CHAPTER II

LITERATURE REVIEWS

2.1 CRITERIA AND INDICATORS

2.1.1 Conceptual framework

Generally in sustainable forest management, criteria are clearly specified elements that define the scope and key output of sustainable forest management (SFM). They reflect a series of ecological, economic and social aspects of forest in question. Indicators provide measurable components of the criteria. Several indicators are specified for each criterion and can be monitored to examine changes over time.

C&I literally mean to criteria and indicators, but practically it defines a hierarchy that is composed of 3 main conceptual levels constituting the C&I framework. The hierarchy of C&I in this study is categorized into 3 categories: principles, criteria, and indicators (Prabhu et al., 1996; International Tropical Timber Organization [ITTO], 1998; Mendoza et al., 1999; Ritchie et al., 2000) (Figure 2.1).

Principles

Principles define fundamental truths or laws as the basis of reasoning or action. Principles in the context of sustainable forest management are seen as the primary framework for management. They refer to functions of the forest ecosystem or to relevant aspects of the social system that interacts with the forest ecosystem. They provide the justification for criteria, indicators and verifiers.

Criteria

Criteria are defined as standards by which the progress towards meeting the principle can be judged. A criterion describes a state or situation that should be met to comply with the management objectives. They act as subjects of intention which defines the particular state or condition of forest. Groups of criteria can support each principle which they belong to.

Indicators

Indicators are the components or variables of the forest or management system that indicate the state or conditions required by a criterion. They give the information or meaningful messages which made up from one or more data elements. Moreover, these characteristic of indicators are fitting with the useful definition of ecosystem indicators (Landres, 1992) which is described as "*an indicator is any variable or component of the forest ecosystem or the relevant management systems used to infer attributes of the sustainability of the resource and its utilization*". The indicators in this study have been theoretical identified and formulated so that a change in any one of them would give information that is both necessary and significant in assessing the forest ecosystem integrity. They are also ecologically meaningful, practical and easy to monitor, and are based on the possibility of research knowledge and statistics. They provide information that enhances the specificity or the ease of assessment of a criterion which they belong to. That mean they reflect meaning, precision and desired condition of a criterion.

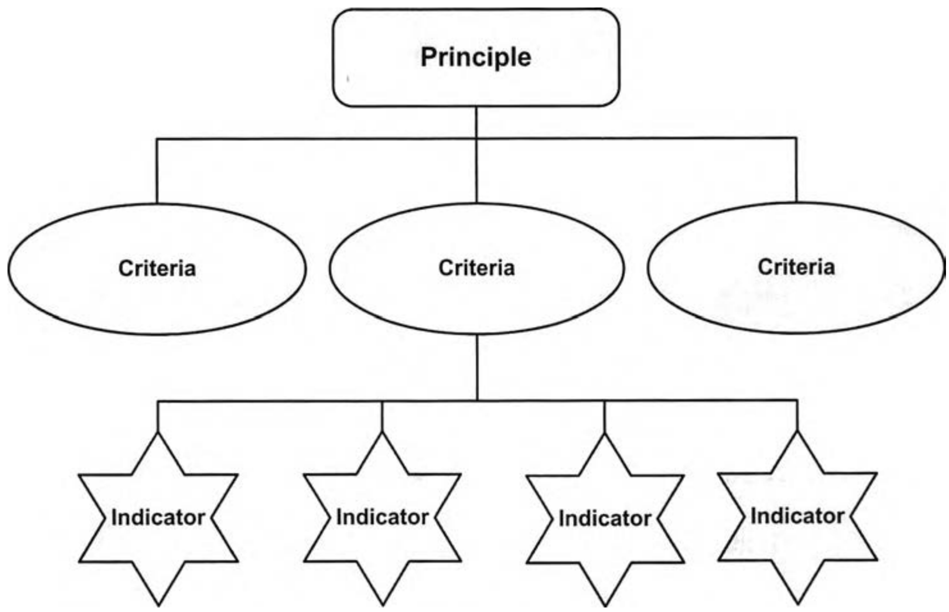

Figure 2.1 Framework of criteria and indicators

2.1.2 The Initiatives related to criteria and indicators

During the decade following the United Nation Conference on Environment and Development in 1992 (UNCED), there has been a worldwide consensus that the progress toward sustainable forest management can be assessed using a framework of C&I. While the C&I framework may not be the only mechanism for monitoring and assessing on sustainable forest management, it is the only one that has so far been widely accepted and is being used by many countries (Food and Agriculture Organization of the United Nations [FAO], 2001a).

In 1990, the first guideline for sustainable forest management of natural tropical forests was introduced by ITTO and the manual for the application of C&I of natural forest at forest management unit was published (ITTO, 1999). Since the first introduction of C&I, several C&I processes have been developed specifically for their respective eco-region and/or forest policy framework. The information of major processes was summarized in Table 2.1.

The C&I processes are similar in objectives and approaches but differ in content and structure. Many of conferences and meetings include international organization, international governmental and non-governmental organization effort to streamlining and developing C&I at national level, only a few developed for forest management unit (e.g., ITTO, Tarapoto Proposal, FSC, CIFOR, etc.). The criteria corresponding fairly closely to the same following fundamental key elements of sustainable forest management:

- Extent of forest resources;
- Biological diversity;
- Forest health and vitality;
- Productive functions of forests;
- Protective functions of forests;
- Socio-economic benefits and needs;
- Legal, policy and institutional framework.

Table 2.1: Summary of major criteria and indicators processes/initiatives

Processes	No. of criteria	No. of indicators	Date of Adoption	Applicability			Basis objectives		Region/Forest types
				Regional	National	Forest management unit	Report toward SFM	Accredit SFM certifiers	
ITTO Initiative on Criteria and Indicators	7	66	1992		√	√	√		Humid tropical forests
Montreal Process	7	67	1993	√	√		√		Temperate and boreal forests
Pan-Eurupean Forest Process	6	138	1993		√	√	√		Boreal, temperate and Mediterranean forests
African Timber Organization	28	60	1993	√	√		√		West and Central Africa
Dry-Zone Africa Process	7	47	1995		√		√		North, East and southern Africa
Tarapoto Proposal	12	76	1995	√	√	√	√		Amazon forests
Near East Process	7	65	1996	√	√		√		Near East
Lepaterique Process of Central America	12	93	1997		√	√	√		Central America
Regional Initiative for Dry Forests Asia	8	49	1999		√		√		South and Central Asia
Forest Stewardship Council: FSC	10	56	1994	√		√		√	All types of forests
Center for International Forestry Research: CIFOR	24	98	1995		√	√	√		All types of forests

Source: Modified from FAO, 2001b; and Castañeda, (2000).

While there was no globally agreement set of indicators for those criteria, development of indicators would facilitate national policy and reflect differences in priorities, conditions and ecosystem types. The indicators for any given criterion may vary among regional, national and forest management unit. That means at different management level, national and local, C&I was also different. Broad scale C&I (national level) is being complemented by the development of site-specifics C&I (forest management unit level) or vice versa. Forest management unit level C&I may thus differ among individual forests areas in any country, as well as over time, depending on condition, priority and goal of management of given forest area (Castañeda, 2000).

