes from the ability to integrate different spatial information with higher analytical processes to derive a conclusion about the spatial patterns’ relationship.
In general, GIS include two main components: the computer system (hardware and the software) and the people to operate the GIS. The computer software used in GIS contains the following major component (Peuquet and Marble 1990):

1. A data input subsystem which collects and/or process spatial data derived from existing maps, remote sensors, etc.

2. A data storage and retrieval subsystem which organizes the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis, as well as permitting rapid and accurate updates and correlations to be made to the spatial database.

3. A data manipulation and analysis subsystem which performs a variety of tasks such as changing the form of the data through user-defined aggregation rules or producing estimates of parameters and constrains for various space-time optimization or simulation models.

4. A data reporting subsystem which is capable of displaying all or part of the original database as well as manipulated data and the output from spatial models in tabular or map form. The creation of these map displays involves what is called digital or computer cartography. This is an area which represents a considerable conceptual extension of traditional cartographic approaches as well as a substantial change in the tools utilized in creating the cartographic displays.

In GIS, there are two types of data to be managed: attribute data and spatial data. Attribute data are the “what things are” and spatial data are the “where things are” (Heywood et al. 1998).
Attribute data

Most spatial data layers have accompanying attributes that are information pertaining to the data. Attributes are actually part of the spatial data and can include geographical information as well as quantitative or qualitative information (Heywood et al. 1998, DerMers 2005). An example of this would be Chiang Mai University. The actual location of the university is the spatial data. Additional data such as the university name, level of education programs, university capacity would make up the attribute data. It is the partnership of these two data types that enables GIS to be such an effective problem solving tool.

Spatial Data

Spatial data are characterized by information about position, connections with other features and details of non-spatial characteristics (attribute data). Spatial objects in the world can be thought of as occurring as four easily identifiable types; points, lines, areas and surface. Inside the GIS, real-world objects will be represented explicitly by three of these types of object. Point, lines and areas can be represented by their respective symbols (DerMers 2005).

1. Point feature are spatial phenomena, each of which occurs at only one location in space and represent the areas that are too small to be considered as polygon. For the sake of conceptual modeling, these objects are assumed to have no spatial dimension (no length or width) although each can be referenced by its location coordinates.
2. Linear or line objects are conceptualized as occupying only a single dimension in our coordinate space, for example roads, rivers, regional boundaries, fence, hedgerows, or any kind of object that is fundamentally long and very skinny. The
scale at which we observe these objects once again places a fundamental limitation on our ability to conceive of them as having on width (note, however, the Makomg River is quite wide and could be a raster image rather than a vector, depending on scale).

3. To describe the locations of two-dimensional areas in space, area entities or polygon are represented by a series of lines that begin and end at the same location are used to define features such as fields, buildings or administrative areas.

4. Adding the dimension of height to the area features allows people to observe and record the existence of a three-dimensional called “surface”. A surface can be used to represent topography or non-topographical variables such as pollutant levels or population densities.

All GIS software has been designed to handle spatial data (also referred to as geographical data). The spatial referencing of spatial data is important and should be considered at the outset of any GIS project. If an inappropriate referencing system is used, this may restrict future use of the GIS. Several methods of spatial referencing exist, all of which can be grouped into three categories: geographic co-ordinate systems, rectangular co-ordinate systems and non co-ordinate systems.

**Geographic co-ordinate systems**

The only true geographic co-ordinates are latitude and longitude and the location of any point on the Earth’s surface can be defined by a reference using latitude and longitude. Lines of longitude (also known as meridians) start at one pole and radiate outwards until they coverage at the opposite pole. Latitude gives the location, north or south of the equator, of a place on earth. Lines of latitude are the horizontal lines shown running east-to-west on maps (Figure 1A). Using lines of
latitude and longitude any point on the earth’s surface can be located by a reference given in degree, minutes, and second (Figure 1B). For example, the city of Moscow represent as a point can be given a geographical co-ordinate reference using latitude and longitude of 55 degree 45 minutes north and 36 degree 0 minutes east (55° 45′N 36° 0′E).

