CHAPTER 2

LITERATURE REVIEW

2.1 Concept of land use change

Land use refers to the ways in which, and the purpose for which, human beings employ land and its resources (Briassoulis, 2000). Land use can be broadly defined as the level of spatial accumulation of activities such as production, transaction, administration and residence with highly dynamic relationships between them. Land use reflects the nature of social and economic activities in an area, as well as interactions with other areas. It results from the complicated interactions between the land system and the social economic systems (Jianquan, 2003).

Land use has been a concern primarily of social scientists: economists, geographers, anthropologists, planners, and others. The term denotes the human employment of the land. Land uses include settlement, cultivation, pasture, rangeland, recreation, and so on. Land use change at any location may involve either a shift to a different use or an intensification of the existing one.

Land cover is a concern principally of the natural sciences, denotes the physical state of the land. It embraces, for example, the quantity and type of surface vegetation, water, and earth materials. A land use change is likely to cause some land cover change, but land cover may change even if the land use remains unaltered.

A forest will steadily shrink if a constant rate of timber extraction or shifting cultivation exceeding growth is maintained.

The realms of land use change are connected in the terminology we adopt by the proximate sources of change, those human actions that directly alter the physical environment. It is through the proximate sources that the human goals of land use translated into changed physical states of land cover. Example of proximate sources represents the point of intersection between the core concerns of the natural and the social sciences, between physical processes and human behavior. On one side, these proximate sources produce land cover changes or alterations of the properties of the land surface. They may take the form of either conversion or modification and they may lead as well to secondary environmental impacts: trace gas emissions, biodiversity loss, soil erosion and degradation and microclimatic change, water flow and water quality changes are example. On the human side of the chain, the proximate sources reflect human goals mirrored in land uses (Turner and Meyer, 1994).

2.2 Definitions of land use change

Land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater, and it also includes those structures created solely by human activities such as mine exposures and settlement (Lambin et al, 2003; Chrysoulakis et al, 2004; Baulies and Szejwach, 1998). On the other hand, land use is the intended employment of and management strategy placed on the land cover by human agents or land managers to exploit the land cover and reflects human activities such as industrial zones, residential zones, agricultural fields, logging, and mining among many others (Zubair, 2006; Chrysoulakis et al, 2004).

Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to non-agricultural uses (Quentin et al, 2006).

Land use and land cover changes may be grouped into two broad categories as conversion and modification. Conversion refers to changes from one cover or use type to another, while modification involves maintenance of the broad cover or use type in the face of changes in its attributes (Baulies and Szejwach, 1998).

According to Lambin (2005) sustainable resource use refers to the use of environmental resources to produce goods and services in such a way that over the long term, the natural resource base is not damaged so that future human needs can be met. One of the most significant global challenges in this century relates to management of the transformation of the earth's surface occurring through changes in land use and land cover (Mustard et al., 2004).

Therefore, land use and land cover change research needs to deal with the identification, qualitative description and parameterization of factors which drive changes in land use and land cover as well as the integration of their consequences and feedbacks (Baulies and Szejwach, 1998). However, one of the major challenges in land use change analysis is to link behavior of people to biophysical information in the appropriate spatial and temporal scales (Codjoe, 2007). But, it is argued that land use and land cover change trends can be easily assess and linked to population data, if the unit of analysis is the national, regional, district or municipal level.

2.3 Empirical evidence on the causes of land use change

2.3.1 Proximate versus underlying causes

McConnell and Keys (2005) noted that land use is defined by the purposes for which humans exploit the land cover. There is high variability in time and space in biophysical environments, socio-economic activities and cultural contexts that are associated with land-use change. Identifying the causes of land use change requires an understanding of how people make land use decisions and how various factors interact in specific contexts to influence decision making on land use. Decision making is influenced by factors at the local, regional or global scale. Proximate (or direct) causes of land use change constitute human activities or immediate actions that originate from intended land use and directly affect land cover.