2.1.3 Key elements for developing criteria and indicators

Pettersen (2001) proposed that C&I that are nominated for monitoring and assessing toward sustainable forest management should be characterized with the following key elements:

- Understandability
  Indicators need to be easily understood by user without special knowledge and should have broad applicability and clear relevance to objectives. Complex indicators are likely to be rejected by public.
- Cost-effectiveness and timeliness
  C&I need to be collected in a cost effective manner and on a regular basis consistent with the rate at which the indicator is expected to change. It is unlikely that C&I that are costly to monitor will persist in the long term and it should also be monitored in reasonable timeframe.
- Measurability
  Qualitative or descriptive C&I are less reliable in determination. The cardinal or quantitative C&I is more preferable than the ordinal or qualitative C&I as they can be used to rank the value of indicators according to the changing of environment or time.

- Reliability

  Indicators should provide a convincing demonstration of the degree to which objectives are being met. They should be based on the observation and defensible database.

- Sensitivity

  C&I should change as condition change. Practical and confidently sensitive C&I have value in reflecting the state/progress of sustainable forest management.

- Independence

  Different C&I should measure different outcomes. Interdependent C&I are difficult to interpret. The relationship among them should clearly understand.

- Scope

  The broader scope/applicability (e.g., geographic scope) of C&I, the greater degree to which comparison made to contribute to national /management unit level reporting. Where the scope only applies to specific forest area or attributes, efforts should be made to seek relationships with more broadly defined indicators.

- Contribute to forest policy

  Appropriate C&I should be facilitating their result in streamlining appropriate forest policy.

- Scale

  C&I should be properly developed to suit the scale which they are being applied (*i.e.* national, regional, and local).

2.2 Theoretical concept of ecological integrity

Theoretical definitions of integrity are including those of Cairns (1977): "the maintenance of the community structure and function characteristic of a particular locale deemed satisfactory to society", and Karr and Dudley (1981): "the capability of supporting and maintaining a balanced, integrated, adaptive, community of organisms having species composition, diversity, and functional organization comparable to that of natural habitats of the region". Ecological integrity concept is inevitably corresponding with health of ecosystem. A healthy ecosystem is the system that free from distress syndrome and maintain its organization (stability and sustainability) and autonomy over time and is resilient to stress (Costanza et al., 1992 Andreasen et al., 2001).

An overall concepts of sustainability focuses on maintaining ecosystems and their components and processes in a way that they continue to provide goods and services to human need. Generally, forests are renewable resources which we can harvest with justifiable expectations that, within an acceptable time frame, forests can provide their products and other values. However, there are many forests being harvested today that cannot be legitimately considered to be renewable. According to this perception, ecological rotation (ecological succession) plays a major role in sustainability (Kimmins, 1996). Stability can be defined by many kinds of ecological variables such as population size and the biomass of species or a focal group of species (Pimm, 1999). The stability of a system is a measure of its sensitivity to disturbance or perturbation. Stability reflects the ability of a system to return to the equilibrium after a disturbance. The actual return to the equilibrium state depends in part on external pressures placed on the system, but the degree of stability is an intrinsic property of the system itself. Resilience is a measure of the ability of a system to absorb changes which in turn reflect to the speed with which the system returns to it former state after it has been perturbed and displaced from that state (Begon et al., 1996). With the presence of many different of functional group species, the stability ecosystem ability to maintain its strucrture and function when face of disturbance and whereas the resilience ecosystem could recover from disturbance (Odum, 1996; Ludwig, Walker, Holling, 1997; Peterson, Allen, and Holling, 1998). The ecosystem that has high integrity could be resistant to environmental change and will rapidly recover after the perturbation.

The concepts of ecological integrity have been widely accepted as an important key for natural resources management and environmental protection. It is a fundamental of Clean Water Act which is used by the U.S Environmental Protection Agency (EPA) as for environmental quality. Many of indices have been developed, tested and widely used, but most of them are indices of biotic integrity (IBI) (Andreasen et al., 2001). Karr's IBI, a well-known index, was applied to aquatic community (Karr and Chu, 1999 cited in Andreasen et al., 2001).

As a fundamental concept in ecology, ecosystem attributes represent 5 attributes that corresponding to the ecological integrity concept (Kimmins, 1996). There are:

1. **Structure**. Ecosystem comprises of biotic and abiotic components. Biotic components are autotrophic stratum that means mostly to producer in the trophic structure and heterotrophic stratum that means to consumer and decomposer in the trophic structure. Abiotic components are energy (e.g., solar energy, heat), matters (e.g., organics, inorganic), and environmental factors (e.g., climate, edaphic, topographic) which important to the mechanism of ecosystem components (Odum, 1983; Gajaseni, 1997). Terrestrial ecosystem, for example, consists of complexes of plant and animal organism together with abiotic components such as soil and atmosphere which regulate biotic components and vice versa (Kutintara, 1999).
2. **Function**. The exchange of energy and matters between abiotic components and living components. Both abiotic and biotic are composed of energy and matters which express in term of physical-chemical entity. Within this entity, energy and matters are exchange between different components which some are the characteristic of life but some are not. Function of ecosystem are mostly involved in 3 processes that are production process results from working process of ecosystem components (emergent property), transformation process which transfer the productivity to the heterotrophic stratum under the interaction of ecosystem components, and recycling process which is the most important in sustaining the system in term of recycling the matter back into the system (e.g., weathering, decomposing) (Gajaseni, 1997).
3. **Complexity**. Ecosystem composes of different hierarchy from the smallest unit (species) to the biggest unit (community). Complexity is the results of high level of biological integration of ecosystem which also referred to complexity of structure and function redundancy. However, high complexity system has the more efficiency to control its inner mechanisms than low complexity system, but complexity are not positive relevant to stability of system (Gajaseni, 1997).

4. **Interaction and interdependency**. Ecosystem components, variables of both biotic and abiotic, are interconnected and interacting. Therefore, the changes of any components, positive or negative, are subsequently changed in almost all other.
5. **Temporal change**. Ecosystems are dynamic. There are continuous exchange of energy and matter, and the state (structure and function) undergoes change over time.

The changing of ecosystem due to disturbance or stress could be identified by signs of its response. Most of those signs are involve in nutrients cycle, productivity, trophic structure, change in species abundance, etc. (Gajaseni, 1997). Effects of environmental stresses will be expressed in different way in different levels of ecological organization. The signs or indicators representing ecosystem normality or health of ecosystem should be corresponded to the hierarchy of organization. Costanza (1992, 1999) mentioned that the responses of ecosystem to disturbance are involved in: processes of metabolism and function of the system (system vigor); the hierarchy of organizations and their interdependent (system organization); and reconstruction after undergo disturbance force (system resilience).

To manage an ecosystem, the ecosystem attributes that mentioned above are still not clear regarding what exactly should be of concern in any of ecosystem attributes when ecosystem experiences disturbances or stress. Thus, another interesting conceptualizes framework of ecological attributes fall into a perspective of biodiversity. Biodiversity is often described at 3 fundamental levels: ecosystem diversity, species diversity, and genetic diversity (Norse et al., 1986; Office of Technology Assessment [OTA], 1987). Unfortunately, most definitions of biodiversity fail to mention processes such as inter-specific interactions, disturbances, and nutrient cycles, which play an important role in maintaining biodiversity (Noss, 1990). Simple, comprehensive, and operationally definition of biodiversity are unlikely to be found (Noss, 1990).

