# Vulnerability Study of National Park
# as Approach to Integrate Nature Conservation and Regional Development

*(case study Lore Lindu National Park, Central Sulawesi, Indonesia)*

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**Double Degree ITC – ITB Program**
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# Vulnerability Study of National Park as Approach to Integrate Nature Conservation and Regional Development
*(case study Lore Lindu National Park, Central Sulawesi, Indonesia)*

by :

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***Disclaimer***

*This document describes work undertaken as part of a program of study at the Faculty of Geo-information Science and Earth Observation (ITC), University of Twente and School of Architecture, Planning and Policy Development, Bandung Institute of Technology (ITB). All views and opinions expressed there in remain the sole responsibility of the author and do not necessarily represent those of the institutes.*

# Abstract

*Due to the ever increasing demand for space and resources, conservation has become the last resort for protecting nature and environment. Protected areas become more valuable for today's and future life, given their essential function as biodiversity reserve, landscape conservation, indigenous people protection, ecosystem services and many other functions. In the recent years, in many places in the world, conservation areas are being threatened by human activities. Vulnerability assessment has become necessary in order to improve efficiency and effectiveness for management. Besides that, the vulnerability information can be a consideration for regional management authorities.*

*Based on the management aim of Lore Lindu National Park, there are 3 types of vulnerability that should be assessed in order to derive a vulnerability map of national park: vulnerability to landscape diversity loss, vulnerability to biodiversity loss and vulnerability to forest loss. At the end of the analysis, all vulnerability types are united into one integrated vulnerability map.*

*To produce each separate vulnerability map and the integrated vulnerability map, identifying criteria and weighing of the criteria through expert judgment are the most crucial parts. The criteria and weight for vulnerability of landscape diversity loss are: proximity to road (4.85); proximity to pathway (2.46), proximity to settlement (5.21), proximity to river (2.11), proximity to existing agriculture (4.46), physical factors (2.96) and population density (6.00). The criteria and weight for vulnerability of forest loss are: proximity to road (6.23); proximity to pathway (4.08), proximity to settlement (4.00), proximity to river (2.31), proximity to existing agriculture(3.62), slope steepness (2.77) and population density (4.85).While the criteria and weight for vulnerability of biodiversity loss are: proximity to road (4.39); proximity to pathway (4.39), proximity to settlement (5.14), proximity to river (2.14), proximity to existing agriculture(4.57), slope steepness (2.00) and population density (5.29).*

*In addition to all criteria mentioned, the current state of the element at risk should be considered. Landscape uniqueness was used as current state for the vulnerability assessment of landscape diversity loss, forest cover is used as current state for vulnerability assessment of forest loss, and for the vulnerability assessment of biodiversity loss, the habitat of endangered species and unique species was used to represent the current state.*

*In the last part of this thesis the integrated vulnerability map is crossed with LLNP spatial plan map and land cover map, resulting in 19 different management units. For each unit a vulnerability guided management alternative is proposed.*

*Keywords: vulnerability, Lore Lindu National Park, threat, conservation areas*

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**Eru Nurfilmarasa Dahlan**
Enschede The Netherlands
September, 2010

*I dedicated this piece of work for the greatest Ayahanda and Ibunda,*
*my beloved wife (Rina Wulandari) and my children (Nasya Putri Raudhah and Andra Aulia Hakim)*
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# I. Introduction

## 1.1 Background

Due to an ever increasing pressure on our environment, conservation areas have become increasingly important for protecting biodiversity, landscape diversity, indigenous people and ecosystem services. In the recent years, in many places in the world, conservation areas are being threatened by human activities. For forest conservation areas, these threats can be categorized into: deforestation, forest degradation and fragmentation which affects their existence (Tejaswi, 2007). Tropical deforestation and habitat fragmentation are increasingly recognized as being among the most important issues in global change (Van Laake and Sánchez-Azofeifa, 2004).

The problem of deforestation and forest degradation is increasing especially in the tropical areas. FAO (1996) stated that tropical deforestation estimates for 1990–1995 cite 116,756 $km^2$ per year globally, with 47,000 $km^2$ per year attributed to tropical South America—the majority of that in Brazil. Indonesia, harboring 10% of the world's tropical rainforest (World Bank, 1994), also experiences the same problem. In 1996 total coverage of forest of Indonesia is 120.6 Million Ha or 69% of total land area (Government of Indonesia-FAO, 1996). While in 2003, the forest cover in Indonesia area has decreased to approximately 90 million ha or equivalent to 46% of total land area. The Ministry of Forestry (2008) also reported that the deforestation rate in 2000-2005 is 1.08 million ha per year.

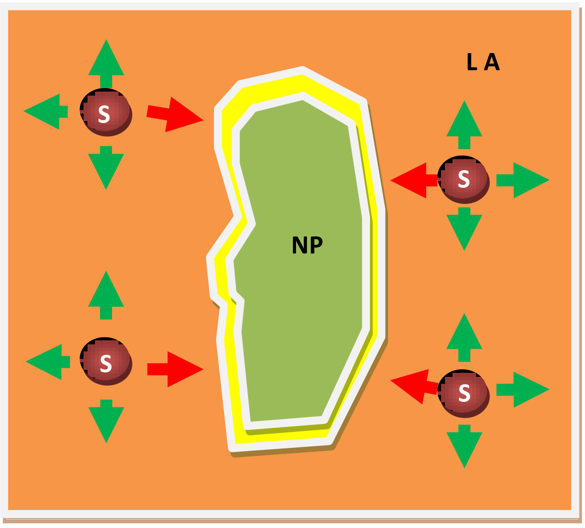
There are some factors causing deforestation and degradation of forest and conservation areas. Rudel and Roper (1997) mentioned that West Africa and Central America have the most fragmented tropical rain forests in the world and deforestation is most likely driven by smallholders. The Ministry of Forestry-GOI (2008) reported that deforestation in Indonesia caused by illegal logging, conversion to agricultural area and forest fire.

In other literature, Sunderlin and Resosudarmo (1996) categorized the cause of deforestation in Indonesia into 2 types, which are: agent and underlying factors. Based on underlying factors, un-integrated development is a serious problem, especially due to the decentralization process in Indonesia. The decentralization process has caused a dichotomy in the management of the area. The regional/local government is responsible for socio economic development while the central government is responsible for nature conservation.

Decentralization has been motivating regional/local authority to optimize regional development since the issuance of Act No. 22 Year 1999 on regional autonomy. Nevertheless, decentralization consequently caused many problems such as lack of capacity of local government, environmental problems, power sharing between central, provincial and local, development disparity among local autonomy areas etc. The regional government tries to optimize their revenue by maximizing the use of natural resources which leads to conflicts with nature conservation activities.

In spite of the legal status of a national park, deforestation, forest degradation and fragmentation continue to affect national parks. This indicates that the national policy and legislation on nature or biodiversity conservation is not effective. The main reason being the lack of integration between national spatial planning and regional development policy. The local/regional government is responsible for regional development, while central government deals with nature/biodiversity conservation As a consequence, nature or biodiversity considerations are not included in local regional planning process.

In order to overcome the problem; park management and local/ regional government should be provided with more comprehensive information of conservation goals which can be incorporated in the spatial planning process. Information that will help to improve the effectiveness of planning is information about vulnerability (Wilson *et al.*, 2005b). With this type of information, a threat to the national park can be considered and the spatial direction of local/regional development can be (re)directed away from the most vulnerable areas ***Figure 1***.




Note:
NP : National Park areas;
LA : Local government
S : Settlement
Green arrow: desired development direction
Red arrow: development direction as threat

**Figure 1. Direction of local regional development**

Vulnerability research is required to be done in the area since the assessment has not yet been done. Besides that vulnerability assessment is still challenging, because there is no standard theoretical and methodological system (Li *et al.*, 2009). Metzger *et al.* (2006) also mentioned that the studies on integrating vulnerability assessment and policy is very limited. Integrating vulnerability and regional planning becomes increasingly important as the pressure on LLNP is potentially higher in the future (LLNP, 2004).

Spatial planning (including nature conservation) always are related to a particular tract of land, hence have a spatial component. The use of Geographical Information System (GIS) and Remote Sensing (RS) enable the analysis, modeling and visualization of spatial data as input for the planning process. The produced maps or classified RS images can be used as visual communication tools to give clearer understanding for the user.

## 1.2 Research problem

Lore Lindu National Park is an important conservation site in Indonesia. It is facing a serious threat from human activities, resulting in deforestation, forest degradation and fragmentation. LLNP management (2004) mentioned that 14,770 ha of the areas are degraded.

Lore Lindu National Park has a function to protect biodiversity, landscape and sociological things such as megaliths and other ancient artifacts, but on the other hand local people who live in the surrounding areas have a low level standard of living and heavily depend of natural resources in the national park. The national park management wants to preserve the areas, while the local government wants to improve the standard of living of the local population in the surrounding areas.

Due to this dichotomy in responsibility nature and biodiversity conservation, have not been integrated into the regional development. Lack of information and understanding of nature or biodiversity goals is assumed to be one of the causes of this problem.

## 1.3 Objectives

Vulnerability information can help prioritizing areas for protection. (Pressey and Taffs, 2001) and regional development policy (O'Brien *et al.*, 2009). Vulnerability assessment should be geared to management aims of LLNP which are landscape, biodiversity and forest ecosystem services protection. Hence the assessment will include assessment for vulnerability of landscape diversity loss, vulnerability of biodiversity loss and vulnerability of forest loss. For planning purposes, the information should be simplified into one integrated vulnerability map which can be used for regional planners.

Main objective of this study is to assess vulnerability of Lore Lindu National Park and its surroundings as a means to integrate conservation policy and local regional development.
The specific objectives of this study are:

1. To identify criteria for vulnerability of landscape diversity loss, biodiversity loss and forest loss.
2. To assess the weight of each criterion for each type of vulnerability assessment

3. To assess the weight of the individual vulnerability types for the compilation of the integrated vulnerability map
4. To analyze vulnerability of national park by combining vulnerability of landscape diversity loss, vulnerability of biodiversity loss and vulnerability of forest loss
5. To recommend alternatives for national park authority and local/regional authority in order to improve the effectiveness of management coordination in the area.

## 1.4 Research question

1. Which criteria determining to each vulnerability type can be identified, to produce each vulnerability map?
2. How to prepare the map used for the analysis?
3. What is the weight of each criterion to produce each type of vulnerability map?
4. How to integrate weight and spatial data to produce vulnerability maps?
5. How to integrate vulnerability maps into one integrated vulnerability map?
6. What are the consequences of vulnerability assessment to national park authority and local/regional authority?

## 1.5 Research framework

The framework of research is presented in the ***Figure 2***. Threat to National park existence is the key issue, while vulnerability information becomes an important factor in overcoming the problem how to integrate two different authorities (local/regional government and national park authority).

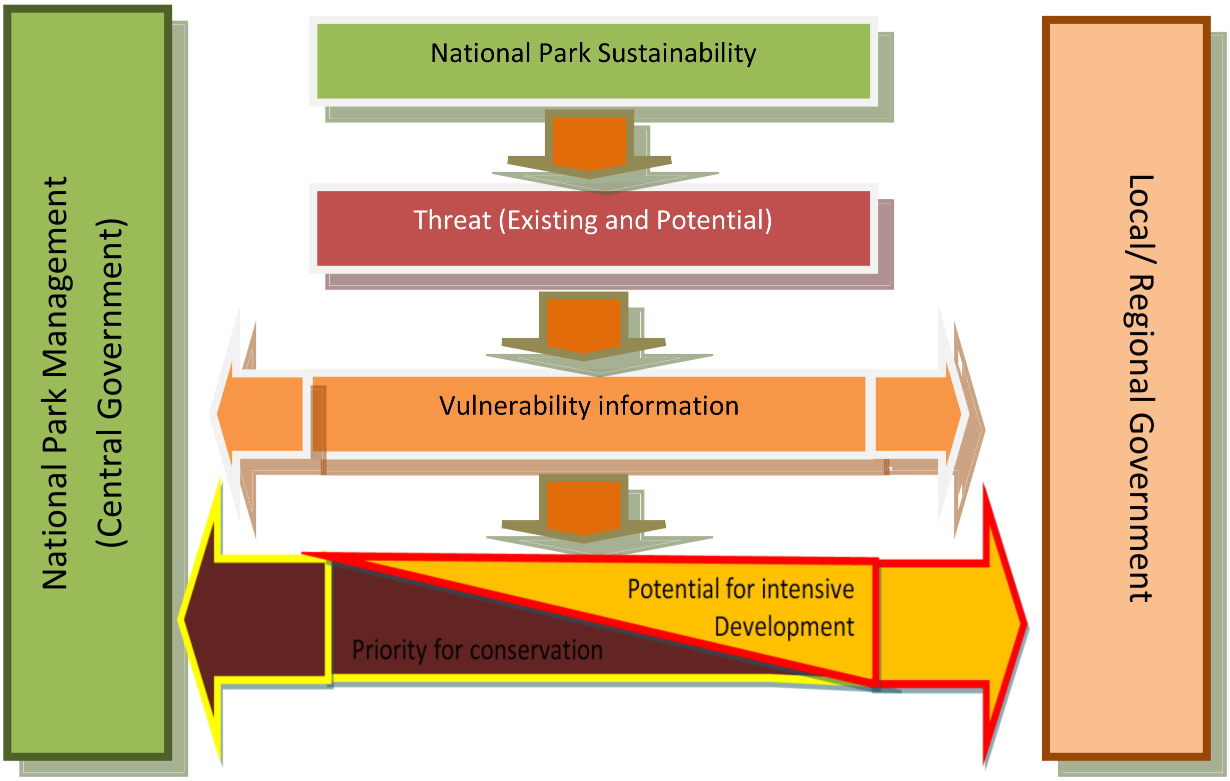



**Figure 2. Research Framework**

# II. Concept and Definition

## 2.1 National park definition

A national park is defined as "*a natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible*" (IUCN, 2010). Indonesian Law No. 41/1999 defines National park as "*a nature conservation area which has an original ecosystem, managed by the zoning system utilized for the purposes of research, science, education, plants or wildlife protection, tourism and recreation*".