(Leemans et al, 2003) explained that the causes involve a physical action on land cover. Underlying (indirect or root) causes are fundamental forces that underpin the more proximate causes of land cover change. They operate more diffusely (i.e., from a distance), often by altering one or more proximate causes. Underlying causes are formed by a complex of social, political, economic, demographic, technological, cultural, and biophysical variables that constitute initial conditions in the human environment relations and are structural (or systemic) in nature.

McConnell and Keys (2005) aimed to proximate causes generally operate at the local level (individual farms, house-holds, or communities). By contrast underlying causes may originate from the regional (districts, provinces, or country) or even global levels, with complex interplays between levels of organization. Underlying causes are often exogenous to the local communities managing land and are thus uncontrollable by these communities. Only some local scale factors are endogenous to decision makers. An important system property associated with changes in land use is feedback that can either accentuate or amplify the speed, intensity or mode of land use change or constitute human mitigating forces, for example via institutional actions that dampen, impede or counteract factors or their impacts. Examples are the direct regulation of access to land resources, market adjustments or informal social regulations (e.g., shared norms and values that give rise to shared land management practices).

Place based research followed by systematic comparative analyses of case studies of land use dynamics have helped to improve understanding of the causes of land use change. These syntheses produced general insights on sectoral causes of land use change and on the mode of interaction between various causes. They identified dominant pathways also referred to as spirals, trajectories or syndromes leading to specific types of change. What has been lacking so far is the development of an integrative framework that would provide a unifying theory for these insights and pathways of land use change and a more process oriented understanding of how multiple macro structural variables interact to affect micro agency with respect to land (Wiggins, 1995; McConnell and Keys, 2005).

2.4 General insights on sectoral causes of land use change

2.4.1 Multiple causes

Geist et al, (2002; 2004) explained land use change is always caused by multiple interacting factors originating from different levels of organization of the coupled human environment systems. The mix of driving forces of land use change varies in time and space, according to specific human environment conditions. Driving forces can be slow variables with long turnover times, which determine the boundaries of sustainability and collectively govern the land use trajectory or fast variables, with short turnover times such as food aid or climatic variability. Biophysical drivers may be as important as human drivers. The former define the natural capacity or predisposing conditions for land-use changes. The set of abiotic and biotic factors that determine this natural capacity varies among localities and regions. Trigger events, whether these are biophysical (a drought or hurricane) or socioeconomic (a war or economic crisis), also drive land use changes. Changes are generally driven by a combination of factors that work gradually and factors that happen intermittently.

2.4.2 Natural variability

(Puigdef´abregas, 1998 and Geist et al, 2002; 2004) noted that natural environmental change and variability interact with human causes of land use change. Highly variable ecosystem conditions driven by climatic variations amplify the pressures arising from high demands on land resources, especially under dry to sub-humid climatic conditions. Natural and socioeconomic changes may operate as synchronous but independent events. Natural variability may also lead to socioeconomic un-sustainability, for example when unusually wet conditions alter the perception of drought risks and generate overstocking on rangelands. When drier conditions return, the livestock management practices are ill adapted and cause land degradation. Land use change, such as cropland expansion in dry lands, may also increase the vulnerability of human environment systems to climatic fluctuations and thereby trigger land degradation.

2.4.3 Economic factors

Available case studies highlight that, at the timescale of a couple of decades or less, land use changes mostly result from individual and social responses to changing economic conditions, which are mediated by institutional factors. Opportunities and constraints for new land uses are created by markets and policies and are increasingly influenced by global factors (Agrawal and Yadama, 1997 and Lambin et al, 2001). Economic factors and policies define a range of variables that have a direct impact on the decision making by land managers, e.g., input and output prices, taxes, subsidies, production and transportation costs, capital flows and investments, credit access, trade and technology (Barbier, 1997). Internal consumption affects land less than external demand, so subsistence croplands consequently decrease while land under crops for markets increases with a parallel increase in agricultural intensity. Market access is largely conditioned by state investments in transportation infrastructure. The unequal distribution of wealth between households, countries, and regions determines geographic differences in economic opportunities and constraints. Its affects, for example, who is able to develop, use, and profit from new technologies that increase efficiency in land management (Indian et al, 2001).

