Kyoto Mechanism and the Conservation of Tropical Forest Ecosystem
T. Okuda, Y. Matsumoto (Eds.), 2004

Landscape Ecology: Concepts and Application on CDM

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Abstract
The main objective of this paper is to develop a conceptual framework on how landscape ecology approach can be applied on Clean Development Mechanism (CDM) activities with special reference in LUCF sector. The development of the conceptual framework is based on three basic principles in landscape ecology, that is, structure (S), function (F) and change (C). The landscape ecological approach is widely used in landscape planning and management especially in developed countries whereas it is gradually gripping among developing countries particularly related to forest conservation and management. This approach has been adopted due to that it provides information about how is the relationship between landscape structure, or pattern and ecological processes through time. Through this relationship, assessment and evaluation of the landscape can be made which subsequently some alternative strategic planning and management could be formulated. Based on this principle, we developed the concept of SFC approach, which we discuss on how it can be applied in CDM.

1. Introduction

The tropical rainforest is recognised globally as the main landscape element that play the crucial role in maintenance the stability and quality of the environment. The sequestration of CO_2 and to regulate the cycle of other gases in the atmosphere are among the major roles played by the tropical rainforest. According to Dixon et al. (1994) and Schlesinger (1997) tropical forest ecosystem account approximately 20% of total terrestrial carbon stock, which mean that degradation or deforestation of the ecosystems would contribute much of the carbon emission to the atmosphere. The importance of tropical rainforest for environmental conservation is due to its uniqueness and complexity that contains high diversity of flora, fauna and other life organisms, which basically through trophic levels and food web between flora, fauna and their habitat substrate.

It was not until in the middle of the 20th century that tropical rainforest degradation, deforestation and fragmentation has emerge as a central issue that has been discussed and debated at local, regional and international levels (e.g Tole, 1998; Koop and Tole, 2001; Laurance, 1999). Degradation, fragmentation and deforestation of tropical rainforest may alter the atmospheric chemical components and biogeochemical cycles (Hashimoto et al., 2000), wildlife habitat (Wardell-Johnson and Williams, 2000; Carlson, 2000) and functioning of the ecosystems (Terborgh, 1992), which ultimately affects the environment not only at the local level but also at the global scale.

In response to this destructive scenario of global environment, the Kyoto Protocol was established in 1997 as a subsequent to the Environment World Summit in Rio de Janeiro, in

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1992, which so-called Rio the Summit, as an additional legally binding instrument to the Framework Convention on Climate Change (FCCC) developed during the Summit. In Kyoto Protocol, Clean Development Mechanism (CDM) is one of the three flexible mechanisms that permit signatory countries to meet their commitments partially or fully.

The Clean Development Mechanism (CDM), which contained in Article 12 of the Protocol, is a cooperative mechanism to assist developing countries in achieving sustainable development by promoting environmentally friendly investment. This allows governments of private entities in industrialized countries to implement emission reduction projects in developing countries and receive credit in the form of certified emission reductions' or CERs. The centre point or key business of CDM is to cater and decreased the emission of principle gases that may cause greenhouse effect, for example, carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrous oxide (NO) to the atmosphere. This is an alternative way for developed or industrialized countries (Annex 1 countries) to comply the greenhouse gasses (GHG) reduction commitments under Article 3 of Kyoto Protocol.

Thus far, the CDM mechanism in land use change and forestry (LUCF) sector to achieve the compliance level of GHG emissions is limited to afforestation, reforestation and deforestation. The afforestation and reforestation (A/R) are involve replanting activity on degraded areas whereas deforestation is related with forest conservation and forest management project, which is in jeopardy of exclusion. However, in order to optimise benefits of the CDM mechanism some kind of wide range perspective approach needs to be considered before implementation of the CDM activities. This is to ensure to benefits all parties or stakeholders (both in developing and developed countries) and successful of the project through the mechanism. The landscape ecology concept is currently widely employed in land use planning and management (Turner et al., 2001) as well as in forest management and monitoring (Boyce and Haney, 1997) especially among the European countries, the United States and Canada. The approach is now have been gripping among tropical countries, which is reflected by various research publications in international journals and discussion at international fora.

The main objective of this paper is to develop a conceptual framework on how landscape ecology approach can be applied to CDM with special reference on LUCF sector in the context of tropical region. How the principles and concepts in landscape ecology are applicable and potential to be used in CDM is discussed.