The characteristics of biodiversity should be classified into the major components at several level of ecosystem organization. These would be conceptual enough to identified specific and practical indicators to assessing and monitoring the status of ecosystem. The conceptual framework recognized 3 attributes of ecosystem as compositional, structural and functional attributes at genetic, population, community-ecosystem, and landscape level (Franklin et al., 1981; Noss, 1990;

Zacharias and Roff, 2000). This conceptual of biodiversity is fundamentally consistent with the definition of ecological integrity proposed by Crain (1977), and Karr and Dudley (1981). Compositional attributes include the variety of genetics of population, the composition of species, and the composition of community or ecosystem, and the spatial and temporal distribution of community/ecosystem throughout a landscape. Structural attributes include biotic and abiotic features that provide a complexity as the different pattern of habitat or patches at different levels of ecosystem organization. Functional attributes involve the processes, ecological and evolution, including environmental regime (climatic, hydrologic, and geologic), gene flow and nutrient cycling (Zacharias and Roff, 2000). In addition, all 3 attributes are interdependent and higher level of organization incorporate and constrain the behavior of lower level (O'Neill et al., 1986). Even the higher levels (landscape) are important but the lower levels (species) contain the basis mechanism for wheeling many higher levels. Thus, monitoring and assessing should be conducted at multiple levels of ecosystem organization and at multiple levels of spatial and temporal scales. Moreover, Noss (1990) proposed indicators variables that gathered from various literatures for inventorying, monitoring, and assessing corresponding to the compositional, structural, and functional attributes at multilevel of ecological organization as showed in Table 2.2.

Table 2.2: Ecological hierarchy and key characteristics

Level / Elements	Composition	Structure	Function	Inventory level/tools
Genetic	Allelic diversity; presence of particular rare alleles, deleterious recessives or karyotypic variants	Population size; heterozygosity; chromosomal or phenotypic polymorphism; generation over lap; heritability	Inbreeding depression; out breeding rate; rate of genetic drift; gene flow; mutation rate; selection intensity	Elctrophoresis; DNA sequencing; offspring-parent regression; sib analysis; morphological analysis
Population/Species	Absolute or relative abundance; frequency importance; cover value; biomass; density	Dispersion range, population structure; habitat variables; individual morphological variability	Demographic processes (growth rate, mortality rate, recruitment); population fluctuation; physiology; life history, phenology, acclimation; adaptation	Censuses (observation, counts, capture, radio tracking); remote sensing; habitat suitability index; species-habitat modeling; population viability analysis
Community/Ecosystem	Identity, relative abundance, frequency, richness, evenness, and diversity of species and guilds; presence and proportion of focal species; dominance-diversity curves; life form distributions; similarity coefficients; C4-C3 plant ratio	Substrate and soil variables; slope and aspect; vegetation biomass; foliage density and layering; horizontal patchiness; canopy openness and gap proportions; abundance, density, and distribution of key physical features; structural elements; water and resources availability	Biomass and resource productivity; herbivory, parasitism, and predation rate; colonization and local extinction rate; patch dynamics, nutrient cycling rate; human intrusion rate and intensities	Aerial photographs and remote sensing data; ground-level photo station; time series analysis; physical habitat measures and resource inventories; censuses; mathematical indices (diversity, layering, dispersion)
Landscape/Region	Identity, distribution, richness, and proportion of patch (habitat) types; collective pattern of species distributions	Heterogeneity; connectivity; spatial linkage; patchiness; porosity; contrast; grain size; fragmentation; configuration; patch size; frequency distribution; perimeter-area ratio; pattern of habitat layer distribution	Disturbance processes (areal extent, frequency or return interval, rotation period, intensity, severity); rates of nutrient cycling, energy flow, and erosion; patch persistence and turn over rates geographic and hydrologic processes; human disturbance trend	Arial photograph (satellite) and remote sensing data; GIS; mathematical indices (patterns, connectivity, layering, edge, morphology, autocorrelation, fractal dimension)

Source: Noss, (1990).

As conceptual framework of ecosystem integrity, to assess and monitor forest ecosystem integrity, goals should be focus on forest ecosystem structures, functions/processes attributes within the range of variation characteristic of the disturbance regime. Ecology plays an important role to develop the understanding of those issues and to identify the range of variation of key processes within which a variety of management objectives may be pursued. The conservation of forest ecosystem integrity is a necessary condition for sustainable management of the forest. Forest ecosystems management develops and applies understanding of how forest ecosystems maintain and sustain themselves over the long period of time. Integrity and functions of ecosystem could be measured via the following aspects the energy balance, the water balance, and the matter balance (Müller and Wiggering, 1999). Structure of ecosystem could be indicated via variation of patch size, habitat fragmentation and connectivity of landscape (Riitters et al., 1995). Direct and indirect indicators such as decomposition, soil properties and the ecosystem processes, biogeochemical and hydrological, could be used to represent the function of ecosystem (Syer et al., 1994). De Leo and Levin (1997) suggested that for assessment of ecological integrity relevant to disturbances, some of the macro-level indicators such as primary productivity or other measures of energy and matter flow could be use for determining the resilience and stability of ecosystem.

As following Noss (1990), Dale and Beyeler (2001) stated that a suite of ecological indicators should be representing the key characteristics of ecological hierarchy under the following aspects; structure, function and composition of ecosystems. They categorized of ecological integrity components as organism, species, population, ecosystem and landscape and suggested the suitable indicators as displayed in Table 2.3. An ecological integrity approach should maintain key ecosystem characteristics of forest; conserve native biodiversity characteristic of forest and manage human disturbance (Alberta Forest Conservation Strategy [AFCS], 1997).

Thus, the compositional, structural, functional attributes and, as well as, disturbance play a major role that underlie the ecosystem integrity (Franklin et al., 1981; Norse et al., 1986; Office of Technology Assessment [OTA], 1987; Noss, 1990; Müller, Hoffmann-Kroll, and Wiggering, 2000; The nature Conservancy [TNC], 2000; Zacharias and Roff, 2000; Oliver, 2002).

Table 2.3: The categories of ecological integrity components and suggested indicators

Hierarchy	Processes	Indicators
Organism	Environmental toxicity	Physical deformation
	Mutagenesis	Lesions
		Parasite load
Species	Range expansion or contraction	Range size
	Extinction	Number of population
Population	Abundance fluctuation	Age or size structure
	Colonization or extinction	Dispersal behaviour
Ecosystem	Competitive exclusion	Species richness
	Predation or paratism	Species evenness
	Energy flow	Number of trophic levels
Landscape	Disturbance	Fragmentation
	Succession	Spatial distribution of communities
		Persistence of habitats

Source: Modified from Dale and Beyeler, (2001).

2.3 Human interventions and ecological hierarchy of forest ecosystem at forest management unit

In the context of forest management unit, in this study aiming at cultural forest, intervention means all kind activities that occurred in forest area, not including large-scale conversion to other land use (Prabhu et al, 1996). There are many different types of intervention taking place in cultural forest since the intense activities such as selective logging and charcoal making to common activities such as collecting of non-timber forest products (NTFPs). Roads or walking trails have been established for finding NTFPs and used as a shortcut to go to rice field. As the forest areas are usually surrounded by communal cropland, man-made fires often occur. The impacts of these interventions are different in accord with the processes of each ecosystem hierarchy (Table 2.4).

Collecting NTFPs is a significantly common intervention by local people in cultural forest of Northeastern Thailand. NTFPs could be distinguished into 3 types: reproductive structures (fruits, seeds, and flowers), non-reproductive structures (leaf, bark, branches, latex, firewood), and whole individuals (hunting small mammals, lizards, amphibians, insects) (Stork et al., 1997). The impacts of these activities are affecting to habitat and population levels of forest ecological integrity components (Table 2.5).

