IDENTIFICATION OF HIGH CONSERVATION VALUE FOREST (HCVF) RELATED TO SOIL AND WATER CONSERVATION

The use of remote sensing and GIS to support forest certification in Indonesia

Yohanes Budi Sulistioadi
March 2004
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… To my father and mother …

… With all my pride…
ABSTRACT

Indonesian forests are in critical situation. Very high rate of forest degradation resulted from unsustainable forest management, rampant illegal logging, forest area encroachment, conversion and natural disaster, i.e. fire, all together urges rapid improvement of management system of Indonesia’s forest resources (Holmes 2002). Forest certification is one tool that can support the achievement of sustainable forest management goal. Under current operation of Joint Certification Protocol between FSC and LEI in Indonesia, forest management units must be able to show the required (process and) performance indicated in LEI Criteria and Indicators as well as FSC Principles and Criteria to attain certification of their products (FSC 2002; LEI 2002). Nevertheless, the gap between current practices and performance required by forest certification schemes is still enormous.

The management of High Conservation Value Forest is one of FSC principles for sustainable forest management (FSC 2000). However, some difficulties were found when forest management unit tries to identify the HCVF, since the definition, terms and available guideline for HCVF identification are necessarily generic and global (Jennings et al. 2002). Therefore, this study tries to implement a detailed method for identification of High Conservation Value Forest (HCVF) in a natural production forest. Based on the national guideline provided by Smartwood and ProForest, remote sensing and GIS were employed as essential tools and proven useful to support the identification process. Three sub-elements of High Conservation Values related to soil and water conservation were chosen to assess, i.e. forest areas function as source of drinking water for communities (HCV 4.1), forest area as part of critical catchment (HCV 4.2) and forest area critical to erosion control (HCV 4.3). The analysis was supported by ancillary data and incorporating various spatial analyses including terrain analysis, catchment delineation, spatial overlay and raster map calculation. Satellite image classification was done to identify the major land cover types in the study area, which facilitated the analysis of potential soil erosion risk. Universal Soil Loss Equation as an empirical model was applied to have indication on potential erosion risk in the study area.

As the result of the analysis, 17542 ha (21%) out of total extent of the study area, which is 83240 ha, contributes to drinking water supply for twenty-one settlements in and around the forest management unit. The inhabitants of these settlements mainly depend on surface water provided by the rivers and their tributaries. In case of contribution of forest areas to critical catchments, no forest areas are assigned as such, since two major river systems around the study area (i.e. Segah and Kelay Rivers) are not assigned as critical catchments according to assessment done by the Ministry of Forestry of Indonesia. However, the study area contributes to 6.75% and 2.81% of total catchment area of Segah and Kelay River, respectively. According to how critical is the study area to erosion control, 7934 ha (9.53%) of the study area are assigned as critical to erosion control, since those areas potentially prone to high erosion risk, especially when the natural vegetation cover removed.

As the implication of the identified HCVF area, the responsible forest management unit should applies special care and consideration when logging practice takes place in the identified HCVF areas. Further, the forest management unit is encouraged to establish a management plan to maintain/or enhanced the identified HCVF. Consistent to the FSC principle 9, the management plan of the identified HCVF should incorporate active participation of the affected communities. Moreover, the integrated forest management plan should be made publicly available and as the last action with regard to the identified HCVF, the forest management unit should establish a monitoring programme to ensure the existence of the value provided by the identified HCVF.

Keywords: HCVF, forest certification, remote sensing, GIS, soil, water, conservation
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LIST OF ABBREVIATIONS AND ACRONYMS

ASTER  Advanced Spaceborne Thermal Emission and Reflection
AVSWAT  ArcView® extension for Soil and Water Assessment
BAPLAN  Badan Planologi Kehutanan (Indonesian Forestry Planning Agency)
BFMP  Berau Forest Management Project
BRLKT  Balai Rehabilitasi Lahan dan Konservasi Tanah
        (Land Rehabilitation and Soil Conservation Agency)
CERFLOR  Certificação Florestal
CAR  Correction Action Request
CSA  Canadian Standards Association
DBH  Diameter at Breast Height
DEM  Digital Elevation Model
Ditjen RRL  Direktorat Jenderal Reboisasi dan Rehabilitasi Lahan
        Directorate General of Reforestation and Land Rehabilitation
ERS  European Remote Sensing Satellites
ESRI  Environmental System Research Inc.
ETM  Enhanced Thematic Mapper
FMU  Forest Management Unit
FSC  Forest Stewardship Council
GFTN  Global Forest and Trade Network
GCP  Ground Control Point
GIS  Geographic Information System
GPS  Global Positioning System
HCV  High Conservation Value
HCVF  High Conservation Value Forest
HLL  Hutansanggam Labanan Lestari
HRV/IR  High Resolution Visible/Infra Red
HPH  Hak Pengusahaan Hutan (Forest Concession Holder)
ILWIS  Integrated Land and Water Information System
ISO  International Organisation for Standardisation
ITC  International Institute for Geo-Information Science and Earth Observation
ITTO  International Tropical Timber Organisation
JERS  Japanese Earth Resources Satellite
JCP  Joint Certification Protocol
MrSID®  Multi-resolution Seamless Image Database
LEI  Lembaga Ekolabel Indonesia (Indonesian Eco-label Institute)
MTCC  Malaysian Timber Certification Council
NASA  National Aeronautics and Space Administration
NGO  Non-Governmental Organisation
P&C  Principle and Criteria
PEFC  Pan European Forest Certification
RKL  Rencana Karya Lima Tahun (Five-Year Working Plan)
SFI  Sustainable Forestry Initiative
SFM  Sustainable Forest Management
TPTI  Tebang Pilih Tanam Indonesia
        (Indonesian Selective Timber Harvesting and Plantation System)
UN-CED  United Nations Conference on Environment and Development
UNEP-WCMC  United Nations Environmental Programme – World Conservation and Monitoring Centre
USDA-ARS  United States Department of Agriculture – Agriculture Research Service
USLE  Universal Soil Loss Equation
WWF  World Wide Fund for Nature
1. INTRODUCTION

1.1. Indonesia’s Forest

Indonesia has considerable extent of tropical rain forest. The forest ecosystems vary from mangrove, swamp, riparian forest and hilly *dipterocarp* forest to montane and cloud forest (FWI/GFW 2002). Forest management operations in islands outside Java started officially in early 1970's. Timber extraction, together with the development of wood processing industries, which started in early 1980’s, became the second largest contributor to foreign exchange earnings, which supported the country's economy until late 1990's (Worldbank 2001). This sector also has increased the number of employment in the forest area as well as in the wood industries. Moreover, development of remote areas where forest management operations are located should be considered as improvement of local economy as well. Not only for country's economy, local people are mostly dependent on the existence of the forest. The use of non-timber forest products, fruits, as well as traditional medicine had been served by Indonesia’s tropical forest for ages.

While most of the forests in the Java Island are plantation forests, the other major islands outside Java (e.g. Kalimantan, Sumatera, Papua) consist of natural forests, which remain intact from large-scale commercial exploitation until early of 1970. Based on the forestry act No. 41/1999, all forests within the country, except the forests that are grown in a private land, are owned by the state. According to the biophysical condition of the forest, forest area are managed as Conservation Forest, Protection Forest, Limited Production Forest, Production Forest, Plantation Forest and Conversion Forest (BAPLAN 2001). Timber extraction activities are allowed only in the Limited Production Forest and Production Forest, which reach the extent of approximately 44 million ha. To carry out forest management operations, Indonesian Government delegated this area to 359 Forest Management Units (FMU), which are owned by state, private, district, local cooperatives, or even shared among them. A detail forest management guideline named “Selective Cutting and Plantation System”, or TPTI (Tebang Pilih Tanam Indonesia) had been formulated for forest management units.

Despite of the presence of TPTI as a formal procedure for forest management operations and several voluntary-based improvement in forest management system (e.g. guideline for application of Reduced Impact Logging, Criteria and Indicators of Sustainable Forest Management), Indonesia’s forest is highly degraded (Holmes 2002). The rate of deforestation in Indonesia is reported as high as 1.67 million ha per year (BAPLAN 2001). Unsustainable practice of timber extraction operations carried out by forest management unit (HPH/Hak Pengusahaan Hutan) for more than 20 years has contributed greatly to the rapid forest degradation in Indonesia. Therefore, these facts should be considered in improving the existing forest management system in Indonesia (Worldbank 2001).

1.2. Forest Certification

The idea behind forest certification is that consumers, with concern to deforestation and forest degradation, will prefer to buy timber products from well-managed forests. The process of certification identifies these forests, and the products coming from them. Through certification, individual forests are assessed against publicly available standards. Once the standard compliance is verified, the forest owner obtained the right to label his/her products. At the point of sale, the label tells the consumer that the product is sourced from a forest that meets certain environmental and social standards (Rametsteiner 2003). Furthermore, forest products certification should incorporate a pair of assessment, which is forest certification and chain of custody (timber tracking certification). Only by achieving satisfactory result of these two assessments, a forest management unit is able to attach “eco-label” on its products (LEI 2002), (FSC 2002). From the side of the market, the developed countries are increasingly requiring environmental-friendly products (Rametsteiner et al. 2001). As can be seen in Figure 1 in the next page, garden furniture with FSC-certified label is on sale in a store in Enschede, The Netherlands.
Worldwide, over 30 countries and initiatives are working on - even had completed - national standards and schemes for forest certification. The four largest forest certification system operating in the world could be recognized by: the Forest Stewardship Council (FSC), the Pan-European Forest Certification (PEFC), the Canadian Standards Association’s Sustainable Forest Management Standard (CSA) and the Sustainable Forestry Initiative (SFI) (Ozinga 2001). In addition, there are some country initiatives such as, Malaysian Timber Certification Council (MTCC) from Malaysia, Lembaga Ekolabel Indonesia (LEI) from Indonesia, Certificação Florestal (CERFLOR) from Brazil and National Scheme from Ghana. The first two are operational, while the latter two still in process of finalization (Atyi and Simula 2002). However, the Forest Stewardship Council is currently the only independent and credible certification scheme in the market. So far, this is the only scheme that brings labelled products to the marketplace and offers a good option to consumers (Ozinga 2001).

Figure 1. FSC-certified products in a Dutch store

In Indonesia, the FSC certification scheme is carried out under Joint Certification Protocol (JCP) with Lembaga Ekolabel Indonesia (LEI). The Memorandum of Understanding between LEI and FSC signed in September 1999 and renewed in March 2003, thus declare that any forest management units in Indonesia should fulfil both FSC and LEI system requirements to receive sustainable forest management label on their products. It means all principles, criteria and indicators of both forest certification systems (FSC and LEI) should be complied by forest management units in order to achieve sustainable forest management (LEI 2002).

Conformity to the standards of sustainable forest management can only be achieved if those sets of sustainable forest management standard are clearly understood and interpreted into general forest management plan and implemented in the forest management operations on a daily basis, i.e. integrated to the existing “standard operational procedures”. In the situation of Indonesia, there is a large gap between existing forest management practices and compliance to sustainable forest management standard as prescribed in FSC Principles and Criteria (Jarvie 2002).

1.3. High Conservation Value Forest (HCVF)

One of the FSC principles is the management of High Conservation Value Forest (HCVF). This is relatively a new principle, which has been developed to replace the previously used concept of old growth or virgin forest. Through this principle, FSC requires unique approach in managing forest ecosystem and conserving the biodiversity value (FSC 2001). In this case, forest management unit should maintain or enhance such value, not preserve it. The key of HCVF principle is the concept of conservation values. This principle is not concerned with the conservation of a single rare species or community rights, but HCVF is concerned with specific conservation value such as concentration of biodiversity or the hydrological function of the area (Jennings et al. 2002).
FSC Principles and Criteria introduced High Conservation Value Forest as any forest area that possess **one or more** of the following **High Conservation Value (HCV)** (FSC 2000):

- **HCV 1**: Forest areas containing globally, regionally or nationally significant concentrations of biodiversity values (*e.g.* endemism, endangered species, refugia)
- **HCV 2**: Forest areas containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance
- **HCV 3**: Forest areas that are in or contain rare, threatened or endangered ecosystems
- **HCV 4**: Forest areas that provide basic services of nature in critical situations (*e.g.* watershed protection, erosion control)
- **HCV 5**: Forest areas fundamental to meeting basic needs of local communities (*e.g.* subsistence, health)
- **HCV 6**: Forest areas critical to local communities’ traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities)

As mentioned above, when a forest area contains **ONE or MORE of those values** then it should be classified as High Conservation Value Forest. FSC principle 9 about HCVF is of extreme relevance to the Indonesian context where the ecological, environmental and social context warrants that most managers of primary forest are operating in an HCVF context. However, Indonesian concessionaries that have expressed interest in certification have faced difficulties with the criteria related to FSC principle 9, *i.e.* to interpret and meet such criteria (Daryatun et al. 2002). Apparently, most forest management units have no clear understanding what ecological requirements are being asked by the certification system, especially according to identification and management of High Conservation Value Forest (Jarvie 2002).

### 1.4. Role of Spatial Information in HCVF Identification

Spatial information is very useful to support the process of HCVF identification. At the initial phase of HCVF identification, the existing eco-region, surrounding landscape and forest type occur in forest management unit should be determined spatially. This information will support the initial steps in identification of High Conservation Values (HCV) (Jennings and Jarvie 2003).

Furthermore, assessment of High Conservation Value is preferably completed by a spatial analysis. The spatial analysis then should focus on landscape and forest management unit scale and involving information about forest types, topography, logging history (FMU spatial plans), existing protected area(s), spatial location of community and its land use, threats (including disputed titles, conversion and degradation), watersheds and political and geographical boundaries. Spatial analysis concerning such spatial information aforementioned should lead to a conclusion about the status and threats to identified HCVF (Jarvie 2002).

However, not all elements of High Conservation Value Forest can be assessed through spatial analysis. Considering particular elements of HCVF such as: forest areas as part of critical water catchments and forest areas with high risk of erosion (HCV elements no 4), the use of remote sensing and GIS has proved to be useful in supporting the analysis. Some examples are: watershed identification and prioritisation (Khan et al. 2001; Randhir et al. 2001; Tripathi et al. 2003) and erosion hazard prediction (Lin et al. 2002; Lufafa et al. 2003; Mati et al. 2000; Misra and Teixeira 2001; Ranieri et al. 2002; Shi et al. 2004; Shrimali et al. 2001).
1.5. Problem Statement

Indonesian forests are in critical situation. Very high rate of forest degradation resulted from unsustainable forest management, rampant illegal logging, forest area encroachment, conversion and natural disaster, i.e. fire, all together urges rapid improvement of management system of Indonesia’s forest resources (Holmes 2002; Worldbank 2001). Forest certification is one tool that can support the achievement of sustainable forest management goal, even though the gap between current practices and performance required by forest certification schemes is still enormous. Under Joint Certification Protocol carried out by FSC and LEI, each forest management unit should be able to show the required (process and) performance indicated in LEI Criteria and Indicators as well as FSC Principles and Criteria (FSC 2002; LEI 2002). In contrast, most of the forest management units in Indonesia face difficulties in interpreting and implementing FSC principle and criteria in their operations.

The FSC principle about High Conservation Value Forest (HCVF) is relatively a new term and it is difficult to measure since it put more emphasis on value and conservation importance of a forest area than the results of measurements. Even the general guidelines for identification of HCVF (e.g. global and national guideline) are available, but detailed interpretation and field implementation of such guidelines are not available. Therefore, it is an important issue to develop and implement a detailed method to identify the presence of HCVF so that the forest management units in Indonesia can understand what is required by FSC principle of HCVF.

The use of remote sensing and spatial information to support identification of HCVF is certainly potential. Some of the HCVF elements could be assessed through the remote sensing and GIS analysis resulting the location of forest area containing some High Conservation Values (HCV). One HCV element, which is potentially assessed by the support of remote sensing and GIS is:

| HCV 4 | Forest areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control) |

By identifying land cover types using remote sensing approach, supported by some existing spatial data, an integrated analysis can be carried out to assess forest area, which:

- Functions as unique source of drinking water for local communities (HCV 4.1)
- Part of critical major catchments (HCV 4.2)
- Has critical erosion risk (HCV 4.3)

Ancillary data that can be used are topographic information and its derived products (DEM, slope map and other terrain features), secondary data about the source of drinking water for local communities, stream network map and some additional data to support prediction of potential soil erosion risk (after Rainforest Alliance and ProForest 2003).

1.6. Research Objectives

The ultimate objective of this research is to develop and implement a detailed method for the identification of High Conservation Value Forest (HCVF) related to soil and water conservation. The methods are developed based on the national guideline provided by Smartwood and ProForest for HCVF identification in Indonesia.

Specifically, this research is aimed at developing and implementing the appropriate methods to identify forest areas that provide basic services of nature, which are:

- Forest areas function as unique source of drinking water for local communities
- Forest areas as part of critical major catchments
- Forest areas critical to erosion control
1.7. Research Questions

Based on the objectives mentioned above, this research tries to answer following questions:
1. How can the HCVF, which related to soil and water conservation, spatially identified?
2. Where are the forest areas function as unique source for drinking water for local communities?
3. Where are the forest areas as part of critical major water catchments?
4. Where are the forest areas critical to erosion control?

1.8. Research Approach

This research identifies the presence of High Conservation Value Forest (HCVF) in the study area based on the general approach as follow:

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**Figure 2.** General research approach
2.1. Sustainable Forest Management (SFM) Certification

Sustainable forest management certification is defined as a formal and voluntary procedure whereby a third party certifier gives a written assurance that the quality of forest management practiced by a defined manager or group conforms to pre-defined standards (Bass 1998). Certification is often followed by verification of the chain of custody of products from certified forests, and labelling of the products, so that they can be proven not have been mixed with, or substituted by, products from other forests. In this way, certification attempts to link market demands for forest products produced to high environmental and social standards, with producers who can meet such demands.

Often shortened as forest certification, sustainable forest management certification should consists of three main components (Nussbaum 2000):

- **The standard**
  The standard must be clear, unambiguous and publicly available so there is clarity about what compliance with the standard means. It must also be ‘auditable’ so that certification bodies can audit against it.

- **Certification system**
  All certifications against the standard must be carried out by a third party, independent organisations following clear, defined procedures. Certification is usually carried out by the organisations specialising in certification called certification bodies. Certification bodies must have the systems, procedures and personnel to ensure credible, replicable certification of forest organisations against the standard. To ensure that all of the certification bodies meet a consistent high standard, they must in turn be ‘certified’ through the approval and monitoring of an accreditation programme.