2.4.4 Technology factors

Improving agricultural technology as much as providing secure land tenure and giving farmers better access to credit and markets can potentially encourage more deforestation rather than relieving pressure on the forests. The differing impact of agricultural development on forest conversion depends on how the new technologies affect the labor market and migration, whether the crops are sold locally or globally, how profitable farming is at the forest frontier as well as on the capital and labor intensity of the new technologies (Angelsen and Kaimowitz, 2001).

2.4.5 Demographic factors

At longer timescales, both increases and decreases of a given population also have a large impact on land use. Demographic change does not only imply the shift from high to low rates of fertility and mortality but it is also associated with the development of households and features of their life cycle. The family or life cycle features relate mainly to labor availability at the level of households, which is linked to migration, urbanization and the breakdown of extended families into several nuclear families (Lambin et al, 2001).

Forest clearing is caused by a variety of actors with differing effects recent in migrants practice slash and burn agriculture, their children's families shift to fallow agriculture, long settled families have diversified production, small families have crop or livestock combinations (associated with high rates of forest losses), large families have perennial production modes (associated with low rates of forest losses) and small ranchers are displaced by large ranchers and upland croppers are displaced by lowland ranchers (Humphries, 1998 and Walker et al, 2002).

Life cycle features arise from and affect rural as well as urban environments, they result from households' strategic responses to both economic opportunities (for example, market signals indicating higher crop profitability) and constraints due to economic crisis conditions. They shape the trajectory of land use change, which itself affects the household's economic status. Therefore, a population analysis of great nuances is required (Walker and Homma, 1996; Sunderlin et al, 2001). Migration in its various forms is the most important demographic factor causing land use change at timescales of a couple of decades (Angelsen and Kaimowitz, 1999; Geist and Lambin, 2002). Migration operates as a significant driver with other non demographic factors, such as government policies, changes in consumption patterns, economic integration and globalization (Indian et al, 2001). Some policies resulting in land use change either provoke or are intricately linked with increased migration (Fearnside, 1997 and Indian et al, 2001).

The growth of urban aspirations, the urban rural population distribution and the impact of rapidly growing cities on ecosystem goods and services are likely to become dominant factors in land use change in the decades to be come in major urban or peri-urban areas or in remote hinterland or watershed areas (Fox et al, 1995; Humphries, 1998 and Mertens et al, 2000). Many new urban dwellers in developing countries still own rural landholdings. Although the growth of urban areas creates new local and regional markets for livestock, timber and agricultural products, it also increases urban remittances to the countryside (Lambin et al, 200).

2.4.6 Institutional factors

To explain land use changes, it is also important to understand institutions (political, legal, economic and traditional) and their interactions with individual decision making (Ostrom et al, 1999; Agrawal and Yadama, 1997). Access to land, labor, capital, technology and information is structured and is frequently constrained by local and national policies and institutions. Land managers have varying capabilities to participate in and to define these institutions. Relevant nonmarket institutions include: property rights regimes, environmental policies, decision making systems on resource management (e.g., decentralization, democratization and the role of the public of civil society and of local communities in decision making), information systems related to environmental indicators as they determine perception of changes in ecosystems, social networks representing specific interests related to resource management, conflict resolution systems concerning access to resources and institutions that govern the distribution of resources and thus control economic differentiation (Batterbury and Bebbington, 1999).

There is often a mismatch between environmental signals reaching local populations and the macro level institutions (Redman, 1999). Therefore, the rules used for making policies are important to ensure that local users are able to influence resource management institutions. Institutions need to be considered at various scales to identify the local mediating factors and adaptive strategies and to understand their interactions with national and international level institutions (Poteete and Ostrom, 2004).