Table 2.4: Human interventions and impacted processes of each categories of forest ecosystem

Interventions	Landscape level		Habitat level				Species level
	Natural disturbance	Dispersion	Regeneration	Local extinction	Ecosystem processes	Trophic dynamics	Reproduction
Selective logging	▲	▲	▲	▼	▲	▼	▼
Grazing			▲	▼	▼	▼	▼
Fire			▲	▼	▼		
Harvesting non-timber forest products (NTFPs)							
Reproductive structure			▼	▼		▼	▲
Non-reproductive structure							▲
Whole individual				▼			▲
Agriculture	▲	▲			▲		
Roads	▼	▲	▼				
Enrichment planting			▲			▼	▼

Source: Stork et al., (1997).
▲ Severe impacts
▼ Small impacts

Table 2.5 Components of forest ecosystem integrity and processes that are affected by human interventions

Intervention / Indicators	Landscape pattern	Habitat diversity	Guild Structure	Taxic richness	Population structure	Nutrient cycling Decomposition	Water quality/ quantity
Fire		✓	✓	✓	✓		
Harvesting non-timber forest products (NTFPs)							
Reproductive structure		✓			✓		
Non-reproductive structure		✓			✓		
Whole individual		✓			✓		
Agriculture	✓	✓	✓		✓	✓	✓
Roads	✓	✓	✓				
Enrichment planting		✓	✓	✓	✓		

Source: Stork et al., (1997).

2.4 Characteristics of cultural forest and criteria and indicators

The Northeast is the biggest region (167,715 km^2) of Thailand (515,133 km^2) (Royal Forest Department [RFD], 2000). In the past, it was one of the most civilization regions of Southeast Asia. The location is between latitude 14° 6′ 50" N to 18° 6′ 48" N and longitude 100° 50′ 48" E to 105° 48′ 22" E. Since the inception of the first national economic and social development plan to the eighth (1961-2001), Thailand had gone through rapid economic development, however, only some urban sectors have benefited from such plan while the most of rural sectors still have been left in poverty. Around 1973-1976, almost of the Northeastern forest area was taken to the logging concession that result in rapidly diminishing forest area (Danthanin et al., 1993). Today, the Northeastern has 26,955 km^2 of forest area compare to 41,494 km^2 in 1976 (RFD, 1989, 2000). Forest areas are fragmented and scattered all over the Northeastern region. Cultural forests or community forests are one of those patchy forests. However, these patchy forests play a major role in supporting the livelihood systems of many of the poor, even highly modified or degraded landscapes. There are 19 Provinces of the Northeastern region of Thailand.

Maha Sarakham Province, the "Heartland" of the Northeastern region, is one of 19 Provinces of the Northeastern. Maha Sarakham had the lowest total forest area, 197 km^2 or 3.49% of the province area, compared to Loei Province, standing on the top rank with the highest forest area of 4,504 km^2 or 43.23% of total province area (RFD, 2000). The boundaries of Maha Sarakham Province are as the following:

To the North: Kalasin Province, and Khon Kaen Province,

To the South: Surin Province, and Burirum Province,

To the East: Roi Ed Province, and Kalasin Province, and

To the West: Khon Kaen Province, and Burirun Province.

Natural forest types in Maha Sarakham Province can be classified into 4 types. There were dry dipterocarp forest, inundated forest, dry evergreen forest, and mixed deciduous forest. The major forest type in this area is dry dipterocarp which occupied 128.54 km^2 while mixed deciduous occupied only 4.32 km^2 (Table 2.6).

Under the Forest reserved area legislation, most of the forest areas in Maha Sarakham Province are National Forest reserve area. They occupied 407 km^2 (254,321 rai) or 7.36 % of total province area (Maha Sarakham Province Forest Office, 1998).

Table 2.6 Forest types of Maha Sarakham Province

Forest type	Area (km^2)
Dry dipterocarp forest	128.54
Inundated forest	10.67
Dry evergreen forest	5.50
Mixed deciduous forest	4.32
Total	149.03

Source: RFD, (2000).

Historically, Northeastern communities established their villages close to forest area and tightly related with forests as life-supporting system and traditional ceremony. The forests are recognized as cultural forest. Currently, most of local communities are still relying on forest and settle nearby forest area (Ganjanapan, 2000).

Cultural forest, conceptually, meaning as forest management unit is generally named for community forest in the Northeastern region of Thailand. The management systems and objectives vary from livestock herding to collecting non-timber forest products. Forest management systems are often based on "*traditional or cultural, year-round, community-wide largely self-contained and ritually sanction way of life*" (Ritchie et al., 2000). Forest dependent peoples recognize their forest resources from many different perspectives. They may view as a place once inhabited by their ancestors. The forest also exists in people's memories, which are connected to name of places, myth and folklore. In addition, cultural forests are the "life supporting space" and people use that "space" for many kinds of activities such for their physical requirements, social requirement, economic requirement and spiritual requirement (Walai Rukhavej Botanical Research Institute, 1998). With the innumerable of the forests, people intend to conserve their wealthy forests and it still appears over time.

Most of cultural forests in the Northeastern region are patches of forest ecosystem and categorized as dry dipterocarp forest, mixed deciduous forest and dry evergreen forest. Almost of forest area are located in the National reserve forest and state properties, only some area are private land. Forests are highly fragmented and scattered among the village area of the Northeastern region. Several of forest areas cannot be identified under satellite image and there is no recently report of exact total areas. Almost all villages in the Northeastern region always have forest of different size. These forests and forest products constitute an integral part of daily life of local people such as natural market, ceremonial purposes as well as providing numerous products necessary for spiritual value and subsistence. There are non-timber forest products include foods, medicinal plants, firewood, fiber, tools, building materials, livestock foraging, recreation, and incentive income by selling non-timber forest products.

Cultural forest in the Northeastern region can be categorized into 7 main types. There are headwater forest, temple forest, Don Pu Ta forest, Tam Lae or public forest area, cemetery forest, school forest, and plantation forest. Although most of them are consist of small areas, they provide a variety of habitats for indigenous plants and animals. Among the cultural forest types, there are 2 forest types that play an important role in local villagers' life. The first is Don Pu Ta forest, the most pristine and sacred area that, before rice growing season, ancestor spirit will be worshipped through the annual ceremony. All villagers will be participated in this holy annual ceremony. The suggestions of prophet's leader will be stringently practiced. The second is Tum Lae forest, the most utilization area. (Walai Rukhavej Botanical Research Institute, 1998; Jumrusphan and Kunuratana, 2000). To date, community forest management has become widely accepted that it is an effective approach for forest management. There are many efforts of local organization and NGO's to push community forestry legislation into national law. Several social science research results indicated effectiveness of participation of community in community forestry (Sandewall, 1997; Karaket, 1999; Lertna, 2001; Kluenkeaw, 2000). Practically, local organizations manage their cultural forest under their own indigenous knowledge with some supporting of local universities.

Recently, cultural forests were often regarded as anachronism. This view results in the diminishing of the forest area and sometime was eradicated in some area. Anyway, recent study present of "how and why" these cultural systems are viable and valuable, and still critical to the functioning of many rural social system (Walai Rukhavej Botanical Research Institute, 1998). People, especially rural people, still depend on forest resources for their survival. Like the growing of global, national awareness of biodiversity lost and increasing carbon dioxide in atmosphere, cultural forest are increasingly motivated to claim for their "space".