- **Accreditation**
  This is the process of ‘certifying the certifiers’ and must be carried out by a competent, independent body capable of ensuring that all certification bodies provide a consistent interpretation of the standard through approved procedures and processes.

According to the standard, (Agung and Hinrichs 2000; Bass 1998; Ghazali and Simula 1998) there are two types of certification standard, i.e. performance standard and management (process) standard. The first type establishes quantitative and qualitative targets or indicators against which the assessment of forest conditions or management interventions can take place. The latter type defines the characteristics of the management system to be applied. ISO is well known as the organisation that conducts certification based on management (process) standard, while performance standard certification is the one that applied by many organisations that concerned with development of sustainable forest management standards and certification schemes. Performance standards of sustainable forest management can be hierarchically derived from the principles, criteria, and their verifiers’ indicators (Ghazali and Simula 1998).
Up to year 1998, there are currently eight regional on-going processes at intergovernmental level related to the development of criteria and indicators which provide a general framework for work to promote sustainable forest management (Ghazali and Simula 1998). They are: ITTO (tropical forest countries), African Timber Organisation (ATO), Pan-European Process, Montreal Process (non-European boreal and temperate forest countries), Tarapoto Proposal (countries in Amazonian Basin), Dry-Zone Africa (UNEP/FAO Initiative), North Africa and Near East, and Central America. Intergovernmental Criteria and Indicator processes are complemented by non-governmental initiatives, of which the Forest Stewardship Council (FSC) process has been developed specifically for certification purposes. However, to date there are only two internationally recognized and operational forest certification schemes (i.e. Forest Stewardship Council (FSC) and Pan-European Forest Certification (PEFC) Scheme) (Bass and Simula 1999). Another twelve national certification scheme also well developed, in which ten of them are operational starting from year 2000 and in particular, two schemes from tropical countries (i.e. MTCC and LEI) had mutually recognized by FSC certification scheme (Atyi and Simula 2002).

Although different certification bodies may have slightly different procedures and use slightly different terminology, the general mechanism in forest certification (based on FSC certification system) is shown below (Agung and Hinrichs 2000; Handford and Nussbaum 2001; Nussbaum 2000).

<table>
<thead>
<tr>
<th>General mechanism of forest certification (based on FSC certification system):</th>
</tr>
</thead>
</table>
| **1. Application and Proposal**  
Most certification bodies require forest enterprises interested in certification to complete an application form. A financial proposal then will be provided for free and without any commitment to continue with the process. |
| **2. Pre-assessment or Scoping**  
The certification body (CB) makes a preliminary visit to the applicant with three main purposes:  
a. To allow the CB to gain some idea of the applicant’s operation and thereby plan for the main assessment  
b. To give the applicant the opportunity to discuss the certification process and understand it better  
c. To identify any gaps between the current performance of the applicant, and the requirements of the standard |
| **3. Close gaps**  
Following the pre-assessment/scoping visit the applicant needs to address any gaps identified between current management and performance and that required by the standard. Once this process is complete, the applicant confirms to the certification body that they wish to proceed with the main assessment. |
| **4. Stakeholder consultation**  
As soon as there is confirmation that the applicant wishes to proceed to a main assessment, the certification body begins a process of public consultation to collect input from interested parties on the performance of the applicant. |
| **5. Main assessment**  
The main objective of the main assessment is to collect objective evidence that verifies whether each requirement of the standard is being met. To do this requires an audit team, which between them combine expertise in:  
a. Auditing techniques and the requirements of the standard  
b. Legal, technical, economic, environmental and social requirements of sustainable forest management  
If the team collect objective evidence show that a requirement of the standard is NOT being met (a non-compliance) a corrective action request (CAR) is raised which must be addressed by the applicant either prior to certification (Major CARs) or after certification within an agreed timeframe (Minor CARs). |
| **6. Report and Peer Review**  
The results of the assessment, including the actions taken in response to CARs, are set out in a report, which for FSC certification must include a public summary of all results. This report is sent to a number of independent specialists in the field for a peer review. |
| **7. Certification**  
Once all non-conformances have been adequately addressed, and the report has been successfully peer reviewed, a decision can be made to certify the applicant. The certificate is valid for five years subject to successful annual surveillance visits. |
To work properly, the practice and results of forest certification must be credible to the market and stakeholders, and therefore transparent and independent. To ensure this, an assessment of the skills, procedures and impartiality of certifiers themselves is required; this is called *accréditation* of certification bodies. FSC is taking a lead in developing global-level accreditation of forest certification bodies (*Bass 1998*), while for many countries that have developed forest certification standard and scheme, national accreditation councils for forest certification bodies are exist (e.g. LEI for Indonesia).

Market for certified wood products is mainly for west-north European countries. Especially the UK, Belgium, Netherlands and Germany, are becoming strongly aware of certification (*Rametsteiner et al. 2001*). There are also emerging North American markets. As above-mentioned, buyers groups - most of them organised by WWF - have committed themselves to buying only certified products after a certain date. More significantly, they are committed to FSC-certified products - at present. Certainly, there is no doubt that retailers are very much the motor behind certification at present, using the power of advertising to create demand amongst consumers. However, this demand is not creating a ‘green premium’ for certified products. Rather, it is a question of market access (*Bass 1998*).

### 2.2. High Conservation Value Forest (HCVF)

#### 2.2.1. Defining High Conservation Value Forest (HCVF)

The management of High Conservation Value Forest (HCVF) is defined as Principle 9 in FSC Principles and Criteria. This principle is the cornerstone of the FSC system for recognising forests that have high conservation value and consequently need special protection, and the concepts inside moved the emphasis away from giving special status to old growth or virgin forest as the most important forests. Thus certification bodies, which conduct site evaluation, and National Initiatives, which are developing regional forest stewardship standards for these forests, are expected to interpret this concept at the regional and local level and determine what special measures or constrains are required in forest management units with identified high conservation values. The standards may then set limitations on access, harvesting and other inference (*FSC 2001*).

In accordance to identification, management and maintaining such high conservation value, precautionary approach should be used in order to ensure no harmful activities affect the existence of HCVF. Operationally, precautionary approach is defined as: “Where there is a threat of significant reduction or loss of the attributes that make a forest management unit a HCVF, based on existing scientific and indigenous/traditional knowledge, early preventive action, including halting existing action, should be taken to avoid or minimize such a threat despite lack of full scientific certainty as to causes and effects of the threat” (*FSC 2001*).

Considering the precautionary approach and based on literature review and some experiences, some major issues concerning the existence of HCVF in Indonesia (*Jarvie 2002*):

1. In global and regional contexts, all primary forests in Indonesia are HCVF
   At a global level, Indonesian primary forest land functions as a host of enormously varied and unique biodiversity.
2. Indonesian HCVF contain a variety of forest ecosystems and characteristics
   The forest ecosystems vary from *Dipterocarp* forest in Kalimantan and Sumatera, while *Matoa* forest dominates the eastern part of Indonesia. All have unique ecosystems functions and face different sorts and levels of threat.
3. HCVF can be managed by forest management unit
   Only with great care and a sound knowledge of the values contained, FMU is able to maintain and even more enhance the HCVF
4. HCVF is not just virgin forest
   Burned, logged or otherwise affected forest can still categorised as HCVF. These forests still contain important biodiversity, ecosystem functions and social values.
The implications of development of the HCVF principles are closely related to the framework of sustainable forest management certification, especially compliance to principle 9. Therefore, forest management unit should complete the four steps as follows (FSC 2001):

1) Identification of the HCVF by means of its key attributes
2) Fit the management regime to be compatible with maintaining or enhancing HCVF attributes
3) Certification decision based on the proposed management regime
4) Monitoring the status of the key attributes over time in certified systems

2.2.2. Identification and Management of HCVF

The six elements comprising the HCVF are necessarily generic, inclusive and contain many terms such as “significant” or “critical” that is not specific. Therefore, this approach may be appropriate at the global scale, but in practice it is extremely difficult for forest management unit to obtain such interpretations (Jennings et al. 2002; Jennings and Jarvie 2003). However, the presence of Global Toolkit for HCV Identification provides guidance for a national level process on how to utilise existing initiatives and approaches and methods for assessment when national guidelines is not yet in existence. In case of national High Conservation Value have been defined, this information then could be used to identify and delineate occurrence of HCVF in a specific forest area.

In the absence of a national set of High Conservation Values (HCV) as resulted from implementation of the Global Toolkit in a particular country, it is also possible to assess the presence of HCV within particular forest area or landscape. However, this requires case-by-case local interpretation and decision making to define local HCV, which would require appropriate technical expertise, such as knowledge of the conservation and social issues that constitute the HCV (Jennings et al. 2002). As a starting point in identifying HCV in a particular forest area (e.g. a FMU), it is necessary to have detailed definition of each of the HCV present. Ideally, each definition of HCV elements has clear and measurable parameter and threshold to be designated as HCV. In common case, where no national definition of HCV exist, then it should be done prior further analysis (e.g. spatial analysis) (Jennings and Jarvie 2003). The next step after HCV are defined is identifying existing information and needs of collecting new data and information. This is a crucial step to avoid redundancy of data and information collection. Of course examining the quality of existing information is definitely required. Analysis then can be carried out to examine and identify the presence of forest areas containing the identified HCV. These are the general steps required for the preliminary assessment of High Conservation Value Forest (HCVF). Once the assessment is complete, the process should continue into management and monitoring phase of the identified HCVF. Before, forest management unit should revise the general forest management plan according to the identified HCVF. The general processes in identifying and managing High Conservation Value Forest (HCVF) is presented in Figure 4.

2.2.3. Role of HCVF Identification and Management in Forest Certification

By identifying and managing HCVF with appropriate measures, the forest management unit has starting point to comply other ecological principles within FSC forest certification standard (i.e. principle 6), which addresses most environmental management and principle 9, which deals with the management of high conservation value itself (FSC 2000; FSC 2001; Jarvie 2002). Some more social criteria within FSC P&C could also be supported, though not directly, e.g. Criteria 2.2, 2.3 of Principle 2 about tenure rights and responsibilities, criteria 3.1, 3.2 and 3.3 of Principle 3 about indigenous people’s right (Daryatun et al. 2002).
2.3. Remote Sensing and its Application in Forestry

2.3.1. Remote Sensing Basics

Even though some other definitions exist, but there is a common understanding about remote sensing, that data on characteristics of the earth’s surface is acquired by a device that is not in contact with the object measured (Janssen et al. 2001). Remote sensing makes use the electromagnetic energy and it operates in several regions in the electromagnetic spectrum. The visible part of electromagnetic spectrum is the most common part used in remote sensing, since optical devices, including human eyes, could detect such electromagnetic energy in this part. However, some earth’s feature could be detected also using electromagnetic energy in the range of ultraviolet and microwave. Hence, remote sensing technique could be distinguished based on the electromagnetic energy range used, as optical remote sensing and microwave remote sensing. (Janssen et al. 2001; Lillesand and Kiefer 1979). The basic of most remote sensing operations is the spectral reflectance characteristics of earth features that could be captured by sensors. By interpreting common reflectance of each earth feature, one can, for example, differentiate the land cover type occur (Lillesand and Kiefer 1979).
2.3.2. Application of Remote Sensing in Forestry

Initial application of remote sensing in forestry manifested through aerial photographs interpretation. Remote sensing, in form of aerial photographs interpretation, can play important role in various activities in forestry (Lillesand and Kiefer 1979). Some examples of the forest management activities supported are forest type and tree species composition identification, estimation of harvestable timber volume, assessment of forest damage caused by disease and insect infestations, monitoring logging and reforestation, forest recreation resource inventory and mapping, wildlife census and management, planning forest roads and monitoring power line right-of-way vegetation ingrowths.

Along with the development of computer-assisted satellite image classification, many remote sensing applications, which supporting tropical rain forest management in general have been studied. Various techniques in radiometric, spectral and spatial enhancement have been applied with various results as well.

Considering optical satellite data as information source, different band combinations with supervised classification was employed to differentiate forest cover type of tropical forest in Thailand (Trisurat et al. 2000), while classifying forest type in Peruvian Amazon using Landsat TM is supported by low-pass filter and image segmentation (Hill 1999). Texture classification of logged forest in Tropical Africa using machine-learning algorithm proved increasing classification accuracy comparing to the classification that makes use of spectral information only (Chan et al. 2003). Some remote sensing applications in differentiate forest-non-forest area and quantification of deforestation in scope of landscape scale study are also well documented (Imbernon and Branthome 2001; Millington et al. 2003; Peralta and Mather 2000).

In relation with biodiversity studies, remote sensing has been combined with ground survey for all plants and animals occurrence in biodiversity assessment of Sango Bay, Uganda (Fuller et al. 1998). A sophisticated study about assessment of representative ness of existing ecosystem-level protected natural areas in Eastern Andes, Colombia utilises remote sensing and GIS extensively to derived ecosystem types map (Armenteras et al. 2003), while geospatial modelling technique was used in characterising biodiversity at landscape level in India (Roy and Tomar 2000).

Considering the use of non-visible satellite data (e.g. microwave/RADAR sensor, hyperspectral images), a number of remote sensing applications, with various RADAR satellite data sources and image enhancement and classification techniques, have proven that RADAR satellite data is useful for supporting forest management and environmental monitoring (e.g. fire damage assessment and potential) (Hoekman et al. 2001; Couturier et al. 2001; Siegert and Hoffman 2000; Sugardiman 2000). Instead of forest fire potential and damage assessment, another study deals with monitoring deforestation and land use in Indonesian tropical rain forest also done using texture analysis technique and ERS-SAR as data source (Kuntz and Siegert 1999).

Regarding to use of hyperspectral data, an airborne hyperspectral data has been analysed to distinguishes forest type composition in Massachusetts, US (Martin et al. 1998). Another experiment of remote sensing using hyperspectral data attempts to differentiate spectral reflectance of tropical plant species. Twenty-one different species from North Queensland, Australia were sampled, and the result will be used to support vegetation mapping that use hyperspectral data (Hartini 2001).

Remote sensing is proven to be useful to support forest certification (Wielaaard 2000). For Indonesian LEI forest certification scheme, according to LEI Criteria and Indicators, remote sensing definitely can be used for assessment of 11 indicators, while for another 14 indicators may offer potential use and another 32 indicators definitely cannot be assessed through remote sensing applications. Some practical experiment of usage of remote sensing to support SFM certification process has been done in Indonesian tropical rain forest and in general, remote sensing is proved as a potential tool to support the assessment of some important indicators (Aguma 2002; Dahal 2002; Bhandari 2003; Yijun 2003).
2.4. Soil Conservation

2.4.1. Definition

Soils of the humid tropics are very variable, ranging from the youngest to about the oldest, from the most fertile to the least fertile in the world. Generally, it is understood that soils formed in humid tropics climates are highly weathered, leached and therefore, infertile. Reddish and Yellowish colours of soils in the tropics indicate the presence of iron oxides, thus supports the general assumption that once the vegetation above the soil surface cleared, the soil would turn into a laterite, a brick pavement or even a desert (Lieth and Werger 1989).

Soil erosion is one form of soil degradation besides soil compaction, low organic matter content, loss of soil structure, poor internal drainage, salinisation and soil acidity problems. In particular, soil erosion is defined as: “physical removal of topsoil by various agents, including falling raindrops, water flowing over and through the soil profile, wind velocity and gravitational pull” (Lal 1990). Historically, soil erosion began with the beginning of intensive agriculture activities, where people removing protective vegetation cover and growing various food crops on disturbed soil surface. In addition, some other large-scale opening of vegetation through commercial logging, preparation of timber and crop estates, and expansion of human settlement accelerated it.

Nowadays, soil erosion is almost universally recognized as serious threat to human’s well being. This is confirmed by facts of active supports given by most governments to soil conservation programmes (Hudson 1995). A general figure of rain erosion susceptibility is presented in Figure 5.

![Figure 5. General distribution of rain erosion throughout the world (Hudson 1995)](image)

2.4.2. Factors Affecting Soil Erosion

Agents of erosion are the carriers or the transport system in the movement of soil (e.g. water, wind). Factors of erosion are those natural or artificial parameters that determine the magnitude of perturbation, e.g. climate, topography, soil, vegetation and management. Erosion may not occur even the agents and factors are present. There are the causes of erosion, which are human activities such as farming practices, deforestation and cropping systems that facilitate the effects of agents and factors of erosion and accelerate the various erosion processes (Bergsma 1996; Lal 1990). The factors affecting soil erosion by water are:
Chapter 2

1. Climatic Erosivity
   Erosivity refers to the aggressivity of the climate, or more precisely the energy of such climatic elements to cause erosion. Climatic factors that affect erosivity are precipitation, wind velocity, water balance, mean annual and seasonal temperatures, etc.

2. Soil Erodibility
   Erodibility is the susceptibility of soil to erosion. This is an inherent property of the soil and is influenced by soil characteristics (e.g. texture, structure, permeability, organic matter content, clay minerals and contents of iron and aluminium oxides).

3. Landforms
   Erosion also affected by terrain relief through degree and length of slope, slope shape and slope aspect. In general, the higher the slope gradient, the more soil erosion by water occurs.

4. Human
   Human activities affects soil erosion through their measures to natural resources. Human activities related to erosion are deforestation, grazing, faulty farming system and cropping intensity. However, some activities in terms of soil conservation measures are reducing the amount of soil erosion (e.g. contouring, planting).

2.4.3. Estimating Soil Erosion Risk
   Measuring soil erosion losses for different soils, crops and management alternatives, and other conditions is an expensive and time-consuming process. Hence, several attempts have been made to predict soil erosion from basic factors (Kirkby and Morgan 1980; Lal 1990). The most widely used soil erosion estimators is Universal Soil Loss Equation (USLE) developed by US Department of Agriculture (Weischmeier and Smith 1978), which is most ideal for the conditions of medium-textured soil, slope length not exceeds 400 feet, slope gradients range from 3-18% and consistent cropping and management system. Universal Soil Loss Equation (USLE) estimates annual soil loss caused by rain erosion by multiplying the factors in the equation of:

   \[ A = R \times K \times L \times S \times C \times P \]

   Where
   - \( A \) = Estimated soil loss per year (ton/ha/year)
   - \( R \) = Rainfall-runoff erosivity index (MJ *mm/ha*h*yr)
   - \( K \) = Soil erodibility factor (ton*ha*h)/(ha*MJ *mm)
   - \( L \) = Slope length and steepness factor (dimension less)
   - \( C \) = Cover management factor (dimension less)
   - \( P \) = Support practice factor (dimension less)

   Several improvements were established to facilitate the application of USLE in various conditions, e.g. for estimating single-storm events, for use on the watershed, range land, forested land, flat lands (Lal 1990). Moreover, the USDA Agriculture Research Service has modified the USLE into Revised Universal Soil Loss Equation (RUSLE) (Renard et al. 1997) by providing some corrections in determination of some factors based on the latest information available for using erosion-prediction approach, while all the factors and the equation were remaining the same.