Many land use changes are due to ill defined policies and weak institutional enforcement, as exemplified by the widespread illegal logging. On the other hand, recovery or restoration of land is also possible with appropriate land use policies. Consolidation of landholdings and the shift from communal, traditional systems to formal, state sanctioned regimes is a trend observed throughout the developing world (McConnell and Keys, 2003). Examples of policies that influence land use change are state policies to attain self-sufficiency in food, taxation, fiscal incentives, subsidies and credits, price controls on agricultural inputs and outputs, decentralization, infrastructure support, low investments in monitoring and formally guarding natural resources, land consolidation, nationalization and collectivization, structural adjustment measures and international environmental agreements (Jepson et al, 2001; Xu et al, 1999 and Remigio, 1993).

With increasingly interconnected market forces and the rise of international environmental conventions, the impact of institutional drivers moves from the local to the global level. Land degradation is more prominent when macro policies, either capitalist or socialist, undermine local adaptation strategies. In particular, perverse subsidies for road construction, agricultural production, forestry and so forth are thought to be one of the biggest impediments to environmental sustainability (Myers and Kent, 2001).

2.4.7 Cultural factors

Numerous cultural factors also influence decision making on land use. Land managers have various motivations, collective memories and personal histories. Their attitudes, values, beliefs and individual perceptions influence land use decisions for instance through their perception of and attitude toward risk. Land use decisions have intended and unintended consequences on ecosystems, these depend on the knowledge, information and management skills available to land managers. Culture is often linked with political and economic inequalities, (e.g., the status of women or ethnic minorities that affect resource access and land use). Understanding the controlling models of various actor may thus explain the management of resources, adaptive strategies, compliance or resistance to policies, or social learning and therefore social resilience in the face of land use change (Leemans et al, 2003 and Indian et al, 2001).

2.5 Situation of land use and forest cover change in Laos

During the last decades of the twentieth century, the loss of forest land in Lao PDR rapidly increased due to various land-use practices, such as shifting cultivation, commercial logging, commercial agriculture and tree plantation. According to the results of the last reconnaissance survey of forest cover in 2002, the total land area of Lao PDR covered by natural forest (canopy density of higher than 20 percent and height of above 5 meters) was 9,824,700 hectares or roughly 41.5 percent of the total land area, while the dry lands (lowland dry dipterocarp forest) covered approximately

1,317,200 hectares or 13.88 percent of the total land area; almost all of this land area is located in the central and southern parts of the country (MAF, 1998).

In 1982, forest cover was 11, 636, 900 hectares or about 49 percent, in 1992 it was 11,168 000 hectares or 47 percent and in 2002 it was 9,824,700 ha or 41.5 percent. This shows a rapid decrease from 1992 to 2002 by 1,343,300 hectares or about 5.5 percent, while from 1982 to 1992 the decrease was only 468,900 hectares or about 2 percent. The area of dry dipterocarp forest increased from 1,235,100 hectares in 1982 to 1,317,200 hectares in 2002 generated mostly by unsustainable harvesting or commercial logging. It is planned to assess forest cover and land use from 2002 to 2012, which will reveal the current change of land use throughout the country. But it can be assumed that the area of dry dipterocarp forest will have been reduced due to the active conversion of this land category into commercial tree plantations (eucalyptus, acacia, rubber, etc) and agricultural crops production (sugarcane, cassava, corn etc) which is attributable to liberalized economic investment. Land degradation assessment in dry lands in Lao PDR is urgently needed (MAF 1998).

2.6 The causal factors of land use and forest cover change in Laos

Understanding the drivers of land use and land cover change is a complex issue. The causes attributed to land use change are multivariate in nature interrelated and differentiated at local, national as well as regional scale. The drivers of tropical deforestation are complex socio-economic processes. (Lambin et al, 2003) explained the underlying forces of deforestation that underpin the more obvious or proximate causes of tropical deforestation. In terms of spatial scale, underlying drivers may operate directly at local level or indirectly from the national or global level.