2. Landscape Ecology: the Concept

Landscape ecology is considerably a new emerging paradigm (Gustafson, 1998) that integrated between spatial approach (geography) and ecosystem approach (ecology) for landscape planning and land management (Naveh and Lieberman, 1984; Forman and Godron, 1986). Landscape ecology also offers new concepts, theory, and methods that are disclose the pivotal of spatial patterning on the dynamics of interacting ecosystems (Turner et al., 2001). Integrated essence of this expanding applied science in the domain of traditional ecology and geography is generally put emphasis on the causes and consequences of spatial heterogeneity (landscape change) across a range of scale due to human-induced activities.

Since its emergence in the international scientific community for the past two decades, there are various ways of definition of landscape ecology, which among others are:

- Landscape ecology focuses on spatial relationship among landscape element, or ecosystems, the flows of energy, mineral nutrients, and species among elements and the ecological dynamics of the landscape mosaic through time (Forman, 1983).

- Landscape ecology focuses explicitly upon spatial patterns, specifically, landscape ecology considers the development and dynamics of spatial heterogeneity, spatial and temporal interactions and exchange across heterogeneous landscape, influence of spatial heterogeneity on biotic and abiotic processes, and management of spatial heterogeneity (Risser et al., 1984 in Turner et al., 2001)

Based on these various definition, there are three fundamental principles in landscape ecology, that is, structure, function and change (Forman, 1983; Forman and Godron, 1986; Forman, 1995; Turner et al., 2001; Farina, 2002). Structure refers to spatial relationship between different ecosystems, whereas function refers to spatial interaction between elements, that is, ecological processes, for example nutrient cycle and energy flow and finally, change refers to alteration on structure and function in particular landscape through time (Forman and Godron, 1986). Generally, these three principles are related to each other and the most important notion is that landscape structure or pattern has strong relationship with ecological processes (McGarigal and Marks, 1995), which is naturally change through time. Many studies has described that changes in landscape spatial structure may cause a change in function of ecosystem (e.g Bunnell et al., 2003; Atauri and de Lucio, 2001; Estrada et al., 1997).

The ability to quantitatively describe landscape structure is a prerequisite to understand the function and change of landscape (O'Neill et al., 1988; Turner and Gardner, 1991). Therefore various metrics that so-called landscape metrics or indices have emerged with the purpose is to describe the spatial structure of a landscape at the particular time (Turner et al., 2001; Farina, 2002). Landscape metrics provide information about the contents (composition) and distribution (configuration) of elements that characterized the land mosaic. Composition characterised the quantity and quality of landscape by type or category of element and its proportion present on particular landscape and it is non-spatially explicit characteristic. Among the landscape metrics used to characterize landscape composition includes proportion, richness, evenness and diversity (Riitters et al., 1995; O'Neill et al., 1997). Configuration describes the geometry or physical distribution of element types within a land mosaic. Its relates to spatially-explicit characteristics of type of element in a given landscape. Configuration measures spatial characteristics such as size, shape, isolation and core area. The landscape metrics used to quantify landscape configuration includes perimeter-area ratio, fractal dimension, mean shape index, contagion and proximity index (McGarigal and Marks, 1995).

In landscape planning and management, landscape structure or pattern usually can be quantified at three levels, i. patch level; ii. formation level and iii. landscape level. Patch level measure the landscape structure at only one particular patch element in land mosaic, whereas formation level involve the quantification of all the same types of landscape elements and landscape level quantified the landscape structure as a whole, with combination of various type of patches (McGarigal and Marks 1995). This approach is relatively synonymous with biodiversity management and assessment that involve three levels of assessment, which is, the genetic diversity, species diversity and ecosystem diversity (Fig. 1). This provides an idea that in landscape ecological approach the relationship or interaction between spatial pattern and process can be evaluated at different scale. Therefore related to landscape management and planning the application of landscape ecology is depends on the level of management to which we intend to mitigate. For example, *in-situ* conservation of wildlife in particular isolated small forest patch (fragmented forest), quantification of landscape structure may be more useful at patch level, but if some corridors are considered to be developed, thus, both formation and landscape levels application are needed.