Based on Government regulation no P.57/2007, a national park should be managed using a system of spatial zoning, which are :

a. Core Zone (*Zona inti*): area which is absolutely restricted
b. Wilderness Zone (*Zona Rimba*): zone for wild fauna, exploration area and limited use of (forest) ecosystem services.
c. Utilization Zone (*Zona Pemanfaatan*): zone which limited activities such as research activity, tourism forest, fauna and flora rehabilitation, natural and eco tourism, camping area are allowed.
d. Special used zone (*Zona Pemanfaatan Khusus*): "a zone to accommodate local communities that have been residing in the area since before it was designated as a national park, or to accommodate public facilities and infrastructure such as telecommunication towers, roads and electricity installations"

## 2.2 Forest degradation and deforestation

The protected areas are supposed to be managed to protect the diversity of animals and plants, their interaction with biotic and abiotic factors and especially to protect threatened species (Rana and Samant, 2010). Nevertheless, protected areas in Indonesia are facing very serious threats from human activities such as logging, hunting, poaching mining, agriculture expansion, infrastructure development (MOF, 2010). In the area of Lore Lindu National Park (LLNP), LLNP management (2004) reported forest degradation and deforestation through illegal logging and agricultural conversion, animal hunting, non timber resource extraction.

In the context of forest degradation, FAO (2004) mentioned 2 difference types: deforestation and forest degradation. The difference between deforestation and forest degradation is illustrated in ***Figure 3***.

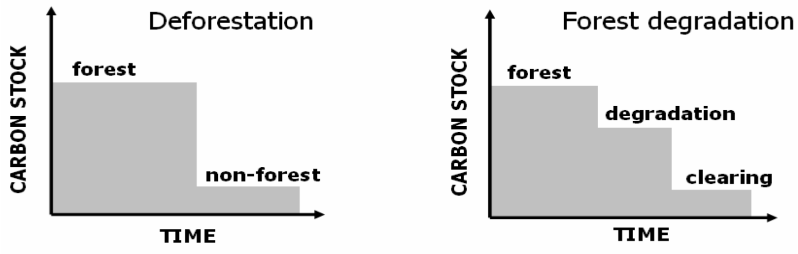



**Figure 3. The differences between deforestation and degradation (adopted from De Fries *et al.* (2006))**

## 2.3 Vulnerability definition

Gallopín (2006) and Li (2009) show that, although widely used and discussed, there is little agreement on the definition of the concept "vulnerability within the scope of hazard and risk assesment (Alexander, 2005; Birkmann, 2007; Wu and Takara, 2008) define vulnerability as the condition of society or elements at risk that also determine potential hazard impact. While in the socio-ecological literature, the term of vulnerability is also used to indicate environmental change (Adger, 2006). He also mentions that vulnerability is usually used to describe or express a negative condition.

For nature conservation purposes Pressey *et al*. (1996) defined vulnerability as "the imminence of biodiversity loss to certain threat". Vulnerability can also express external impacts caused by environmental change (Kværner *et al.*, 2006). In the context of this research, researcher defined vulnerability to national park as a threat or negative impacts, which potentially occurs to national park and its resources (landscape, biodiversity and forest).

In assessing vulnerability, there is no single approach and method (Li *et al.*, 2009). Nhuan *et al.* (2009) mentioned that vulnerability assessment can be done based on several different themes such as: environmental vulnerabilities, human and insecurity, coastal vulnerability and natural hazards. Li *et al*. (2009) identified and categorized some methods that have been applied by some researcher which are: comprehensive evaluation method, principal component analysis, artificial neural network, landscape evaluation method and the most used is Analytical Hierarchy Process (AHP).

According to Wilson et al (2005b), vulnerability deals with 3 dimensions: exposure, intensity and impacts. They also stated that exposure is explained as "the probability of a threatening process affecting an area in the certain time, while intensity explained magnitude, frequency and duration". Impacts were described as effects of threatening process on certain features.

## 2.4 Vulnerability analysis

There are several ways to determine vulnerability. Some researcher use mathematical modeling (Wilson *et al.*, 2005a), Principal Component Analysis (Li *et al.*, 2006) and the other use Analytical Hierarchy process/AHP (Wang *et al.*, 2008; Li *et al.*, 2009). In this study the AHP is applied for the following reasons: (1) potential resources such as landscape uniqueness, forest condition and habitat could not be mathematically modeled; (2) historical data is not available and (3) the most important is AHP can deal with a lot of criteria and structured the complex problem into a simple and understandable hierarchical structure (Li *et al.*, 2009).

AHP deals with criteria and weight factors. A criterion is consists of factors and constraints should be measurable and evaluable (Eastman *et al.*, 1995). Mendoza *et al.* (1999) mention that "*A Criterion can, be seen as a 'second order' principle; one that adds meaning and operationality to a principle without itself being a direct measure of performance*".

Determining criteria is not only selecting the criteria for different vulnerability types (viz. loss of landscape diversity, loss of biodiversity and loss of forest resources) but also how to deal with criteria to produce one integrated vulnerability map. The selection of evaluation criteria plays a key role in a vulnerability assessment and the criteria should be operational, indicative and representative (Alewell and Manderscheid, 1998).

## 2.5 Vulnerability type related to national park

Vulnerability assessment should bear significance to the management aims of the national park. Hence the identification of vulnerability of landscape diversity loss, biodiversity loss and forest loss, was determined based on the LLNP management plan 2004.

### 2.5.1 Vulnerability of biodiversity loss

In the context of biodiversity conservation, there are a lot of indicators to measure vulnerability such as:

1) Previous or projected rates of habitat loss (Williams and Marsh, 1998; Lindenmayer and Fischer, 2006)
2) Size or growth rates of human populations (Meyer and Turner, 1992; Abbitt *et al.*, 2000)
3) Densities of threatened species or species richness ((Bibby, 1992. ; Rickkets, 2001).
4) Gaston *et al.* (2002) mention distribution or habitat of endangered species,
5) Accessibility is an important criterion for vulnerability of biodiversity loss since accessibility determines people activity in certain areas (Pressey and Taffs, 2001; Orsi and Geneletti, 2010).

In this research, distribution or habitat of endangered species and human activities (accessibility) were chosen as the basic concept for the analysis of vulnerability of biodiversity loss.

### 2.5.2 Vulnerability of landscape diversity loss

Landscape plays an important role in land use, land management and environmental conservation (De Villotta *et al.*, 2001). In the landscape perspective, vulnerability analysis is defined as: "*the inverse of impact adsorption capacity or the susceptibility of landscape to change when a new land-use is developed* (De Villotta *et al.*, 2001)".

Landscape analysis deals with ecosystem/landscape type assessment. The degree of representativeness of ecosystem can be assessed by expressing the importance of an ecosystem type in a bio-geographical context. This bio-geographical representativeness is the key for the assessment of vulnerability to landscape loss.

### 2.5.3 Vulnerability of forest loss

Dien (2004) mentioned vulnerability to forest degradation as the likelihood that forest resources can be influenced or degraded by human activities. Clearly, it is explaining the relationship between the people needs of forest resources with the potential forest resources that available especially in the LLNP areas.

LLNP-management (2004) mentioned that there are various resources that are used by local people such as: woods, rattan, herbal medicine, but the most attractive resources is logging.

## 2.6 Vulnerability assessment and regional development

Besides the vulnerability assessment process, the use of the result from is very important for planning and decision making (Mehlman *et al.*, 2004). Pressey and Taffs (2001) mentioned that vulnerability assessment can be used as a guide for decision making in the determining level of protection necessary and the urgency of protection. While Wilson *et al.* (2005b) explain how vulnerability analysis can improve the effectiveness of planning. Another advantage of vulnerability assessment is that the outcome can be used as input information for regional development plan (O'Brien *et al.*, 2009). Integrating principles of equity with the identification of vulnerability is important element of adaptation decision making (Adger, 2006).

## 2.7 The application RS and GIS in the vulnerability analysis

Vulnerability assessment is inextricably associated with spatio-temporal dimension. Analysis, modeling, mapping and monitoring of it can best be done with the help of RS and GS technique (Tempfli *et al.*, 2009).

In literature numerous examples can be found of the use of these tools for vulnerability assessment. Wang *et al.* (2008) used RS and GIS for assessing regional vulnerability in the Tibetan Plateau. Pressey and Taffs (2001) used GIS technique for analyzing vulnerability and determining priority location for conservation. Ippolito *et al.* (2009) assessed the ecological vulnerability in the scope of river basin using GIS technique. Mehaffey *et al.* (2008) applied GIS to asses vulnerability from development pattern.

# III. Method

## 3.1 Study area

Lore Lindu national park is located in the middle of Sulawesi Island (*see* **Error! Reference source not ound.**). Administratively it is a part of Central Sulawesi Province. Lore Lindu has a total area of approximately 218,000 ha and was declared a National Park in 1983 after the UN meeting in Denpasar, Bali, Indonesia.

The Park has a rugged topography with an altitudinal range of 250-2,340 m a.s.l. The Park is rich in animal species, with 117 species of mammals, 88 species of birds, 29 species of reptiles and 19 species of amphibians. There are endemic animals like Tonkean macaque (*Macaca tonkeana tonkeana*), Babirusa (*Babyrousa babyrussa celebensis*), Diannae Tarsier (*Tarsius diannae*), Lesser Sulawesi tarsier (*T. pumilus*), Bear Cuscus (*Ailurops ursinus furvus*), Small Cuscus (*Strigocuscus celebensis callenfelsi*), Sulawesi rat (*Rattus celebensis*), Maleo fowl (*Macrocephalon maleo*), Sulawesi palm civet (*Macrogalidia musschenbroekii musschenbroekii*), Gold snake (*Elaphe erythrura*) and (*E. janseni*), Sulawesi frog (*Bufo celebencis*), and six fish species, including an endemic species in Lake Lindu, (*Xenopoecilus sarasinorum)*.


**Figure 4.Map of Study Area**

Lore Lindu National Park represents various ecosystem types, including lowland tropical forest, sub-montane forest, montane forest, and mixed forest . The plant species that can be found in both lowland tropical forest and sub-montane forest include *Eucalyptus deglupta*, *Pterospermum celebicum*, *Cananga odorata*, *Gnetum gnemon*, *Castanopsis, argentea*, *Agathis philippinensis*, *Philoclados hypophyllus*, medicinal plants, and rattans. Part of the Park is covered by a sub-alpine forest at an altitude of 2,000 m asl. This forest is frequently blanketed with mist, and consists of short trees and mosses management (LLNP-management, 2004).

Besides the riches of its natural resources, the Park also has some impressive groups of megaliths which are among the best megalithic monuments in Indonesia (see ***Figure 5***). Lore Lindu National Park was declared as a UNESCO Biosphere Reserve in 1977.

There are 60 villages at the periphery of LLNP, of which 8 located in 2 enclave areas (LLNP-Management, 2004). According to ADB (2008), the standard of local people who live in surroundings of LLNP is below the provincial poverty line. The annual household income approximately is $250. The main daily activity of the villagers is farming. ADB (1997) reported that 70 % of the population is indigenous; the remaining 30 percent are immigrants. The majority (91%) of the population is concentrated along the river valleys that also from the Park perimeter. The report also mentions that the average population densitiy for these areas is 17.7 and 6.5 persons/square kilometer ($km^2$). The more densely populated villages may reach 476 persons/$km^2$.


**Figure 5. Megaliths in LLNP**

## 3.2 Method description

This chapter is divided into 6 stages corresponding with the research questions 1 (*see* ***section 1.5***). A flowchart of activities is presented in ***Figure 6***. A list of data and materials used is presented in ***Appendix 1***.