There are also a growing number of communities living around forest area that could be a positive or negative effect to the forest. This, combined with the lesson learned by many governments around the world that local people cannot be forcibly keep out of the forests, clearly indicated that the need for consideration of local community as local managers in efforts for sustainable forest management. Therefore, C&I approach could be the appropriate way to achieve sustainable management of forest. C&I can be identified at various management levels: global; regional; national and forest management unit level. National level C&I have been developed to serve as the framework tools for reporting and monitoring, not as the standard with which to direct assessing sustainable forest management (Forestry Stewardship Council [FSC], 1994; Center for International Forestry Research, 1999; ITTO, 1998, 1999, 2002). On the other hand, C&I at forest management unit level have been developed for assessing sustainable forest management and, at least, as tools to facilitate the implementation of better management practices. In order to performing sustainable forest management at forest management unit level, it requires the development of site specific and field verifiable measurement which can be reflected the real situation of forest in question. As mentioned above, it is unlikely that a single set of C&I will apply as a standard for everywhere forest. C&I at forest management unit level are locally specific to the site (Prabhu et al., 1999).

Following conceptual framework of Noss (1990), literature reviews, preliminary survey at study site, and management objective of cultural forest of study site, the initial set of C&I were set up. In addition, disturbance of human activities were considered as additional aspects of ecological integrity. Thus, assessing and monitoring disturbances will continuously represent external disturbance intensity to forest ecosystem.

According to the conceptual framework of ecological integrity attributes the selection of indicators consistent with structure and composition, functional, and disturbances were described as following:

Compositional and structural attributes: This attributes are grouped according to spatial scale, landscape level, habitat level, and population level. At landscape level, forest landscape features such as patch size, heterogeneity, and connectivity play a major role in controlling of species composition and abundance as well as population viability of specific species. As these features, 9 indicators were selected. There were:

1. Areal extent of each patch/vegetation type to total forest area
2. Number of patches/vegetation type per unit area
3. Largest patch size/vegetation type
4. Number of gap
5. Largest gap size
6. Patch distribution pattern
7. Similarity of patch/vegetation type
8. Average, minimum, and maximum distance between patches of the same cover type
9. Area-weight patch/vegetation size

At habitat level, assessing and monitoring at this level must rely on the ground-level checking and measurement. Indicators at this level could be considering from forest community ecology concept such as abundance of species and diversity species richness, life-form, key species or guild which acting as key ecological role (e.g., pollinator, seed disperser or bird), and any other habitat variables in ecology and biology. As these features, 8 indicators were selected.

1. Vertical stratification
2. Canopy cover
3. Frequency distribution of leaf size and shape
4. Species diversity
5. Abundance of key stone species
6. Abundance of nest of social bee
7. Abundance of bird species
8. Abundance of butterfly species

At population/species level, indicators focus on biodiversity assessment. A target of assessing and monitoring could be aimed at all populations of interesting species. Population structure, population fluctuation and growth rate were considered as the important aspects. The 3 indicators were selected.

1. Density and size class of tree
2. Height class of sapling
3. Relative abundance of seedling and sapling

At genetics level, because of assessing and monitoring at this level need specific knowledge and highly cost. Moreover, to conserve wild populations census in demography aspect is significance enough to the viability of population (Lande, 1988). Thus, in this study assessment at population/species level is considered enough.

Functional attributes: According to the small spatial scale of cultural forest, global level of forest ecosystem function such as conserve of global carbon cycle and prevent flooding seem unsuitable. In this study, production process (productivity), transformation process, and recycling process were considered as the major aspects (Gajaseni, 1997). In addition, function characteristics at site specific level relate to forest humidity such as soil moisture and air humidity conservation were considered. Thus, the function indicators will be categorized into 2 main aspects: conserve soil and water, and yield and forest products. Regarding with functional attributes, 15 indicators were selected.

Conservation of soil and water

1. Frequency occurrence of detritivorous soil fauna of selected group
2. Soil pH and conductivity
3. Decomposition rate determines from leaf bag
4. Quantity of leaf litter and small woody debris (under 10-cm diameter)
5. Soil nutrient contents
6. Frequency occurrence of soil erosion
7. Abundance of epiphytic species
8. Abundance of epiphytic mosses
9. Abundance of bole climbers
10. Abundance of amphibian species
11. Percentage of ground cover

Yield and forest products

12. Basal area
13. Above ground biomass
14. Number of species removed from the forest (for sale/subsistence use)
15. Quantity of certain species harvested from the forest

Human disturbance aspects: To implementing theoretical concepts of forest ecosystem integrity, site-specific of human disturbances from harvesting activities were assessed. In general, most of harvesting activities in cultural forests were collecting of non-timber forest products (NTFPs). As displayed in Table 2.4 and 2.5, all kinds of activities were significantly impacted at habitat and population-species level. There were 5 indicators selected to reflect disturbances that originated from human activities.

1. Number of stumps
2. Frequency occurrence of charcoals/burned logs
3. Frequency occurrence of fire
4. Frequency occurrence of garbage/wastes
5. Number of walkways/trails

2.5 Overview of research in criteria and indicators

Noss (1990) constructed a matrix of indicator variables for inventorying, monitoring, and assessing terrestrial biodiversity of 3 attributes: composition, structure, and function. According to biodiversity concepts, 4 levels of organizations that were landscape, ecosystem-community, population-species and genetics are considered. In addition, inventory and monitoring tools and techniques are supplied for each scale (see Table 2.2).

Forest Stewardship Council (FSC) (1994) proposed the FSC's Principle and Criteria to apply for all tropical, temperate and boreal forests. The purpose of these C&I are for accredit certification organizations in order to guarantee the authenticity of their claims.

Koop, Rijksen, and Wind (1995) proposed the indicators for rapid ecological assessment that indicated the structural and functional aspects of forest ecosystem. The different groups, Forest structure indicators, light indicators, atmospheric indicators, and land use disturbance of indicators can be used to assess the surrogate status of forest ecosystem integrity (Table 2.7).

Table 2.7 The indicators for rapid ecological assessment

Indicators	Diagnostic method and descriptions
A. Forest structure indicators	
Lower basal area	The Bitterlich method. The tree bigger than the thumb were counted.
Presence of big tree	Tree bigger than 50 and 100 cm-dbh were counted.
Maximum tree height	Ten height class of tree were classified.
A distinct layered structure	Vertical layer were classified into 1, 2, and multi layered.
Characteristic diameter distributions	Curve of dbh class will be considered as undisturbed (reverse J-shaped) or disturbed (J-shaped)
B. Light indicators	
Indicators groups of pioneer tree species	The number of stems of pioneer tree species group must be counted.
Light demanding species or group of species	Grass, ginger, fern, herbaceous lianas species were recorded as present or absent.