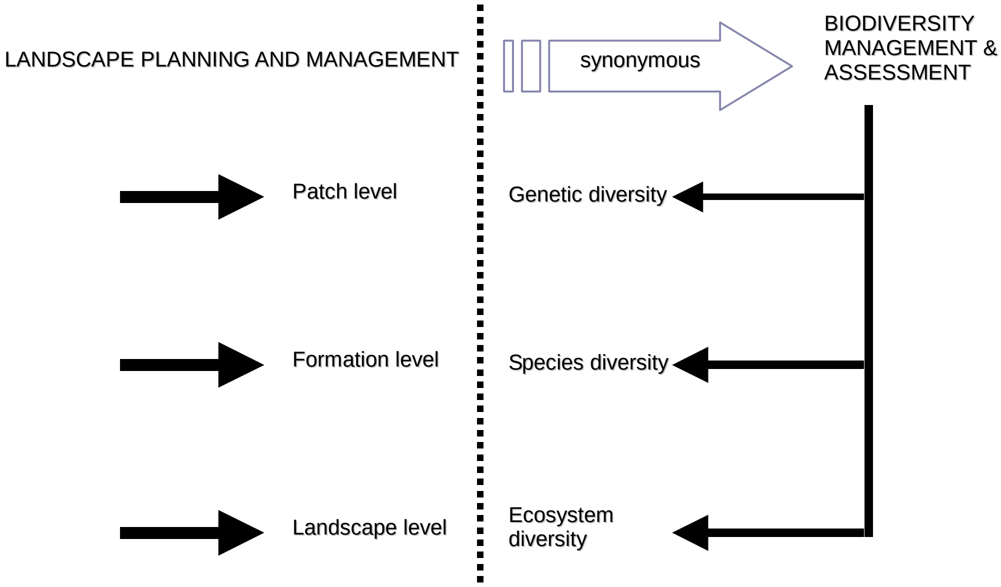

Fig. 1 Illustrates the three levels of landscape structure quantification usually used in landscape planning and management and its synonymous with level of biodiversity management and assessment.

Table 1 Matrix relationship between landscape structure or pattern and function (ecological process)

Landscape structure elements	Landscape functions or ecological processes			
	Water	People	Wildlife	**Atmosphere**
LUCF	Filtration, infiltration, water cycle regulation	Timber, recreation, aesthetics	Main habitats to forest wildlife species, mainly interior species	**Carbon cycle/sequestration, biogeochemical cycles**

Source: Modified from Leitao and Ahern (2002)
***Bold**: based on this paper*

3. SFC Approach

Developing a basic understanding of the dynamic interaction between structure and function is the most effective manner for planners and decision makers to understand (Leitao and Ahern, 2002). In the context of CDM, atmospheric gases cycles particularly carbon (C) are considered as ecological processes or function and usually influenced by changes in landscape structure (LUCF) through time. Therefore, based on relationship matrix developed by Leitao and Ahern (2002), we illustrate, as in Table 1, how is the relationship between landscape structure and function with inclusion of atmospheric gases and LUCF as landscape structure or element.

The integrated essence in landscape ecology provides an opportunity for planners and resource managers to make assessment and evaluation based on the scenario developed through the quantification of landscape structure and pattern. The quantification with various landscape metrics or indices can describe how a land mosaic has evolved through time and its degree of changes. This information is very useful to be used for evaluating alternative land