**Figure 1** A: Latitude and longitude (Heywood et al. 1998); B: Calculating the latitude and longitude of places.

**Rectangular co-ordinate systems:** The systems most often operate with two-dimension map projected from this reference globe. These reference systems obtained by projecting the lines of latitude or longitude from our presentation of the world as a globe onto a flat surface using map projection. The line of latitude and longitude become the grid lines on a flat map. However, when large areas of the globe are projected onto a flat surface, the grid will tear and stretch. Therefore, all rectangular
co-ordinate systems are designed to allow the mapping of specific geographical regions. A good example of a rectangular co-ordinate system is the Universal Transverse Mercator (UTM) plan grid system. It has been adopted for much remote sensing work, topographic map preparation, and natural resource database development because it allows precise measurement using the metric system of measurement, which is accepted by many countries and by the scientific community at large. The basic unit of measurement is the meter (Figure 2).

**Figure 2** The zones used in the UTM spatial co-ordinate system. UTM divides the earth from latitude 84 degree north and 80 degree south latitude into 60 numbered vertical zones that are 6 degrees of longitude wide (DerMers 2005).

**Non co-ordinate systems:** This system provides spatial references using a descriptive code rather than a co-ordinate. Postal codes, widely used throughout the world, are an example. The basic purpose is to increase the efficiency of mail storing and delivery rather than to be an effective spatial referencing system for GIS users. Even so, there are several advantages to such systems. They are important to the postal services and
are therefore maintained and updated and they offer coverage of all areas where people reside (Heywood et al. 1998, DerMers 2005).

**Spatial Data Model**

All spatial data sources used in GIS are derived from aerial photographs, satellite images, census data and particular maps. At present there are two main ways in which computers can handle and display spatial data. These are the vector and raster approaches.

**Vector spatial data**

Vector spatial data uses a two-dimensional Cartesian (x,y) co-ordinate system to store the shape of a spatial entity. In the vector world, the point is the simplest spatial entity which is represented by a single (x,y) co-ordinate pair. Line and area entities are constructed by connecting a series of points into chains and polygons (Figure 3). The more complex the shape of a line or area feature the greater the number of points required represent it (DerMers 2005).

![Figure 3 Vector spatial data.](image)
**Raster spatial data**

Raster spatial data is one of a family of spatial models described as tessellations. In the raster world, individual cells are used as the building blocks for creating images of point, line, area, network and surface entity. The basic building block is the individual grid cell and the shape. Character of an entity is created by the grouping of cells. The size of the grid cell is very important as it influences how an entity appears. In a simple raster data structure, different spatial features must be stored as separate data layers. However, if the entities do not occupy the same geographic location (or cells in the raster model), then it is possible to store them all in a single layer, with an entity code given to each cell. This code informs the user which entity is present in which cell. Figure 4 shows how different land uses can be coded in a single raster layer. The value 1, 2 and 3 have been used present at a given location.

![Feature coding of cells in the raster spatial data](image)

**Figure 4** Feature coding of cells in the raster spatial data: (A) entity model, (B) cell value; 1-residential area, 2-forest and 3-farmland (Heywood et al. 1998).
GIS Data Input

Spatial data can be obtained from many different sources, in different formats and can be input into GIS using a number of different methods. All data in analogue form need to be converted to digital form before they can be input into GIS. Four methods are widely used: keyboard entry, manual digitizing, automatic digitizing and scanning. Keyboard entry may be appropriate for tabular data or for small numbers of co-ordinate pairs read from a paper map source. Digitizing is widely used for the encoding of paper maps and data from interpreted air photographs. Scanning represents a faster encoding method for these data sources, although the resulting digital data may require considerable processing before analysis is possible. For example, maps, which may come as paper sheets or digital files, may be input by digitizing, scanning or direct file transfer; aerial photographs may be scanned into a GIS and satellite images may be downloaded from digital media. In addition, data can be directly input to GIS from field equipment such as Global Positioning System (GPS) receiver or from sources of ready prepared data from data retailers or across the internet. Once in a GIS, data almost always need to be corrected and manipulated to ensure they can be structured according to the required data model. Digital data must be downloaded from their source media (diskette, CD-ROM or network) and may require reformatting to convert them to an appropriate format for the GIS being used (Heywood et al. 1998).
**Data Analysis**

1. Measurements in GIS-lengths, perimeters and areas

Calculating lengths, perimeters and areas is a common application of GIS. However, it is possible that different measurements can be obtained depending on the type of GIS used (raster or vector) and the method of measurement employed.