   USLE, Stehlik Model, “Morgan, Morgan and Finley” (MMF) model, are empirical models (Morgan 1986), there are some other models were developed considering each sub-process occurs in soil erosion caused by rain (i.e. raindrop splash, detachment by surface run-off, and transportation by surface run-off). Some of the models are EUROSEM (European Soil Erosion Model), CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems), ANSWERS (Areal Non-Point Source Watershed Environment Response Simulation) and WEPP (Water Erosion Prediction Project) (Hudson 1995). However, the simplicity and possibility in incorporating limited data leads to prediction of soil erosion using USLE-based models in GIS environment (Angima et al. 2003; Mati et al. 2000; Millward and Mersey 1999; Yazidi 2003). In general, the capabilities of map overlay and calculation provides by GIS allows the prediction and modelling of soil erosion risk.
2.5. Water Resources and Tropical Forest Management

2.5.1. Hydrological Processes in Tropical Forest

Hydrology deals with the circulation of water and its constituents through the hydrologic cycle (Mulloch and Robinson 1993). Water evaporates from the oceans and the land surface, and then it is carried over the earth in atmospheric circulation as water vapour. The water vapour precipitates again as rain or snow, and then intercepted by trees and vegetation, provides runoff on the land surface. Runoff infiltrates into soils, recharges the groundwater and then discharges into streams and ultimately flows out into the oceans from which it will eventually evaporate and therefore repeat the whole cycle (Maidment 1993).

According to the situation in humid tropics, particularly in forested land, some specific characteristics are applied to the tropical forest hydrology, as presented in Figure 6 (Bruijnzeel 1990; Joseph 1999). High rainfall intensity is the precipitation input to the forest in humid tropics. Small part of the precipitation drop to the forest floor directly without any contact with the canopy, which then called as direct throughfall. The tree canopy intercepts some part of the precipitation and evaporates back into the atmosphere during and immediately after the rainstorm. The other part of precipitation reaches the forest floor as crown drip and through the branches and trunks as stemflow after the storage capacities of the canopy and the trunks have been filled. The sum of direct throughfall, crown drip and stemflow comprise the net precipitation.

When the rainfall intensities below the forest exceed the infiltration capacity of the soil, the unabsorbed rainfall becomes overland flow. The rest of the rainfall infiltrates to soil and form the groundwater flow, which takes one of several routes to the stream channel, and therefore called throughflow. However, some part of infiltrated water is taken up by the forest and returns to the atmosphere via transpiration.

Overland flow and throughflow comprises the streamflow, which starts at the channels and most likely flows down to the river and ends at the ocean.

Figure 6. Hydrological cycle in hillslope forest (Bruijnzeel 1990)
In general, infiltration capacities of forest soils are high and infiltration excess overland flow in forests is a seldom case, even under intensive rainfall. This explains how the existence of forests reducing the amount of runoff, while throughflow becomes main contributor for stormflow (Bruijnzeel 1990; Cheng 2002). Comparing to other vegetation cover, the interception losses will be higher from forest than other shorter crops, primarily because of increased atmospheric transport of water vapour from their aerodynamically rough surfaces, while in dry condition, transpiration from forests is greater because of generally increased rooting depth of trees compared with shorter crops and their consequent greater access to soil water. In addition, both in dry and wet condition, evaporation from forests is higher than shorter crops and consequently runoff will be decreased from forested areas. Nevertheless, in case of global climate, the effect of the existence of forest to local amount of rainfall is considerably small and therefore, not significant (Calder 1999).

Regarding soil erosion and slope stability; surface erosion, which usually starts with overland flow, is minimised with the presence of well-developed litter or understorey layer. In addition, the cases of shallow mass movements (e.g. less than 1 m deep) are reduced by the greater slope stability as consequences of well root network (Bruijnzeel 1990). However, the effects from the existence of forest stands are minimum on disastrous landslides, debris flows and floods caused by extreme natural events, such as great earthquake and rainstorm, such as in Taiwan (Cheng 2002).

Considering water quality and supplies of water from a catchment, streams draining forested catchments usually contains low amount of sediments and harmful chemicals (Cheng 2002), therefore forested catchments results in better water quality (Calder 1999; Joseph 1999).

2.5.2. Effects of Forest Management to the Hydrological Features

Commercial logging operations in tropical forests cause adverse effects on the soil and water conditions as well as degrading the remaining forest stands. The agents of these effects are poor road construction practices, use of crawler tractor in log skidding and clearance for other infrastructures. Road construction may results in severe mass movement while log skidding operation may results in heavy soil compaction (Pulkki et al. 2001).

From a study in the USA, forest harvesting resulted in an increase in total streamflow, baseflow, and ground-water recharge (Bent 2001). In Malaysia and Suriname, selective logging caused significant rises in streamflow and dissolved nutrient concentrations (Bruijnzeel 1990). Another study in Malaysia indicates that the extensive logging regime resulted in a decline in saturated permeability and changes in moisture retention of soils, which affects unsaturated zone hydrology (Brooks and Spencer 1997). In Indonesia, a comparison between remaining forest stands after the implementation of Reduced Impact Logging (RIL) and conventional logging were observed and resulting in the superiority of RIL in preventing land and water degradation. As reported, RIL lessen the effects of logging on water yield and runoff, erosion, sediment yield and nutrient losses (Mastur et al. 1999). Another study in Indonesia shows that highest runoff rate was found in the skid trails. Canopy cover, sapling density, litter depth and woody debris appeared to be important factors that determine the amount of soil loss. However, the roles of these factors were less significant compared to the rainfall in determining the magnitude of runoff (Hartanto et al. 2003).

Considering the on-site and off-site effects of forest harvesting to the hydrological features of tropical forest, special care should be taken in any forest management operations (e.g. by minimising the disturbance created by timber extraction and road construction). Even more, monitoring of the on-site and off-site effects of logging operations should takes place to ensure the nature of hydrological functions of the forest (Rainforest Alliance and ProForest 2003).
2.5.3. Drinking Water Supply for Rural Areas in Tropics

Water supply defined as “a maximum sustainable rate at which water can be withdrawn from existing sources without causing undesirable ecological, human health, economic, legal or other consequences” (Dingman 2002). Water supply is identical to "safe yield", which is the rate of water utilisation (withdrawal) that can be maintained more or less indefinitely and relied upon as a measure of the water source.

Water resources problems in the humid tropics relate to both quantity and quality. Access to safe drinking water supplies is a continuing problem in the tropics. It is estimated that globally, 1.2 billion people lack of safe drinking water, and that in developing countries, 50% of the population still have no reasonable access to safe water supplies (Coughanowr 1994). Problems related to water quality is mainly related to water-related diseases, while accessibility in terms of time and energy spent by people for transporting water, and in-balance water demand and supply are some of major problems in water quantity (McDonald and Kay 1988).

Sources of water for daily use in rural area can be varying depend upon the availability (Howard et al. 2002):

- **Spring**
  Spring is where underground water flows to the surface. Springs can make very good water supplies since they are properly protected against contamination

- **Dug Wells**
  Dug wells are usually shallow wells dug by hand, although some may be quite deep, and they are often lined with bricks. However, unless artesian water is tapped, many dug wells go dry or have very little water in dry periods because it is difficult to sink wells below the water table without using more sophisticated techniques

- **Boreholes**
  Depending on the depth of the groundwater, either a hand-pump or motorised-pump may be required to bring the water to the surface. Boreholes usually provide good quality water, but the water sometimes contains harmful chemicals, such as fluoride and arsenic, or nuisance chemicals such as iron

- **Piped Water Supply**
  Small piped water systems are usually fed by gravity, either from protected springs or from surface water above the village, although some may be supplied from boreholes fitted with motorized pumps. Most piped water supplies include storage tanks so that water is always available, even when demand is heaviest.

- **Rain Water**
  Rainwater is usually collected by households for their own use. If the rainwater is to be used for drinking, it is better to collect it from a roof, rather than from a ground catchment where it may become contaminated.

- **Ponds, River, Streams and Lakes**
  Ponds, river, streams and lakes have traditionally been used as sources of drinking water. Although they are easily contaminated, the water quality can be improved by careful use, e.g. using disinfectant.

Considering the advantages of water quality resulted from forested catchments, protecting the forested catchment from high intensity logging and even worse, conversion into agriculture field and other crop field will maintain the quality of surface water (Cheng 2002). In the situation where there are a considerable number of villages downstream of the forested catchments, which are depends upon surface water from streams and rivers as their source of drinking water, the justification to apply conservation measures to the forested catchments becomes definitely clear (Rainforest Alliance and ProForest 2003).
3. STUDY AREA, MATERIALS AND METHODS

3.1. Selection of Study Area

Keeping in mind the overall objective of this research, a number of criteria in selecting the study area were considered:

1. A forest management unit, which is in process of achieving forest certification under Joint Certification Protocol between LEI and FSC
2. A forest management unit, in which the presence of High Conservation Value Forest is not yet identified
3. A forest management unit, which has cooperation agreement with ITC as education institute and authorize such research activities to be conducted within its area

Therefore, Labanan forest managed by PT Hutansanggam Labanan Lestari (previously PT Inhutani I Labanan) was chosen since it has been in cooperation with ITC for years. In general, the project aims at supporting achievement of forest certification and improvements of the current forest certification scheme operating in Indonesia.

3.2. Description of Study Area

3.2.1. Location

Forest area managed by PT Hutansanggam Labanan Lestari (previously PT Inhutani I Labanan) is situated in the Berau District, part of East Kalimantan Province in Indonesia. Previous management of PT Hutansanggam Labanan Lestari, which is PT Inhutani I, also manages some other sites surrounding. Geographically, the forest management unit lies between 1° 45' to 2° 10' N, and 116° 55 and 117° 20' E (Figure 7 in page 19). The land use status of PT Hutansanggam Labanan Lestari is presented in table 1 (Smartwood 2001):

<table>
<thead>
<tr>
<th>Land Status</th>
<th>Total Area (ha)</th>
<th>Conservation and Protection</th>
<th>Operable Production Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logged Area (ha)</td>
<td>60983</td>
<td>22490</td>
<td>38493</td>
</tr>
<tr>
<td>Un-logged Area (ha)</td>
<td>16681</td>
<td>1522</td>
<td>15159</td>
</tr>
<tr>
<td>Non-Productive Area (ha)</td>
<td>5576</td>
<td>5576</td>
<td>0</td>
</tr>
<tr>
<td>Total Area (ha)</td>
<td>83240</td>
<td>29588</td>
<td>53652</td>
</tr>
</tbody>
</table>

3.2.2. Soil and Topography

Acid, (very) deep, strongly weathered and (moderately) well-drained soil with a subsoil clay horizon (classified as Ultisols) is dominant soil type in the undulating to rolling plains and hills of the Labanan area. They are also found overlying sedimentary (sandstone) and metamorphic rocks (schist and claystone). In the locations where erosion is a dominant feature (very to extremely steep slopes) or where drainage is impeded (valley bottoms), poorly developed and intermediate soils are found. Heavy clay and shallow to deep soils - classified as Vertisols and Inceptisols - are found in the undulating plains overlying limestone neutral (Mantel 1998). The labanan landscape can be classified into four classes:

1. Level Land
   These are the floodplain adjacent to the river Sidu’ung, Kelay and Segah
2. Sloping Land
   These are undulating to rolling and hillocky plains that are dominant landforms in this area
3. Steep land
   These are medium to high gradient hills with steep to extremely steep topography
4. Complex Landforms
   These are limestone-associated landscape consisting of undulating plains with rock outcrops
3.2.3. Vegetation Composition

Labanan forest can be classified into lowland mixed *dipterocarp* forest, since it dominated by *dipterocarpaceae* family. This family contributes about 25% of the total number of species, 50% of the basal area and 60% of the stand volume. The most common species occur in this area is *Shorea parvifolia*, *Dipterocarpus acutangulus*, *Shorea pinanga* and *Shorea hopeifolia*. Other common family are *Euphorbiaceae*, *Myristicaceae*, *Ebenaceae*, *Sapotaceae* (Partomiharjo et al. 1999).

3.2.4. Management Situation

Being managed by PT Inhutani I since 1976, most of the natural forest in Labanan area has been logged. Logging activities have been done under Indonesian selective cutting and planting system (TPTI). According to TPTI system, the forest management unit can only harvest commercial timber species with diameter (DBH) ≥ 50 cm in the production forest. Logging intensity in this site ranges from 42-173 m$^3$/ha (Fauzi 2001). The annual allowable cut for PT Inhutani I is approximately 50000 m$^3$ per year within a rotational logging block of approximately 1500 ha. However, the company is implementing conservative logging regime, resulting in the average timber harvest rate as low as 31208 m$^3$ per year (Smartwood 2001). Threats to the forest management unit are illegal logging and conversion of forest to agriculture as implication of area opening by the forest management unit. Up to now, there are two villages inside the Labanan concession boundary; both are under spontaneous resettlement promoted by the government. The forest areas are increasingly converted to agriculture field (Fauzi 2001). Labanan forest is managed under adaptive collaborative management (ACM). PT Inhutani I, local cooperatives, district government and provincial government are the shareholders. However, PT Inhutani I is responsible for all technical aspects related to forest management operations (Wastono 2003).

3.3. Materials

A Landsat 7 ETM+ image set with path and row attributes 117 and 59 acquired at 31st of May 2003 was used to identify the land cover types. Additional spatial data that support the analysis are described in more detail in the next section. GPS receiver, compass, clinometer, diameter tape, measurement tape, canopy densiometer and digital camera were used to carry out field data collection. Some main softwares involved in this study are: Word Processing and Spreadsheet Application (*e.g.* Microsoft Word, Excel), ERDAS® Imagine 8.6, ArcView® 3.3, ArcGIS® 8.3, and some additional tools such as GPS points retrieval software.
Figure 7. Location of the study area
3.4. Preparation and Pre-Processing

3.4.1. Literature Study and Discussion

Prior to fieldwork, literature study was done with more emphasis on understanding of ecological and social context of the study area, the progress on the development of guidelines for HCVF identification and thorough study on where remote sensing and GIS can contribute to the identification of HCVF. Specifically to understand the ecological context of the study area, the situation of the study area according to existing eco-region, flora and fauna composition in general were reviewed. The social context of the study area was studied through the general information about local community. To make sure whether the methods developed in this study are in line with the general guideline of HCVF identification, inputs were sought from people concerning to the development of HCVF identification guideline and progress of SFM certification achievement by the forest management unit (e.g. national FSC and LEI accredited certification body, experts, forestry department, forest management unit officer).

3.4.2. Image Pre-processing and Enhancement

The use of remote sensing in this study is mainly to distinguish major land cover types that occur in the study area. A full-band set of Landsat ETM+ image acquired in 31st May 2003 had been collected prior to fieldwork. In accordance to geometric aspects of image, a cross check to the geo-referencing quality was done before the use of this data set for preliminary classification and as reference during fieldwork. For this purpose, the 2003 image was geo-referenced based on the previous image (2002) and road map as major feature. In case of difficulties due to atmosphere condition during image acquisition, haze removal functionality in ERDAS was employed to enhance the interpretability of the image, but the image that resulted was not as good as expected. To increase the interpretability of the image, linear contrast stretch was applied in this study as the initial attempt of image enhancement. Finally, a pseudo-natural colour composite of the image (RGB 543) was prepared and followed by the preliminary image classification. A print out of the satellite image for reference during fieldwork was also prepared. As a step in preliminary image classification, unsupervised classification had been carried out resulting seven class of different land cover type. Figure 8 shows a flowchart, which describes the processes mentioned in this section.

![Image Pre-processing and Enhancement](image)

**Figure 8. Image Pre-processing and Enhancement**
3.4.3. Visual Image Classification

After the pre-processing and enhancement to the image were done, visual image classification to determine occurrence of forest and land cover types was carried out. Based on the texture of the satellite image (Stellingwerf et al. 1986), the study area was classified into some major forest and land cover types. The result of the visual image classification was used as the basis for stratified random sampling strategy in determining the location and distribution of the sample plots. However, the result of the visual image classification is only considered as general, rather than actual, land and forest cover types, since it was not supported by the data from the field.

3.5. Fieldwork

3.5.1. Collection of Field Sample Data

As essential procedure in image classification, field sample data should be provided in order to establish relationship between spectral reflectance of the image and land cover. The study area was stratified according to the map resulted from visual interpretation and the field sample plots were located accordingly. Some of field sample data collected from preceding fieldwork in the study area were added, with condition of no changes occurred in the land cover types of corresponding location.

Geographic location of each field sample data was obtained using Global Positioning System (GPS). A notable advance in this research was the use of mobile GIS technology supported by ArcPad® from ESRI. Using MrSID™ compression, the satellite image was compressed so that it could be stored in small amount of memory of a pocket PC. By connecting the GPS to the pocket PC, actual location of the user is displayed on the screen, superimposing the satellite image. Where GPS coverage is low (e.g. used under very dense forest canopy), a reference point assigned and additional measurements were done to obtain the location of the data sample point. At each field sample point, forest/land cover type and additional important information were noted.

3.5.2. Collection of Biophysical Data

For every sample-points mentioned above, an assessment of structure and composition of the vegetation was carried out through measurement of diameter and identification of the species name of individual pole and tree as well as average canopy cover percentage of the plot. To limit the extent of measurements, plots with radius 12.62 m (area 500 m²) were established to accommodate the assessment of pole and tree structure and composition. Layout of the plot for pole and tree samples is illustrated in Figure 9. Allocation of these plots was done under stratified random sampling technique, keeping in mind that delineation of pre-defined forest type was done before fieldwork and functions as strata, in which sample plots chosen randomly within each stratum. Additional data collected within tree’s plot were elevation, aspects and slope.