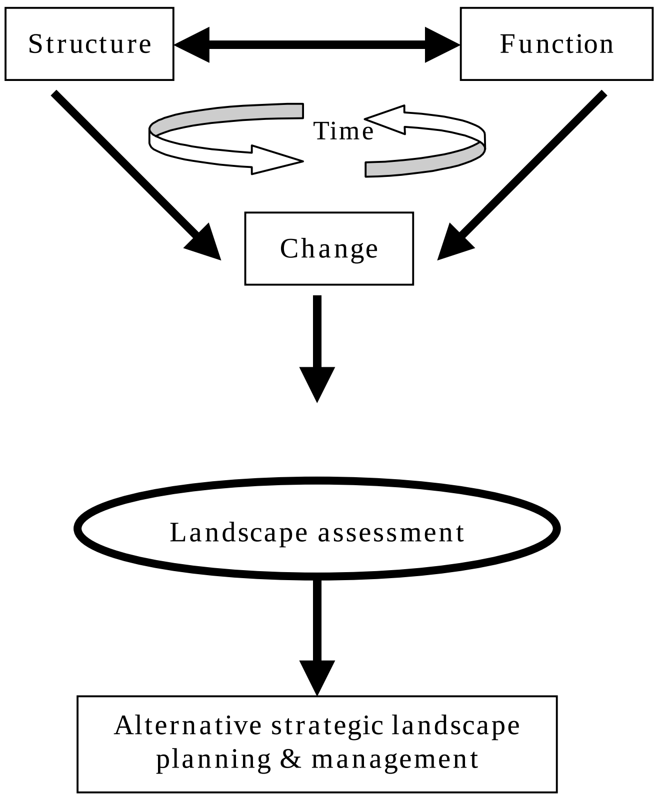

Fig. 2 The schematic concept between landscape ecology and spatial development

management strategies, influenced the decision makers to make amendment on the current legislation and/or formulation of new development policies. This can ensure the efficient approach for spatial development as well as to balance between development and environment (O'Neill et al., 1997). The schematic concept between landscape ecology and spatial development is illustrated in Fig. 2.

Based on this concept, it can be seen that landscape ecology has provides a tool on how we can make assessment and evaluation on the current management practices. However, in broad perspective it also provides some kind of instrument that can be implemented to asses or to make judgement on what is the finest management practices that can be developed to unravel the current problems. In other words, based on current and past scenarios developed using the landscape ecological approach, a feasibility assessment of the proposed alternative can be conducted to ensure its maximum contribution.

In CDM, the selection of activities or projects in LUCF sector is usually arbitrary, which means that without scientifically assessment and detail evaluation of its feasibility. We argued that because CDM usually involve an investment of large sum amount of money as well as involvement of several organizations from the host country (developing country), and perhaps participation from local community, therefore feasibility study is needed to ensure the successful of the project and will give benefit to all the parties involved. Therefore, based on the three fundamental principles in landscape ecology we proposed the SFC approach. This approach has a potential to be applied for feasibility assessment for determination of CDM projects or activities.

4. The Conceptual Framework

The LUCF sector in CDM activity is restricted to afforestation, reforestation and deforestation. Although the definition of these three activities are debated because it could affect the eligibility of CDM projects particularly in developing countries, it is not our intention to raise this issue in our attempt to develop the conceptual framework. Based on definition given in the Kyoto Protocol, generally in developing our framework we defined that afforestation and reforestation

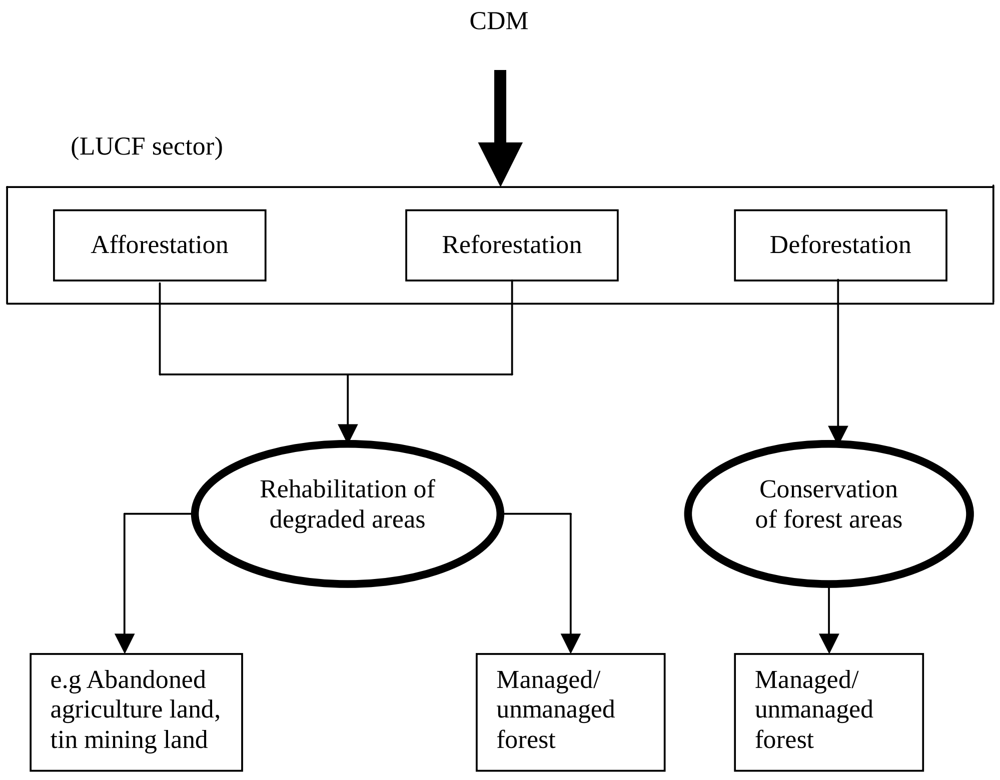

Fig. 3 The two activities 1. rehabilitation of degraded areas and 2. conservation of forest areas are used as a basis for development of the conceptual framework and also shows their relationship with the three LUCF sectors in CDM.

is generally involve the rehabilitation of degraded areas, while deforestation is engage to the conservation of forest areas.