Table 2.7 The indicators for rapid ecological assessment (continued)

Indicators	**Diagnostic method and descriptions**
Light demanding exotic invader species	The exotic species that reflect to a severe disturbance over a long periods.
C. Atmospheric moisture indicators	
Epiphytic ferns, lower than 5 m in height, on small tree and lianas	Only recognizable common species groups or families were recorded.
Epiphytic filmy ferns on small tree and lianas	Only recognizable common species groups or families were recorded
Epiphytics and epiphllylus mosses on leaves	Mosses types such as feature, hanging, and ramiculous type were recorded.
The upper limit of the moss carpet on tree boles	Observe the upper moss line on the tree boles.
Presence of herbaceous bole climbers	Herbaceous bole climbers that stick their leaves to the tree bole.
D. Disturbance of history land use	
Number of stumps	Evidence of logging will be observed. Number of stumps will be recorded.
Presence of charcoal, burnt stumps or logs	Recorded in positive (+) or negative (–) trend.
Number of tree species more than 25cm in dbh	The tree species that represent in primary forest
Number of commercially valuable rattan species	Rattan species that commercially valuable will be counted.
Number of planted exotic trees	Exotic of tree species will be counted.
Presence of human paths	Walkway and paths will be recorded as present or absent.
Presence of dike from man-made	Man-made dike will be recorded as present or absent.

Source: Modified from Koop et. al., (1995).

Keddy and Drummond (1996) proposed the 10 parameters relating to macro-scale properties of forest ecosystem that were measurable and readily for assessing forest integrity. These parameters provided the significant properties of forest ecosystem that can be considered for indicators framework. All 10 parameters were described as:

1. Basal area: Basal area of tree species per area was widespread used in forest structure assessments. However, changing of basal area could because of both human and environmental disturbance.

2. Crown composition. Canopy species compositions were different in late successional stage and early successional stage.
3. Quality and quantity of coarse woody debris. Coarse woody debris provided the micro-habitat and also nesting material of mammal or bird species. The quantity and decay stage of debris also indicate disturbance history and stage of succession.
4. Number of herbaceous species in recruitment stage. Disturbance in between recruitment stage can represent by abundance and diversity of this guild.
5. Number of species coverage of tree trunk and branched. Different in species composition and abundance of moss, liverwort, and lichen can be represented a change in forest ecosystem. However, these compositions depend upon forest type.
6. Density of wildlife tree. Wildlife tree provide the habitat such as cavity, and food resources for wildlife species.
7. Fungi species group. Ecological roles of this group were recognized in the nutrients cycling pathways as the detritivorous guild. However, the relations between habitat and fungi community were not clearly understood.
8. Abundance of bird species. The variations of bird species abundance per unit area are not directly relating to successional stage of forest because there were different in distribution range in different bird species. In some cases, forest type, structure, and density of tree in forest were influent on the distribution and abundance of bird population especially site-specific bird species such as hornbill. Thus, a further study of relation of bird species and forest characteristics is needed to do in each case of interesting.
9. Number of big carnivorous species. The presence of top predator species in food chain refers to the integrity of trophic level. Migrations of a wide homerange species like a big carnivorous species indicate the fertility of ecosystem at landscape level.
10. Area of forest. The greater of forest area, the higher of capacity serving for a variety of species.

Stork et al. (1997) developed the framework criteria and indicators for the assessment of biodiversity conservation. These set of C&I are for forest management unit level, with management objectives aiming toward sustainable management of forest. C&I were categorized into 2 sets: a primary set that recommended for use and a secondary set that could be used to substitute for a primary set in case of the prior set are not practical. However, this set of C&I have not been tested in the field.

International Tropical Timber Organization (ITTO) (1998) developed C&I for sustainable management of natural tropical forests. C&I that consistent with ecological aspects were showed in Table 2.8.

Table 2.8 Ecological C&I for sustainable forest management of natural tropical forest

Criterion: Forest ecosystem health and condition
Indicator: Area of forest damaged by human activities and degree of damage. Indicator: Area and degree of forest damage by natural causes. Indicator: Existence and implementation of quarantine and phytosanitary procedures to prevent the introduction of pests and diseases. Indicator: Existence and implementation of procedures to prevent the introduction of potentially harmful exotic plant and animal species. Indicator: Availability and implementation of procedures covering use of chemicals in the forest, and fire management.
Criterion: Biological diversity.
Indicator: Statistics of protected area in each forest type (number, extent, percentage, sizes, and percentage of boundaries demarcated). Indicator: Percentage of total number of protected areas connected by biological corridors or 'stepping stones' between them. Indicator: Existence and implementation of procedures to identify endangered, rare and threatened species of forest flora and fauna. Indicator: Number of endangered, rare and threatened forest-dependent species. Indicator: Percentage of original range occupied by selected endangered, rare and threatened species. Indicator: Existence and implementation of a strategy for in situ and/or ex situ conservation of the genetic variation within commercial, endangered, rare and threatened species of forest flora and fauna. Indicator: Existence and implementation of management guidelines. Indicator: Existence and implementation of procedures for assessing changes of biological diversity of the production forests, compared with areas in the same forest type kept free from human intervention.

Table 2.8 Ecological C&I for sustainable forest management of natural tropical forest (continued)

Criterion: Soil and water.
Indicator: Extent and percentage of total forest area managed primarily for the protection of soil and water.
Indicator: Extent and percentage of area to be harvested for which off-site catchment values have been defined, documented and protected before harvesting.
Indicator: Extent and percentage of area to be harvested which has been defined as environmentally sensitive (e.g., very steep or erodible) and protected before harvesting.
Indicator: Extent and percentage of area to be harvested for which drainage systems have been demarcated or clearly defined and protected before harvesting.
Indicator: Percentage of length of edges of watercourses, waterbodies, mangroves and other wetlands protected by adequate buffer strips.
Indicator: Existence and implementation of procedures to identify and demarcate sensitive areas for the protection of soil and water.
Indicator: Availability and implementation of guidelines for forest road lay-out, including drainage requirements and conservation of buffer strips along streams and rivers.
Indicator: Availability and implementation of harvesting procedures.
Indicator: Existence and implementation of procedures for assessing changes in the water quality of streams emerging from production forests as compared with streams emerging from the same forest type kept free from human intervention.

Source: Modified from ITTO, (1998).

Burger and Kelting (1999) suggested using the soil-based indicators to assess stand-level sustainability of intensively managed forest. To monitor soil indicators such as soil function and soil attributes that influence soil function. The list of soil functions including: support forest productivity; regulate forest hydrologic cycle; regulate carbon balance; and bio-remediate waste products. To perform those functions soil attributes must be promoted root growth, regulating water supply and mineral nutrients, promote optimum gas exchange, promote biological activity, and regulating carbon cycle. They also suggested that the indicators should be simple and measurable surrogates of those attribute such as soil temperature for biological integrity and nitrogen mineralization mineral cycle and nutrients attributes.

Center for International Forestry Research (CIFOR) (1999) proposed the CIFOR's criteria and indicators generic templates for tropical natural forest management. These suites of C&I were developed after the research at large-scale natural forests managed for commercial timber production in Indonesia, Côte d'Ivoire, Brazil, Cameroon, Germany, Austria and USA.

Geomatic International Inc. (1999) proposed the method including criteria to screen and selected the 25 core variables from 37 top-ranked ecosystem components which were abiotic components, biotic component (ecosystem structure) and biotic components (ecosystem function). The suites of 25 core variables were shown as a framework that was used for monitoring and comparison among their Network's Ecological Science Cooperative sites located across Canada.

ITTO (1999) developed the manual for the application of criteria and indicators for sustainable management of natural tropical forests at forest management unit level. The ecological criteria and indicators were the same as apply for natural forests that showed in Table 2.8.