![Figure 9. Plot layout for biophysical data collection](image-url)
3.5.3. Collection of Secondary Data and Interviews

Based on the list of information requirements for HCVF identification (see appendix 5), the following spatial data were collected to accomplish HCVF identification for element 3 and 4:

1. Contour line map
2. Stream network map
3. Distribution of rainfall intensity map
4. Soil type map
5. Location of settlement map

All these data were collected from database of PT Inhutani I and Berau Forest Management Project (BFMP). A simple check to the georeference quality of these data was carried out by finding out whether there was a shift in geographical position. In practice, an observation was done to check whether the data coincide with existing river as a natural feature. A shift to the map coordinates might be applied if necessary. Some interviews were also carried out with FMU officer, some experts in forest management / certification and some key person who had done the preliminary assessment of HCVF. In general, the interviews were focused on the method developed to identify HCVF. The results of the interviews are considered in identifying the presence of HCVF.

3.6. Data Analysis and Preparation of Image Classification

3.6.1. Biophysical Data

After fieldwork, biophysical data were processed to come up with structure and composition of vegetation in the study area. Basal area of each tree was calculated through the following formula:

$$BA = \frac{\pi \times (DBH)^2}{4}$$ (3.1)

Where:  
- **BA**: Basal Area (m$^2$)
- **DBH**: Diameter at breast height (meter)

By summing the basal area of all trees in each plot, basal area of each plot was defined. Basal area and tree density per plots are extrapolated into figures in per hectare, while canopy cover percentage is considered as average cover. These figures, with additional information such as slope, aspect and elevation represent biophysical situation of the sample plots. Forest type in each sample plots is defined based on the scientific name of tree species found in the study area and reference about species composition in relation with forest type (Lieth and Werger 1989; MacKinnon et al. 1996; Whitmore and Burnham 1975). Additional features found in sample plots (e.g. stilt roots and flooded ground surface as sign for swamp forest) are also considered.

3.6.2. Geometric Correction and Cloud Masking of the Image

During field survey, ground control points (GCPs) data were collected to facilitate geometric correction of the image. Geometric correction tool from ERDAS was used to carry out this task. After completing this task, it was found that previous geo-referencing could not perfectly coincide with the ground control points collected from the field. Therefore, transformation and resampling were done to the satellite image based on the GCPs collected from the field. Cloud masking was done by digitising cloudy part of the satellite image, then replace the pixel value with zero. These area then labelled as “no data” area.

3.7. Image Classification and Accuracy Assessment

For each sample plots visited on the ground, the corresponding coordinates were transferred from GPS to a spreadsheet (e.g. Excel’s table) and overlaid on the image. Half portion of the sample plots was used as training sample point for image classification, while another half portion was used as test samples for accuracy assessment. In this study, image classification with maximum likelihood algorithm was carried out using ERDAS 8.6, using RGB 543 band combination for visualisation.
The first step in the use of this classification algorithm is selecting the signature for each class (ERDAS 2002). Before starting up the signature editor, a (point) shapefile containing the coordinates of training sample plots with their attributes (presenting land cover types) were displayed over the image. Then, the area surrounding the sample plots, which known to have same cover type were selected. The separability among signatures was also evaluated through the calculation of transformed divergence distance between each pair of signatures, which was done automatically in ERDAS® signature editor. Since the goal of the image classification is to differentiating major land cover type, therefore water body, bare soil, agriculture field, grassland and forest were assigned as land cover types occur in the study area. These classes were the targets of image classification process. After all training sample points allocated into the signatures the classification algorithm run.

A classified image, either in raster or vector format is the ultimate goal of image classification. However, the quality of the classification process had to be proven. By comparing classified image with the independent field checkpoint (i.e. test samples) data, accuracy of the classification process was assessed. Error matrix and Kappa statistics are two approaches used to prove the accuracy of image classification. ERDAS® accuracy assessment tool is a tool that can facilitate these two approach (i.e. error matrix and Kappa statistics. By having the classified image displayed on screen, independent field check points were added through conversion of checkpoint coordinates into text file, and assigning the columns contain X and Y coordinates. Based on the land cover type observed in the field, the land cover types of the corresponding checkpoints were input. The next steps were running the automatic computation of error matrix and Kappa statistics, and interpreting the results.

3.8. Deriving Digital Elevation Model (DEM)

Digital Elevation Model (DEM) is an essential intermediate product that was derived in this study. DEM is used as main input in watershed delineation and calculating slope length and slope steepness for prediction of potential erosion risk. In this study, a Digital Elevation Model was derived from contour line map with original scale of 1:25,000 and contour interval 12.5 metres. The general process of deriving the DEM is presented in figure 10. The contour line map was generated by PT Mapindo Parama through photogrammetric process that made use of a set of aerial photographs covering the whole study area (Wastono 2003). The contour line map was digitised and stored in format of ESRI PC Arc/Info® line coverage by the company. Since the elevation interpolation algorithm requires point map as the input, the contour line map was converted into grid (which have same grid cell size with desired DEM grid cell) and then converted into point coverage. After the conversion done, spline point interpolation of ArcView® was carried out to produce elevation grid with resolution of 30 metres. Spline interpolation method was chosen since it gives smoothest surface model without spending too much time for computing (McCoy and Johnston 2002), but keeps the best quality of the result (Hengl et al. 2003).

To obtain good quality DEM, a minimum grid size used in computation should be considered. The suitable grid size required for a good quality DEM was calculated as half of the contour line density of the contour line map over the whole study area (Hengl et al. 2003):

\[ P = \frac{A}{2 \times \sum l} \]  

Where:  
- P : Suitable grid size for DEM derivation (m)  
- A : Extent of the area to be computed (m²)  
- l : Length of each contour line (m)

In this study, total length of contour line was calculated by summing the value of “perimeter" for all contour line, from attribute table of the contour line map. As the result of this calculation, the optimum grid size for DEM of the study area was 43.8 m.
The capability of the computer system used for data conversion and point interpolation (e.g., Carrara et al. 1996; Xie et al. 2003) and the extent of the area being computed, which is approximately 2000 km$^2$, are among the limiting factors in deriving a DEM from a contour line map in this study. Nevertheless, the grid size of 30 metres was chosen to have more detail result and to have the same grid cell size with other spatial data (i.e. land cover type map).

The derivation of the DEM from the contour line map in this study was a manual-iterative process, therefore any mistakes caused by error from the source contour line map should be corrected and most of the time, the critical error can only be detected after the DEM was derived and visualised. When the error comes from the original contour line map (e.g. error in code assignment, digitising error), then the contour line map was corrected, while if errors were caused by the data deficiency (e.g. steep slope of riverside, hilltops, or flat area), correction were made by adding (estimated) elevation points to the point coverage.

![Figure 10. Process of deriving Digital Elevation Model (DEM) from contour line map](image)

### 3.9. Delineation of Catchment Partitions

Map of catchment partitions is another intermediate product in this research, which was used as essential input in identification of HCV element 4.1 and 4.2. Drainage basins, catchments, or subcatchments are the fundamental unit in land and water resources analysis (Beven and Moore 1993; Dingman 2002). However, further details about the analysis involving this map will be explained in the next section.

As an initial step before delineating the catchment partitions, the stream network map was analysed to separate the major rivers from the stream network. This step was done through a visual inspection on the nature form of the major rivers, followed by removal of all the tributaries from the map. Information about the major river systems exist in the study area was compiled from working map of the FMU, which contains the major river systems, and a list of major river systems in the study area (BRLKT 2003). By having the map of major river systems, the outlets of the catchments in the study area were defined.
Catchments in the study areas were identified physically by using existing stream network map and Digital Elevation Model (e.g. Beven and Moore 1993). By considering terrain relief and existing stream network, catchment partitions are defined. Two methods (automatic and manual digitising) were implemented in the process of catchment delineation. Soil and Water Assessment Tool extension for ArcView® (AVSWAT) (Figure 11a) was used in this study to facilitate automatic catchments delineation and mapping. AVSWAT needs only Digital Elevation Model (DEM) in Arc/Info® Grid format to delineate catchment partitions with the following sub-processes (Neitsch et al. 2001):

1. Digital Elevation Model set up and sink removal

   Before all pre-processing carry out, map projection and measurement units of the DEM used should be checked. “Focusing area mask” was added (even it is only optionally required) to limit the extent of calculation and available stream network was also added to help analysing the result of automatic stream definition. As the last sub-process, the sink removal function eliminates the non-draining zone (sinks).

2. Stream definition

   In this sub-process, the initial stream network and sub-catchment outlets are defined based on the minimum drainage area required to form the beginning of a stream. AVSWAT actually provides minimum, maximum and suggested area for initial stream definition. In this study, a value close to the minimum area was chosen to obtain detail stream network.

3. Inlet and outlet definition

   This sub-process allows user to refine the inlets and outlets of the (sub) catchment defined by previous sub-process. Outlets are defined as the most downstream (i.e. lowest) locations of the respective sub-catchment. Inlets are defined as either the outlet of sub-catchment upstream (part of overall catchment that is not intended to be simulated) or point sources of discharge. In this study, inlets were not defined since the absence of supporting data.

4. Selection of main outlet

   In this sub-process, main outlet of particular catchment studied was chosen. The main outlet must be the most downstream outlet among all other outlets. By finishing this step and launch the sub-catchment parameter calculation function, the AVSWAT calculates and delineates the sub-catchment parameters automatically.

![AVSWAT](a)

![Manual Delineation](b)

**Figure 11.** (a) Automatic (AVSWAT) and (b) manual delineation (ArcMap®) of catchment partitions
Visual interpretation of digital elevation model and stream network, which followed by manual digitising as presented in a “screen shot” in Figure 11b, was also applied to represent analytical method. This manual method considers the following criteria in order to determine catchment boundaries (divide) and partitions (Beven and Moore 1993; Dingman 2002):

- Catchment boundary (divide) should not cross any river/stream
- In most cases, the top-ridge always become catchment boundary (divide)
- A catchment or sub-catchment must have only one main outlet, i.e. the lowest point
- In case of sub-catchments partitioning, interior nodes or junction where the stream joins other stream can be considered as “outlet”

Even the manual digitising and visual interpretation was time-consuming, this method was applied since the study area is not limited to only one major catchment. In fact, the study area comprises of two major catchment (Segah River and Kelay River) and another two minor catchments (Sidu’ung River and Siagung River) (BRLKT 2003). Hence, the manual method was implemented since the process can concentrate to several catchments.

3.10. Preliminary Assessment of High Conservation Value Forest (HCVF)

Assessment of High Conservation Value Forest comprises preliminary assessment and full assessment. Preliminary assessment emphasis on the identification of (spatial) occurrence of forest containing High Conservation Values (HCV). This process involves analysis of spatial information. Full assessment refers to verification the identified HCV. However, the full assessment is beyond the scope of this study, since it requires the preliminary assessment of HCVF to be done first (Rainforest Alliance and ProForest 2003). Because of the limitation of this study, only HCV elements related to soil and water conservation are assessed. Information requirements and output maps representing these elements are described in Table 2.

<table>
<thead>
<tr>
<th>No</th>
<th>High Conservation Value and Elements</th>
<th>Information Requirements [Identification Task]</th>
<th>Output [Pre Assessment]</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Forest functions as unique source of water for drinking water</td>
<td>Officially designated, important or legally protected water catchments Communities depend upon drinking water</td>
<td>Map of forest areas function as unique source of drinking water for local communities</td>
</tr>
<tr>
<td>4.2</td>
<td>Forest as part of critical major catchments</td>
<td>Areas with high risk of flooding or drought, critical watershed for reservoirs, irrigations, river recharge or hydroelectric schemes</td>
<td>Map of forest areas contribute to critical major catchments</td>
</tr>
<tr>
<td>4.3</td>
<td>Forest critical to erosion control</td>
<td>Spatial information on areas that had serious erosion, landslide or avalanches</td>
<td>Map of forest areas critical to erosion and terrain stability</td>
</tr>
</tbody>
</table>

3.10.1. Identifying Forest Areas Function as Unique Sources of Drinking Water

Some of the regulatory functions of forest, related to water conservation, are absorption, storage and release of water (MacKinnon et al. 1996), which are extremely important. In situation that a particular forest area protects and maintains water supplies for people or communities, without any other alternative sources of drinking water (i.e. unique), then the forest areas are critical and should be considered as High Conservation Value Forest, as presented in Figure 12 (Rainforest Alliance and ProForest 2003). The sources of drinking water means also water for other essential daily needs (Howard et al. 2002). However, an exception should be made when the communities have access to a ready replacement source of water that not influenced directly by the existence of forest area within the forest management unit (e.g. supplied by local drinking water company that use other source of water intake, that can fulfill communities’ needs in reliable way and at an acceptable cost).
The presence of HCV element 4.1 was assessed through an inventory of communities within and surrounding the study area that depend on the river and its tributaries as source of drinking water. The location and extent of villages in and around the study area were delineated through visual interpretation of Landsat ETM+ Image, supported by point map of the location of the villages. According to the data and documents available (BFMP 2000), result of interviews and some field observations, the source of drinking water for communities in and around the study area was defined and incorporated into the analysis.

Based on the location of these particular villages, the delineated catchments, which contain streams that pass through the settlement area of these villages, were chosen and assigned as forest area function as unique source of drinking water to communities (e.g. US-EPA 1997), and therefore the forest areas were assigned as HCV 4.1 (Rainforest Alliance and ProForest 2003).

3.10.2. Identifying Forest Areas as part of Critical Major Catchments

If a forest area comprises large proportion of a catchment, then it has critical role in maintaining water quality and quantity. According to the similar HCVF study, forest area comprises 38% of a critical catchment was defined as HCVF (Daryatun et al. 2002). As the importance of the catchment increased, in terms of flooding or drought risk or water usage, the services provided by the forest become more critical. According to the HCVF guideline, all forest areas lies within super-priority catchment and priority catchment areas (i.e. in Indonesia’s case are catchment priority I and II) should be considered as High Conservation Value Forest (Rainforest Alliance and ProForest 2003). In case of Indonesia, major catchment prioritisation was done by Ministry of Forestry of Indonesia, in particular by Directorate General of Reforestation and Land Rehabilitation (Anonymous 1987). The criteria used by the Ministry of Forestry of Indonesia in prioritising major catchment are described in Table 3.
### Table 3. Criteria for catchment prioritisation in Indonesia (Anonymous 1987)

<table>
<thead>
<tr>
<th>No</th>
<th>Criteria and Weight (in %)</th>
<th>Sub-Criteria</th>
<th>Weight (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land and Soil (44.7%)</td>
<td>- Critical land</td>
<td>28.0</td>
<td>Determined by other set of criteria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Erosion risk</td>
<td>12.5</td>
<td>Calculated through USLE* formula</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Land cover</td>
<td>4.2</td>
<td>Determined by remote sensing</td>
</tr>
<tr>
<td>2</td>
<td>Hydrology (19.8%)</td>
<td>- Sediment load</td>
<td>10.0</td>
<td>Result of river flow monitoring system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Index of water usage</td>
<td>4.9</td>
<td>Determined by ministry of public works</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Coefficient of variation (CV)</td>
<td>3.7</td>
<td>Determined by ministry of public works</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Water quality</td>
<td>1.2</td>
<td>Based on criteria of Min. of Environment</td>
</tr>
<tr>
<td>3</td>
<td>Socio Economic (22.8%)</td>
<td>- Population pressure</td>
<td>15.0</td>
<td>Calculated through Otto’s equation**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- People awareness on Soil Conservation</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Number of poor families within the catchment area</td>
<td>4.6</td>
<td>Determined by National Development Agency (BAPPENAS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Number of undeveloped villages</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Investment (8%)</td>
<td>- Protection value of water infrastructure</td>
<td>4.0</td>
<td>Defined by valuation of existing water infrastructures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Value of the tax objects</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Regional Development Policy (4.7%)</td>
<td>- Protection Area</td>
<td>1.7</td>
<td>Determined by the presence or absence of such area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Designated Area</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Special Area</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Eastern of Indonesia</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

* Universal Soil Loss Equation for prediction of yearly soil erosion risk
** An equation to calculate population pressure, available at (Anonymous 1987)

Considering the complexity of the process of major catchment prioritisation, which is far beyond the scope of this study, therefore the given list of critical water catchments (BRLKT 2003) was used to decide how critical are the major catchments that correspond to the study area. The presence of HCV element 4.2 was assessed through an observation of the extent of the catchments within study area, which potentially contribute to the quality and quantity of water in the pre-defined critical major catchments (i.e. catchments priority level I and II). Considering the precautionary approach suggested in identification of HCVF (Jarvie 2002), if the forest area comprises at least 30 % of the entire critical major catchments, the forest area then can be defined as significant part of critical major catchments, and therefore assigned as forest area containing HCV 4.2 element (Daryatun et al. 2002; Rainforest Alliance and ProForest 2003). The decision scheme in identifying the presence of HCV element 4.2 is described in the flowchart in Figure 13.

---

**Figure 13.** Decision scheme to identify forest area as part of critical major catchment
Operationally, vector editing and table operation functions in of ArcView® were extensively used to select water catchment partitions that fulfil the criteria to be assigned as areas containing HCV elements 4.1 and 4.2. The spatial analysis done to determine the presence of HCV elements 4.1 and 4.2 are described in Figure 14.

Figure 14. Spatial analysis for identification of HCV elements 4.1 and 4.2

3.10.3. Identifying Forest Areas Critical to Erosion Control

Dominant soil in the tropical rain forests in Indonesia is the red-yellow podzolic (Acrisols), which is highly vulnerable to erosion. Exposed tropical soils degrade quickly due to leaching of nutrients, burning of humus, laterisation of minerals and accelerated erosion of top soil (MacKinnon et al. 1996). Forest areas, which are important in maintaining terrain stability (i.e. to control excessive erosion, which can lead to landslides and serious siltation), in an area where the consequences are severe, should be considered as HCVF (Rainforest Alliance and ProForest 2003).