The rehabilitation of degraded areas might include, for example, the abandoned agriculture land and unused mining land. The rehabilitation activities may also include unmanaged private forest land or individual land and also the managed forest, which is in the authority of the government and managed by the forestry or related government department. The rehabilitation of managed forest is particularly refers to the area that experienced severe deforestation due to various human-induced activities such as illegal logging and forest fire. The conservation of forest area is engage solely on protection of managed forest (that is under the government authority). Conservation of forest activity is argued as the better way or has greatest potential for carbon mitigation, where this activity involves avoidance of deforestation through natural

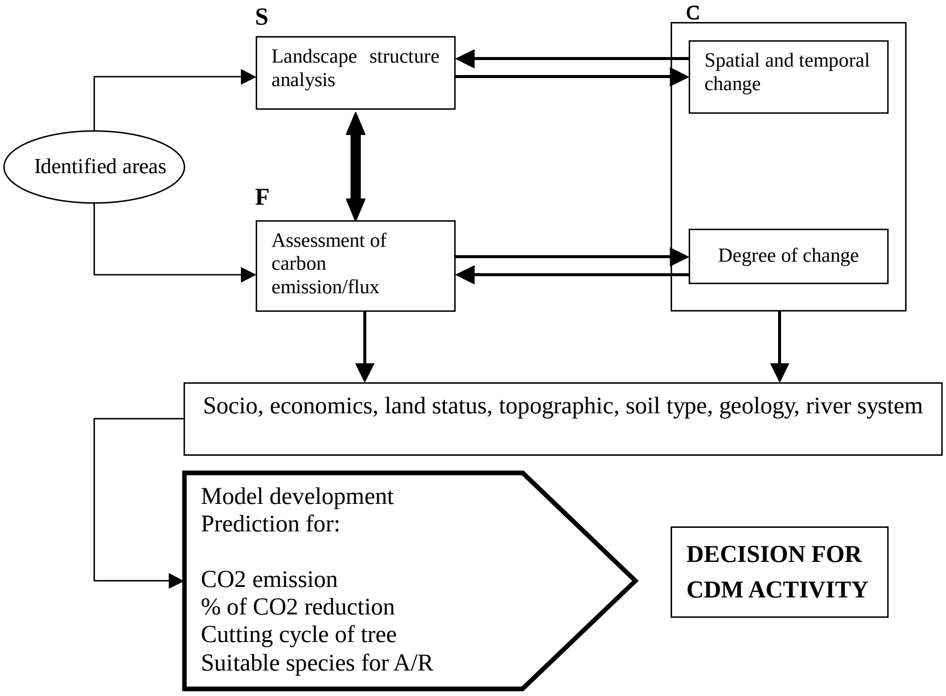

Fig. 4 Conceptual framework illustrates on how landscape ecological concept (SFC approach) can be applied to CDM for rehabilitation of degraded areas.

forest protection and conservation (Watson et al., 2000). According to Brown et al., (1996) reduced the rate of deforestation could sequester approximately 12-15% of carbon emissions.

Therefore, in developing our framework the inclusion of landscape ecology concepts involve two main activities, that is, i) rehabilitation of degraded area and ii) conservation of forest area and these are illustrated in Fig. 3.

4.1. Rehabilitation of degraded area

Figure 4 illustrates the framework where the landscape ecology concept (the SFC approach) is applied in the CDM. In this framework, the first step is to identify several degraded areas potential for consideration in CDM activity. The criterion used to select these areas is based on the definition of afforestation and reforestation of Kyoto Protocol. Selection for several areas is necessary to make certainty that the outcome of the selection process would be resulted the practical choices of areas for CDM activity.