Ranger and Turpault (1999) used the measuring of soil nutrients budgets as a diagnostic tool for sustainable forest management. They described that: the main inputs to the forest ecosystems are atmosphere inputs and weathering of soil minerals; and the main output to the forests ecosystems are lost, associated with deep drainage during the rotation and during the regeneration phase and losses of nutrients associated with biomass removals.

Smith, Lowe, and Proe (1999) reported that workshop of the IEA Bioenergy Task XII suggested the ecological or environmental indicators for sustainable forest management were:

- ratio of total soil reserved (exchangeable soil /organic matter reserved);
- soil organic matter quality;
- porosity, water holding capacity, aggregation indices;
- amount of eroded area;
- soil micro-organism assessment;
- "signal" species in field vegetation;
- crop tree responses and nutrients deficiency symptoms;
- maintenance of balance nutrients budgets (input-output estimates); and
- another of significant ecosystem specific indicators.

Dumroese et al. (2000) founded that the soil quality standards and guidelines of USDA Forest Services those are: soil physical (soil displacement, compaction, and rutting and pudding); soil erosion (surface erosion); organic matter content; and fire effects (burned condition) could be used for indicate sustainable forest management. They also suggested that guideline should be continually refined because its threshold of variables do not adequately account for nutrient distribution after they examine the changes in some variables such as soil carbon, nitrogen, erosion, and cation exchange capacity in various climatic and elevation gradient of Pacific Northwest.

Muhtaman, Siregar, and Hopmans (2000) developed the core set of C&I for industrial plantation in Indonesia using CIFOR, ITTO, Lembaga Ekolabel Indonesia (LEI), World Wide Fund for Nature (WWF), and Smartwood Programme criteria and indicators' template as the candidate framework set. The core set of 3 principles, 14 criteria, and 57 indicators were developed under social, management/production and ecology aspects. There were 1 principle, 3 criteria, and 9 indicators correspond with ecological aspects as showed in Table 2.9.

Table 2.9 C&I under ecological aspects for industrial plantation in Indonesia

Principle: Ecosystem function is maintained or improved.
Criterion: Structure and ecosystem function is maintained.
Indicator: Judicious use of fertilizer, and chemicals for pest, disease and weed management.
Indicator: Protected area and conservation area are maintained.
Indicator: Endanger flora and fauna are protected.
Indicator: Microclimatic change and hydrologic function are improved.
Indicator: Stand growth quality is satisfactory.
Criterion: Soil and water resources are maintained or improved.
Indicator: Physical and chemical properties of soil are maintained.
Indicator: Water quality is maintained.
Criterion: Adverse environment influence is maintained.
Indicator: Fire prevention is in force.
Indicator: Genetic diversity of plantation species is maintained.

Source: Modified from Rasmussen et al., (2000).

Rasmussen et al., (2000) mentioned that Thailand agreed to adopt ITTO criteria and indicators for sustainable management of natural tropical forests as their common framework, thus prompting Thailand to adjust its original set. The research and development of C&I at forest management unit level were conducted at Mae Moh

Forest Industry Organization (FIO) teak plantation and Doi Inthanon National Park. The ecological C&I for Mae Moh teak plantation and for Doi Inthanon National Park were showed in Table 2.10 and Table 2.11, respectively.

Table 2.10 Ecological C&I for Mae Moh teak plantation

Principle: Ecosystem balanced is pursued
Criterion: Environmental impact assessment is made prior to any site-disturbing operation.
Indicator: Environmental impact assessment in the management plan for site disturbing type of operations.
Criterion: Silvicultural management is site-adapted and incorporates ecological balance as an important objective.
Indicator: Selection of tree species is based on economic and social considerations as well as site-adaptability. Indicator: A maximum size for clear-cut areas is determined. Indicator: Seed sources are specified, and certain diversity in genetic origin should prevail. Indicator: Evidence on how exotic species outperform native species is provided.
Criterion: Key environmental services provided within the FMU are maintained or restored.
Indicator: An adequate amount of the FMU is set aside as conservation areas. Indicator: Key habitats are identified and protected. Indicator: The size of the protected area is revised and adjusted on the basis of new knowledge. Indicator: Connective corridors are established through the FMU wherever necessary. Indicator: The management plan prescribes soil and water protection strips. Indicator: Streams are monitored for sediments, water yield and water quality, and action is taken accordingly.
Criterion: Use of chemicals are minimized and comply with national and international
Indicator: Documentation exists for the minimum use of biological control agents. Indicator: Evidence that contamination with pesticides is below standard limits. Indicator: Environmental elimination of exceeding chemicals (solid or liquid, pesticides or fuel) and containers is carried out. Indicator: Awareness of emergency procedures exists for clean-up following accidents with chemicals.

Source: Modified from Rasmussen et al., (2000).

Table 2.11 Ecological C&I for Doi Inthanon National Park

Principle: Ecological balance is maintained.
Criterion: Ecosystem diversity is maintained.
Indicator: Indicator 1: Statistics of the forest management unit must exist and be regularly updated. Indicator: Management zones are defined, delineated, mapped and updated according to the present state, in a participatory way. Indicator: A representative variety of ecosystems must be protected for both environmental and educational reasons. Indicator: Key habitats1 are selected and protection of biological corridors between them has been considered. Indicator: Stand growth quality is satisfactory
Criterion: Species diversity is maintained.
Indicator: Indicator 1: Endangered, rare, endemic and threatened species of flora and fauna are being protected. Indicator: The presence of indigenous species is not being threatened by introduced species. Indicator: Selected indicator species representing key conditions for species diversity are being surveyed regularly.
Criterion: Soil and water management is being implemented.
Indicator: Village networks for soil and water functions exist.
Indicator: Government support is provided to the monitoring network.
Criterion: Pollution and chemical contamination are being minimized.
Indicator: Restrictions for the use of pesticides on fields in riparian areas or inside or next to the forest areas exist. Indicator: Waste is minimized and disposed of efficiently.
Criterion: Uncontrolled forest fires are minimized.
Indicator: An effective observation and control system for preventing forest fires exists. Indicator: Community participation in fire protection exists.

Source: Modified from Rasmussen et al., (2000).

Sankar, Anil and Amruth (2000) developed the set of C&I for teak and eucalyptus plantation in India based on ITTO, Amazon Cooperation Treaty A.C., Montreal Process, African Timber Organization, Scientific Certification Systems, Smartwood Programme, The Soil Association Marketing Company Ltd., Bhopal-India Process, and National Forest Policy C&I template. There were 3 principles, 21 criteria and 57 indicators were developed under the policy, ecology, social, and management aspects. The criteria and indicators under the ecology aspects were showed in Table 2.12.