2.6.1 Population pressures

Rising of population in Southeast Asia as well as in the country in 1990 Lao PDR has total population 4,023,726 people with the growth rate 2.2% population density was 19 per square kilometre. In 2000 population was 5,497,459 people the growth rate is about 2.5%, density is about 25 people per square kilometre and population in 2010 is about 6,368,162 people with the growth rate about 1.7% and density is 27 people per square kilometre that is often cited as the most important cause of deforestation. This is due to the increase number of rural families seeking land to cultivate, fuel wood and timber. There are also increased demand for agricultural and forest products. Population increases also induce technological or institutional change (MAF and NAFRI, 2005).

2.6.2 Improvement of infrastructure and utilities network

The provision of infrastructure in the Lao PDR includes transportation, telecommunication, postal, electricity, water supply, sewerage and gas pipeline. It is also very necessary for the Lao government to expand infrastructure network into rural areas to allow progress into these areas. In fulfilling such a need for excellent road network requirement, extensive corridors need to be provided. In most cases, their road construct through tropical forests that have been allowed to be converted. Besides the above factors, there are many other driving forces of land use change.

Other factors that cause land use and land cover change include land settlement scheme, large scale commercial agriculture, commercial logging, hydropower and dam construction (MAF, 2005).

2.6.3 Commercialization of agricultural production

Raintree and Soydara (2002) described that the upland farming system in Laos was based on long history of extensive land including shifting cultivation practices due to low population density. The upland farming systems in Laos is also characterized for its high dependency on forest resources and its diversified activities. However, over the last decades, improved economic relations with neighboring countries and infrastructure development have been rapidly integrating rural communities into market economy and influencing the farming systems. There are greater pressures on commercially valuable forest resources and increased competition for agricultural land as more farmers are becoming engaged in commercial agricultural production. Commercialization of upland agriculture is also supported by government of Laos as an alternative to shifting cultivation practice, which has long been blamed as the source of forest destruction and a way to alleviate rural poverty particularly in upland areas (MAF and NAFRI, 2005).

2.6.4 Land tenure

The Lao land titling program was developed in the mid 1990s through the Land and Forest Allocation Program (LFAP) is to cover the entire country. Land reforms and titling had no effects on increasing productivity or food security

(Vandergeest, 2003) and were sometimes directly connected to impoverishment of rural farmers. The concept of permanent agriculture was based on lowland notions and uses of space. Paddy cultivation, gardens, orchards and plantations were acknowledged as the only land uses that deserve titling (Lao Consulting Group, 2002). Swidden techniques, foraging activities, hunting and gathering and cattle grazing were either underestimated or simply ignored. This is crucial to bear in mind since "the Land Allocation Program issues temporary land use certificates to upland farms only if they meet the 'permanent' criteria of land uses" (ADB 2001). In other words, upland swidden farmers had no choice but to comply with the reforms and change their entire livelihood system if they wished to be granted temporary land use certificates. Meanwhile, in order to grow enough rice, many villagers were forced to travel to remote areas or old village sites to practice swidden farming in old abandoned fallows or forested areas that remained unnoticed by inaccessible to officials. Such poor implementation was not in accord with policy objectives and has induced severe hardship for the affected swidden farmers (ADB, 2001). The most negative effects were the creation of a new land sale market (Aubertin, 2002) and the ways in which the reforms redefined the meaning and control of space sometimes forcing local people to be displaced. "The displacement impacts of the new land tenure reform policies are largely due to the way in which the policies reinforce this reorganization of space" In many ways the land reform is a program that incorporates various grassroots developments and community based management ideas through improved tenure security and formal recognition of village forests (Vandergeest, 2003).

2.6.5 Contract farming

One of the main driving forces of rapid expansion of commercial agriculture is improved trade relationship with neighboring countries and increased flow of investment from countries such as China. Since the early 1990s trade relations with neighboring countries, particularly China and Thailand increased the flow of investment and goods from neighboring countries into northern Laos. The contract farming emerged when the regional border with China was opened in 1992. The first wave of contract farming began with rice production in the lowland areas as Chinese companies brought hybrid rice varieties to the local farmers. Incurring Chinese investment also promoted intensive use of lowland fields as the Chinese farmers and investors sought land to cultivate vegetables and watermelons during the dry season. By mid 1990s, contract farming for sugarcane rapidly expanded in the upland areas of the northern part of Laos as the Chinese sugar processing companies signed contracts with local villagers. However, contracts with Chinese investors were usually informal often without written form (Lyttleton et al, 2004).