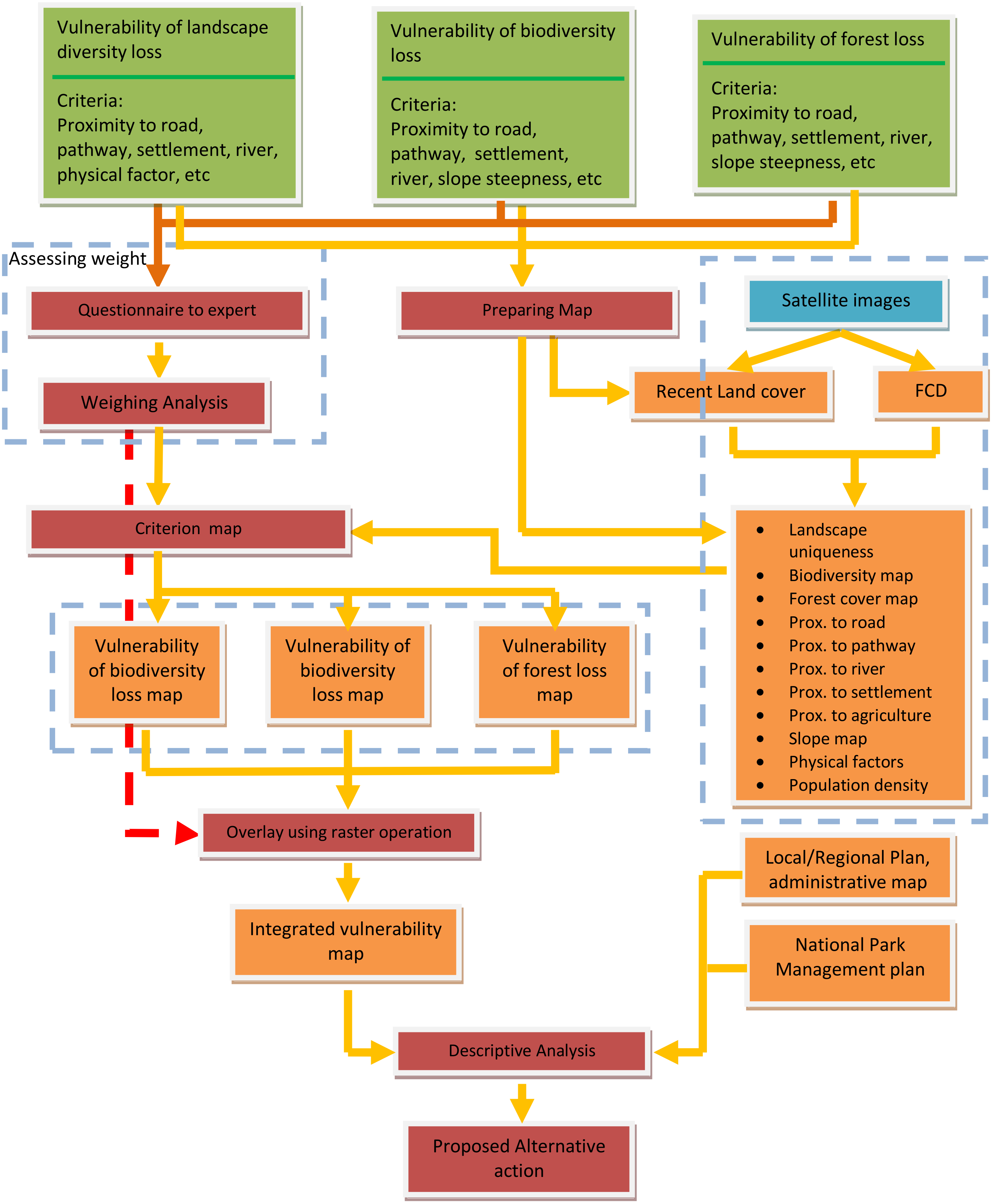



**Figure 6. Flowchart of research activities**

### 3.2.1 Identifying and selecting criteria for each vulnerability

This section refers to the method which was applied to answer research question 1 (*see **section 1.4***).

Identifying criteria was done through literature survey and discussion with some experts. Those method was following suggestion from Malczewski (1999) which mentioned that literature study, analysis and opinion of experts can be sources for determining criteria.

To help identify the criteria for each vulnerability type, the framework from Wilson (Wilson *et al.*, 2005b) was applied, where the exposure, intensity and impact were identified. From those information, then the criteria were determined.

In the process of identification of criteria, researcher found several exposures for each type of vulnerability type. This is obvious since all of the vulnerability are within one system and correspond one another. To reduce the overlapping and simplify the analysis, researcher decided to choose only one exposure, which is only the main exposure, for each type of vulnerability. The intensity and impacts then identify based on the exposure determined.

From the list of criteria found, the proper crtiteria were selected which can be used to express vulnerability in a spatial context. The standardized score or rank is determined then. There is no standard method in determining score for vulnerability, but in this research, researcher decided to use the range 1 – 5 because at the end, the expected vulnerability class will be in 5 classes ranging from: very low, low, medium, high and very high.

### 3.2.2 Map preparation

The method for this section is developed to answer the research question no 2 (*see **section 1.5***). In this section the procedure used for the various maps is described.

#### *3.2.2.1 Preparing recent land cover map*

Although land cover is not one of the criteria, the information is needed to produce other maps such as biodiversity map and landscape uniqueness map. The correlation between land cover map and other maps is explained in the section 3.2.2.3 and 3.2.2.4. The flowchart of the production of the landcover map is presented in the ***Figure 7***.

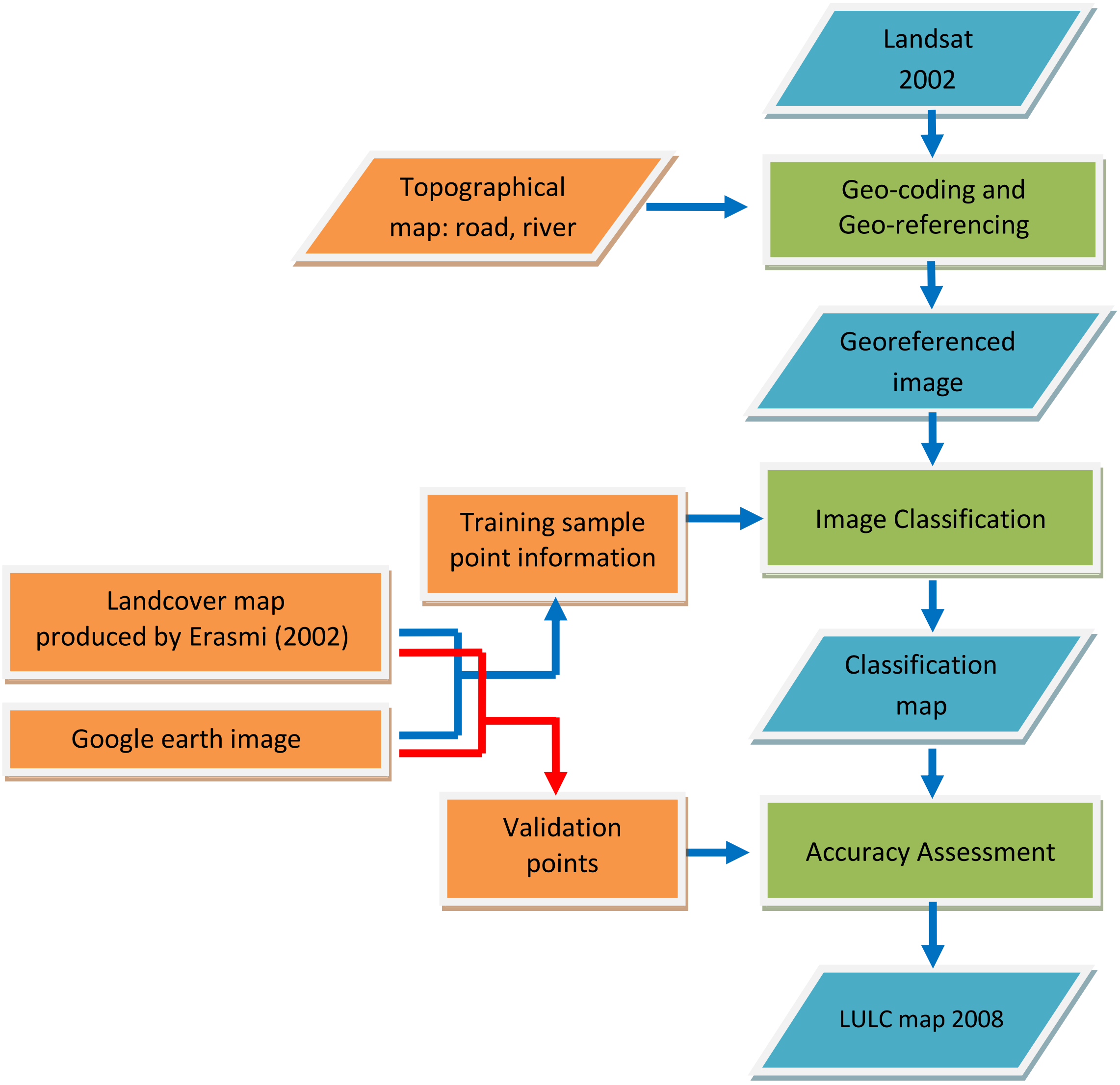



**Figure 7. Flowchart of preparing land cover map**

For the landcover map, a Landsat TM-7, image from 2002 which is downloaded from http://glovis.usgs.gov/ was used. Generating the land cover map consisted of three steps:

- Geo referencing and geo-coding

  Geo-referencing and geo-coding the image is the process of giving coordinate and determining image or map into certain coordinate system (Tempfli *et al.*, 2009). It is needed for geometrically correct overlay various layers in GIS or image processing. In this process, road and river map are chosen as reference map.

- Supervised Classification

  The supervised classification using Maximum Likelihood was done by using software ERDAS Imagine 9.3. The Maximum Likelihood algorithm is considered more accurate, because the calculation process considers not only the cluster center but also the shape, size and orientation of the clusters (Tempfli *et al.*, 2009) of the ground truth for "training areas" was derived from the existing land cover map year 2002 that produced by Erasmi *et al*. (2004) and high resolution Google earth image. Total training sample areas follows the rule from Tempfli *et al.* (2009), which is N+1 (N is number of classes).

- Accuracy Assessment

Accuracy assessment should be done because in the process of supervised classification, researcher used a set of samples of training areas. Validating the result of classification is considered important to make the classification result reliable.

The accuracy assessment was executed based on the set of independent validation points using ERDAS software. For validation process, researcher used minimum 10 points for each class which also derived from land cover map year 2002 that produced by Erasmi *et al*. (2004) and high resolution Google earth image. The allocation of exact validation points is follow heuristic rules that mentioned by Baraldi *et al.,* (2005): the number of validating points for each class should be proportional according to the area in each class.

### *3.2.2.2 Preparing current situation map*

Since vulnerability was defined in relation to loss (eg. vulnerability to landscape diversity) the current state was assessed for each vulnerability type (landscape diversity, biodiversity, forest loss). In each type of vulnerability there should be a current state condition which is potentially being exposed. The current state condition is determined based on vulnerability type. For vulnerability of landscape diversity loss, the current state condition is landscape uniqueness, while for vulnerability of biodiversity and forest loss are endangered/unique species habitat and forest coverage

#### 3.2.2.2.1 Generating forest resources map using FCD Mapper

Due to lack of information concerning the actual extend of the forest, the actual are under forest was estimated through LANDSAT (E)TM imagery in combination with the Forest Canopy Density Mapper software version 2.0, which is developed by JOFCA for ITTO (Rikimaru *et al.*, 2002)

This software involves biophysical spectral response modeling in predicting forest coverage (expressed in cover %), based on a number of indices which can be calculated from the digital numbers in the various spectral bands. The indices used are: Advance Vegetation Index (AVI), Bare Soil Index (BI, Shadow Index (SI) and Thermal Index (TI) (Rikimaru *et al.*, 2002). A more detailed description of the FCD mapper procedure can be found in ***Appendix** 2* and detail process in ***Appendix 3***.

#### 3.2.2.2.2 Preparing landscape uniqueness map

Landscape uniqueness was chosen as the current state in the basis of assumptions that the more unique the more severe the effect of landscape loss. In analyzing landscape uniqueness, basic information that has to be acquired is landscape (ecosystem) types.

The landscape uniqueness map was mainly derived from ecosystem map (*see **Appendix 4***) which is produced by TNC in 2004. There are 7 types of ecosystem that described in the map, which are: lowland forest ecosystem, lower montane ecosystem, upper montane, cloud forest, savanna/grass ecosystem, wetland and lake ecosystem.

Since the map has no information about agriculture area or ecosystems that have been degraded, the map should be updated. To update the recent condition about the landscape that had been lost, researcher overlaid non forested area from landcover map produced with the ecosystem map to produce landscape uniqueness. Detail workflow of the process is presented in ***Appendix 5***.

To complete the preparation of landscape uniqueness map, the landscape type map produced should be ranked to get priority value based on potentially damaged or loss issue based on uniqueness (both uniqueness in LLNP level and Sulawesi region level). The rank is determined from the lower to higher susceptibility to loss. For the LLNP level, the smaller the area (in ha), the higher the value of uniqueness vice versa. While for the Sulawesi region level, the higher the percentage of area of each type of ecosystem compare to the area of the same type of ecosystem, the higher the value of uniqueness.

### *3.2.2.3 Preparing biodiversity map*

The biodiversity map was produced based on the habitat of species map from LLNP management. As a proxy for biodiversity only endangered species and unique species were included (see ***section 2.4.2****)*.

