2. LITERATURE REVIEW

2.1 Population Supporting Capacity and Adaptive Strategies

Population supporting capacity is generally known as the man-land balance or maximum number of population that can be supported without any degradation of natural resource (Street, 1969; Brush, 1975)

Most of the studies aiming at examining the population supporting capacity under shifting cultivation condition were based on the determination of physical potential such as soil, climatic, and temperature (Higgins et al., 1982). Beets (1990) clarified the factors that formed the basis for this assessment of supporting capacity which were;

- the land area which was available for cultivation;
- the length of the cultivation and fallow periods;
- the subsistence requirement; and
- the actual area cultivated per member of population.

A model for calculating carrying capacity of shifting cultivation system was presented by Brush (1975). The model indicated the critical population size which was determined by cultivation period, fallow period, acreage needed per capita, and total arable land.

Western (1989) conducted a study in Palawan, Philippines to project the changes in land use and in agricultural system over 25 years and hence referred to the change in population carrying capacity. Six ecological zones were assigned and carrying capacity for each of them was carried out under three development strategies imposed. Furthermore, future trends were anticipated and compared to each other. Similar study was conducted in Tanzania by Mwalyosi (1991). He also pointed out the declining of carrying capacity and suggested how to achieve sustainable development.

Upland communities respond to population pressure in terms of changes in the basic production system and in patterns of cooperation in the use of forest resources. The responses to these problems have included the use of irrigated agriculture and migration to the lowlands (Kunstadter et al., 1978). It was also reported that population pressure made farmers shifted to more intensive production systems and leading to shortened fallow periods (Cruz, 1986).

A recent study of a watershed in northern Thailand (Fox et al., 1995) investigated the human-induced changes in landscape patterns through time. This study revealed the dynamic changes in land cover and landscape patterns through a 38 year period. Farmers cleared forests to provide land for swidden cultivation, rice paddies, and more recently, fruit and vegetable cash crops. The conclusion illustrated that the dynamics of populating growth, migration into remaining frontiers, and responses to national and international market forces result in a demand for land that produces food and fiber.

Fukui (1991) examined the rice/population balance in a northeast Thai village and described the social changes when the rice supporting capacity was exceeded. He pointed out that migration, off-farm waging to increase cash income, and seeking for the new land were the adaptive strategies of the people in this community. Burutpat (1990) illustrated rice sharing and exchanging system within the highland community when they lacked of rice. The strong kinship system and tightness of community were expressed.

Assessing food supporting capacity of the land requires the reliable method for estimating cultivated areas for staple food. The verification of the adaptive strategies used to cope with food deficiency also required spatial information on land use dynamics. Integrating of remote sensing data and GIS can effectively provide the essential information.

Asakura et al. (1991) gave a good example of using remote sensing (RS) and GIS to enhance the estimation of supportable population of the earth. However, this study was a global scale method of assessing the carrying capacity and is not suitable for the scale used in this study.

In this study, rice cultivated area will be obtained from land use map classified from the integration of GIS technique and aerial photograph interpretation with the use of recently developed orthophotograph technique to obtain the most accurate information on land use and land use changes in the study area.

2.2 Geographic Information System (GIS)

GIS is a set of, an organized collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information. A GIS data is often conceptualized as thematic category or layer of information. This layer may contain information that has been captured from aerial photographs, satellite data, conventional map or other sources. The GIS data has two major components, locational or geographical, and accompanying feature attribute database. Locational databases are usually created by digitizing conventional maps. Attribute database identify what the features represent in the form of numeric or textual information (ESRI, 1995).

The two major ways to represent GIS data are raster and vector. Vector represents three main geographical entities which are point, line, and area . Raster represents the set of cells located by coordinates (Burrough, 1986). In the ARC/INFO (ESRI, 1995), a vector based GIS package, series of points and arcs are implemented to handle coordinates of the features, while its INFO module handles the descriptions features and how each feature relates to each others.

The development of GIS package and the use of GIS grew dramatically in the 1980s. GIS is now commonplace for business, government, and academia to use this technology for many diverse application. ARC/INFO workstation has been continuously developed to handle and integrate both vector and raster GIS database.

The current growth of computer hardware and software have resulted in enhancing the automated GIS to collect, store, transform, and displaying complex spatial data. The recent improvement of optical scanning systems provides a great potential to satisfy the enormous desire information for GIS (Leberl and Olson, 1982; Cartensen and Campbell, 1991; Williamson, 1992).