2.6.6 Government policy

Lao government recently has responded to this issue. Officials have attempted to catch up with this destruction. Numerous of decrees and regulations were issued in the past decades, this included the Land and Forest Allocation Decree (LFA), which is considered as a significant national policy method that aims to arrest the rate of deforestation, as well as to maintain the environment and welfare of local people for the present and in the future.

In recent years, development in the forestry sector has emphasized conservation, land use planning, and resource tenure. These three aspects of forest management are not easily separated. At the present time, according to government policy, the land allocation system is a tool to stabilize shifting cultivation in order to conserve forest areas. However, after land has been allocated to communities, there is no proper land use planning made at the community level, which has led to a situation where some villagers have tended to return to forest area. Therefore, land tenure and land use planning play important roles in supporting the government policy on land allocation.

Natural resources utilization is one of the most important issue that government has paid more attention to, thus in 1993, decree No. 169/PM of Laos Government was issued entitling “the Management and the Use of Forest and Forestland”. After the decree had been made, various committee and organization were set up in order to implement the decree with different translation and procedures which mainly based on actual suitable condition of the localities (MAF, 1998).

2.7 Impacts of land use and forestland cover change

Land use change can be defined as a change of an existing land use category or a change in the intensity of an existing land use (Turner and Meyer, 1994). While population pressure is often claimed as the source of resource deprivation and environmental destruction, land use change is caused by a range of factors that are both direct and indirect factors (Lambin et al, 2003). In particular, it is important to consider the power relationship and institutional factors that affect decision making on land and resource management, and the choice of development as they bear impact on local resources (Blaikie, 1985). The changing land use is also a part of agrarian transformation as farmers in rural areas adapt their farming practices and reallocate resources for agricultural production (Hayami and Kikuchi, 1981).

Land use change, especially the conversion of forest to other uses, has been associated with environmental degradation issues that have directly increased the real cost of development. The most important impact caused by rapid paced land use configuration is the distribution, abundance of plant and animal population. Comprehensive records of potential loss of biodiversity has been estimated at a loss of between 15,000 and 50,000 species per year (Manokaran, 1993).

2.8 Classification using remote sensing

Spectral resolution is the size and number of wavelengths, intervals, or divisions of the spectrum that a system is able to detect. Fine spectral resolution generally means that it is possible to resolve a large number of similarly sized wavelengths, as well as to detect radiation from a variety of regions of the spectrum (Engineering manual, 2003). Digital sensors record the intensity of electromagnetic radiation (ER) from each spot viewed on the Earth's surface as a digital number (DN) for each spectral band. The exact range of DN that a sensor utilizes depends on its radiometric resolution. For example, a sensor such as Landsat MSS measures radiation on a 0-63 DN scale whilst Landsat TM measures it on a 0-255 scale.

According to the Modified UNESCO Classifications scheme, there are only about 157 different land cover types and no study site will have all of those different land cover types (GLOBE toolkit, 2003). Hence, it will be necessary to group pixels together into a smaller number of closely related "classes", based on spectral similarity. This is done in a process known as “Classification”. There are two major approaches of classification of remotely sensed images for various applications.

In a supervised classification, the software is “trained" to recognize that certain types of pixels represent specific land cover types. Knowledge of the area and information collected during field work are important inputs, which are used by the software to classify the pixels into similar groups based on sample signatures specified.

In an unsupervised classification or "clustering", the desired number of groups, or "clusters", will be inputs to the software (GLOBE toolkit, 2003). The software then groups the pixels according to similar spectral characteristics in order of decreasing brightness. These groupings are not made on the basis of land cover, but on the similarity in spectral characteristics of the pixels. It is also common to come across a third approach known to be hybrid classification that combines both supervised and unsupervised classification techniques.