Since some habitat maps were only available as point maps, a buffer was created around these points. The width of the buffer was based on literature. For the habitat of Sulawesi Macaque (*Macaca tonkeana*), the buffer distance refer to (Pombo, 2004), who mentions a homerange of macaque of 1.5 $km^2$. For Sulawesi Deer the home range refer to (Reynolds *et al.*, 2001), which mentioned 3 $km^2$. For the tarsier, (*Tarsius spectrum*)the home range is 3.07 km2, refer to (Gursky, 2003). For the Babirusa (*Babyrousa babyrussa*), the home range of wild pig (note: wild pig and babirusa has similar characteristics) was used which can disperse up to 10 km since the home range data on the Babirusa was not available. Detail process of preparing biodiversity map is explained in the ***Appendix 6***.

### *3.2.2.4 Preparing individual criteria*

The maps were prepared based on the spatial criteria as described in section 3.3.1. The legend for each criterion map is expressed in 5 classes, since the expected vulnerability class are 5 classes.

#### 3.2.2.4.1 Preparing proximity map

This analysis requires the measurement of objects, the components of objects or the relationship between objects (distance to one or some points). To get information about distance in each of pixel, interpolation process is needed. One of the interpolation techniques in determining distance that can be used is *euclidean* distance or distance transform. ESRI (2010) mentioned that *euclidean* distance function can calculate distance based on the distance of surrounding cell source to the center of the source cells. For each cell, the distance is calculated using principle of triangle which is shown in the ***Figure 8***. In simple understanding, the Euclidean distance raster explain the closeness with also considers the direction of each cell to the nearest source.

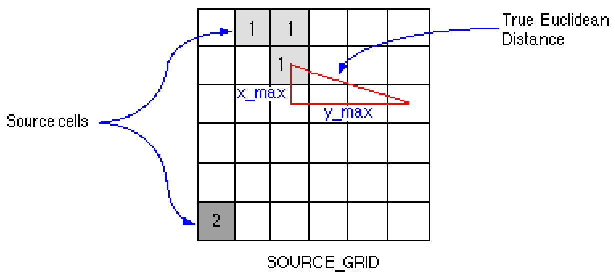



**Figure 8. Euclidean distance calculation (sources: ESRI, 2010)**

Euclidean distance function can help the researcher in constructing distance map of river, road settlement etc. With this function, the distance map will be in raster format which has type continuous raster. The distance map was produced by using ArcGIS software in the menu: Spatial Analyst Tools> Distance>Euclidean Distance.

#### 3.2.2.4.2 Preparing physical factors Map

Two Physical factor maps that used in the analysis: soil type and rainfall (map are shown in ***Appendix 7***). The maps were provided by LLNP management. The maps should be reclassified based on vulnerability rank to be used for vulnerability assessment from 1 to 5 (low to high).

#### 3.2.2.4.3 Preparing Slope Map

Slope map was derived from Digital Elevation Model – Shuttle Radar Topographic Mision (DEM-SRTM) which has spatial resolution 90 m. The DEM was downloaded from website: http://seamless.usgs.gov.

To produce slope map, ArcMap 10 software was used . The slope was classified into 5 classes from flat (0 – 10$^o$) to very steep (> 40$^o$). Assuming that the steeper the slope, the less vulnerable to human influence

#### 3.2.2.4.4 Preparing population density map

The data on population density was derived from population sensus data from 2004 (see ***Appendix 8***). The underlying assumption for the ranking of the population density was, that the higher the density, the bigger the buffer around the settlement where an impact on the surrounding area can be expected. The maximum distance is the same as the maximum distance of proximity to settlement (7.5 km).

Firstly, the population was categorized into 5 classes. Next, a buffer was calculated for each class. ***Table 1***.

**Table 1 . Weight of population density effect**

| Population (pupils) | Max. Distance (km) |
|---|---|
| 0 – 1,000 | 1.5 |
| 1,000 – 2,000 | 3.0 |
| 2,000 – 3,000 | 4.5 |
| 3,000 – 4,000 | 6.0 |
| 4,000 – 5,000 | 7.5 |

### 3.2.3 Weighing of the criteria

There are three main processes: determining importance level of criteria, checking inconsistency and summarizing criteria.

#### *3.2.3.1 Determining importance level of criteria*

The underlying assumption for weighing of the criteria was that not all criteria are equally important. To assess relative importance of the criteria for vulnerability assessment was based on expert judgment. According to De Lange *et al.* (2009) the methods for vulnerability assessment are: (1) Expert judgments, (2) input of stakeholder, (3) ranking and mapping and (4) quantification, where expert judgment is the most used in the analysis and gives more reliable results.

For this purpose a questionnaire was designed with a pair wise comparison of the criteria (*see **Appendix 9)***. The questionnaire was distributed to 14 experts, which have experience in the field of nature conservation or natural resource management. Each expert was asked to express the relative importance of two criteria from the same level using a scale which is presented in ***Table 2***.

**Table 2. The scales used in determining the weights of the criteria, adopted from (Saaty, 1990)**

| Intensity of importance of absolute scale | Definition | Explanation |
|---|---|---|
| **1** | Equal importance | Equal importance of two elements |
| **3** | Moderate importance of one over another | Weak importance of a criteria compare to another |
| **5** | Essential or strong importance | Strongly important criteria compare to another |
| **7** | Very strong importance | Criteria is strongly favored and its dominance |
| **9** | Extreme importance | Absolute importance |
| **2,4,6,8** | Intermediate values between the two adjacent judgment | |
| **1/3, 1/5.1/7, 1/9** | Reciprocal values of the previous appreciation | |

The pair wise comparison was chosen, because this method gives a comparison between one criterion to another so that the weighing can be more objective. In the developing a pair-wise comparison matrix, each factor is rated against every other factor by assigning a relative important value between 1 and 9 (*see **Table 2***). If the factor on the vertical axis is more important than the factor on the horizontal axis, the value will be varies from 1 to 9. Adversely, the value will be varies between the reciprocals 1/2 and 1/9.

The pair-wise comparison analysis used a pair-matrix (*see **Figure 9***), where the main diagonal is always equal to 1. It can be seen that the eigenvector corresponding to the largest eigen value of the matrix provides the relative priorities of the factors (Saaty, 1979). Weight value can be obtained from the horizontal summary of value which reflects the relative importance of various factors from the matrix of paired comparisons. This process was followed for each expert.

| Criteria | Prox to Road | Prox to pathway | Prox to Settlement | Prox to River | Prox to existing agric | Physical factors | Population density |
|---|---|---|---|---|---|---|---|
| Prox to Road | 1 | 5 | 3 | 9 | 3 | 9 | 1 |
| Prox to pathway | 1/5 | 1 | 1/5 | 1 | 1/5 | 3 | 1/7 |
| Prox to Settlement | 1/3 | 5 | 1 | 7 | 5 | 7 | 1/5 |
| Prox to River | 1/9 | 1 | 1/7 | 1 | 1/7 | 3 | 1/5 |
| Prox to existing agric | 1/3 | 5 | 1/5 | 7 | 1 | 5 | 1/3 |
| Physical factors | 1/9 | 1/3 | 1/7 | 1/3 | 1/5 | 1 | 1/9 |
| Population density | 1 | 7 | 5 | 5 | 3 | 9 | 1 |

**Figure 9. Example of pair wise comparison matrix**

### *3.2.3.2 Checking of inconsistency*

It is important to check the consistency of the expert, since an expert's judgment can be subjective. Based on Saaty (Saaty, 1990) the consistency of the judgments could be obtained because this matrix is a consistent matrix. For example: if criteria 1 is considered more important than 2 and criteria 2 more important than criteria 3, it must be so that criteria 1 more more important than criteria 3. In AHP (Analytical Hierarchy Process), an index of consistency, known as the consistency ratio (CR), is used to indicate the probability that the matrix judgments were randomly generated (Saaty, 1990). The formula for calculating CR are:

$$CR = \frac{CI}{RI} \qquad CI = \frac{\lambda\,\mathrm{max} - n}{n - 1}$$

Where: CI : Consistency Index
CR : Consistency Ratio
λ max: the largest ' Eigen' value

The maximum acceptable value for CR is 0.1. If the value is more than that, the weighing process should be repeated and the expert should be informed.

### *3.2.3.3 Calculating and summarizing weight from all experts*

After the weighing through expert judgment is completed, the next step is summarizing and recapitalizing it and the average of all weights from each criterion is calculated.

Dealing with expert judgment is dealing with subjectivity from the experts (Li *et al.*, 2009) and the results may be biased (Cowling *et al.*). Based on Saaty (1990), if CI is more than 0.1 means that expert produce bias in determining weight so that re-communication to the expert should be done. But, since researcher was deal with many experts and due to limitation of time, the suggestion was not been done. In order to establish if there was agreement between the expert judgement or not, the Friedman test was applied.

Friedman's ANOVA test is one of non-parametric statistical test which is similar to parametric repeated measures ANOVA but it is used for non-parametric data. This test was used in order to detect differences in weights across multiple experts involved. The procedure involves ranking each row, then considering the values of ranks by columns.

The combination of AHP and ranking with the Friedman test is a new technique to derive a quantitative method for weight.

To test the weighing result, the hypothesis are :

*Ho : There is no significant differences between weights upon criteria*

*H1: There is a significant difference between weights upon criteria*

Researcher test the hypothesis with critical value ($\alpha = 0.05$)

To check which criterion that gives significance result, researcher used post hoc test of friedman's ANOVA statistic. To run the analysis, researcher used R-software with script that downloaded from: http://www.r-statistics.com/2010/02/post-hoc-analysis-for-friedmans-test-r-code/.

### 3.2.4 Creating vulnerability maps

Each vulnerability type map is produced based on a specific set of criteria (*see* ***section 4.1***) The map is produced by using the weighted overlay function and model builder in the ArcGIS 10 software. The weight derived from expert judgment is input information for weight map in the overlay process.

Raster overlay is one technique in GIS for getting new information from two or more different raster layer. In raster overlay, there is a technique called weighted sum overlay, which is consider the weight/scale of each value of factor or layer to create an integrated analysis (ESRI, 2010). The illustration for the weighted overlay is mention in the ***Figure 10.***

The raster overlay can be used for overlaying different type of vulnerability map and also to produce one integrated vulnerability map. To help the overlay processes, researcher use model builder tool is ArcGIS 10 software. The work flow in developing vulnerability using model builder is presented in ***Figure 11, 12*** and ***13***.