In this study, an estimation of potential erosion risk in the study area was carried out to identify the areas with high erosion risk. To spatially estimate the potential erosion risk, distribution of rainfall intensity, slope length and slope steepness factor derived from Digital Elevation Model (DEM), soil map and land cover map were used to establish a map of potential erosion risk. A universal model developed by USDA-ARS, Universal Soil Loss Equation (USLE) (Weischmeier and Smith 1978) is used to estimate the erosion risk of the study area, with the following equation:

\[
A = R \times K \times L \times S \times C \times P
\]

Where
- \( A \): Estimated soil loss per year (ton/ha.year)
- \( R \): Rainfall-runoff erosivity index (MJ *mm/ha*h*yr)
- \( K \): Soil erodibility factor (ton*ha*h)/(ha*MJ *mm)
- \( LS \): Slope length and steepness factor (dimension less)
- \( C \): Cover management factor (dimension less)
- \( P \): Support practice factor (dimension less)
Universal Soil Loss Equation (USLE) was applied since it requires a simple data set for inputs (Millward and Mersey 1999; Shi et al. 2004) and compatible with Geographic Information System (GIS) in the field-scale (Gobena 2003; Mati et al. 2000; Yazidi 2003). However, the amount of annual soil loss predicted in this study cannot be interpreted as actual value in any sense. This is because the situation in this research is fairly different from original situation in which USLE model was developed (e.g. agricultural field, with slope length maximum 400 feet and slope gradient range between 3-18% and consistent cropping and management system) (Weischmeier and Smith 1978). Therefore, the resulted prediction of soil loss remains only as an indication to which area is prone to serious erosion rate, especially when the natural vegetation cover is removed. The following flowchart illustrates the general process in estimating relative soil loss in GIS environment.

![Flowchart of Calculating Relative Soil Loss by Rain Erosion](image)

To assess the presence of forest area functions as critical soil erosion control, the amount of relative soil loss by rain erosion is compared to the common soil loss tolerance. The soil loss tolerance, according to most literatures (Hudson 1995; Kirkby and Morgan 1980; Lal 1990; Mati et al. 2000; Morgan 1986; Shi et al. 2004; Tripathi et al. 2003; Weischmeier and Smith 1978) range from 10 to 12.5 ton/ha/yr, even though 11 ton/ha/yr is widely used as soil loss tolerance. Therefore, when the amount of potential soil loss by rain erosion exceeds 11 ton/ha/yr, the areas classified as “high erosion risk”.

USLE estimates annual soil loss (caused by sheet and rill erosion) by rain erosion based upon six factors as mentioned before (i.e. rain erosivity, soil erodibility, slope length, slope steepness, crop management and support practice factor) (Renard et al. 1997; Weischmeier and Smith 1978). The assignment of value for each factor is described as follow:
Identification of High Conservation Value Forest (HCVF) Related to Soil and Water Conservation

Chapter 3

Rainfall-runoff Erosivity Factor (R)

The R factor represents the erosivity of the rainfall at a particular location. Rainfall Erosivity (R) is originally calculated as a product of storm kinetic energy (E) and the maximum 30-minute storm depth (I_{30}) summed for all storms in a year. An average annual value of R is determined from historical weather records and is the average annual sum of the erosivity of individual storms (Weischmeier and Smith 1978). Regarding the study area, available dataset are records of monthly rainfall amount (mm/month) and raindays (days/month), as well as an isohyet map representing the general distribution of annual rainfall. As common situation found in developing countries, there was no rainfall intensity data collected in the rainfall station. Therefore, the following equation, which is derived for tropical areas (El-Swaify et al. 1985), was used to calculate R-Factor based on annual rainfall amount.

\[
R = 38.5 + 0.35P
\]  
(3.4)

Where

- \( R \): annual rainfall-runoff erosivity factor (MJ.mm.ha^{-1}.h^{-1}.yr^{-1})
- \( P \): annual rainfall amount (mm) summed from monthly recorded rainfall amount (mm)

\( P \) value was derived from averaged annual rainfall record collected from two rain station, i.e. Labanan Jaya Village (1991-1999) and Berau Airport (1971-1999), which are 2411 mm/yr and 1996 mm/yr, respectively. Considering the spatial variation of the rainfall amount, the isohyet map, with additional data from the rain stations, was interpolated to grid map with 300 metres cell size to come up with spatial distribution of annual rainfall. The grid map of annual rainfall was resampled to 30 metres to allow spatial overlay with grid map of other factors of USLE. All climatic data were collected from BFMP (Berau Forest Management Project), which was operating in the study area.

Soil Erodibility Factor (K)

The soil erodibility factor is the average long-term soil and soil profile response to the erosive power of rainfall and runoff. Soil erodibility factor represents the effect of soil properties and soil profile characteristics on soil loss. To determine the K-value for each soil type, the following equation was used (Weischmeier and Smith 1978), given the silt fraction does not exceed 70%:

\[
K = \frac{2.1 \times 10^{-4} \times (12 - OM) \times M^{1.14} + [3.25 \times (S - 2)] + [2.5 \times (P - 3)]}{100}
\]  
(3.5)

Where:

- \( K \): Soil Erodibility Factor (t.ha^{-1}.MJ^{-1}.ha.mm^{-1}.h)
- \( OM \): Organic matter content (%)
- \( M \): Product of primary particle size fractions
  \[ M = (% \text{ Silt} + % \text{ Very Fine Sand}) \times (100 - % \text{ Clay}) \]
- \( S \): Code of Soil Structure
- \( P \): Code of Soil Permeability

Among all dataset collected from BFMP, the result of 1998 soil survey, which covering the whole study area, provides most complete information on soil properties and detail characteristics of each profiles, which had been sampled. There were 35 samples collected during the survey (see appendix 4 for complete soil profile characteristics), which are representing almost all land systems occurred in the study area.

To avoid over estimation of organic matter content and to have reliable soil texture and properties (Rossiter 2004), only soil horizons with minimum 5 cm depth were calculated to come up with estimated K-value. This is because of high concentration of organic matter from abundant litter on the ground surface of the forest.
Identification of High Conservation Value Forest (HCVF) Related to Soil and Water Conservation

Chapter 3

Table 4. Soil profiles and their distribution to the land systems in the study area (Mantel 1998)

<table>
<thead>
<tr>
<th>Profile_ID</th>
<th>Land_Syst</th>
<th>Soil_USDA</th>
<th>Soil_FAO</th>
<th>Particle_Class</th>
<th>Distr_ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDKAL002</td>
<td>BKN</td>
<td>Typic Haplaquox</td>
<td>Haplic Acrisol</td>
<td>Silty Loam</td>
<td>55</td>
</tr>
<tr>
<td>IDKAL003</td>
<td>KPR</td>
<td>Chromic Hapludert</td>
<td>Eutric Vertisol</td>
<td>Silty Clay Loam</td>
<td>75</td>
</tr>
<tr>
<td>IDKAL012</td>
<td>GBJ</td>
<td>Lithic Eutropept</td>
<td>Eutric Leptosol</td>
<td>Clay</td>
<td>25</td>
</tr>
<tr>
<td>IDKAL013</td>
<td>GBJ</td>
<td>Lithic Hapludert</td>
<td>Eutric Vertisol</td>
<td>Silty Clay</td>
<td>20</td>
</tr>
<tr>
<td>IDKAL030</td>
<td>KPP</td>
<td>Typic Eutropept</td>
<td>Eutric Cambisol</td>
<td>Clay Loam</td>
<td>30</td>
</tr>
<tr>
<td>IDKAL031</td>
<td>KPP</td>
<td>Typic Hapludalf</td>
<td>Haplic Lixisol</td>
<td>Loam</td>
<td>5</td>
</tr>
<tr>
<td>IDKAL032</td>
<td>KPP</td>
<td>Typic Paleudult</td>
<td>Haplic Alisol</td>
<td>Loam</td>
<td>35</td>
</tr>
<tr>
<td>IDKAL036</td>
<td>KPP</td>
<td>Typic Eutropept</td>
<td>Eutric Cambisol</td>
<td>Loam</td>
<td>30</td>
</tr>
<tr>
<td>IDKAL006</td>
<td>KPR</td>
<td>Chromic Hapludert</td>
<td>Eutric Vertisol</td>
<td>Clay</td>
<td>45</td>
</tr>
<tr>
<td>IDKAL007</td>
<td>KPR</td>
<td>Fluvaquentic Eutropept</td>
<td>Gleyic Cambisol</td>
<td>Silty Clay Loam</td>
<td>10</td>
</tr>
<tr>
<td>IDKAL008</td>
<td>KPR</td>
<td>Oxyaquic Hapludert</td>
<td>Eutric Vertisol</td>
<td>Silty Clay Loam</td>
<td>35</td>
</tr>
<tr>
<td>IDKAL015</td>
<td>KPR</td>
<td>Typic Eutropept</td>
<td>Eutric Cambisol</td>
<td>Silty Clay Loam</td>
<td>10</td>
</tr>
<tr>
<td>IDKAL003</td>
<td>LWW</td>
<td>Aquic Kandidult</td>
<td>Gleyic Acrisol</td>
<td>Loam</td>
<td>0</td>
</tr>
<tr>
<td>IDKAL020</td>
<td>LWW</td>
<td>Aquic Paleudult</td>
<td>Haplic Acrisol</td>
<td>Loam</td>
<td>35</td>
</tr>
<tr>
<td>IDKAL021</td>
<td>LWW</td>
<td>Tropic Fluvaquent</td>
<td>Dystric Fluvisol</td>
<td>Clay</td>
<td>20</td>
</tr>
<tr>
<td>IDKAL026</td>
<td>LWW</td>
<td>Typic Paleudult</td>
<td>Haplic Acrisol</td>
<td>Sandy Loam</td>
<td>45</td>
</tr>
<tr>
<td>IDKAL004</td>
<td>MPT</td>
<td>Typic Paleudult</td>
<td>Haplic Acrisol</td>
<td>Sandy Loam</td>
<td>50</td>
</tr>
<tr>
<td>IDKAL005</td>
<td>MPT</td>
<td>Typic Paleudult</td>
<td>Haplic Acrisol</td>
<td>Sandy Clay Loam</td>
<td>25</td>
</tr>
<tr>
<td>IDKAL009</td>
<td>MPT</td>
<td>Typic Dystropept</td>
<td>Dystric Cambisol</td>
<td>Silty Loam</td>
<td>0</td>
</tr>
<tr>
<td>IDKAL010</td>
<td>MPT</td>
<td>Typic Hapludult</td>
<td>Ferric Alisol</td>
<td>Clay</td>
<td>0</td>
</tr>
<tr>
<td>IDKAL011</td>
<td>MPT</td>
<td>Typic Hapludult</td>
<td>Ferralic Cambisol</td>
<td>Silty Clay</td>
<td>0</td>
</tr>
<tr>
<td>IDKAL017</td>
<td>MPT</td>
<td>Typic Kandidult</td>
<td>Haplic Acrisol</td>
<td>Loam</td>
<td>10</td>
</tr>
<tr>
<td>IDKAL024</td>
<td>MPT</td>
<td>Oxyaquic Eutropept</td>
<td>Eutric Cambisol</td>
<td>Sandy Loam</td>
<td>15</td>
</tr>
<tr>
<td>IDKAL025</td>
<td>MPT</td>
<td>Typic Dystropept</td>
<td>Dystric Cambisol</td>
<td>Clay Loam</td>
<td>0</td>
</tr>
<tr>
<td>IDKAL026</td>
<td>MPT</td>
<td>Typic Kandidult</td>
<td>Haplic Acrisol</td>
<td>Sandy Clay Loam</td>
<td>10</td>
</tr>
<tr>
<td>IDKAL029</td>
<td>MPT</td>
<td>Typic Kandidult</td>
<td>Haplic Acrisol</td>
<td>Sandy Loam</td>
<td>10</td>
</tr>
<tr>
<td>IDKAL033</td>
<td>PDH</td>
<td>Typic Dystropept</td>
<td>Dystric Cambisol</td>
<td>Loam</td>
<td>0</td>
</tr>
<tr>
<td>IDKAL018</td>
<td>TWB</td>
<td>Typic Hapludult</td>
<td>Haplic Acrisol</td>
<td>Clay Loam</td>
<td>15</td>
</tr>
<tr>
<td>IDKAL019</td>
<td>TWB</td>
<td>Aquic Eutropept</td>
<td>Gleyic Cambisol</td>
<td>Sandy Loam</td>
<td>80</td>
</tr>
<tr>
<td>IDKAL001</td>
<td>TWH</td>
<td>Typic Paleudult</td>
<td>Haplic Acrisol</td>
<td>Sandy Loam</td>
<td>15</td>
</tr>
<tr>
<td>IDKAL002</td>
<td>TWH</td>
<td>Typic Paleudult</td>
<td>Haplic Acrisol</td>
<td>Clay Loam</td>
<td>50</td>
</tr>
<tr>
<td>IDKAL014</td>
<td>TWH</td>
<td>Typic Tropaquept</td>
<td>Dystric Fluvisol</td>
<td>Clay</td>
<td>10</td>
</tr>
<tr>
<td>IDKAL016</td>
<td>TWH</td>
<td>Aquic Paleudult</td>
<td>Haplic Acrisol</td>
<td>Clay</td>
<td>0</td>
</tr>
<tr>
<td>IDKAL034</td>
<td>TWH</td>
<td>Typic Hapludult</td>
<td>Haplic Acrisol</td>
<td>Loam</td>
<td>0</td>
</tr>
<tr>
<td>IDKAL035</td>
<td>TWH</td>
<td>Typic Paleudult</td>
<td>Haplic Acrisol</td>
<td>Clay Loam</td>
<td>25</td>
</tr>
</tbody>
</table>

In this study, land systems map was the only spatial data that geographically represents the soil types (therefore, should represent K-value as well) throughout the study area. In addition, the soil profiles data collected during 1998 field survey did not represent all land systems and soil types contained. Moreover, there are some soil profiles that represents land systems, which do not exist in land system map produced by BFMP (distr. 0% in Table 4). Some examples are presented in Table 4, when the total proportion is more or less than 100%, there should be incomplete or over-complete representative profiles. The solutions for these situations are presented in table 5.

Table 5. Solutions for incomplete or redundant soil profile characteristics data

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>No representative soil profile for a particular soil type or land system</td>
<td>Replace K-value from soil profile, which has similar parent materials with corresponding soil type or land system</td>
</tr>
<tr>
<td>Some profiles representing one soil type in a land system</td>
<td>Average the K-value of those profiles</td>
</tr>
<tr>
<td>A profile does not represent any land system</td>
<td>Drop the soil profile from final K-value calculation</td>
</tr>
<tr>
<td>A land system contains proportions of some soil types along with derived K-value</td>
<td>Based on the proportions, calculate the weighted-average of K-value for corresponding land system</td>
</tr>
</tbody>
</table>

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Slope Length and Slope Steepness Factor (LS)

Slope length (L) is defined as horizontal distance from the origin of overland flow to the point where the slope gradient decreases considerably, so that the deposition begins, or where runoff becomes concentrated in a defined channel (Weischmeier and Smith 1978). Slope length of 400 feet (~120 metres) is recommended practical limit in application of USLE, and originally L-factor is the actual horizontal distance of the field of experiments where actual erosion is measured.

In this study, the slope length was estimated through determination of flow accumulation (Bernie 1999 as cited by Yazidi 2003). The technique is based on the principle that flow distributes according to relative slope of downhill pixels and slope length is indeed a horizontal projection of field surface (Renard et al. 1997). Digital Elevation Model (DEM) was used as main source of the estimation of slope length. Using AVSWAT extension for ArcView®, the DEM was preprocessed to delineate and add the depressions and sinks that indicate the route of flow. The next sub-process was determination of flow direction and then flow accumulation. The flow accumulation grid map is actually an intermediate product of water catchment delineation process, as mentioned in section 3.9. Flow accumulation is defined as the amount of pixels contributing to the flow in a particular pixel. Since the resolution of the DEM used is 30 metres, the slope length limit of 120 metres were converted to flow accumulation value of 4 pixels. Therefore, any flow accumulation value exceeds four pixels will be assigned to four as the maximum slope length. The following equation was applied into ERDAS® Spatial Modeler to produce the desired L-factor map.

\[ L = (\text{Flow} \_\text{Accumulation} \times \text{Pixel Size} \div 22.13)^{0.4} \]  

Slope steepness factor (S) reflects the influence of slope gradient on soil erosion. The equation provided by (Renard et al. 1997) was used to calculate the slope steepness factor.

\[ S = 10.8 \times \sin \theta + 0.03 \quad \text{for slope} > 9\% \]  

\[ S = 16.8 \times \sin \theta - 0.50 \quad \text{for slope} \leq 9\% \]  

By multiplying L and S factor map in ERDAS® Spatial Modeler, the LS factor map was produced.

Cover Management Factor (C)

C factor reflects the effects of vegetation cover on soil erosion, hence, this factor is often used to compare relative impacts of management options on conservation plan. In this study, a land cover type map was produced as the result of image classification of Landsat ETM+ Image (section 3.7). In accordance to this, a set of derived C-value was derived by BFMP based on the land use classification carried out during the phase of the project. Map of C factor then produced by comparing C-value derived by BFMP with most literatures (Bergsma 1996; Lal 1990) and assigning each classes in the classified image. Table 6 shows the C-value assignment for five classes of major land cover types resulted from image classification.

<table>
<thead>
<tr>
<th>Land Cover</th>
<th>C Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Body</td>
<td>0</td>
</tr>
<tr>
<td>Forest</td>
<td>0.01</td>
</tr>
<tr>
<td>Grassland</td>
<td>0.25</td>
</tr>
<tr>
<td>Agriculture Field (Hill Rice)</td>
<td>0.60</td>
</tr>
<tr>
<td>Bare Soil</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 6. C-value assignment for major land cover type
Support Practice Factor (P)

P factor of USLE is the ratio of soil loss with a defined support practice to the corresponding soil loss with upslope and downslope tillage (Renard et al. 1997; Weischmeier and Smith 1978). Since no conservation measures took place in the study area (especially in forested area), the P factor was assigned as a value of 1, which means no effort was made neither to control nor to reduce the effects of erosion.

Assessing forest areas with high erosion risk

By multiplying all factors derived above (i.e. R factor, K factor, LS factor, C factor and P factor) in ERDAS® Spatial Modeler, an estimated erosion risk map was produced. To identify forest area which is, by nature, has high erosion risk, the resulted soil erosion risk map was reclassed according to the land cover type map. Any forest areas with estimated soil loss more than 11 t.ha\(^{-1}\).yr\(^{-1}\) then was assigned as “forest areas with high erosion risk”, and therefore comprise the HCVF 4.3.
4. RESULTS

4.1. Visual Image Interpretation

After the pre-processing and image enhancement to the image done, visual image classification to determine dominant forest type was carried out. Based on the texture of the satellite image (Stellingwerf et al. 1986), the study area was classified into five land cover types as follows:

- Lowland Dipterocarp Forest / Flat (LDF/F)
- Lowland Dipterocarp Forest / Hilly (LDF/H)
- Swamp Forest
- Riparian Forest
- Settlement

The map of dominant forest and land cover types is presented in Figure 16.