2. Queries

Performing queries on a GIS database to retrieve data is an essential part of most GIS projects. Queries offer a method of data retrieval and can be performed on data that are part of the GIS database or on new data produced as a result of data analysis. There are two types of query that can be performed with GIS: spatial and aspatial. Aspatial queries are questions about the attributes of features such as the number of luxury hotels and the name “How many luxury hotels are there?” and “What are the names of hotels?” Information about “where” is a spatial query. For example, if a user wants to find where the luxury hotels are in Chiang Mai, the location of the hotels will be reported and could be presented in map form.

Queries can be made more complex by combination with questions about distances, areas and perimeter, particularly in a vector GIS. Individual queries can be combined to identify entities in a database that satisfy two or more spatial and aspatial criteria, for example, exploring the number of luxury hotels which have more than 20 bedrooms. Boolean operators are often used to combine queries of this nature. These use AND, NOT, OR and XOR, operations that are also used for the combination of different data sets by overlay.
3. Buffering and neighborhood functions

There is a range of functions available in GIS that allow a spatial entity to influence its neighbors or the neighbors to influence the character of an entity. The most common example is buffering, or the creation of a zone of interest around an entity. Buffering is very simple conceptually but a complex computational operation. Creating buffer zones around point features is the easiest operation; a circle of the required radius is simply drawn around each point. Creating buffer zones around line and area features is more complicated (Figure 5).

![Figure 5 Buffer zones around (A) point, (B) line and (C) area features (Heywood et al. 1998).](image)
For example, the question “Which hotels are within 200 m of a main road?” could be approached in a number of ways.

- One option would be, first, to produce a buffer zone identifying all land up to 200 m from the main roads.
- Second, to find out which hotels fall within this buffer zone using a point-in-polygon overlay.
- Then a query would be used to find the names of the hotels.

An alternative approach would be to measure the distance from each hotel to a main road and then identify those which are less than 200 m away. This example illustrates that in most GIS data analysis there is more than one method of achieving an answer to the question. In this example, repeated measurement of distances from hotels to roads could be time-consuming and prone to human error. Thus, the first approach using buffering would be a more efficient method.

4. Integrating data-map overlay

The ability to integrate data from two sources using map overlay is perhaps the key GIS analysis function. Using GIS, it is possible to take two different thematic map layers of the same areas and overlay them one on top of the other to form a new layer (Figure 6). As with many other operations and analyses in GIS there are differences in the way map overlay is performed between the raster and vector worlds. In vector-based systems map overlay is time-consuming, complex and computationally expensive. There are the three main types of vector overlay; point-in-polygon, line-in-polygon and polygon-in-polygon. In raster-based systems it is just the opposite-quick, straightforward and efficient (Heywood et al. 1998).
Figure 6 Vector overlay; point-in-polygon (upper row), line-in-polygon (middle row) and polygon-in-polygon (lower row); the output (right column) can be obtained.

2.4 Application of GIS in vector-borne diseases

In the study of vector-borne diseases, maps have played an important role in orienting investigators to local conditions and in guiding epidemiological activities within the study area. GIS provide the specialized methods available that extends ability to work with spatial data well beyond that of paper maps. Use of GIS makes it possible to collect, manage, analyze, and report spatial information about vector-borne disease. With this information, spatial relationships associated with vectors, host, pathogens, and the environment can be compared to learn more about the complex nature of these interactions (William 2004). Among all environmental factors, temperature, rainfall, relative humidity and land use types have been considered essential since they can directly influence the population dynamic of insects (Lysyk 1993, Byrd and Butler 1997, Herrero et al. 2004, Boussaa et al. 2005, Siddig et al. 2005). Application of GIS in various infections in the world such as malaria, onchocerciasis, lymphatic filariasis, trypanosomiasis and leishmaniasis are briefly reviewed.
**Malaria:** GIS technologies, remote sensing and meteorological were integrated with field research to predict anopheline mosquito population dynamics, characterize the breeding habitats of larval and adult anopheline mosquito, determine the nature and extent of factors influencing malaria transmission, distinguish between places at high risk and describe the patterns of malaria risk/map malaria risk in many countries of the world such as Africa, Brazilian Amazon, China, India, Kenya, Korea, Mexico, Thailand and Uganda (Beck et al. 1994, Hu et al. 1998, Najera 1999, Srivastava et al. 1999, Lindblade et al. 2000, Yang et al. 2002, Keating et al. 2003, Afrane et al. 2005, Kengluecha et al. 2005, Minakawa et al. 2005, Sithiprasasna et al. 2005a, Bogh et al. 2007, Gil et al. 2007).