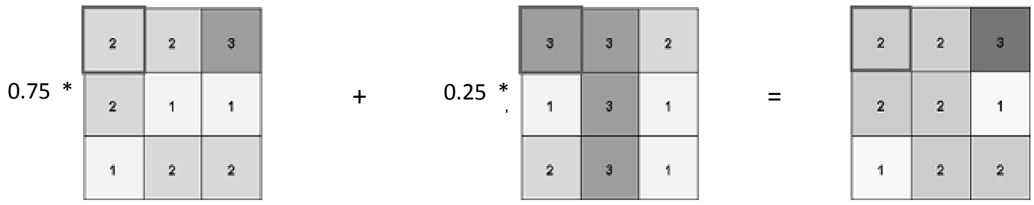



**Figure 10.** Weighted overlay illustration (adopted from ESRI, 2010)

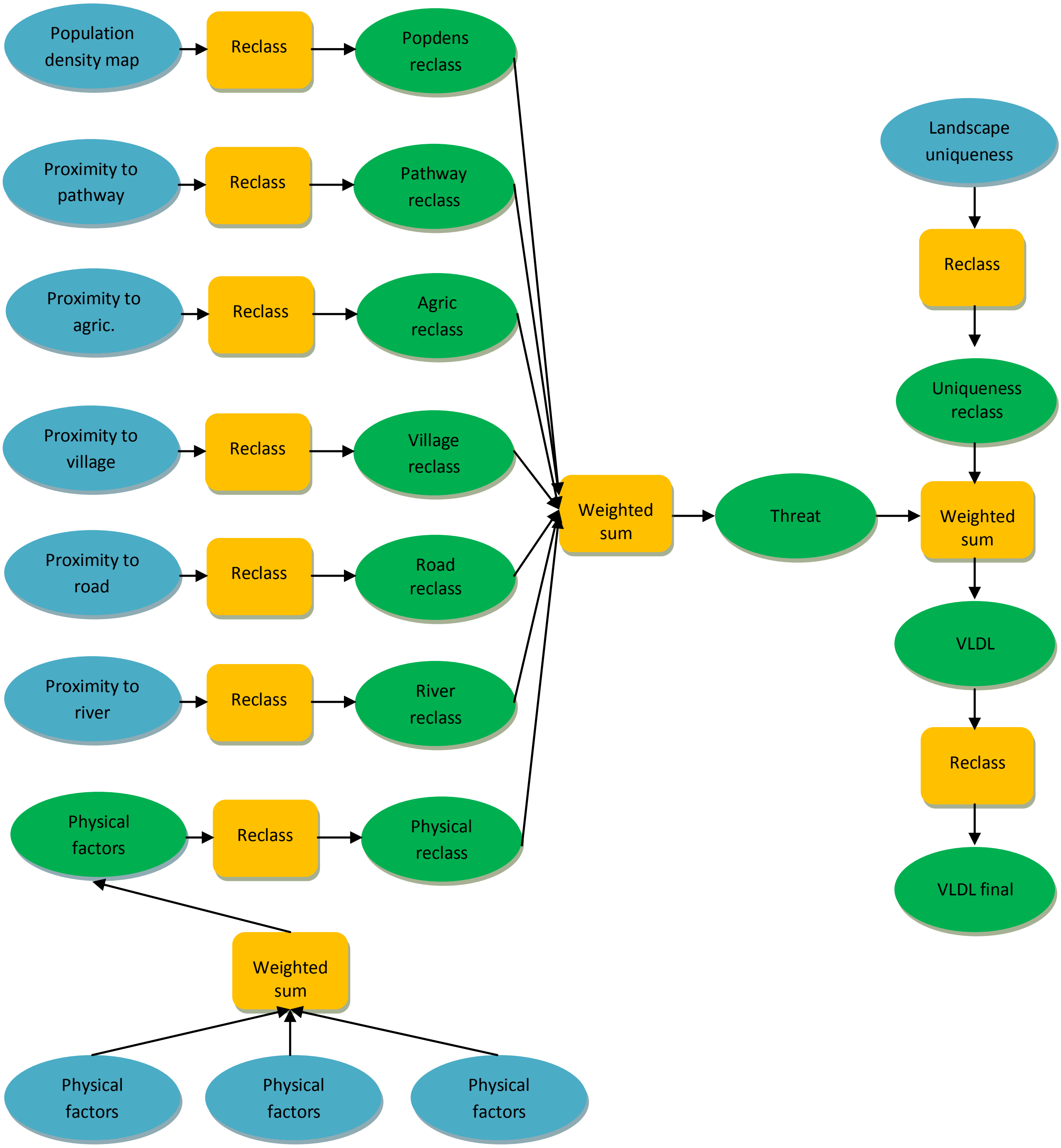



**Figure 11. Developing Map of Vulnerability to landscape diversity loss**

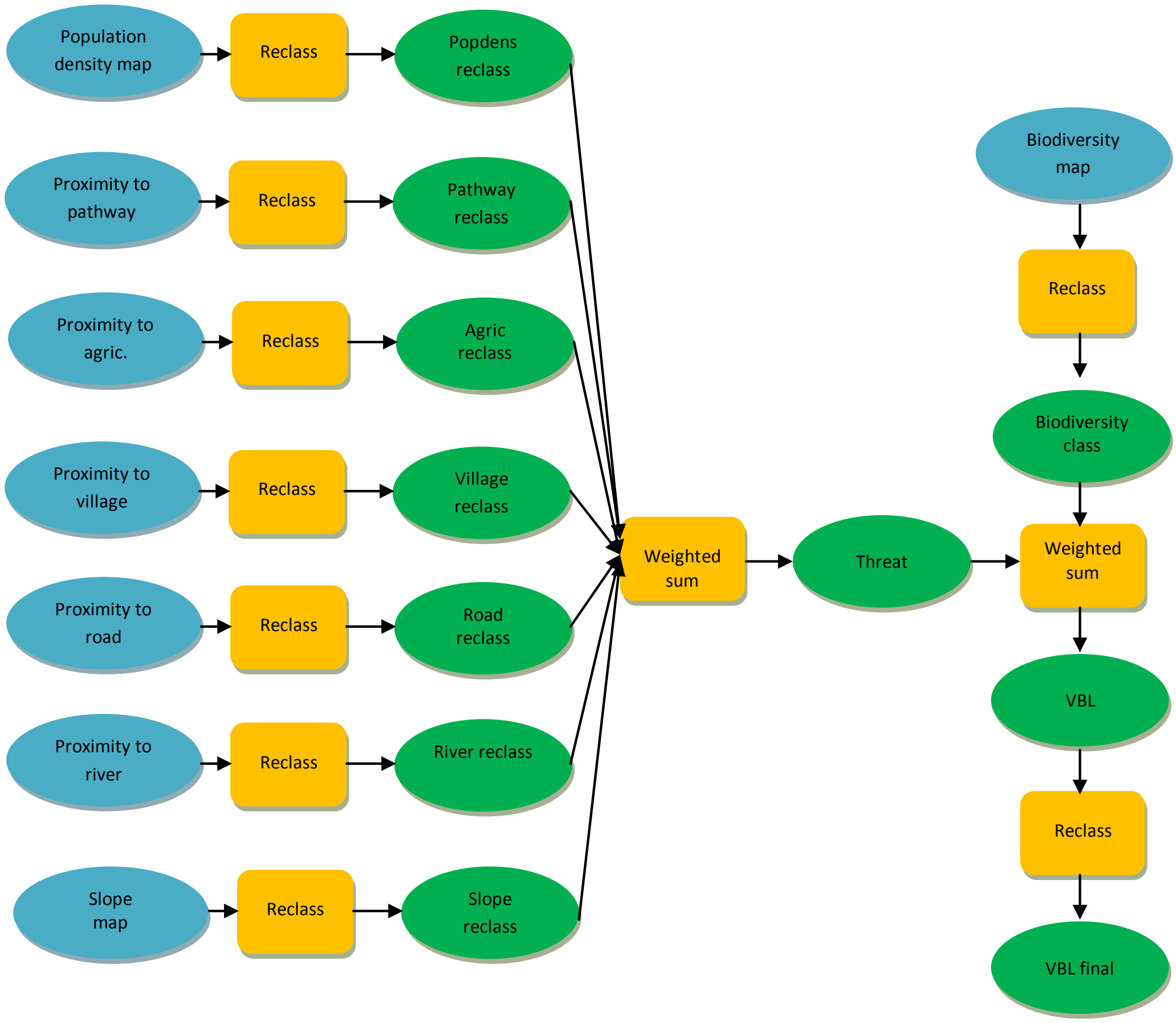



**Figure 12. Developing Map of Vulnerability to biodiversity loss**

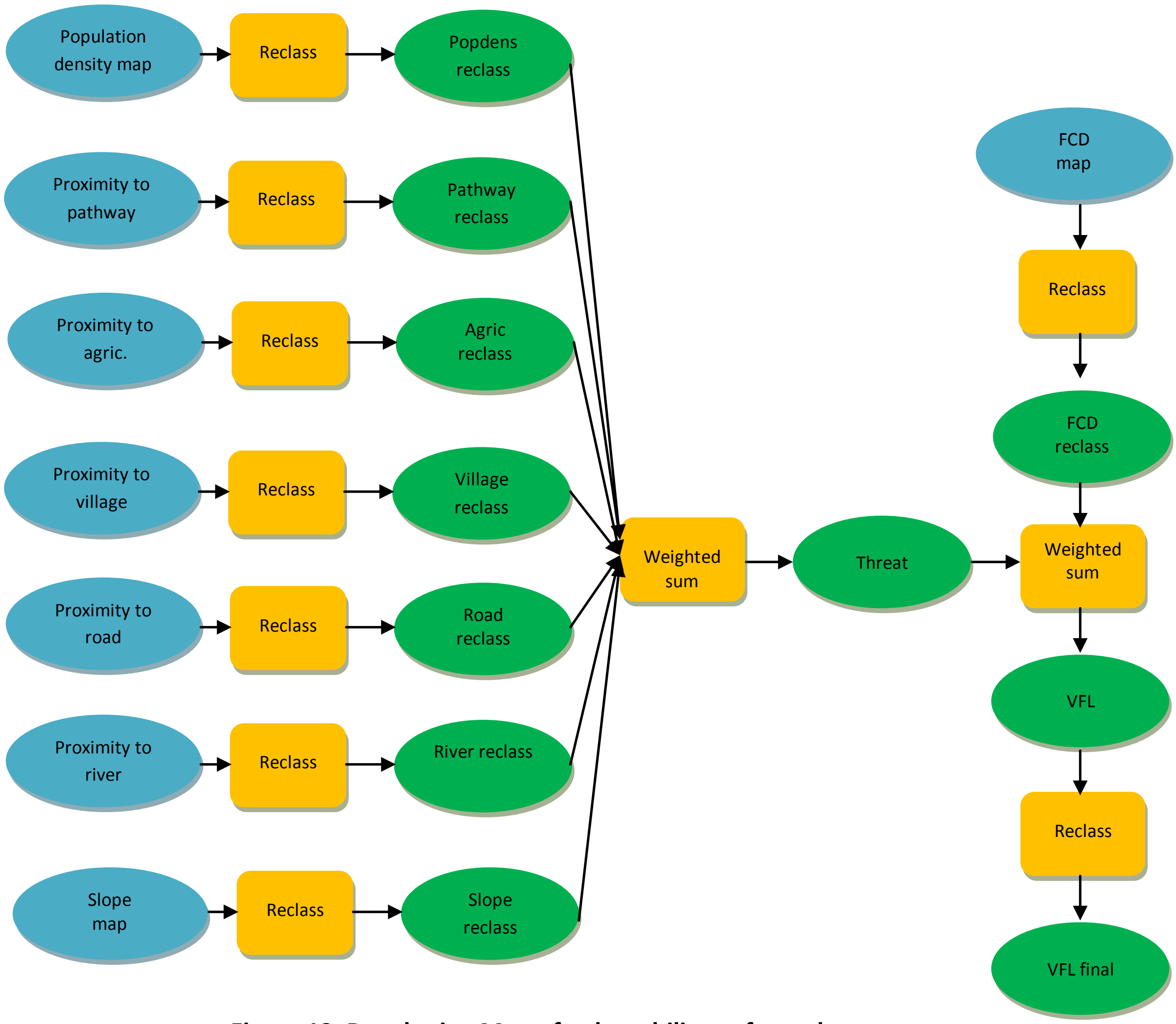



**Figure 13. Developing Map of vulnerability to forest loss**

## 3.2.5 Integrating all vulnerability maps

Integrating all vulnerability maps into one integrated vulnerability map is to give information that easier to understand for stakeholders and also easier to analyze in the next step of analysis. This integrated maps, is one of the output for stakeholders about condition of the study areas.

Integrating all vulnerability maps is done through raster weighted overlay by using ArcGIS software. The process is described in the ***Figure 14***.

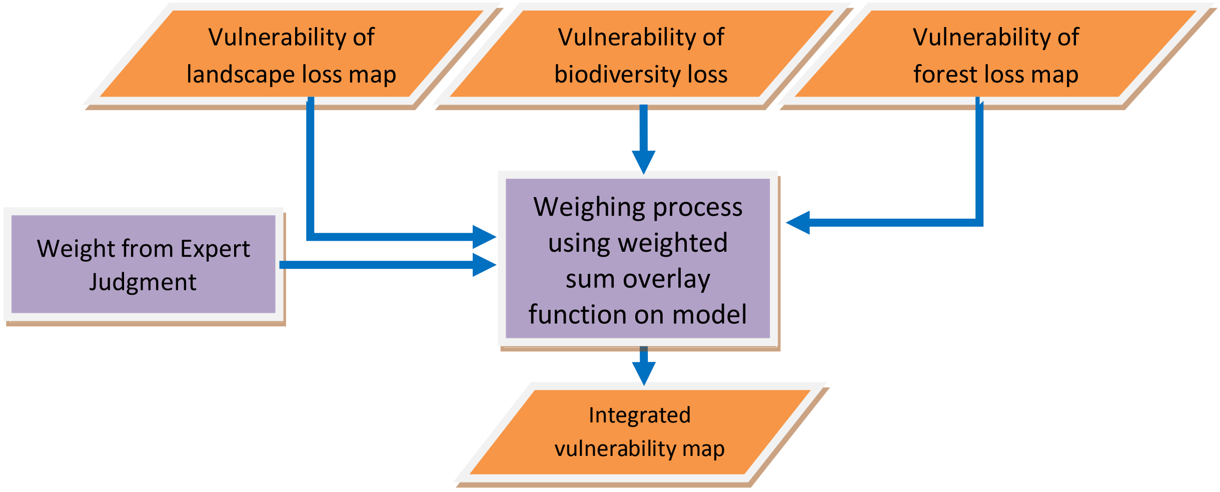



***Figure 14*. Work flow of generating integrated vulnerability map**

The weighing process (questionnaire and weight calculation) also done simultaneously with weighing process in determining each vulnerability type (vulnerability of landscape diversity loss, biodiversity loss and forest loss). The hypothesis also determined to assess the weight. For testing the weight, the hypothesis are:

*Ho : There is no significant differences between weights upon vulnerability type*

*H1: There is a significant difference between weights upon vulnerability type*

Researcher test the hypothesis with critical value (α = 0.05)

### 3.2.6 Implication of vulnerability analysis to national and local/regional policies

Integrating the vulnerability assessment with government policies is also an important part. The process of integration was done through a qualitative study, which correlates the vulnerability result with national park spatial plan and local/regional plan. The proposed alternative for management then determined based on some literature found and existing regulation.

One source used to determine proposed alternative is come from adaptation and mitigation matrix developed by Taylor et al. (2007). While some government regulation that used as consideration are: Law no. 5/1990 about conversation on natural resources, Law No. 41/ 1999 about forestry, Government regulation No. 76/ 2008 about forest rehabilitation and reforestation, Government regulation No. 6/2007 about collaborative management and Ministry of forestry decree No. 51/2008 about National Movement of Reforestation and Rehabilitation .