2.3 Spatial Information System and Land Use Classification

During the last two decades spatial information system which comprises of aerial photograph interpretation, RS and GIS have been widely used for planning resources management, environmental observation, and monitoring land uses. Kushawa (1991) revealed the effort to apply the RS techniques to classify the shifting cultivation conditions in Northeast India. Dwivedi and Sankar (1991) studied the dynamics of shifting cultivation by using Landsat MSS data at 1:250,000 scale. This study revealed that multitemporal Landsat MSS was successfully used for monitoring the spatial distribution of shifting cultivation.

Many studies in the past employed the satellite data to estimate area and/or detect the change of paddy rice (Dimyati et al., 1991; Vibulsresth et al., 1991; Tennakoon et al., 1992).

Satellite data and GIS have been used extensively in the study and analysis of the natural resource or even urban area. However, many studies still required aerial photographs to aid the analyzing process, serve as base or reference data, refine and evaluate the results (Moreira et al., 1986; Gangodawila, 1987; Thorp, 1993; Fox et al., 1995).

The strength of aerial photographs is its high spatial resolution comparing to other remote sensing data sources available in Thailand. Interpretation of the features can be achieved by the basic characteristics or variations of shape, size, pattern, tone (or hue), texture, shadows, site and association (Lillesand and Kiefer, 1994). These characteristics may be assessed manually with a stereoscope, some of them can be done automatically in a GIS.

Bonham-Carter (1994) provided a map analytical tool called "thinness ratio" which recognize the variation of polygon object's shape on the map. It is a relationship between the area and the perimeter of a particular polygon object on the map. The *Thinness ratio* can be expressed as $4\Pi A / P^2$ where A and P represent the area and perimeter of an object respectively. This provided the method to differentiate and compare the shape of different objects on the map.

Aerial photograph image also have textural characteristics that vary with the underlying geology and ground cover. The texture can be assessed quantitatively and implemented in a raster GIS. Textural characteristics can be expressed as *entropy* or *diversity* and is defined as:

$$Entropy = -\sum_{i=1}^{k}\left(p_i \log p_i\right) \qquad \text{.............................} \quad (1)$$

where p_i is the proportion of the cells in the neightbourhood with value *I*, and *k* is the number of pixels in the neighbourhood (Bonham-Carter,1994; Eastman, 1997).

The tone (hue) of the features on the aerial photograph can also be quantitatively assessed through the distribution of the digital number (DN) of the scanned photo and displayed as a histogram. This feature is the basic capability of any raster GIS such as IDRISI (Eastman , 1997).

2.3.1 Aerial Photograph and Displacement Errors

Aerial photography is a subset of a broad discipline called remote sensing which is used to identify and study the object on earth surface at a remote distance, usually to serve resource planning and management purposes. (Paine, 1981).

In general, aerial photograph is acquisited using an airplane to photograph a series of images using a large roll of special photographic film. The film is then processed and cut into negatives, and finally developed to printed photographs. The most common size for negatives is 9" x 9". The final scale of the aerial photograph depends on the height of the aircraft when the photo was taken. Aerial photographs are taken with an overlap between each aerial photograph (Figure 2.1), to ensure that a final mosaic can be assembled (Ermapper, 1996).