Table 2.12 C&I under ecological aspects for teak and eucalyptus plantation in India

Principle: Ecosystem integrity of the plantation-dominated forest landscape is maintained.
Criterion: Impacts on biodiversity of the forest landscape are maintained.
Indicator: Endangered plant/animal species are protected. Indicator: Strategies to ensure maintenance of variable metapopulations of indigenous biota in plantation landscape. Indicator: Landscape units that are of great importance to the wildlife are conserved and access is not affected. Indicator: Area under natural forests on ridges, steep slopes and swamps has to be maintained or improved.
Criterion: Maintenance of the health and vitality of plantation ecosystems.
Indicator: Protection of the plantation against fire, pests and diseases. Indicator: Based on the identification of key biological areas, roughly 10% of the total area under forest management (not including stream or roadside buffers) is designate as a "conservation zone". Indicator: No chemical contaminant of food chains and ecosystem. Indicator: Regulation for the introduction of single provenance/clones. Indicator: Minimization of impacts of monocultures through mixed cropping. Indicator: Genetic diversity is maintained.
Criterion: Productive capacity of the land is maintained or improved.
Indicator: Optimal stocking (as per the management plan) so as to minimize canopy opening. Indicator: Measure for conserving or improving stability of ecologically fragile localities are implemented. Indicator: Nutrients losses due to short rotations are replenished on scientific basis. Indicator: No inadvertent ponding or water logging as a result of forest management.
Criterion: Watershed functions of the land are maintained or enhanced.
Indicator: Water quality is maintained or enhanced.

Source: Modified from Sankar, Anil, and Amruth (2000).

Andreasen et al. (2001) mentioned that the terrestrial index of ecological integrity would be a useful tool for ecosystem manager and decision maker and proposed that to develop ecological integrity index should consider: multi-scaled; grounded in natural history; relevant and helpful and flexible; measurable; and comprehensive.

Camacho-Sandoval and Duque (2001) proposed the indicators for biodiversity assessment "Harmony with Nature" under "the 4th State of Nation Report" for monitoring biodiversity of Costa Rica. They also showed how harmonized of those suite of indicators to the indicators set of The Convention on Biological Diversity. The set of their indicators were categorized into the main aspects as:

- ecosystem quantity indicators;
- ecosystem quality indicators;
- population density indicators;
- harvesting/use indicators;
- infrastructure indicators;
- pollution indicators;
- alien/invasive species and climatic change indicators;
- habitat management indicators;
- spatial habitat indicators;
- use-indicators;
- ecosystem goods indicators; and
- ecosystem services indicators.

Quigley, Haynes, and Hann (2001) reported that The Interior Columbia Basin ecosystem Management estimated, from broad scale, the composite ecological integrity by clustering condition among variables representing 3 components integrity ratings: forest land, rangeland, and aquatic integrity. Composite integrity rating provides an estimate of system condition that responsive of change and management practices from broad scale and categorized into three condition rating (high, moderate, and low). They developed a list of indicators for each component of integrity as:

Forest land

- Level of expansion of exotic species
- Consistency of tree stocking levels with long-term disturbances
- Level of snags and down woody material

- Absence or presence of wildfire
- Change in fire severity and frequency

Rangeland

- Level of expansion of exotic species
- Influence of grazing on vegetation patterns and composition
- Level of disruption to hydrologic regime
- Change in fire severity and frequency
- Level of increases in bare soil
- Level of expansion of woodlands

Aquatic

- Presence of native fish and other aquatic species
- Distribution and connectivity of high quality habitat
- Presence of relevant life history stages for native species
- Mosaic of strong, well connected populations of native and desired non-native fish
- Resilience of population of native and desired non-native fish to natural disturbance

Xu et al. (2001) proposed a set of ecological indicators involve in structural, functional and system-level aspects for Lake Chao, China. The structural indicators included phytoplankton cell site and biomass, the zooplankton body size and biomass, species diversity, macro-zooplankton and micro-zooplankton biomass, the zooplankton/phytoplankton ratio, and the macro-zooplankton/micro-zooplankton ratio. The functional indicators encompassed the algal C assimilation ratio, resources use efficiency, community production, gross production/respiration (P/R ratio), gross production/standing crop biomass (P/B ratio), and standing crop biomass/unit energy flow (B/E ratio). The system-level indicators consisted of ecological buffer capacities, exergy, and structural exergy. They also designed the Direct Measurement procedures and Ecological Modeling Method to assess a list of selected indicators.

Dale, Beyeler, and Jackson (2002) classified understory plant species of longleaf pine following Raunkiaer's life form and used the species richness, and percent cover of understory vegetation as indicators of different human disturbance intensity (light, moderate, heavy, and remediation level).

ITTO (2002) formulated the ITTO guideline for the restoration, management and rehabilitation of degraded and secondary forests. These guidelines provided a powerful information issues for policy-maker and forest manager who want to restore and manage degraded or secondary forests. The guidelines developed from literature review and many tropical stakeholders. They provided the 2 main sections: section 1 policy planning and management principles (31 principles and 105 recommend actions); and section 2 stand-level principles (18 principles and 55 recommended actions).

Oliver (2002) selected the indicators for vegetation assessment from the site-based 21-compositional, 20-structural and 21-functional indicators under the context of species diversity conservation (Table 2.13). Delphi approach was used to structuring an e-mail-based group communication of 47 Australian experts but the prioritized for importance and feasibility will be conducted in further study.

Canadian Council of Forest Minister [CCFM] (2003) revised a previous developed set of C&I to implement toward sustainable forest management. The framework involves in ecological components: conservation of biological diversity; maintenance and enhancement of forest ecosystem condition and productivity; conservation of soil and water resources; and forest ecosystem contributions to global ecological cycles and human dimensions of sustainability include: the multiple benefit of forests to society and accepting society's responsibility for sustainable development.

DeKeyser, Kirby, and Ell (2003) developed an index of plant community integrity for quantitatively assessing the quality of seasonal wetland community. They selected 46 seasonal wetlands that represent a range of disturbance from well-managed native rangeland to heavily disturbed cropland and analyzed them into 5 quality classes (very good, good, fair, poor, and very poor) via a metric value of:

- species richness of native perennial plant species;
- number of genera of native perennial plant species;
- percentage of total species list (annual, biennial, and introduced);
- number of native perennial plant species; and
- coefficient of conservatism of native species.

Table 2.13 Composition, structure, and function indicators under biodiversity context

Composition	Structure	Function
Presence of rare/threat plant species	Density of tree hollows	Clearing history
Presence of increase/decrease plant species	Heterogeneity of living tree dbh	Grazing pressure-ferals
Evidence of rare/threat animal species	Heterogeneity of perennial grass butts sizes	Grazing history
Richness of native climbers	Heterogeneity of tree hollow sizes	Grazing pressure-native animals
Richness of native epiphytes	Heterogeneity of rock types	Landscape function measures
Evidence of increase/decrease animal species	Heterogeneity of dead tree dbh	Evidence of salinisation
Presence of nectivore food plants	Heterogeneity of log sizes	Prevalence of seedlings
Presence of palatable plant species	Density of trees	Prevalence of saplings
Richness of native trees	Density of tall shrubs	Evidence of bioturbation
Richness of native tall shrubs	Density of short shrubs	Flood history
Richness of native short shrubs	Density of chenopods	Drought history
Richness of native mistletoes	Density of perennial grasses	Evidence of pasture improvement
Richness of native chenopods	Density of annual grasses	Years since disturbance
Richness of native perennial grasses	Density of legumes and other forbs	Grazing pressure-sheep
Richness of native annual grasses	Cover of bare ground	Grazing pressure-cattle
Richness of native legumes and forbs	Cover of rock	Cultivation history
Cover of exotic tall shrubs	Cover of litter	Fire history
Cover of exotic short shrubs	Wood load (logs)	Prevalence of dieback
Cover of exotic perennial grasses	Density of dead trees	Density of mistletoe
Cover of exotic annual grasses	Heterogeneity of litter types	Prevalence of flowering
Cover of exotic legumes and forbs		Prevalence of fruit-set

Source: Oliver, (2002).