# IV. Result

## 4.2 Criteria used in the analysis

In determining criteria used in the analysis the framework from Wilson (2005b) which investigated the criteria based on exposure, intensity and impact was applied. For an overview of the criteria selected for all 3 vulnerability types see ***section 4.1.1*** to ***4.1.3.***

### 4.2.1 Criteria for vulnerability of landscape diversity loss

By using framework of Wilson (2005b), researcher found the criteria for determining the vulnerability of landscape diversity loss (*see* ***Appendix 10****).* The summary of the criteria is presented in ***Table 3***.

***Table 3.*** Criteria used based on literature review and investigation for landscape vulnerability analysis.

| Current state | Exposure | Impact | Susceptibility criteria |
|---|---|---|---|
| Landscape uniqueness | Land Conversion to Agricultural area | Change in land cover | • Proximity to road |
| | | Conversion to agricultural fields | • Proximity to pathway |
| | | | • Proximity to river |
| | | | • Proximity to settlement |
| | | | • Proximity to existing agriculture |
| | | | • Physical factors (rainfall, soil type and slope) |
| | | | • Population density |

*a. Current State (Landscape uniqueness)*

Landscape uniqueness was chosen as the criteria in the basis of assumptions that the more unique the more severe the effect of landscape loss. In analyzing landscape uniqueness, basic information that has to be acquired is landscape (ecosystem) types. There are 7 types of landscape/ecosystem exist in the LLNP, which are: Lowland forest ecosystem, lower montane forest ecosystem, upper montane forest ecosystem, cloud forest, savanna and grass, lake ecosystem (LLNP-Management, 2004). Those ecosystems are classified into uniqueness criteria based on the quantity of the area and comparison each landscape type with the same type in the Sulawesi region.

The ecosystems and the uniqueness of landscape in LLNP are described as follows:

- Lowland forest ecosystem. Based on Whitten *et al.* (1987), this ecosystem can be characterized by wet green forest area, a lot of plant material (carbon) and special vegetation such as *Octomeles sumatrana*, *Eucalyptus deglupta* and *Duabanga moluccana*. They also mentioned that lowland forest ecosystem is the richest flora and fauna composition among other ecosystem types in the tropical rain forest ecosystem type. This characteristic made the area valuable to be conserved.

  Based on spatial analysis in from the ecosystem type map (***Appendix 4***), total area for this ecosystem is 6,095 ha or 2.8 % of the total area. If it is compared to total ecosystem in Sulawesi (*see* ***Appendix 11***), this ecosystem type represents 0.06 % from the total ecosystem in Sulawesi.
- Lower montane forest ecosystem. This ecosystem, dominated by vegetation of family of Sapotaceae and Fagaceae (*Castanopsis sp.*), laid on the altitude of 900-1.500 a.s.l (LLNP-Management, 2004). Total area for this ecosystem is 119,679 ha or 54.99% of total area. This ecosystem is the largest ecosystem in the area and represents 3.06% from the total ecosystem in the Sulawesi region.
- Upper montane forest ecosystem. This type of ecosystem lays on the altitude of 1.500-1.800 a.s.l. and can be easily characterized by *Dawsonia sp.* and shrubs like *Begonia spp.*, *Elatostema sp.*, and *Cyrtandra sp.* (LLNP-management, 2004). Total area for this ecosystem is 476 ha or 0.22 % of total LLNP area or 0.01% from the total ecosystem in the region.
- Cloud forest ecosystem. The highest mount in the LLNP area located in the 2.610 a.s.l (mount Rorekatimbu). The cloud forest ecosystem located in the area above 1.900 a.s.l. (LLNP-management, 2004). The report also mentions that cloud forest ecosystem is very unique, which has characterized by species *Rhododendron sp.* and *Phyllocladus hyphophyllus* and tree stem are covered by Moss and algae.

  Total area for this ecosystem is 5,854 ha or 2.69 % of total LLNP area or 3.62% of total ecosystem in the region. This is the highest percentage value of representativeness of ecosystem in the Sulawesi region.
- Wetlands ecosystem. Total wetlands area in LLNP is 21,110 ha or 9.68% compare to total area in LLNP and 3.71% compare to total wetland in Sulawesi region. The wetland areas are concentrated closed to Lindu Lake area and enclave Besoa area.

- Savanna and grass ecosystem. Even the majority of this type of ecosystem is located in the enclave area, this ecosystem also considered important in the analysis since the system are interrelated to ecosystem in national park areas. This ecosystem dominated by *Melastoma sp.* and there are pioneer species such as *Macaranga sp.* in the transition area to the forest area (LLNP-management, 2004). Total area for this ecosystem is 1,487 ha or 0.66 %. Whitten *et al.* (1987) mentioned that this type of ecosystem is not natural, so that this ecosystem is not a priority to be conserved.
- Lake ecosystem. There are some lakes in the LLNP area, but the biggest lake is Lindu lake, which is located in the center of LLNP. Lindu lake itself administratively is located in the enclave area. But this, ecosystem also should be considered as a part of LLNP ecosystem since the interaction among ecosystem are exist and inevitable. Another information that made this area unique is that there is one endemic fish species mentioned living in this lake by Whitten *et al.* (1987) and LLNP (2004).

After analyzing the all landscape by doing ranking based on area percentage compare to LLNP and compare to Sulawesi region (***see Appendix 11).*** The Weight for each type of landscape in the landscape uniqueness are presented in ***Table 4***.

**Table 4. Weight for criteria for landscape uniqueness**

| Landscape type | Standardized weight |
|---|---|
| **Wetlands** | 5 |
| **Cloud forest ecosystem** | 4 |
| **Lowland forest ecosystem** | 2 |
| **Lower montane forest ecosystem** | 3 |
| **Upper montane forest ecosystem** | 1 |
| **Lake ecosystem** | 5 |
| **Savanna and Grass ecosystem** | 1 |

b. Threat to landscape diversity loss criteria (susceptibility to agriculture conversion)

The biggest threat (exposure) to landscape diversity loss comes from land conversion into agricultural fields. The criteria used for vulnerability assessment to landscape diversity loss are:

1. Proximity to road

   Road existence determines accessibility to national park. Accessibility explains how human can give effects to the landscape. The closer the area is to the road the higher the vulnerability of the area.

   Proximity to road is expressed as the *euclidean* distance derived from road map using ArcGIS software. The maximum distance from road that gives effect to vulnerability to landscape is various. Apan and Peterson (1998) mentioned that distance from road that affect the ecosystem is between 4 to 10 km. While Permatasari (2007) mentioned that distance 5 km from road gave the biggest effect to degradation. Loza Armand Ugon (2004) and Wilson *et al.* (2005a) mentioned that 7.5 km distance from road is the maximum effect that road can generate degradation. In this study an arbitrary buffer of 7.5 km is used. The proximity to road map can be seen in the ***Appendix 12***. Since the standard class for the analysis is 5 classes, the proximity to road criteria was also divided into 5 classes, which are presented in the ***Table 5***.

***Table 5.***Weight for proximity to road map

| Distance (km) | Standardized score |
|---|---|
| **0 – 1.5** | 5 |
| **1.5 – 3.0** | 4 |
| **3.0 – 4.5** | 3 |
| **4.5 – 6.0** | 2 |
| **6.0 – 7.5** | 1 |

2. Proximity to pathway

   Another criteria of susceptibility to agricultural conversion is pathway existence. The probability of effect of pathway expressed as the Euclidean distance from pathway which derived from road map using ArcGIS. The maximum distance for bounding the Euclidean process is the same as the proximity to road map (7.5 km). The proximity to pathway map is presented in the ***Appendix 11***. Standard class for proximity to pathway also follows the standard class of proximity to road table (***Table 5)***

3. Proximity to settlement

   Researcher decided to use distance 7.5 km from village for bounding the Euclidean refer to McConnell *et al.* (2004) mentioned that distance to village 7.47 km ≈ 7.5 km was the maximum distance that degradation take place. The map of Euclidean distance of proximity to settlement is presented in the ***Appendix 11***.

4. Proximity to river

Apan and Peterson (1998) mentioned that distance 1 km from river can generate forest degradation. While Permatasari (2007) mentioned that distance from 0-5 km from river is the significant distance of effect of river to degradation. In this research, researcher used distance 1 km from river since the river is less used to access LLNP. The weigh for each class can be seen in the ***Table 6***.

**Table 6. Weight for proximity to river map**

| Distance (meter) | Standardized score |
|---|---|
| **0 – 200** | 5 |
| **200 – 400** | 4 |
| **400 – 600** | 3 |
| **600 – 800** | 2 |
| **800 – 1,000** | 1 |

5. Proximity to existing agriculture

Producing proximity to agriculture map also used distance 1 km, since there is no exact number of information about the effect of existing agriculture to degradation occurrence. The used 1 km distance was taken based on consideration about the potential expansion of existing agriculture in the area. The standardize score the determined as presented in the ***Table 7***.

**Table 7. Weight for proximity to existing agriculture**

| Distance (meter) | Standardized score |
|---|---|
| **0 – 200** | 5 |
| **200 – 400** | 4 |
| **400 – 600** | 3 |
| **600 – 800** | 2 |
| **800 – 1000** | 1 |

6. *Physical factors related to potential agriculture expansion areas*

In the analysis landscape change into agricultural areas, the physical factors that accounted are: slope/topography, soil type and rainfall (Freitas *et al.*, 2010). Silva et al. (2007) mentioned that areas with steep slopes or poor soils are less favorable for agricultural conversion.

In determining score for slope factor, researcher used scoring based on information from Silva *et al.* (2007). Score for each class for slope criteria is presented in the

***Table 8***, while score for soil type criteria and rainfall is presented in the ***Table 9*** and ***Table 10***.

**Table 8. Score for each class for slope criteria**

| Criteria (degree) | Standardized score |
|---|---|
| **Slope class 0 – 10** | 5 |
| **Slope class 10 – 20** | 4 |
| **Slope class 20 – 30** | 3 |
| **Slope class 30 – 40** | 2 |
| **Slope class > 40** | 1 |

**Table 9. Score for each class for soil type criteria**

| Criteria | Standardized score |
|---|---|
| **Alluvial, organosol, hidromorph** | 5 |
| **Brown forest soil** | 4 |
| **Latosol** | 3 |
| **Podsolik** | 1 |

**Table 10. Score for each class for for rainfall**

| Criteria | Standardized score |
|---|---|
| **> 2250 mm** | 5 |
| **1750-2250 mm** | 4 |
| **1250-1750 mm** | 3 |
| **750 – 1250 mm** | 2 |
| **0 – 750 mm** | 1 |

7. Population density

   Socio economic factors (population number, population density, income) are closely related to forest resources use in the tropical country (Mena *et al.*, 2006). In this analysis, researcher only used population density as criterion since the other data were not available.

   The data on population was derived based on population number data from 2004. For the population density it is assumed that the bigger the population the bigger the vulnerable area to be degraded. The maximum distance of effect of population is the same with the maximum distance of the proximity to the settlement (7.5 km) which assumed that the movement of people follows the pattern in the proximity to the settlement criteria. The map was produced using buffer function. The map is presented in ***Appendix 13***.

### 4.2.2 Criteria for vulnerability of biodiversity loss

The criteria that used in the analysis of vulnerability to biodiversity loss is presented in the ***Appendix 14***. The summary of criteria is presented in ***Table 11***.

**Table 11. Criteria used in the analysis of biodiversity vulnerability**

| Current state | Exposure | Impact | Criteria |
|---|---|---|---|
| • Endangered species habitat<br>• Unique species habitat | Human activities related to habitat degradation, egg collection and animal hunting | • Biodiversity decreasing or even extinction | • Proximity to road |
| | | • Decreasing population | • Proximity to pathway |
| | | | • Proximity to river |
| | | | • Proximity to settlement |
| | | | • Proximity to existing agriculture |
| | | | • Slope steepness |
| | | | • Population density |

a. *Current State*

- *Distribution or habitat of endangered species*

  Ideally, Vulnerability analysis for biodiversity is assessing each biodiversity feature, because it very much related to different patterns of species and levels of threat. But since the most risk species catch the most attention in the vulnerability, analysis can be prioritized into endangered species (Gaston et al., 2002).

- *Unique species*

  Conserving biodiversity, especially for animal, can not only concern to conserve large areas. As we know that some species require more than just large areas. For their life, wildlife need specific habitat or vegetation types which is specific from the other habitat (Pressey and Taffs, 2001) after (Leopold, 1933; Dunning et al., 1992; Kozakiewicz, 1995; Mysterud et al., 2001). This characteristic is considered in the analysis since some species occupy specific location as their habitat.

b. Threat to biodiversity loss (habitat loss, illegal extraction, hunting, egg)

In general, threat to biodiversity loss is also almost the same with the landscape loss. For biodiversity vulnerability analysis, accessibility is the potential expression of people activities in threatening biodiversity such as habitat degradation, hunting, maleo’s egg illegal collection and trapping. Based on investigation the accessibility factors (proximity to road, pathway, river and settlement) are the same with the factors that is used in determining landscape vulnerability. The difference is the physical factor influenced, which is only slope steepness which also account for accessibility. The standardize weight for slope steepness also follows the weight in the vulnerability of landscape loss diversity criterion. Besides all accessibility factors, socio economic factor also accounted. But, due to data availability, the population density was the only factor considered.