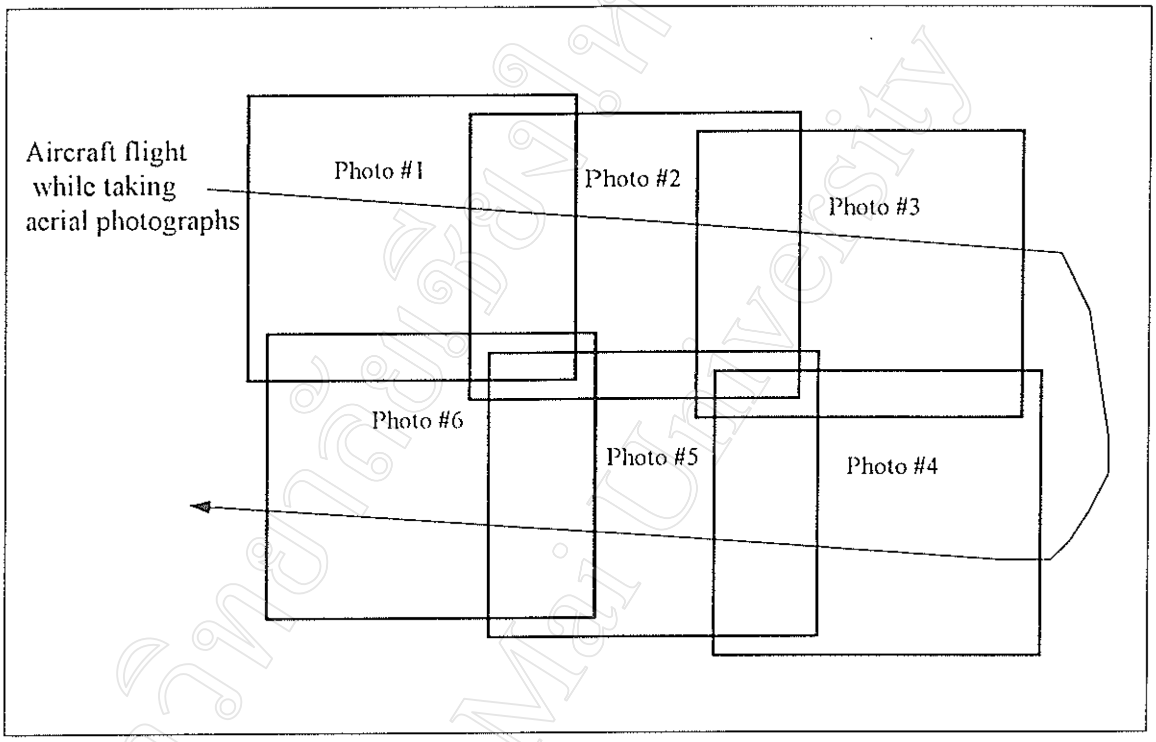

Figure 2.1 Strips of aerial photographs.

(Source: http://www.ermapper.com/applic/airphoto/intro1.htm)

The aerial photograph taken from an airplane does not have a constant scale or is not true to scale because of displacements and distortions due to terrain relief, atmospheric conditions, and camera systems. As the airplane flies along taking photographs of the ground, mountain tops will have a larger scale than valley floors, only objects that are at the same height will have the same scale. In general, if the ground is not flat and horizontal, every point on the ground will have a different scale. This means making a measurement of distance, on the photograph, one of which is higher than the other, the distance will be wrong. Changes in height of the terrain of distance away from the camera also has a effect called relief displacement. The relief displacement can be expressed in the following formula:

$$d = rh/H \qquad \text{(2)}$$

where, d = relief displacement;

h = height above datum of the object point whose image is displaced;

r = radial distance on the photograph from the principle point (photo center) to the displaced image; and

H = flying height above the datum selected of measurement of h.

Tilt displacement is an error caused by camera angle while taking photographs that cause additional variation in scale.

2.3.2 Orthophoto of an Aerial Photograph

In practice, aerial photographs have both relief and tilt displacement that cause variation in scale and displacement of objects from their true positions. Thus these variations have to be eliminated at an acceptable level to obtain reliable the spatial data from aerial photographs.

Traditionally, scale errors in aerial photographs have been corrected using photogrammetric stereo-plotters. These dedicated mechanical computers were designed to determine the correct position of the points while viewing pairs of aerial photographs stereoscopically. In recent years, much of computation associated with this task has been taken over by computers coupled to stereo-viewrs. This method usually requires expensive instrument and specialized skills for operation. To achieve the correction, these following factors are required:

- the camera position related to the ground when the photograph was taken,
- how tilted camera was at the moment of exposure,

- two continuous aerial photos to determine the position of the point using intersection of the photographic ray from this two photos, and
- at least three known points and their ground positions.

Digital orthophoto has been designed to meet increasing requirements for high resolution rectified digital images. It is a computer-compatible technique that operates to remove aerial photographs' displacement errors (TeSelle, 1994; Salamanca Software Pty Ltd, 1994). A number of computer softwares designed to create digital orthophoto image are now commercially available. An example is PhotoGIS (Salamanca Software Pty Ltd., 1994).

PhotoGIS uses the same principle mentioned above but requires only one photograph and the known shape of the terrain. PhotoGIS uses a Triangulated Irregular Network (TIN), a digital surface model to determine the height of the point or the distance along the ray from the photograph to the ground. As the position of the point digitized on the photograph will not be in its true position due to tilt and relief displacement, the height that we interpret for the point in the terrain will also be in error. PhotoGIS determines the corrected position for the point by successive interpolations of height from the TIN.

Thus, the orthophoto of an aerial photograph can be achieved by various techniques but they employ the same fundamental concept. This study attempted to use PhotoGIS due to its full integration and compatibility with ARC/INFO to process orthophoto of aerial photographs taken in the study area. The interpretation of these images together with GIS analysis will produce land use maps in the years required for change detection study.