Using the SFC approach, analysis involves the land use change and landscape structure of the area. These analyses are crucial because significant changes in land use and landscape structure might affect the carbon emission of the particular area. For example, there may be several forest patches at the vicinity of the degraded area. This eventually would influence the carbon fluxes or the emission may be less than area without patch of forest. This will provide some information about the degree of degradation of the area. The analysis is conducted in temporal basis to determine pattern of changes through time. Based on this analysis, the degree of change can be evaluated. However, the temporal analysis for carbon assessment can only be conducted if the previous data about the carbon assessment of the area exists. In contrast, without the historical data the analysis is solely depends on the current assessment and this will relate to the degree of landscape structure change.

Data gathered in the analysis will eventually integrate with data of natural landscape of the area. The natural landscape includes information about the topography, slope gradient, topsoil type, geology and river system. Inclusion of natural landscape in landscape study is proved useful as shown by several studies (e.g Herzog and Lausch, 2001). These natural landscapes are vital because it provides a natural feature of the area, which influence how human change their land use activities in the area. In addition, integration of socio-economic

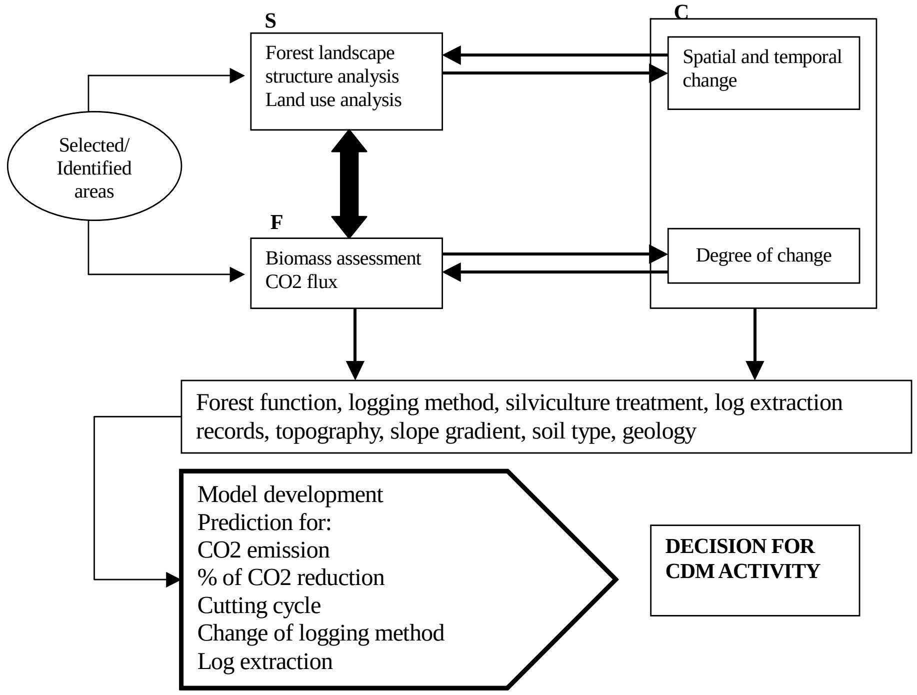

Fig. 5 Conceptual framework illustrats how landscape ecological concept (SFC) can be applied in CDM for conservation of forest areas.

Table 2 Four components used in selection for area in the conceptual framework of conservation of forest area for CDM.

	Components	Description
1.	Forest type	*e.g* Type A, Type B, Type C or Type D
2.	Years after logged	*e.g* 10-y-, 20-y-, 30-y- or 40-y-after logged
3.	Continuous forest	Yes or No
4.	Fragmented forest	Yes or No

Table 3 Examples of combination of the four components to represent areas identified for CDM.

Components	Area 1	Area 2	Area 3	Area 4
Forest type	A	B	C	A
Years after logged	10-years	10-years	30-years	20-years
Continuous forest	Yes	-	Yes	-
Fragmented forest	-	Yes	-	Yes

aspect, such as population, land status and income is widely used in landscape studies (e.g Lopez et al., 2001; Poudevigne and Alard, 1997) and it proved to influence changes in landscape.

With this integration, we proposed that a model to make the right decision for CDM activity could be developed. In this framework the developed model can make prediction about several parameters that need for selection of the suitable area for CDM activity. The prediction parameters may include concentration of CO_2 emission, percent (%) of CO_2 reduction needed, cutting cycle for tree used in rehabilitation of the area and also the suitable species for replanting the degraded area.