### 4.2.3 Criteria for vulnerability of forest loss

The criteria that used in the analysis of vulnerability of forest loss is presented in the ***Appendix 15***. The summary of criteria is presented in ***Table 12***.

**Table 12. Criteria used in the analysis of vulnerability of forest loss**

| Current state | Exposure | Impact | Criteria |
|---|---|---|---|
| • Forest coverage | Human activities related to deforestation, tree log harvesting | • Change in landcover | • Proximity to road |
| | | • Decreasing in Ecosystem services capability | • Proximity to pathway |
| | | | • Proximity to river |
| | | | • Proximity to settlement |
| | | | • Proximity to existing agriculture |
| | | | • Slope steepness |
| | | | • Population density |

*a. Current state : Forest resources-tree log*

LLNP is rich in forest resources. Since there is no data about standing stocks in LLNP, researcher used forest coverage which is predicted from images by using forest cover mapper software is used. Map of forest resource in LLNP resulted from Forest Canopy Density mapper can be seen in ***Appendix 16***.

Based on the map, the score for each type of cover density was determined. The scoring follows the assumption that the higher the percentage of forest coverage the higher the vulnerability. The score is presented in the ***Table 13***.

**Table 13. Score for Forest Resources based on forest density cover**

| Criteria | Standardized score |
|---|---|
| **Forest cover 80-100%** | 5 |
| **Forest cover 60-80%** | 4 |
| **Forest cover 40-60%** | 3 |
| **Forest cover 20-40%** | 2 |
| **Forest cover 0-20%** | 1 |

b. *Susceptibility to forest loss*

In general, Susceptibility to forest loss from human factor is also almost the same with the biodiversity loss. The factors such as proximity to road, pathway, river and settlement and population density were used.

## 4.3 Landcover map

Landcover map produced is used as input for producing landscape uniqueness map and biodiversity map. The map is presented in ***Appendix 17***. The accuracy assessment result of the landcover map produced is 79.59% (detail see ***Appendix 18***).

## 4.4 Weighing result from expert judgment for each type of vulnerability assessment

The principle of the comparative judgment requires comparison of the elements on a pair-wise base involving three steps: development of a comparison matrix at each level of the hierarchy, computation of the weights and calculating the consistency ratio/CR (Saaty, 1990). The example of comparison matrix resulted from the expert is presented in the ***Figure 15***. Judgment from all experts was compiled presented in the table in the ***Appendix 19***.

From the analysis, researcher found some experts that produced Consistency Ratio/CR is more than 0.1 (***see Appendix 19***). Based on Saaty (1990), if CR is more than 0.1, means that expert produce bias in determining weight so that re-communication to the expert should be done. But, due to limitation of time, the suggestion could not been done. For the solution of this, researcher used ranking method with Friedman’s Anova statistical test. The combination of Analytical Hierarchy Process (AHP) and ranking (Friedman’s anova test) method is a new technique to derive quantitative method for weight

The conversion AHP value to ranking value is presented in ***Appendix 20*** and the summary of result from ranking is presented in the ***Table 14.***

| Criteria | Prox to Road | Prox to pathway | Prox to Settlement | Prox to River | Prox to existing agric | Physical factors | Population density |
|---|---|---|---|---|---|---|---|
| Prox to Road | 1.000 | 5.000 | 3.000 | 9.000 | 3.000 | 9.000 | 1.000 |
| Prox to pathway | 0.200 | 1.000 | 0.200 | 1.000 | 0.200 | 3.000 | 0.143 |
| Prox to Settlement | 0.333 | 5.000 | 1.000 | 7.000 | 5.000 | 7.000 | 0.200 |
| Prox to River | 0.111 | 1.000 | 0.143 | 1.000 | 0.143 | 3.000 | 0.200 |
| Prox to existing agric | 0.333 | 5.000 | 0.200 | 7.000 | 1.000 | 5.000 | 0.333 |
| Physical factors | 0.111 | 0.333 | 0.143 | 0.333 | 0.200 | 1.000 | 0.111 |
| Population density | 1.000 | 7.000 | 5.000 | 5.000 | 3.000 | 9.000 | 1.000 |

$\lambda$ max = 7.8 ; CI = 0.13 ; CR = 0.10

**Figure 15. Example of comparison matrix from one expert (Expert no 13)**

**Table 14. Summary of the weight resulted from ranking**

| Criteria | Weight of criteria | | |
|---|---|---|---|
| | Vulnerability of landscape diversity loss | Vulnerability of Forest Loss | Vulnerability of Biodiversity Loss |
| Prox to Road | 4.85 | 6.23 | 4.39 |
| Prox to pathway | 2.46 | 4.08 | 4.39 |
| Prox to Settlement | 5.21 | 4.00 | 5.14 |
| Prox to River | 2.11 | 2.31 | 2.14 |
| Prox to existing agric | 4.46 | 3.62 | 4.57 |
| Physical factors/ slope * | 2.96 | 2.77 | 2.00 |
| Population density | 6.00 | 4.85 | 5.29 |

** slope criteria was used for vulnerability to forest loss and biodiversity loss*

To check the significant differences among criteria, researcher used Friedman's anova test. From the result, researcher found that:

- The weight of criteria in the vulnerability of landscape diversity loss was significantly different, where $p = 0.0000469$, which means that $p < \alpha$, ($\alpha = 0.05$). It means that there is agreement among the experts, since the distribution of the ranking differs significantly from a random distribution. From the post hoc test, researcher found that the most significance differences weight found in the criteria is population density with proximity to pathway ($p = 0.0003105$) and proximity to river ($p = 0.00003919$). Detail calculation result is presented in the ***Appendix 21***.

- The weight of criteria in the vulnerability of forest loss was found significantly different as well (*p* = 0.0000278). It also means that there is agreement among the experts, since the distribution of the ranking differs significantly from a random distribution. The most significance differences weight found in the criteria between proximity to road and physical factors (*p = 0.0002976*) and proximity to road and proximity to river (*p = 0.00002)*. Detail calculation result is presented in the ***Appendix 22***.
- In the vulnerability of biodiversity loss weight assessment, researcher also found the agreement among experts since the result of the Friedman's anova test also found significantly different (*p = 0.001304*). The most significance differences weight found in the criteria between population density and physical factors (p = 0.0013), proximity to existing agriculture and physical factor (*p= 0.0267*), proximity to settlement and physical factors (*p= 0.00262*), proximity to river and population density (*p = 0.00232*), proximity to river and proximity to existing agriculture (*p=0.0403*), proximity to settlement and proximity to river *(p=0.0044)*. Detail calculation result is presented in the ***Appendix 23***.

## 4.5 Weighing result from expert judgment for integrated vulnerability assessment

In order to integrate 3 different type of vulnerability map, researcher used weighing method, similar as weighing in the assessment of 3 types of vulnerability in the previous section. From Friedman statistical test (*see **Appendix 24***), researcher found that there is no significance weight and agreement among those type of vulnerability. Since there is no agreement among the experts, all types of vulnerability were given the equal weight.

From the information above, researcher then produce integrated vulnerability map by doing simple overlay. The map of integrated vulnerability can be seen ***Figure 19***.

## 4.6 Vulnerability map

### 4.6.1 Vulnerability of landscape diversity loss

Map of vulnerability of landscape diversity loss is presented in the ***Figure 16***.

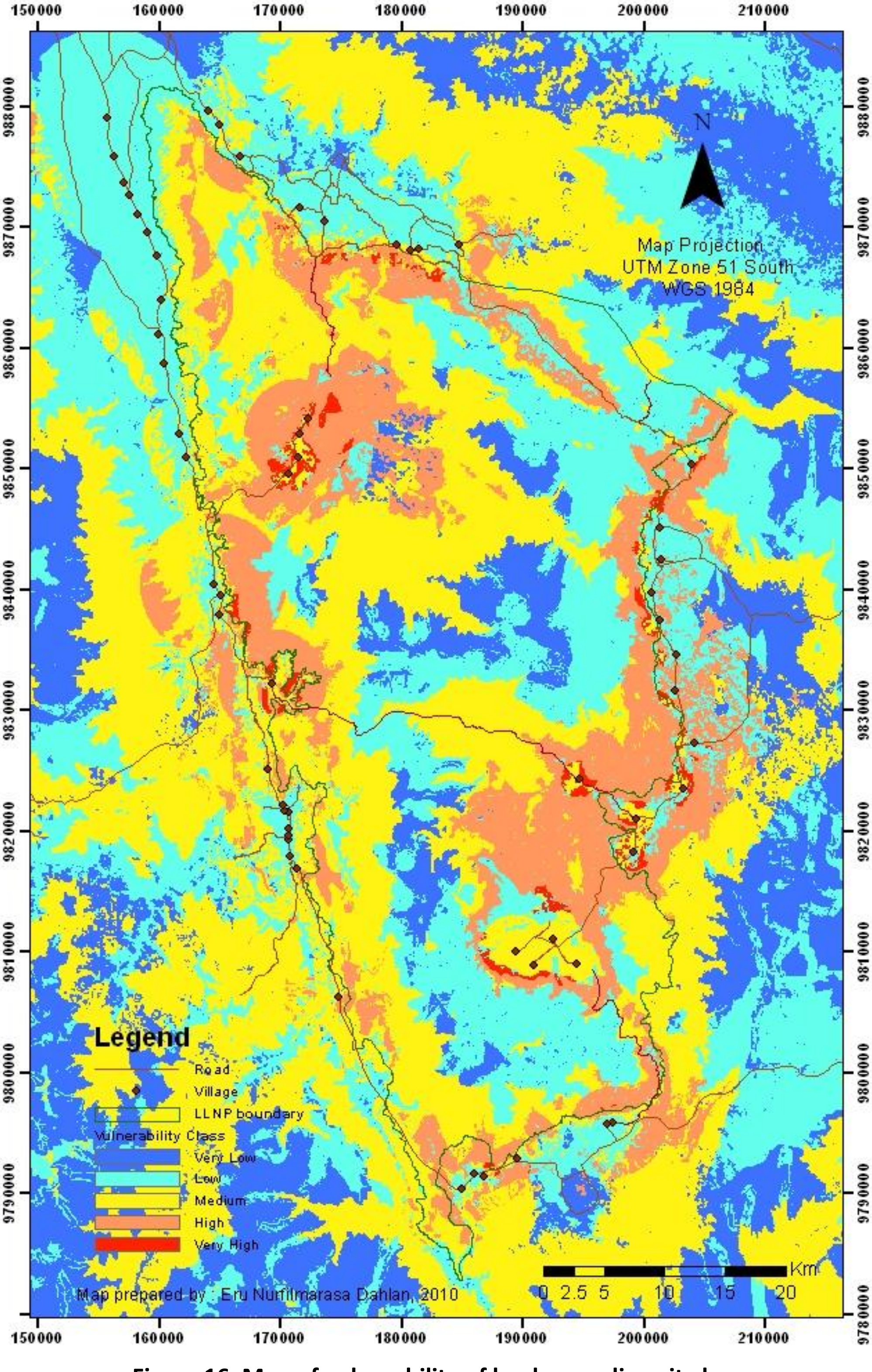



**Figure 16. Map of vulnerability of landscape diversity loss**

### 4.6.2 Vulnerability of forest loss

Map of vulnerability of forest loss is presented in the ***Figure 17***.