2.9 Application of remote sensing and geographic information system for land use change

Remote sensing and geographic information system are land-related and therefore are very useful in the formulation, implementation and monitoring land development in the move towards sustainable development strategy detection (Yeh and Li, 1997). Geographic information system is a systematic process of spatial data collection and processing. It can be used to study the environment by observing and assessing the changes and forecasting the future based on the existing situation (Ramachandra and Kumar, 2004). Remote sensing on the other hand is the process of data acquisition through space or air borne sensors without having any contact with the target objects. It allows the acquisition of multispectral, multi resolution and multi temporal data for the land use change analysis and modeling. Both remote sensing and geographic information system tools have been applied in a number of land use change studies to detect, monitor and simulate land use changes. Because of their cost effectiveness and temporal frequency, remote sensing approaches are widely used for change detection analysis. It has also great potential for the acquisition of detailed and accurate surface information for managing and planning urban regions (Herold et al, 2002). However, computer assisted production of spatially detailed and thematically accurate land use and land cover information from satellite image continues to be a challenge for the remote sensing research community (Civco et al, 2002).

This is due to the heterogeneous nature of land use change which makes discriminating land cover classes difficult. It could also be due to the absence of appropriate classification techniques. However, recent advances in geographic information system and remote sensing tools and methods have enabled researchers to analyze and detect the dynamic nature of land use features in a more efficient way. Some recent researches have also been directed toward quantitatively describing the spatial structure of land use change and characterizing patterns of urban structure through the use of remotely sensed data (Herold et al, 2002).

There is significant variation between various sensor instruments' capability and wealth of information captured and also the applicability depends on the objective of the intended study. There is also clear variation in the spatial and spectral properties of satellite images acquired by different versions of a particular sensor instrument. Landsat instruments can be taken as a good example of showing continuous improvement in radiometric and spectral property of images enabling better understanding of land resources.

Since 1972, the Landsat satellites have provided repetitive, synoptic, global coverage of high resolution multispectral imagery. Their long history and reliability have made them a popular source for documenting changes in land cover and use over time and their evolution is further marked by the launch of Landsat 7 by the US government in 1999. Multispectral Scanner (MSS) data from the U.S. Geological Survey's (USGS) EROS Data Center has provided a historical record of the Earth's land surface from the early 1970s to the early 1990s. The MSS and TM sensors primarily detected reflected radiation from the Earth's surface in the visible and IR wavelengths, but the TM sensor provides more radiometric information than the MSS sensor (GLOBE toolkit, 2003)

The wavelength range for the TM sensor is from the visible (blue), through the mid-IR, into the thermal-IR portion of the electromagnetic spectrum and it has a spatial resolution of 30 meters for the visible, near-IR, and mid-IR wavelengths and a spatial resolution of 120 meters for the thermal-IR band. Each pixel of Landsat TM images contains a wealth of information about the surface materials that reflect light from that pixel to the satellite sensors. Each band in a TM image represents a separate piece of data whose value ranges from 0 to 255 enabling the whole image to contain 2565 (approximately 1.1 billion) different possible spectral combinations. However, it does not mean that each one of these combinations represents a different type of land cover and most of these variations represent very small "un seeable" differences in surface reflectance. ETM+ instrument measures upwelling radiance in the same seven bands as the TM, and has an additional 15 m resolution panchromatic band (Mather, 2004). The spatial resolution of the thermal infrared channel is 60 m rather than the 120 m of the TM thermal band and this instrument has substantially the same operational characteristics as Landsat4 and Landsat5.