As can be seen in Figure 16, lowland dipterocarp forest is the dominant land cover type in the study area. The flat and hilly dipterocarp forests were differentiated since they reflected clearly different texture and terrain relief (as confirmed by the derived DEM). However, the resulted land cover types were used only for stratification of study area to locate the sample plots.
4.2. Vegetation Composition and Biophysical Situation

As the result of field survey for vegetation composition, lowland *dipterocarp* forest, freshwater swamp forest and riparian forest are the forest types found in the study area. Lowland *dipterocarp* forest found as dominant forest type that covers most of the study area, while freshwater swamp forest occurs in the area just behind the riparian forest strip along the river. The occurrence of swamp forest was indicated by the presence of stilt root and flooded ground surface experienced during data collection. An example of the freshwater swamp forest environment is presented below, along with the scheme of common forest types found in the tropics (Lieth and Werger 1989).

![Diagram of common forest types](image)

**Figure 17.** (a) Freshwater swamp forest and (b) scheme of common forest types in the tropics

As presented in Figure 17a above, the white ellipse line emphasis the occurrence of stilt root just behind the small sapling in front, and Figure 17b describes a scheme of common forest types that occur in the humid tropics. LDF stands for Lowland *Dipterocarp* Forest, RF for Riparian Forest and SF for Freshwater Swamp Forest (after Lieth and Werger 1989).

Out of total 1195 individual trees from 172 different species and 38 families (DBH > 10 cm) recorded from 38 plots @ 0.05 ha, 192 trees belong to the family of *Euphorbiaceae* (16%) and another 150 are belong to the family of *Dipterocarpaceae* (13 %), followed by 107 trees (9%) of *Myrtaceae* and 89 trees (7%) of *Lauraceae*. Complete list of tree families found and their percentage from field survey is presented in Figure 18. Compared to the result of previous vegetation composition survey in the study area (Partomiharjo et al. 1999), this result is slightly different in terms of family dominance. However, small percentage of dominant families indicates high flora diversity in the study area (MacKinnon et al. 1996).

From biophysical perspective, the study area has moderate density of trees represented by the average basal area of 34.35 m²/ha, average individual trees density of 31 trees/ha and average canopy cover of 83%. Terrain situation of the study area is varying from the flat floodplain, rolling and large plateau, until hilly and steep areas. According to the field survey, the elevation of the sample plots range from 30 up to 310 m a.s.l, while the slope measured from each sample plots varies from 0 (completely flat) to 74% of slope gradient.
4.3. Image Classification

Image classification is done in order to differentiate major land cover types in the study area. Five classes, namely water body, bare land, grassland, agriculture field and forest were assigned according to sample tests collected in the field and knowledge about the area. The separability of these five classes was also evaluated, through the calculation of (transformed divergence) distance between signatures. The transformed divergence value ranges from 0 to 2000, if the result is greater than 1900, then the classes can be separated. Between 1700 and 1900, the separation is fairly good. Below 1700, the separation is poor (ERDAS 2002). As can be seen in Figure 19, the lowest separability found between agriculture field and grassland. This is explained by spectral reflectance plot presented in figure 20b, where the spectral reflectance of these features are close each other, even in band 4, which is best in differentiating vegetation cover.

Maximum likelihood algorithm was used to classify the image based on the signatures derived. To eliminate small area with different class compared to the pixels surrounding, majority filter with 5x5 kernel was used to smoothen the image and remove the “salt-and-pepper” effect on the classified image. This process also involves knowledge about what are the land cover types in the field. Filtered and classified image is presented in Figure 20a, along with the plot of spectral reflectance of the signatures in Figure 20b.
Figure 20. The classified and filtered image (a) and spectral reflectance plot of the signatures (b)

Figure 21. Condition of Sidu’ung River
Accuracy assessment tool in ERDAS was used to assess the accuracy of the process of image classification, with the result summarized in table 7.

Table 7. Error matrix, accuracy and kappa statistics of image classification

<table>
<thead>
<tr>
<th>Classified Data</th>
<th>Reference Data</th>
<th>Accuracy</th>
<th>Kappa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undclassified</td>
<td>0</td>
<td>74%</td>
<td>0.66</td>
</tr>
<tr>
<td>Bare Land</td>
<td>22</td>
<td>58.33%</td>
<td>0.5299</td>
</tr>
<tr>
<td>Forest</td>
<td>34</td>
<td>91.18%</td>
<td>0.8563</td>
</tr>
<tr>
<td>Water Body</td>
<td>14</td>
<td>28.57%</td>
<td>1</td>
</tr>
<tr>
<td>Agriculture Field</td>
<td>18</td>
<td>72.22%</td>
<td>0.5011</td>
</tr>
<tr>
<td>Grassland</td>
<td>12</td>
<td>58.33%</td>
<td>0.6531</td>
</tr>
<tr>
<td>Column Total</td>
<td>100</td>
<td>74%</td>
<td></td>
</tr>
</tbody>
</table>

Considering the accuracy level that resulted from image classification and by visual evaluation of the classified images, it was found that the maximum likelihood classification gave satisfactory result in order to differentiate major land cover types. Quantitatively, overall accuracy of 74% and kappa statistic of 0.66 indicates that almost three out of four pixels have been successfully assigned to the correct land cover type. Qualitatively, most of the agriculture field along the main roads, around the Sidu’ung River and around the transmigration area in the northern part of the study area were correctly classified. Another clear indications are that all major roads, feeder roads network within the recent logging area in the northern part of the study area, the grasslands around Sidu’ung River, and the settlements in northern and northern-east of the study area were classified successfully.

One important note from the image classification process was the low accuracy of the maximum likelihood to classify some water bodies. In fact, this factor considerably decreased the classification accuracy. As can be seen from the classification accuracy matrix, only four out of fourteen ground truth points were correctly classified as water body. The explanation for this is the width of Sidu’ung River, where several ground truth points were located, which is less than 15 metres wide (a half pixel wide of Landsat ETM+ image). As can be seen in Figure 21, the width of Sidu’ung River is so small (8-12 metres) so that it does not allow the classifier to assign the pixels as water body.
4.4. Digital Elevation Model (DEM)

After several trials for establishing the Digital Elevation Model (DEM), one final version of DEM dataset was built through surface interpolation function of ArcView® Spatial Analyst. The resolution of the Digital Elevation Model used is 30 meters, which is consistent with other dataset used (e.g. classified image). A rapid and relative quality assessment of derived DEM (e.g. how accurate is the terrain relief reasonably represented) (Hengl et al. 2003) was conducted by considering the following criteria (Carrara et al. 1996):

- Elevation value near the original contour lines must have value close to the contour labels
- In each area bounded by a pair of contour line, DTM heights must assume values within the elevation range defined by the two contour labels
- In areas characterized by low relief information such as wide valley bottoms or at hill tops, the elevation patterns must reflect a reasonable or realistic morphology

Actually, no thorough measures were done during this rapid quality assessment, considering time requirements for each process and the extent of the area where the DEM is derived (approx. 2000 km²). Therefore, when the derived DEM adequately satisfies the criteria mentioned above, then it was assigned as the “final result”. From the quality assessment, some types of error were found during derivation of DEM, and presented in two screenshots in Figure 22 (a) and (b).

![Figure 22. Typical error in DEM derivation, (a) human error and (b) unrealistic result](image)

For the first example (Figure 22a), black lines and polygons indicate extremely low elevation within relatively high elevation. The white area is a complex of mountainous area at the western part of study area with elevation range from 500 to 700 m (for contrast visualisation, the image was stretched to the range of 0 – 500 m). To eliminate this type of error, elevation value in the attribute table of the corresponding contour lines were re-assigned to the correct value (through ArcEditor in ArcGIS®), then the rest of the processes (e.g. conversion and interpolation) had to be repeated. For the second type of error, the cause of this error was the complex relief of the riverbank where the riverside is extremely steep, but then it turns to flat slope (e.g. area marked by white dotted line in Figure 22b). Same errors occur in large extent of flat area. In these cases, the spline interpolator then made unpredictable interpolation of the surrounding value. To diminish these artefacts, additional points with known (estimated) elevation were added along the rivers and in flat areas, assuming the elevation of water surface of the river and the flat areas have same elevation value. By applying this strategy, the surface interpolator had more points to interpolate, resulted in better elevation estimation of unknown area.
4.5. Catchment Partitions

This is another part of analysis, which is also time-consuming as of Digital Elevation Model derivation. As mentioned in the previous chapter, automatic and manual-analytical methods were used in delineating catchment partitions for the whole study area, based on derived DEM and existing stream network map. The use of AVSWAT (ArcView extension for Soil and Water Assessment) to automatically delineate catchments, resulted in one major catchment comprises of one major outlet (marked by red circle on the right of Figure 23) and neglected other minor catchments. Even AVSWAT allows manual editing to add known stream networks, including their flow directions and outlets (Neitsch et al. 2001), but the resulted catchment is limited to one catchment, which is out of the purpose of this analysis. In contrast, visual interpretation followed by manual delineation provides better result since it allows delineation of all catchments and sub-catchments, without necessarily having single outlet and therefore all catchments were delineated (Figure 24).

![Figure 23. Delineated catchments by automatic method using AVSWAT](image)

Considering major and minor river systems in the study area (see section 3.9 in page 24), stream network map and division of river systems in Berau area (BFMP 1999; BRLKT 2003), the delineated catchment partitions then were grouped based on river system where the flow of the catchments accumulate. The major river systems are Segah and Kelay River, while the minor river systems are Sidu'ung and Siagung River. The grouped catchment partitions with the river systems identified are presented in Figure 25.
Figure 24. Delineated catchments by manual delineation

Figure 25. Grouped catchment partitions, according to the river systems
4.6. Identified High Conservation Value Forest (HCVF)

4.6.1. Forest Areas Function as Unique Source of Drinking Water (HCVF 4.1)

As the result of the inventory of the sources of drinking water of communities in and around the study area (see section 3.10.1), a list containing the sources of drinking water of community was generated and presented in Table 8.

**Table 8.** List of villages in and around the study area and their main source of drinking water

<table>
<thead>
<tr>
<th>No.</th>
<th>Village Name</th>
<th>Main Source of Drinking Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Batu Balah</td>
<td>Kelay River</td>
</tr>
<tr>
<td>2.</td>
<td>Eksodus Sidu’ung</td>
<td>Sidu’ung River</td>
</tr>
<tr>
<td>3.</td>
<td>Gunung Sari</td>
<td>Segah River</td>
</tr>
<tr>
<td>4.</td>
<td>Labanan Jaya</td>
<td>Wells</td>
</tr>
<tr>
<td>5.</td>
<td>Labanan Makmur</td>
<td>Wells</td>
</tr>
<tr>
<td>6.</td>
<td>Labanan Makarti</td>
<td>Wells</td>
</tr>
<tr>
<td>7.</td>
<td>Long Keling</td>
<td>Kelay River</td>
</tr>
<tr>
<td>8.</td>
<td>Long Lanuk</td>
<td>Kelay River</td>
</tr>
<tr>
<td>9.</td>
<td>Long Pikat</td>
<td>Kelay River</td>
</tr>
<tr>
<td>10.</td>
<td>Merasak</td>
<td>Kelay River</td>
</tr>
<tr>
<td>11.</td>
<td>Nyapa Indah</td>
<td>Kelay River</td>
</tr>
<tr>
<td>12.</td>
<td>Pegat Pura</td>
<td>Segah River</td>
</tr>
<tr>
<td>13.</td>
<td>Sidu’ung</td>
<td>Sidu’ung River</td>
</tr>
<tr>
<td>14.</td>
<td>Teluk Telan</td>
<td>Segah River</td>
</tr>
<tr>
<td>15.</td>
<td>Tepian Asam</td>
<td>Segah River</td>
</tr>
<tr>
<td>16.</td>
<td>Tepian Buah</td>
<td>Segah River</td>
</tr>
<tr>
<td>17.</td>
<td>Trans SP2</td>
<td>Tributaries of Segah River</td>
</tr>
<tr>
<td>18.</td>
<td>Trans SP3</td>
<td>Sidu’ung River</td>
</tr>
<tr>
<td>19.</td>
<td>Trans SP6</td>
<td>Tributaries of Sidu’ung River</td>
</tr>
<tr>
<td>20.</td>
<td>Tumbit Dayak</td>
<td>Kelay River</td>
</tr>
<tr>
<td>21.</td>
<td>Tumbit Melayu</td>
<td>Kelay River + Wells</td>
</tr>
</tbody>
</table>

Based on the delineated catchment partitions and information about the source of drinking water for communities in and around the FMU (Table 8), selection were made to define which catchment partitions function as unique source of drinking water and what are the extents in the area of forest management unit studied. From total of 21 villages in and around the FMU, only three villages (i.e. Labanan Jaya, Labanan Makmur and Labanan Makarti) and 50% of the inhabitants of Tumbit Melayu village use wells (i.e. ground water) as their main source for drinking water, while inhabitants of the other villages use rivers and their tributaries as main supply for their drinking water (BFMP 2000). However, the quality of the ground water collected from the wells and boreholes also depends upon the condition of the catchments upstream. Therefore, the catchment partitions within these particular villages are also considered as important for unique source drinking water. The areas functions as unique source of drinking water are presented in figure 26.

By overlaying the area presented above with the FMU boundary, the working area of the FMU, which functions as unique sources of drinking water for communities is defined. The areas then considered as contains HCVF 4.1 elements. In total, the extent of these areas is 17542 ha, or 21% compared to the whole area of the FMU.
4.6.2 Forest Areas as part of Critical Major Catchments (HCVF 4.2)

According to the result of the prioritisation of major catchments throughout the East Kalimantan Province, which is done by Ministry of Forestry (BRLKT 2003), the priority scale to major catchments in the study area are listed in table 9.

<table>
<thead>
<tr>
<th>No.</th>
<th>Major Catchment</th>
<th>Total Catchment Area (ha)</th>
<th>Priority Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Segah River</td>
<td>879870</td>
<td>III</td>
</tr>
<tr>
<td>2.</td>
<td>Kelay River</td>
<td>658408</td>
<td>III</td>
</tr>
</tbody>
</table>

Based on the definition given by the Ministry of Forestry (Ditjen RRL 2003), priority scale I and II are given to critical catchment that need immediate action with regard to land rehabilitation and soil conservation, while priority III does not need such immediate rehabilitation. Therefore, the two major catchments around the study area were not assigned as critical water catchments, according to the Ministry of Forestry of Indonesia.

However, a calculation to the extent of catchment partitions that contribute to the major catchments (i.e. Segah River Catchment and Kelay River Catchment) was carried out. Through area calculation functions of ArcView®, it is found that the study area only contributes 6.75% and 2.81% to Segah and Kelay River catchments, respectively. Grouped catchments and the river systems is presented in Figure 25 (page 42), while the details of area calculation are presented in table 10.
Identification of High Conservation Value Forest (HCVF) Related to Soil and Water Conservation

**Table 10. Grouped catchment partitions and their contribution to major catchment**

<table>
<thead>
<tr>
<th>No.</th>
<th>River Systems</th>
<th>Catchment Area (ha)</th>
<th>Total Catchment (ha)</th>
<th>Contributions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Segah River*</td>
<td>4936.43</td>
<td>879870</td>
<td>6.75</td>
</tr>
<tr>
<td>2.</td>
<td>Sidu’ung River**</td>
<td>39312.40</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>3.</td>
<td>Siagung River**</td>
<td>15116.51</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>4.</td>
<td>Kelay River</td>
<td>18520.87</td>
<td>658408</td>
<td>2.81</td>
</tr>
</tbody>
</table>

* Catchments area here represents area that contribute directly to Segah River

**The outlet of these river systems are Segah River**

As resulted from the whole process (*i.e.* reviewing the major catchments priorities, catchments delineation and area calculation), it should be concluded that the study area does not contribute to any critical catchments, according to the prioritisation by Ministry of Forestry of Indonesia, therefore it does not contain HCVF 4.2 elements.

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**Figure 27.** Grid map of factors in estimating soil erosion risk, (a) rainfall erosivity, (b) soil erodibility, (c) slope length and steepness and (d) vegetation cover
4.6.3. Forest Areas Critical to Erosion Control (HCVF 4.3)

Factors contributing to annual soil loss estimation were determined using ERDAS® Spatial Modeler, resulting in raster maps of rainfall erosivity (R factor), soil erodibility (K factor), slope length and steepness (LS factor) and vegetation cover and management (C factor). All maps produced are presented in figure 27 in the previous page. As mentioned in section 3.10.3, P factor is not considered in the calculation since it remains constants for the whole area, e.g. no tillage or any other measures to reduce the erosion risk took place, therefore it assigned as single value of 1.

As can be seen in Figure 27a, gradual change of the rainfall erosivity value is caused by the effect of surface interpolation of isohyet map. Distribution of K-value (Figure 27b) is similar with the distribution of the land systems. In this case, land systems became the mapping unit of corresponding K-value. The LS factor (Figure 27c), is definitely affected by the fairly complex slope configuration of the study area, while the C factor (Figure 27d) follows the pattern of the land cover map as resulted from image classification. By multiplying all factors mentioned before, annual soil erosion risk of the study area was estimated. Since the identification of HCVF 4.3 requires the erosion risk in the forested area, then the resulted erosion risk map was masked with land cover type map and resulting in the map of estimated soil erosion risk in the forest area. Annual soil loss of 11 ton.ha\(^{-1}\).yr\(^{-1}\) was adopted as the threshold to differentiate high erosion risk with low erosion risk, therefore a reclassified map of forest area with high soil erosion risk is also produced and presented as orange and red pixels in Figure 28. By having the map of forest area with high soil erosion risk, the HCVF 4.3 is identified. Quantitatively, the extent of the forest area with high erosion risk is 7934.31 ha, which means it comprises 9.53% of total area of the forest management unit.