**Onchocerciasis and Lymphatic filariasis:** remote sensing and GIS technologies were used to be identified the distribution and relationship with environmental variables. Operational guidelines for rapid mapping of onchocerciasis and Bancroftian lymphatic filariasis are available (Hassan et al. 1998, Sabesan et al. 2000, Idowu et al. 2004).

**Trypanosomiasis:** The application of GIS to strengthen epidemiological surveillance for sleeping sickness has been advocated by many researchers to understand the spread of the disease, evaluate risk and test control strategies (Cattand 2001, Muller et al. 2004). In Africa, GIS software and thematic maps were generated on human and animal trypanosomiasis to illustrate epidemiological status (Rogers and Williams 1993).

**Leishmaniasis:** Recent epidemics of visceral leishmaniasis in various parts of the world, particularly in Sudan, underline the need to identify the limiting factors and produce a preliminary visceral leishmaniasis risk map for the whole of Sudan. They
adopted an entomological and GIS approach to delineate the distribution of *Phlebotomus orientalis*. In recent studies, they investigated the developing models to determine which environmental factors explain variability in visceral leishmaniasis presence and incidence (Elnaiem et al. 1998, Elnaiem et al. 2003).

### 2.5 Application of GIS to the study vector-borne disease in Thailand

Two vector-borne communicable diseases, malaria and dengue, are among a number of diseases of particular importance in relation to economic development in Thailand. GIS was introduced to study the interaction between physical environments and disease epidemiology. Tak province represents the endemic region for malaria and has a large number of *Anopheles* species. Epidemiologic and ecologic data on anopheline malarial vectors in such area is complex, related to vegetation distribution, and not well understood. GIS was applied to the examination of the temporal and geographical distribution of man-biting adult *Anopheles* mosquitoes and the determination of whether there was a link between adult mosquito distribution and location of larval habitats. Larval habitats that produce key vector species were identified and this information was incorporated into a decision matrix to identify key areas that are critical to maintaining malaria transmission. The final GIS products included a map depicting the spatial distribution of larval mosquito habitats for various species and a map depicting potential adult mosquito populations in villages proximal to the immature habitats. These associations permitted real-time monitoring and possibly forecasting of the distributions of these anopheline vectors, enabling public health agencies to institute control measures before the mosquitoes emerged as adult and transmitted disease (Sithiprasasna et al. 2003a, 2003b, Sithiprasasna et al.
2004, Kengluecha et al. 2005, Sithiprasasna et al. 2005b). In addition to malaria, epidemiological, digital, and GPS data had been incorporated into GIS databases to better understand the spatial distribution of dengue haemorrhagic fever. Previous study demonstrated that GIS could be used as a powerful tool to monitor the status of *Aedes aegypti* distribution, in an effort to control their breeding sites and to evaluate the impact of control efforts on dengue and dengue haemorrhagic fever transmission (Sithiprasasna et al. 2004). Moreover, the potential of remotely sensed data and GIS technology was applied to the study of spatial and temporal determinants for dengue infection and to investigate the physio-environmental factors such as land use/land cover type affecting dengue incidence. The results demonstrated that physical factors derived from remotely sensed data could indicate variation in physical risk factors affecting dengue haemorrhagic fever (Nakhapakorn and Tripathi 2005, Vanwambeke et al. 2006).

There is no previous study using GIS technology to study the distribution of house fly and blow fly, two most common medically important flies in Thailand. The current study will analyze the seasonal variation in natural populations of *M. domestica* and *C. megacephala* and document the relationship between environmental factors and adult fly abundance using the tool of GIS over 1 year in Chiang Mai. Knowledge of their distributions, including breeding place, and other environmental factors, is beneficial for fly control strategy in future.
3. Purpose of this study

3.1 To determine the spatial and temporal distribution on *M. domestica* and *C. megacephala* in urban and suburban areas of Chiang Mai.

3.2 To determine the relationship of seasonal fly abundance with climatic and physio-environmental factors (e.g., temperature, relative humidity, light intensity and land use types).

4. Significance of this research

The results obtained from this study will be useful for understanding the biology of *M. domestica* and *C. megacephala* and also helpful in predicting the areas or time in which these flies are likely to be present. Furthermore, this information will be aid in helpful to fly control strategies.