The characteristics of the MSS and TM bands were selected to maximize each band's capabilities for detecting and monitoring different types of land surface cover characteristics. For example, MSS band 1 can be used to detect green reflectance from healthy vegetation, while MSS band 2 is designed for detecting chlorophyll absorption in vegetation. MSS bands 3 and 4 are ideal for recording near-IR reflectance peaks in healthy green vegetation and for detecting water land interfaces. MSS Bands 4, 2, and 1 can be combined to make false color composite images, where band 4 controls the amount of red, band 2 the amount of green, and band 1 the amount of blue in the composite. This band combination makes vegetation appear as shades of red with brighter reds indicating more vigorously growing vegetation. Soils with sparse or no vegetation will range from white (sand) to green or brown, depending on moisture and organic matter content. Water appears dark blue to black in color, while sediment-laden or shallow waters appear lighter in color. Urban areas appear blue-gray in color.

2.10 Approaches in image classification

Remote sensing change detection techniques can be broadly classified as either pre- or post-classification change methods. A pre-classification process refers to operations carried out to bring satellite images to the desirable geometric and spectral standard by correcting errors and it is performed prior to image classification. Whereas, post-classification methods refers to activities done after classification of images like computation of class statistics, accuracy assessment and map preparation. Pre-classification methods can further be characterized as being spectral or phenology based. Originally, the post-classification approach was considered to be the most reliable approach and was used to evaluate emerging methods (Weismiller et al, 1977). Factors that limit the application of post-classification change detection techniques include cost, consistency and error propagation (Singh, 1989). Numerous pre-classification change detection approaches have been developed and refined to provide optimal performance over the greatest possible range of ecosystem conditions (Lunetta et al, 2006).

The satellite instruments employed some decades ago provided images with coarse resolution. With advancement in remote sensing science, various sensor instruments with improved radiometric, temporal and spatial resolution were being developed. Hence, this allowed the integration of satellite images acquired by various sensor types in order to better understand land resources dynamics. The use of data from different sensors poses a serious challenge to many change analyses, which can be addressed through use of post-classification comparisons (EPA, 1999).

2.11 Approaches in land use change detection

Research evaluating the comparative performance of various land cover change detection methods has indicated that no uniform combination of data types and methods can be applied with equal success across different ecosystems (Lu et al, 2004). Despite this, the two general approaches to change detection are comparative analysis of independently produced classifications and simultaneous analysis of multi-temporal data. Examples of the simultaneous analysis techniques include image differencing, ratioing, principal component analysis (PCA) and change vector analysis (Singh, 1989). The first approach is straightforward and employs independently classified images being converted to same projections and it has the advantage that it allows compensating for variations in atmospheric and phenological conditions. The method has been criticized as it tends to compound errors that may have occurred in the two initial classifications (Singh, 1989; EPA, 1999).

On the other hand, simple image differencing is a widely used technique that involves taking the mathematical difference between geo-registered images from two dates (EPA, 1999). Even if the method has often been reported to produce excellent results, it has been suggested that image differencing alone may be too simple a procedure to adequately describe many surface changes (Weismiller et al, 1977; EPA, 1999).

A major attribute of the landscape is its spatial pattern and structure. It is shown that the detection of land cover change processes by remote sensing is improved when both spectral and spatial indicators of surface condition like slope and topography are used (Lambin and Strahler, 1994). It is further suggested by this author that spectral indicators are more sensitive to fluctuations in primary productivity associated with the inter-annual variability in climatic conditions. Temporal aspects of natural phenomena are important for image interpretation because such factors as vegetation growth and soil moisture vary during the year and more positive results can be achieved by obtaining images at several times during the annual growing cycle (Lillesand and Kieffer, 2004). Furthermore, changes in landscape spatial pattern are more likely to reveal long term and long lasting land cover changes.

Following image classification as part of the change detection process, accuracy needs to be assessed to evaluate the degree of acceptability of the classification process. A standard accuracy assessment procedure for baseline land cover products involves the use of the error matrix (EPA, 1999) and the standard procedure for one-point-in-time land cover products can be extremely difficult to apply to multi-temporal change analysis products (EPA, 1999). The methods are well established for small areas and single time periods. However, the assessment of accuracies for large areas, past time periods, and change databases can become problematic as it will be difficult to acquire an adequate database of historical reference materials. Accordingly, accuracy assessments are usually limited to the very recent image that serves as a reference using ground control points (GCPs).