4.2. Conservation of forest areas

This framework is related to the notion of deforestation of the Kyoto Protocol. Deforestation of the Protocol is refers to the conservation or protected of the existing forest areas. In this framework, the conservation of forest areas is refers to managed forest, which is covered under the government policy and legislation, and managed by related government department or agency. Generally, the conceptual framework is almost similar as the first framework but there are differences in element regarding the selection of the area and in the application of the SFC approach. The framework is illustrated in Fig. 5.

The selection or identification of forest areas is involved four components in Table 2.

Table 4 Three clusters of parameters practical in determination of area for CDM.

Cluster 1	**Cluster 2**	**Cluster 3**
Forest function	**Natural landscape**	**Forest management**
• Catchment area • Nature education • Research forest • Soil erosion protection	• Slope gradient • Topographic • River system • Geology • Soil type	• Logging method • Silviculture treatment • Log extraction record • Logging cutting cycle

However, the combination of the components to represent the area is made randomly, for example, as shown in Table 3.

Once the selection has been made, temporal landscape analysis will be conducted. In contrast to the first framework, analysis for the second framework involves two components, that is, analysis on the forest landscape itself and secondly land use of the area. In addition to the assessment of carbon emission or fluxes as in the first framework, the biomass of the forest stand is added in this second framework. Forest stand biomass estimation is considered because it reflects how much carbon is stock by the forest areas or the importance of the forest as carbon sink. Regarding the temporal analysis for carbon flux and biomass assessment, it can only be done if records of the previous data exist for the area. If not, results of the current analysis will relate to the degree of landscape structure change.

Consideration of other parameters is also practical in determination of area for CDM. In this framework, the possible parameter can be clustered into three groups as shown in Table 4. In the first cluster, the forest functions, is the reflection of the role of forest, which is not only for environmental protection but also the importance for human benefits such as nature education, scientific research and recreation and vital for conservation of biodiversity. The second cluster is natural landscape, which feature the natural characteristics of the area. The elements in this cluster, such as slope gradient, topographic and river systems represent the physiognomy of the area that influence the characteristic of the vegetation cover, floristic composition and structure of the forest stand. This will influenced the capability of the forest to act as carbon sink or reservoir. The third cluster is regarding the management of the forest. The information of current logging method, for example, is necessary to deliver information of its impact on forest ecosystems. The history of silviculture treatment will inform the effectiveness or capacity of the tree species to act as carbon sink.

With integration of all these information, a model in determination of practical area for CDM activity could be developed. The model can be used to make prediction on, for example, how much CO_2 need to be reduced, rotation of logging cycle, potential for changes in logging method and volume for log extraction for the area.

5. Conclusion

The concept in landscape ecology has been proved potential to contribute effectiveness in landscape planning (e.g Nakamura and Short, 2001; Olsson et al., 2000), forest monitoring and management (Turner et al., 2003; Endress and Chinea, 2001), conservation of biodiversity (Fairbank, 2003) and ecological land evaluation (Nakagoshi and Kondo, 2002). The quantification of landscape structure using the landscape metrics yields complementary information to the conventional statistical data in monitoring changes (Herzog and Lausch, 2001). The contribution of landscape ecology to bridging the gaps between development planning and environmental conservation is generally based on its three principles, that is, structure, function and change.

Based on these three principles, we can determine what had happened in the past, current and in the future. Therefore, some scenarios about the changes in a particular area can be evaluated and what will be happened in the future can also be predicted. In CDM, it is usually involve several stakeholders from developed and developing countries, involving large sum amount of money for its implementation, and also to provide benefits, economically and socially, to people in the host country. Finally, the core business is to meet the compliance of GHG emission within the given time frame. Therefore, it is very important that the CDM activity will meet its target to reduced the GHG emission and successful in terms to give benefits to the host country. Due to this we recommend that a feasibility study based on interaction between landscape structure (LUCF) and ecological process (CO_2 sequestration and cycle) is needed to ensure the selection of CDM projects or activities is in the right path and successful at the final conclusion. With this point, landscape ecology approach can be developed and potential to be applied in CDM LUCF sector in determination of feasibility of the CDM activities.

Acknowledgement

We would like to thank to Dr. Toshinori Okuda of the National Institute for Environmental Studies (NIES) for fruitful discussion on landscape ecology and CDM. This study partially supported by Grant-in Aid for Scientific Research from Ministry of Education, Science and Culture, and COE programme for Social Capacity Development for Environmental Management and International Cooperation, Hiroshima University.

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