![Figure 28. Soil erosion risk in the study area, forest areas with soil erosion risk > 11 ton/ha.yr comprise HCVF 4.3](image-url)
4.6.4. The identified HCVF related to soil and water conservation

Considering the ultimate objective of this research, which is “identifying high conservation value forest related to soil and water conservation”, a final map as compilation of the identified HCVF in the study area is presented in Figure 29. As can be seen in this final map, the concentration of forest areas function as unique source of drinking water for local communities (HCVF 4.1) are in the northern and northeastern part, exactly in the center and the eastern part of the FMU. Forest areas critical to erosion control (HCVF 4.3) are highly concentrated in the steep-hilly forest in the southern part of the FMU and sparsely concentrated in the eastern part of the FMU as well. Considering the current logging operations of the FMU, which is located within the boundary of identified HCVF 4.1 in the northeastern part of the FMU, special attention should be paid to minimize the logging impact to the supply of drinking water for communities in the transmigration settlement (Trans SP6).

Figure 29. Final map of the identified HCVF related to soil and water conservation in the study area
5. DISCUSSION

5.1. Digital Elevation Model Derivation and Catchment Delineation

Digital Elevation Model is the essential input for computer-assisted terrain analysis and hydrological modelling (Beven and Moore 1993). In this study, a DEM was used as an essential input for automatic and manual catchment delineation, and it was also used to compute slope length and slope steepness factors in soil erosion risk estimation. Considering the use of DEM in this study, good quality of a high resolution DEM is required.

There was no quantitative assessment of the resulted Digital Elevation Model carried out, however, visualisation of intermediate derived DEM followed by error corrections on the source data is one immediate solution to obtain such a good quality DEM. As mentioned in section 3.8 and 4.4, the process of deriving a DEM from a digitised contour line map is a manual-iterative process. It means that a lot of operator interventions are required to examine and correct the errors found in the resulted DEM. As experienced in the process, there are considerable number of errors in the source data used (digitised contour line map), which come from the mistakes of operator in assigning the elevation of the contour line, i.e. gross errors/blunders (Tempfli 2001).

Considering the resolution used in the process of DEM derivation, the grid size of 30 metres used in this study is actually above the optimum grid size required to produce good quality DEM from available scale of contour line map, which was calculated as 43.8 m. However, a lot of unpredictable interpolated values were still found in the resulted DEM, as well as peculiar shape found in the slope map computed from the resulted DEM. An explanation of this is the complexity of terrain configuration in the study area, which is varying from flat and gentle floodplain and swamp in the northern part of the area, rolling hills that dominates the eastern part of the area, till rugged terrain and steep hills, which comprises protected forest in the southern part of the area. A pseudo-color composite, i.e. RGB 543 of Landsat ETM+ image 2003, which is draped over the derived DEM, is presented in Figure 30 to give general impression about the landform of the study area.

Figure 30. A pseudo-color composite of Landsat ETM+ image of May 2003, draped over the derived DEM
The high variability of the terrain is resulting in variability in the density of the contour line, since the resolution used in the process remains the same. Consequently, flat areas will have less contour lines and therefore a lower density, while steep and hilly area will have more contour lines and therefore has a higher density. In case of flat areas, the known points as the source of surface interpolation are fewer, while the common interpolation algorithms are more sensitive to the change of neighborhood values than its absolute value. As the result, some kind of “paddy terraces” or “tiger strips” will appear in derived slope and aspect maps (Hengl et al. 2003), particularly in the flat area as presented in Figure 31.

As can be seen in Figure 31, an algorithm failure is exposed in a small part (approximately 9 km²) of the study area. The algorithm of slope (in percent) calculation of ERDAS® failed to create smooth and gradual change of slope from the contour line map, in the relatively flat area. However, any other software (e.g. ArcView® Spatial Analyst and ILWIS) also gave similar result. White distinct line represents the original contour lines while the grey blur line represents value of slope. The grids are separated by 1 kilometre distance. Actually this failure also affected the subsequent calculation based on the slope map, e.g. LS-factor for soil erosion risk assessment.

A possible solution for this situation is partitioning the areas, which have extremely different contour line map density (e.g. flat area and hilly-steep area), apply the surface interpolation and slope algorithms simultaneously, and then join the map carefully. Separating the calculation process allows the user to choose a more suitable grid cell for each partition. By resampling the products of interpolation and slope calculation to a common grid cells, each partition is ready to be mosaicked and comprise the final desired DEM.

Considering the catchment delineation, in fact it is unusual to delineate catchment partitions with several, or even worse, many outlets. A hydrological study usually concentrates only on one outlet and one corresponding catchment (Beven and Moore 1993; Dingman 2002; Maidment 1993). Nevertheless, one of the objectives of this study is to identify the extent of any catchments located in the corresponding forest management unit, which contribute to the water quality and quantity of the river systems. Therefore, all catchments boundary were determined as the first step of the analysis. Given the purpose of the study as mentioned above, manual delineation of catchment partitions is preferable than automatic delineation by using hydrological model extension of GIS software.
5.2. Review of the Methods in Identification of HCVF

The concept of HCVF is relatively new, which has been developed to replace the concept of old growth or virgin forest as the highest priority in conservation measures. HCVF is not dealing with conservation of single rare species or community rights, rather, it is concerning with value provided by the existence of the forest, such as, biodiversity concentration and hydrological functions of the area (Daryatun et al. 2002). The diversity and highly variable conservation context and land use patterns of different regions in Indonesia resulted in the absence of nationally relevant definitions and threshold for each HCV elements. Therefore, region-specific (e.g. based on an island) environmental and ecology consideration should be taken in determining how critical or significant threshold for each HCV elements (Rainforest Alliance and ProForest 2003). All these limitations lead to the difficulties in identifying HCVF.

In this study, straightforward methods were developed to preliminary assess the presence of three HCV sub-elements as part of HCV element 4 (forest areas that provides basic services of nature). Even though the development of the methods used in this study is highly influenced by the national guideline for identification and management of HCVF in Indonesia (Rainforest Alliance and ProForest 2003), details in the use of information from optical satellite data and spatial analysis are some advances offered in this study.

5.2.1. Forest Areas Function as Unique Sources of Drinking Water (HCV 4.1)

Identification of this element requires the information on the situation of water supply to each community in and surrounding the FMU. Even though a general method to identify area within FMU that provides drinking water to communities is mentioned in the guideline (Rainforest Alliance and ProForest 2003), details and threshold in terms of area determination is remain unknown. In this study, delineated catchment partitions derived from available topographic data were used as basic unit of assessment on this HCV element. Based on the information collected from secondary data, the sources of drinking water for each village were listed, followed by visual interpretation to identify which catchment partitions supply (mainly) surface water to the communities. In general, delineation of source water protection area (SWPA) is an important initial step to determine the susceptibility and identification of the contaminant sources that may impact drinking water intakes (US-EPA 1997).

One important step, which preferably should be carried out to comprise satisfactory information of the status of drinking water supply is participatory identification or needs assessment according to water supply for each village (Daryatun et al. 2002; Gouyon 2004; Howard et al. 2002; Mlay 2003). By carrying out this assessment, detail of drinking water sources and even more, detailed status of water supply and demand can be identified. In this study, this step was not done considering constraints in time and resources. A few months work might be needed to complete such assessment for large number of the villages (21 villages) in and surrounding the study area.

Water quality is one critical aspect in the assessment of water supply in rural areas, therefore, such assessment related to water supply to communities should incorporating a simple, reliable and cost-effective water quality assessment. For the situation where the villagers mainly collect drinking water from rivers and streams, a very simple device called “electrical conductivity meter” is advisable to use for early detection of the presence of contaminaton from major ionic solution (Lubczynski 2004; Meijerink 2004). This simple test can be carried out along with the reconnaissance survey with the villagers to identify the sources of drinking water. Other major sources of contamination to drinking water are bacteria and agro-chemicals (WHO 2003). To spatially assess the reliability of identified catchments in providing contaminants-free drinking water, an analysis based on the present land use and estimated sediment load of the catchments can be carried out. As general rule, permanent agricultural land, which makes use of pesticides and other chemicals, will presumably contributes to agro-chemical contamination, while active commercial logging and forest conversion will presumably lead to increase of sediment load brought to the streams and rivers (Meijerink 2004).
5.2.2. Forest Areas as part of Critical Major Catchment (HCV 4.2)

In the identification of this particular element, catchment partitions were defined and function as the basis of the analysis to determine forest areas contribute to critical major catchment. According to the result of prioritisation of major catchment based on criteria from the Ministry of Forestry of Indonesia, the delineated catchments were assessed whether or not they contribute to critical major catchment. This is relevant according to the available guideline for HCVF identification (Rainforest Alliance and ProForest 2003). However, the set of criteria used by the Ministry of Forestry of Indonesia promotes a number of doubts. For better review, the criteria is presented in table 11.

<table>
<thead>
<tr>
<th>No</th>
<th>Criteria and Weight</th>
<th>Sub-Criteria</th>
<th>Weight (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land and Soil (44.7%)</td>
<td>• Critical land</td>
<td>28.0</td>
<td>Determined by other set of criteria</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Erosion risk</td>
<td>12.5</td>
<td>Calculated through USLE* formula</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Land cover</td>
<td>4.2</td>
<td>Determined by remote sensing</td>
</tr>
<tr>
<td>2</td>
<td>Hydrology (19.8%)</td>
<td>• Sediment load</td>
<td>10.0</td>
<td>Result of river flow monitoring system</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Index of water usage</td>
<td>4.9</td>
<td>Determined by ministry of public works</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Coefficient of variation (CV)</td>
<td>3.7</td>
<td>Determined by ministry of public works</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water quality</td>
<td>1.2</td>
<td>Based on criteria of Min. of Environment</td>
</tr>
<tr>
<td>3</td>
<td>Socio Economic (22.8%)</td>
<td>• Population pressure</td>
<td>15.0</td>
<td>Calculated through Otto’s equation**</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• People awareness on Soil Conservation</td>
<td>2.2</td>
<td>Determined by National Development Agency (BAPPENAS)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Number of poor families within the catchment area</td>
<td>4.6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Number of undeveloped villages</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Investment (8%)</td>
<td>• Protection value of water infrastructure</td>
<td>4.0</td>
<td>Defined by valuation of existing water infrastructures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Value of the tax objects</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Regional Development Policy (4.7%)</td>
<td>• Protection Area</td>
<td>1.7</td>
<td>Determined by the presence or absence of such area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Designated Area</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Special Area</td>
<td>1.0</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Eastern of Indonesia</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

* Universal Soil Loss Equation for prediction of yearly soil erosion risk
** An equation to calculate population pressure, available at (Anonymous 1987)

The dominant sub-criteria are critical land, population pressure, erosion risk and amount of sediment load, with pre-defined weight of 28%, 15%, 12.5% and 10% respectively. With regard to determination of critical land, a set of criteria (instead of the one presented above) had been developed by the Ministry of Forestry of Indonesia, which mainly concentrated on assessment of areas allocated for protection forest, protection area outside forest and agriculture development. In general, how critical is the land should be determined by the present land cover, observed erosion rate, slope and measures to reduce the amount of soil erosion (Anonymous 1987). The problem is in the scoring system of observed soil erosion, which determined based on the severity of gully and sheet erosion observed in the field. In relatively large areas of major catchment to be assessed (e.g. approximately 8900 km² for the whole of Segah Catchment), it is impossible to observe the cases of erosion in the field, because soil erosion is a site specific case, which in itself, determined by many factors. The same uncertainty applies to other sub-criteria, such as population pressure and sediment load, which are very site specific, therefore different weighting systems should be considered in determination of catchment priority (Meijerink 2004).

As a solution to overcome the uncertainties of the method for prioritisation of major catchment provided by Ministry of Forestry of Indonesia, a site specific and thorough study on the effect of forest management to the hydrological processes in the particular forest management unit is proposed. This study then should incorporate the assessment of water quality and quantity, sediment load and actual soil erosion resulted from the forest harvesting operations take place in the corresponding catchment.
5.2.3. Forest Areas Critical to Erosion Control (HCV 4.3)

In this study, USLE as an empirical model for estimating soil loss caused by rain erosion was applied. As mentioned in the previous section, the amount of predicted soil loss resulted from USLE is used only as an indication to the distribution of potential risk of soil erosion in the study area. A number of handbooks of soil erosion emphasis that USLE is not suitable neither for assessment of soil erosion of large area, nor catchment scale (e.g. Hudson 1995; Lal 1990). However, limited data on actual runoff, streamflow records and other parameters for calculation of soil erosion potential over a watershed, led to the use of USLE in this study for initial indication of soil erosion, especially sheet and rill erosion, when the natural vegetation cover is removed.

Regarding to the forms of soil erosion occurrence in the forest areas, undisturbed and totally covered forest have no cases of surface runoff, therefore no sheet and rill erosion can be expected (Dissmeyer and Foster 1980; Rossiter 2004). However, when timber extraction takes places, there will be a considerable opening of the area for road construction, as well as gaps resulted from tree felling and log skidding. Therefore, cases of surface runoff and soil erosion will takes place in the area where disturbance occurs. Figure 32, which was taken from a FMU with extremely steep area, shows how the earth moving work during road construction causes incredible runoff (a) and consequently, enormous sediment transport during heavy rain (b), compared to relatively less disturbed stream (c). However, this extreme situation is not comparable with the study area.

As can be concluded from the discussion above, slope and terrain configuration and the erodibility of soil are essential factors in assessing potential erosion risk of forest area (Rossiter 2004). The reasons of this statement are:

- Rainfall intensity and quantity, are presumably less different throughout the area of FMU
- Slope length become in-appropriate factor since many cases of soil erosion occur in the slope length, which is far beyond the limit of experimental plot (e.g. 400 feet in USLE)
- Severe erosion and sediment transport occur in area without vegetation cover, therefore C-factor becomes less variable in extreme sediment transport and soil loss cases
5.3. Implication on the identified HCVF

The whole processes in this study are part of preliminary assessment of High Conservation Value Forest (HCVF), especially the elements related to soil and water conservation. These are actually the initial steps required, before the forest management unit continue to the full assessment to confirm the presence of HCVF through more detail study (Jennings et al. 2002; Rainforest Alliance and ProForest 2003).

In case of HCV element 4.1, a detailed study to assess the quality, availability and threats to the sources of drinking water for each village would be necessary. A participatory survey and planning of drinking water supply is the most preferred approach (Daryatun et al. 2002; Gouyon 2004). Development of management plan and defining necessary action to protect the existing sources of drinking water are the next steps. The last step in this issue is to establish a monitoring programme with active involvement of the communities with close coordination with the FMU (Rainforest Alliance and ProForest 2003). By completing all tasks described above, the FMU will complete the process of identification and management of forest areas as sources of drinking water for the community in and around the FMU (HCVF 4.1). In case of HCV element 4.2, the major catchments, where all catchment partitions in the FMU flow to, were not assigned as critical major catchment by Ministry of Forestry of Indonesia. Therefore, no further study is needed to comprise full assessment of this particular element. However, as required by national forestry regulations and other principles and criteria of forest certification of FSC and LEI, a continuous monitoring process should be carried out to assess the effects of timber extraction activities carried out by the FMU to the hydrological features of corresponding catchments and river systems. In case of HCV element 4.3, most of the areas of high erosion risk are located in the southern hills of the FMU, while another small complex of high erosion risk is occur in the eastern part of the FMU. The steep hilly area in southern part of the FMU is already (internally) designed as protected forest, while the eastern part of the FMU is the logged area, which is fragmented by the provincial road. Therefore the immediate measures are necessary to control the activities in the eastern part of the area, especially because this area is the concentration of illegal logging activities. Even though the illegal loggers do not involve new road construction in their activities, erosion risk caused from massive removal of timber from this area needs serious attention. As experienced from the field survey, the harvesting intensity of illegal logging activities is much higher than regular timber extraction done by the FMU. Even it is beyond the capability of the FMU to fully control and even to stop the illegal logging activities, but any measures to control and reduce the impact of illegal logging activities can be considered as action to manage defined conservation value of this area.

5.4. Contribution to Sustainable Forest Management Certification

In FSC principles and criteria, criteria 9.1 is defined as “assessment to determine the presence of the attributes consistent with High Conservation Value Forest will be completed, appropriate to scale and intensity of forest management” (FSC 2000). By identifying the presence of High Conservation Value Forest (HCVF), in particular those that related to soil and water conservation, the FMU partially comply the FSC criteria 9.1. Criteria 9.2 is defined as “the consultative portion of the certification process must place emphasis on the identified conservation attributes, and options for the maintenance thereof”. Participatory survey, planning and monitoring of drinking water supply for the communities are some consultative process where competent stakeholders are actively working together with FMU to obtain the common goal, which is the protection of sources of drinking water supply. These actions then should be considered as one attempt to comply FSC criteria 9.2. Criteria 9.3 is defined as “the management plan shall include and implement specific measures that ensure the maintenance and/or enhancement of the applicable conservation attributes consistent with precautionary approach. These measures shall be specifically included in the publicly available management plan summary”. By integrating the management plan of the identified HCVF to the FMU working plan, and make it publicly available, the FMU will comply FSC criteria 9.3.
6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Regarding the processes done in this study, some general conclusions are drawn as follows:

- Remote sensing and Geographic Information System had proved to be useful to support the identification of High Conservation Value Forests (HCVF) in the study area.
- The Digital Elevation Model derived from a contour line map is an essential input for analyses of physical hydrological features. The analyses are including catchment delineation, automatic derivation of stream network, flow routing and calculation of flow accumulation.
- Visual interpretation and manual digitising process allow delineation of several catchments simultaneously, while automatic catchment delineation provided by most GIS software concentrates to one catchment. Therefore, manual delineation is preferable to use.
- The national guideline for identification of HCVF in Indonesia, which provided by Proforest, is found very useful in building up the framework of preliminary HCVF identification.
- One limitation in this study is, the absence of a way to validate nor to compare the methods developed in this study. This is understandable since there was no such detailed study published yet, especially those that concern with the use of remote sensing and spatial information. However, this study is certainly contributes to the implementation of FSC principle of identification and management of HCVF in natural production forest.

Related to the research questions, some specific conclusions are drawn as follows:

- A detailed method was developed to facilitate the identification of HCVF related to soil and water conservation, with more emphasis on the use of spatial information.
- 17542 ha (21%) of the forest management unit area functions as unique source of drinking water for communities within and surrounding the FMU area, therefore comprise HCVF 4.1.
- The forest management unit does not have any catchment that contributes to such critical major catchments. This is because major catchments and river systems around the FMU have been designed by the Ministry of Forestry of Indonesia, as not critical for rehabilitation and soil conservation, therefore no HCVF 4.2 was identified.
- 7943 ha (9.53%) of the forest management unit area is prone to serious erosion risk, therefore comprise HCVF 4.3.
- The extent and distribution of the identified areas contain HCV 4.1 and 4.3 elements is presented in a final map (page 47).

6.2. Recommendations

In general, the High Conservation Value Forest (HCVF), which contributes to soil and water conservation, found in the forest management unit area is not dominant, comparing to the total area. However, special care and measures should be considered when the logging practice and any other activities take place in the forest areas contain High Conservation Values. Moreover, the FMU is encouraged to establish a management plan to maintain/or enhanced the identified HCVF.

With regard to HCV element 4.1, which deals with sources of drinking water supply for communities, a thorough process involving participatory identification, establishment of management plan and monitoring of sources of drinking water is proposed as follow up actions of the identified HCVF. According to HCV element 4.2, although no areas in the study area has assigned as HCVF 4.2, a site specific and thorough study on the effect of forest management to the hydrological processes in the particular forest management unit is proposed. This study then should incorporate the assessment of water quality and quantity, sediment load and actual soil erosion resulted from the forest harvesting operations take place in the corresponding catchment. Considering identified areas contain HCV element 4.3, which are the areas of high erosion risk, more intensive control to the identified areas is required, considering the high intensity of disturbance caused by illegal logging activities in the eastern part of study area.
REFERENCES


APPENDICES
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### Remarks:
- LDF/H: Lowland Dipterocarp Forest [Hilly Area]
- LDF/F: Lowland Dipterocarp Forest [Flat Area]
- SWF: Swamp Forest
- RF: Riparian Forest
- N/A: Not Applied (no GPS reading possible for elevation)
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### Appendix 4. Soil Profile Data Collected from 1998 Soil Survey and Calculated K-Value [USLE]

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### Appendix 5. HCVF elements and information requirements for the identification of HCVF

*(after Jennings et al. 2002 and Rainforest Alliance and ProForest 2003)*

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<th>Output (Pre Assessment)</th>
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<td><strong>HCV 1</strong></td>
<td>Forest containing globally, regionally or nationally significant concentrations of biodiversity values (e.g. endemism, endangered, species, refugia)*</td>
<td>Information on officially designated important or legally protected forest areas</td>
<td>Map of protected areas</td>
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<td>Information on all existing and proposed protected forest/areas</td>
<td>Map of range of species or list of areas / habitats of critically endangered species**</td>
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**HCV 2**

Forest area containing globally, regionally or nationally significant large landscape level forests, contained within, or containing the management unit, where viable populations of most if not all naturally occurring species exist in natural patterns of distribution and abundance

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<td>Forest contains viable populations of most or all native species</td>
<td>Map of intact natural forest, which fulfil the criteria in size, composition, structure and fragmentation level</td>
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**HCV 3**

Forest areas that are in or contain rare, threatened or endangered ecosystems

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</table>

**HCV 4**

Forest areas that provide basic services of nature in critical situations (e.g. watershed protection, erosion control)

<table>
<thead>
<tr>
<th>Information Requirements (Identification Task)</th>
<th>Output (Pre Assessment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information on officially designated important or legally protected forest areas and community dependant upon drinking water</td>
<td>Map of forest that provide unique drinking water supplies</td>
</tr>
<tr>
<td>Areas with high risk of flooding or drought, critical watershed for reservoirs, irrigations, river recharge or hydroelectric schemes</td>
<td>Map of forest that has high risk of flooding and/or functions as critical watershed***</td>
</tr>
<tr>
<td>Spatial information on areas that had serious erosion, landslide or avalanches</td>
<td>Map of forest areas critical to erosion and terrain stability****</td>
</tr>
<tr>
<td>Information on areas with high risk of fire and in which forest can act as barrier to fire spread</td>
<td>Map of areas prone to serious fires</td>
</tr>
<tr>
<td>Information on forest important for agriculture and/or fisheries by the effects in wind and microclimate</td>
<td>Map of forest critical for maintaining agriculture and/or fisheries</td>
</tr>
</tbody>
</table>

**HCV 5**

Forest areas fundamental to meet basic needs of local communities (e.g. subsistence, health)

<table>
<thead>
<tr>
<th>Information Requirements (Identification Task)</th>
<th>Output (Pre Assessment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultural groups and local communities rely on the forest to fulfil their basic needs, how far the distance such people travel to the forest, and types of basic needs</td>
<td>Map of range of local communities’ derive basic needs from forest, with buffer zones marked around these communities*****</td>
</tr>
</tbody>
</table>

**HCV 6**

Forest areas critical to local communities’ traditional cultural identity (areas of cultural, ecological, economic or religious significance identified in cooperation with such local communities)

<table>
<thead>
<tr>
<th>Information Requirements (Identification Task)</th>
<th>Output (Pre Assessment)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest that provides value without which a local community would suffer a drastic cultural change and has no alternative</td>
<td>Map of areas where forests are critical importance to local communities traditional cultural identity</td>
</tr>
</tbody>
</table>

* For this entire element, precise spatial analysis is rather difficult to carry out. Habitat mapping is the most possible approach
** For this sub element, full assessment of biodiversity assessment (or if time is limited, a habitat identification) is needed
*** For this sub element, a hydrological map of the study area should be consulted to establish critical watershed map
**** For this sub element, soil and geological map of the study area should be consulted to establish erosion risk map
***** This element is valid only when the communities have no alternatives for fulfilling their basic needs
Appendix 6. FSC Principles and Criteria (FSC 2000)

**PRINCIPLE #1: COMPLIANCE WITH LAWS AND FSC PRINCIPLES**
Forest management shall respect all applicable laws of the country in which they occur, and international treaties and agreements to which the country is a signatory, and comply with all FSC Principles and Criteria.

1.1 Forest management shall respect all national and local laws and administrative requirements.
1.2 All applicable and legally prescribed fees, royalties, taxes and other charges shall be paid.
1.3 In signatory countries, the provisions of all binding international agreements such as CITES, ILO Conventions, ITTA, and Convention on Biological Diversity, shall be respected.
1.4 Conflicts between laws, regulations and the FSC Principles and Criteria shall be evaluated for the purposes of certification, on a case by case basis, by the certifiers and the involved or affected parties.
1.5 Forest management areas should be protected from illegal harvesting, settlement and other unauthorized activities.
1.6 Forest managers shall demonstrate a long-term commitment to adhere to the FSC Principles and Criteria.

**PRINCIPLE #2: TENURE AND USE RIGHTS AND RESPONSIBILITIES**
Long-term tenure and use rights to the land and forest resources shall be clearly defined, documented and legally established.

2.1 Clear evidence of long-term forest use rights to the land (e.g. land title, customary rights, or lease agreements) shall be demonstrated.
2.2 Local communities with legal or customary tenure or use rights shall maintain control, to the extent necessary to protect their rights or resources, over forest operations unless they delegate control with free and informed consent to other agencies.
2.3 Appropriate mechanisms shall be employed to resolve disputes over tenure claims and use rights. The circumstances and status of any outstanding disputes will be explicitly considered in the certification evaluation. Disputes of substantial magnitude involving a significant number of interests will normally disqualify an operation from being certified.

**PRINCIPLE #3: INDIGENOUS PEOPLES’ RIGHTS**
The legal and customary rights of indigenous peoples to own, use and manage their lands, territories, and resources shall be recognized and respected.

3.1 Indigenous peoples shall control forest management on their lands and territories unless they delegate control with free and informed consent to other agencies.
3.2 Forest management shall not threaten or diminish, either directly or indirectly, the resources or tenure rights of indigenous peoples.
3.3 Sites of special cultural, ecological, economic or religious significance to indigenous peoples shall be clearly identified in cooperation with such peoples, and recognized and protected by forest managers.
3.4 Indigenous peoples shall be compensated for the application of their traditional knowledge regarding the use of forest species or management systems in forest operations. This compensation shall be formally agreed upon with their free and informed consent before forest operations commence.

**PRINCIPLE #4: COMMUNITY RELATIONS AND WORKER’S RIGHTS**
Forest management operations shall maintain or enhance the long-term social and economic well-being of forest workers and local communities.

4.1 The communities within, or adjacent to, the forest management area should be given opportunities for employment, training, and other services.
4.2 Forest management should meet or exceed all applicable laws and/or regulations covering health and safety of employees and their families.
4.3 The rights of workers to organize and voluntarily negotiate with their employers shall be guaranteed as outlined in Conventions 87 and 98 of the International Labour Organisation (ILO).
4.4 Management planning and operations shall incorporate the results of evaluations of social impact. Consultations shall be maintained with people and groups directly affected by management operations.
4.5 Appropriate mechanisms shall be employed for resolving grievances and for providing fair compensation in the case of loss or damage affecting the legal or customary rights, property, resources, or livelihoods of local peoples. Measures shall be taken to avoid such loss or damage.

PRINCIPLE #5: BENEFITS FROM THE FOREST

Forest management operations shall encourage the efficient use of the forest's multiple products and services to ensure economic viability and a wide range of environmental and social benefits.

5.1 Forest management should strive toward economic viability, while taking into account the full environmental, social, and operational costs of production, and ensuring the investments necessary to maintain the ecological productivity of the forest.

5.2 Forest management and marketing operations should encourage the optimal use and local processing of the forest's diversity of products.

5.3 Forest management should minimize waste associated with harvesting and on-site processing operations and avoid damage to other forest resources.

5.4 Forest management should strive to strengthen and diversify the local economy, avoiding dependence on a single forest product.

5.5 Forest management operations shall recognize, maintain, and, where appropriate, enhance the value of forest services and resources such as watersheds and fisheries.

5.6 The rate of harvest of forest products shall not exceed levels which can be permanently sustained.

PRINCIPLE #6: ENVIRONMENTAL IMPACT

Forest management shall conserve biological diversity and its associated values, water resources, soils, and unique and fragile ecosystems and landscapes, and, by so doing, maintain the ecological functions and the integrity of the forest.

6.1 Assessment of environmental impacts shall be completed -- appropriate to the scale, intensity of forest management and the uniqueness of the affected resources -- and adequately integrated into management systems. Assessments shall include landscape level considerations as well as the impacts of on-site processing facilities. Environmental impacts shall be assessed prior to commencement of site-disturbing operations.

6.2 Safeguards shall exist which protect rare, threatened and endangered species and their habitats (e.g., nesting and feeding areas). Conservation zones and protection areas shall be established, appropriate to the scale and intensity of forest management and the uniqueness of the affected resources. Inappropriate hunting, fishing, trapping and collecting shall be controlled.

6.3 Ecological functions and values shall be maintained intact, enhanced, or restored, including:
   a) Forest regeneration and succession
   b) Genetic, species, and ecosystem diversity
   c) Natural cycles that affect the productivity of the forest ecosystem

6.4 Representative samples of existing ecosystems within the landscape shall be protected in their natural state and recorded on maps, appropriate to the scale and intensity of operations and the uniqueness of the affected resources.

6.5 Written guidelines shall be prepared and implemented to: control erosion; minimize forest damage during harvesting, road construction, and all other mechanical disturbances; and protect water resources.

6.6 Management systems shall promote the development and adoption of environmentally friendly non-chemical methods of pest management and strive to avoid the use of chemical pesticides. World Health Organization Type 1A and 1B and chlorinated hydrocarbon pesticides; pesticides that are persistent, toxic or whose derivatives remain biologically active and accumulate in the food chain beyond their intended use; as well as any pesticides banned by international agreement, shall be prohibited. If chemicals are used, proper equipment and training shall be provided to minimize health and environmental risks.

6.7 Chemicals, containers, liquid and solid non-organic wastes including fuel and oil shall be disposed of in an environmentally appropriate manner at off-site locations.

6.8 Use of biological control agents shall be documented, minimized, monitored and strictly controlled in accordance with national laws and internationally accepted scientific protocols. Use of genetically modified organisms shall be prohibited.

6.9 The use of exotic species shall be carefully controlled and actively monitored to avoid adverse ecological impacts.
6.10 Forest conversion to plantations or non-forest land uses shall not occur, except in circumstances where conversion:
   a) Entails a very limited portion of the forest management unit; and
   b) Does not occur on high conservation value forest areas; and
   c) Will enable clear, substantial, additional, secure, long term conservation benefits across the forest management unit.

PRINCIPLE #7: MANAGEMENT PLAN
A management plan -- appropriate to the scale and intensity of the operations -- shall be written, implemented, and kept up to date. The long term objectives of management, and the means of achieving them, shall be clearly stated.

7.1 The management plan and supporting documents shall provide:
   a) Management objectives
   b) Description of the forest resources to be managed, environmental limitations, land use and ownership status, socio-economic conditions, and a profile of adjacent lands
   c) Description of silvicultural and/or other management system, based on the ecology of the forest in question and information gathered through resource inventories
   d) Rationale for rate of annual harvest and species selection
   e) Provisions for monitoring of forest growth and dynamics
   f) Environmental safeguards based on environmental assessments
   g) Plans for the identification and protection of rare, threatened and endangered species
   h) Maps describing the forest resource base including protected areas, planned management activities and land ownership
   i) Description and justification of harvesting techniques and equipment to be used

7.2 The management plan shall be periodically revised to incorporate the results of monitoring or new scientific and technical information, as well as to respond to changing environmental, social and economic circumstances.

7.3 Forest workers shall receive adequate training and supervision to ensure proper implementation of the management plan.

7.4 While respecting the confidentiality of information, forest managers shall make publicly available a summary of the primary elements of the management plan, including those listed in Criterion 7.1.

PRINCIPLE #8: MONITORING AND ASSESSMENT
Monitoring shall be conducted -- appropriate to the scale and intensity of forest management -- to assess the condition of the forest, yields of forest products, chain of custody, management activities and their social and environmental impacts.

8.1 The frequency and intensity of monitoring should be determined by the scale and intensity of forest management operations as well as the relative complexity and fragility of the affected environment. Monitoring procedures should be consistent and replicable over time to allow comparison of results and assessment of change.

8.2 Forest management should include the research and data collection needed to monitor, at a minimum, the following indicators:
   a) Yield of all forest products harvested
   b) Growth rates, regeneration and condition of the forest
   c) Composition and observed changes in the flora and fauna
   d) Environmental and social impacts of harvesting and other operations
   e) Costs, productivity, and efficiency of forest management

8.3 Documentation shall be provided by the forest manager to enable monitoring and certifying organizations to trace each forest product from its origin, a process known as the "chain of custody."

8.4 The results of monitoring shall be incorporated into the implementation and revision of the management plan.

8.5 While respecting the confidentiality of information, forest managers shall make publicly available a summary of the results of monitoring indicators, including those listed in Criterion 8.2.
PRINCIPLE #9: MAINTENANCE OF HIGH CONSERVATION VALUE FORESTS
Management activities in high conservation value forests shall maintain or enhance the attributes which define such forests. Decisions regarding high conservation value forests shall always be considered in the context of a precautionary approach.

9.1 Assessment to determine the presence of the attributes consistent with High Conservation Value Forests will be completed, appropriate to scale and intensity of forest management.

9.2 The consultative portion of the certification process must place emphasis on the identified conservation attributes, and options for the maintenance thereof.

9.3 The management plan shall include and implement specific measures that ensure the maintenance and/or enhancement of the applicable conservation attributes consistent with the precautionary approach. These measures shall be specifically included in the publicly available management plan summary.

9.4 Annual monitoring shall be conducted to assess the effectiveness of the measures employed to maintain or enhance the applicable conservation attributes.

PRINCIPLE #10: PLANTATIONS
Plantations shall be planned and managed in accordance with Principles and Criteria 1 - 9, and Principle 10 and its Criteria. While plantations can provide an array of social and economic benefits, and can contribute to satisfying the world’s needs for forest products, they should complement the management of, reduce pressures on, and promote the restoration and conservation of natural forests.

10.1 The management objectives of the plantation, including natural forest conservation and restoration objectives, shall be explicitly stated in the management plan, and clearly demonstrated in the implementation of the plan.

10.2 The design and layout of plantations should promote the protection, restoration and conservation of natural forests, and not increase pressures on natural forests. Wildlife corridors, streamside zones and a mosaic of stands of different ages and rotation periods, shall be used in the layout of the plantation, consistent with the scale of the operation. The scale and layout of plantation blocks shall be consistent with the patterns of forest stands found within the natural landscape.

10.3 Diversity in the composition of plantations is preferred, so as to enhance economic, ecological and social stability. Such diversity may include the size and spatial distribution of management units within the landscape, number and genetic composition of species, age classes and structures.

10.4 The selection of species for planting shall be based on their overall suitability for the site and their appropriateness to the management objectives. In order to enhance the conservation of biological diversity, native species are preferred over exotic species in the establishment of plantations and the restoration of degraded ecosystems. Exotic species, which shall be used only when their performance is greater than that of native species, shall be carefully monitored to detect unusual mortality, disease, or insect outbreaks and adverse ecological impacts.

10.5 A proportion of the overall forest management area, appropriate to the scale of the plantation and to be determined in regional standards, shall be managed so as to restore the site to a natural forest cover.

10.6 Measures shall be taken to maintain or improve soil structure, fertility, and biological activity. The techniques and rate of harvesting, road and trail construction and maintenance, and the choice of species shall not result in long term soil degradation or adverse impacts on water quality, quantity or substantial deviation from stream course drainage patterns.

10.7 Measures shall be taken to prevent and minimize outbreaks of pests, diseases, fire and invasive plant introductions. Integrated pest management shall form an essential part of the management plan, with primary reliance on prevention and biological control methods rather than chemical pesticides and fertilizers. Plantation management should make every effort to move away from chemical pesticides and fertilizers, including their use in nurseries. The use of chemicals is also covered in Criteria 6.6 and 6.7.
10.8 Appropriate to the scale and diversity of the operation, monitoring of plantations shall include regular assessment of potential on-site and off-site ecological and social impacts, (e.g. natural regeneration, effects on water resources and soil fertility, and impacts on local welfare and social well-being), in addition to those elements addressed in principles 8, 6 and 4. No species should be planted on a large scale until local trials and/or experience have shown that they are ecologically well-adapted to the site, are not invasive, and do not have significant negative ecological impacts on other ecosystems. Special attention will be paid to social issues of land acquisition for plantations, especially the protection of local rights of ownership, use or access.

10.9 Plantations established in areas converted from natural forests after November 1994 normally shall not qualify for certification. Certification may be allowed in circumstances where sufficient evidence is submitted to the certification body that the manager/owner is not responsible directly or indirectly of such conversion.

Note:
The FSC Principles and Criteria are publicly available in FSC official website: [http://www.fscoax.org/](http://www.fscoax.org/)