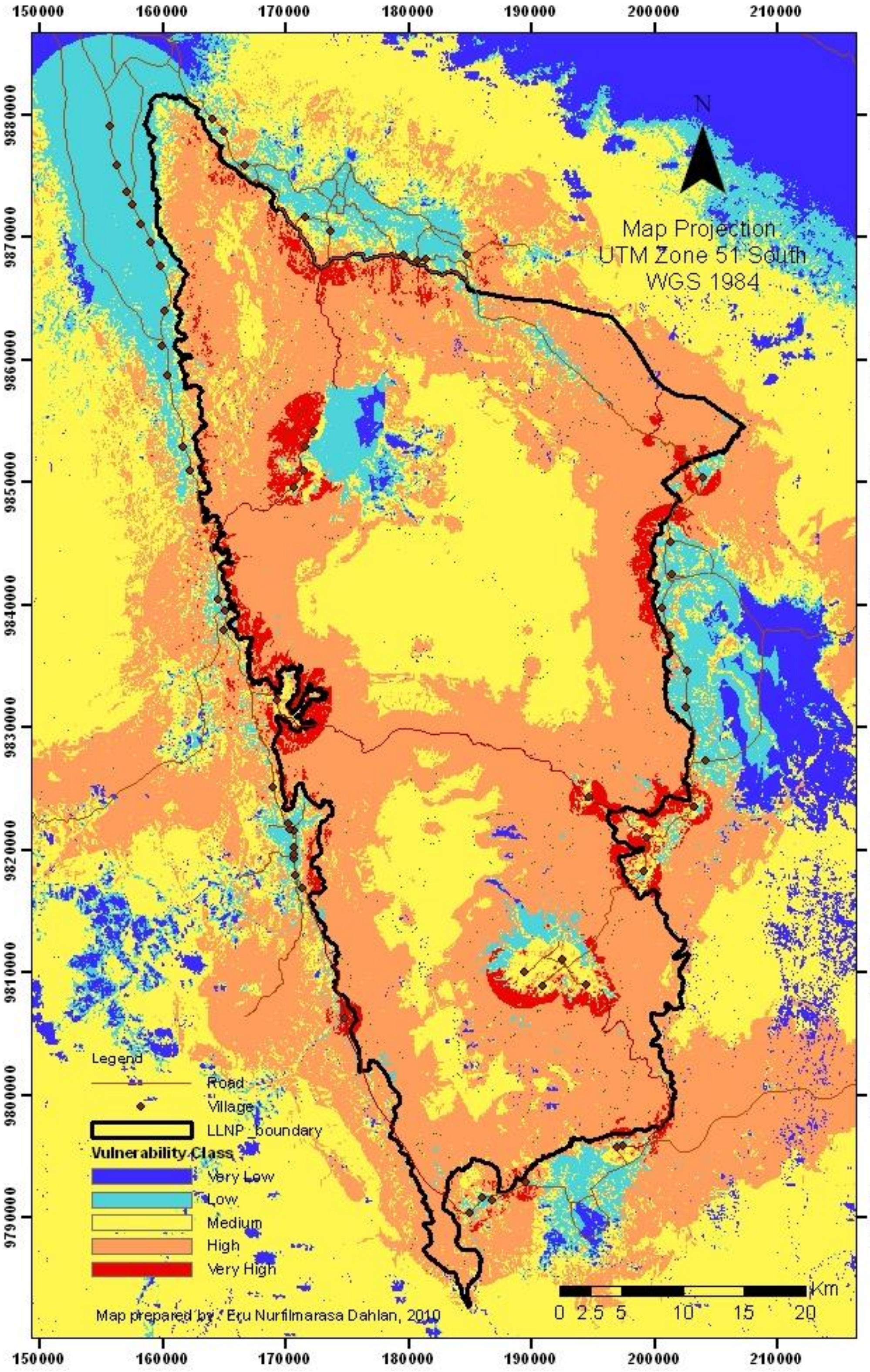



**Figure 17. Map of vulnerability of forest loss**

### 4.6.3 Vulnerability of biodiversity loss

Map of vulnerability of biodiversity loss is presented in the ***Figure 18***.

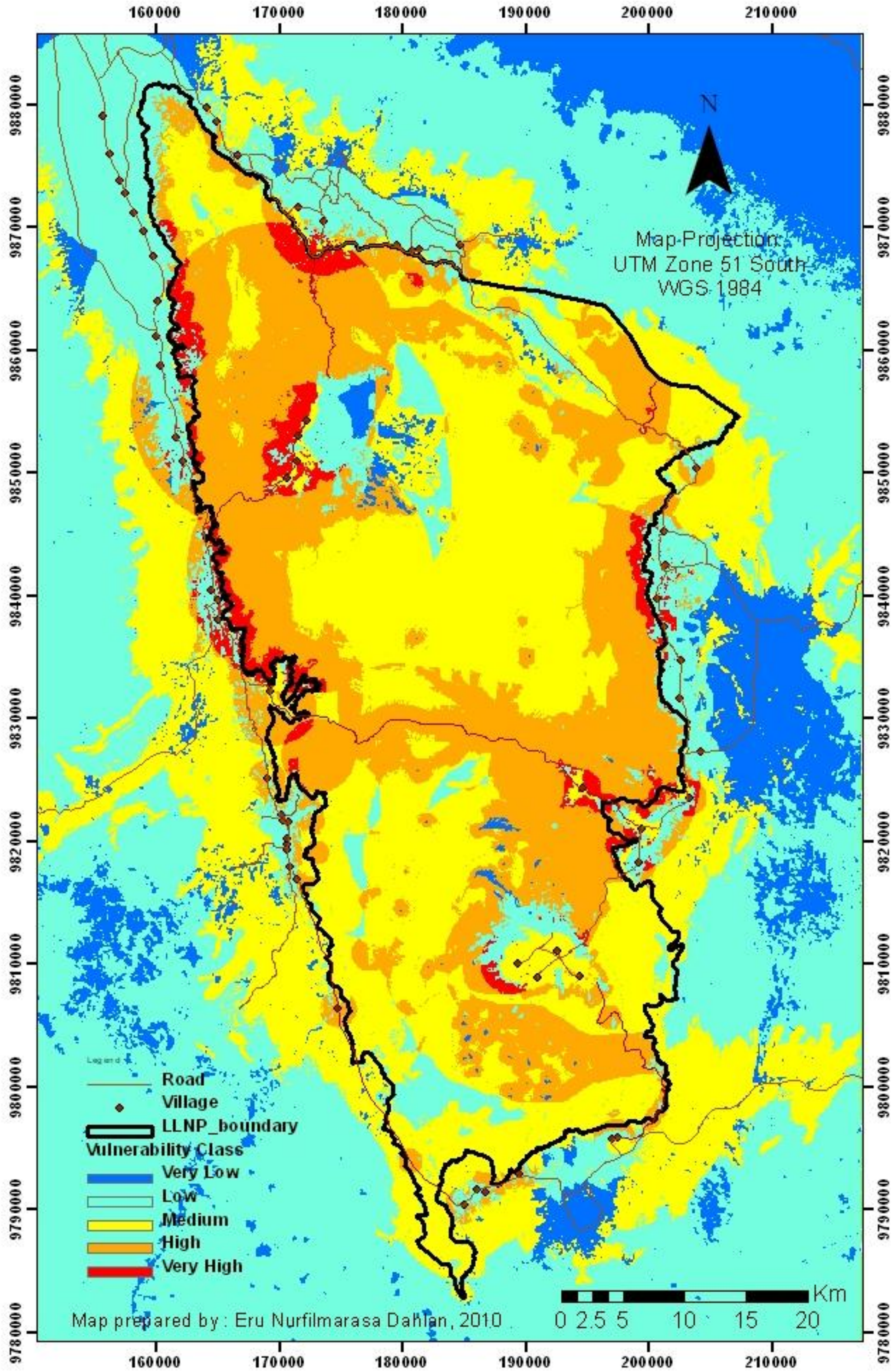



**Figure 18. Map of vulnerability of biodiversity loss**

## 4.7 Integrated vulnerability map

Map of vulnerability of biodiversity loss is presented in the ***Figure 19***.

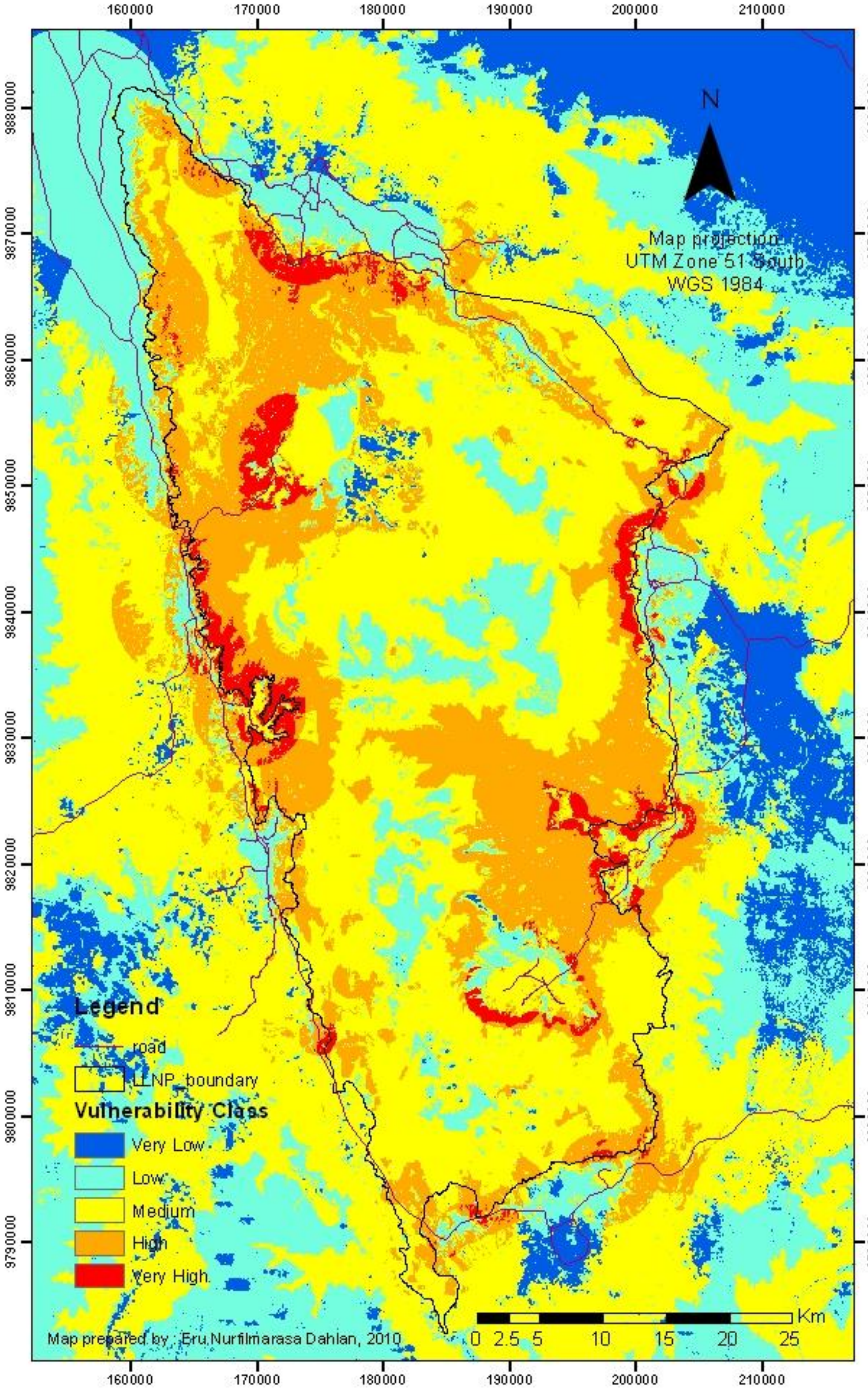



**Figure 19. Integrated vulnerability map**

## 4.8 Implication to National Park and Regional Authority

From the overlaid map between vulnerability map, LLNP spatial plan map (*see* ***Appendix 25***) and land cover map, researcher determined some alternatives which refer to literature survey, national government regulation and local people needs presented in ***Table 15***.

**Table 15. Alternative management for local/regional and national park authority**

| Alt | Vulnerability | LLNP spatial plan | Land cover | Proposed management | Authority |
|---|---|---|---|---|---|
| **1** | High | Core zone | Forest | Extra Protection | NP |
| **2** | High | Core zone | Degraded | Reforestation | NP |
| **4** | High | Wilderness zone | Forest | Extra protection | NP |
| **5** | High | Wilderness zone | Degraded | Reforestation | NP |
| **7** | High | Used Zone | Forest | Community development in collaborative way | NP, LG |
| **8** | High | Used Zone | Degraded | Community development in collaborative way | NP, LG |
| **10** | Medium | Core zone | Forest | Extra Protection | NP |
| **11** | Medium | Core zone | Degraded | Reforestation | NP |
| **13** | Medium | Wilderness zone | Forest | Extra protection | NP |
| **14** | Medium | Wilderness zone | Degraded | Reforestation, community development | NP |
| **16** | Medium | Used Zone | Forest | Community development in collaborative way | NP, LG |
| **17** | Medium | Used Zone | Degraded | Community development in collaborative way | NP, LG |
| **18** | Medium | Used Zone | Open areas | Community development in collaborative way | NP, LG |
| **19** | Low | Core/ wilderness/ used (inside NP) | Degraded (deforested) | Community development in collaborative way, reforestation | NP, LG |

Note:

NP: National Park authority
LG: Local government

# V. Discussion

## 5.1 Criteria and weight of criteria

### 5.1.1 Criteria

The framework of Wilson (2005b) was chosen as a stepping way to derive criteria. In determining criteria, researcher used information coming from other research. For example: research from van Gils and Loza Armand Ugon (2006) which make mention of factors that significantly influence land use degradation are land use regime, distance from road and distance from settlement.

The result of the analysis also revealed that the main criteria are proximity criteria. The importance of proximity criteria ps also described by Jarvis *et al.* (2010) in the sense that distance (decay function) and response of ecosystem are 2 parameters that can be used to assess threats to environment.

There are a lot of information on the relationship between human and nature, but the information is very limited when it comes to distance that can determine maximum proximity effect. Researcher could find some evidence about the effect of human and nature such as information that mentioned by (Freitas *et al.*, 2010) but information about specific distance was limitedly found.

In this analysis researcher used some information from literature review to determined maximum boundary/maximum distance in proximity criteria. Researcher realized that proximity criteria should be derived from research that conducted in the study area. But due to limitation of information, researcher tried to use information from location that has many similarities with study area. For example, researcher only used information that comes from the area located in the tropical country or even closed to study area. Actually, this approach still can produce some bias because of site specific characteristics of location. Nevertheless, this approach is the best solution/ approach to overcome poor data situation.

In the investigation, researcher also found that climate change was also an exposure factor of vulnerability of national park. This is also supported by de Chazal and Rounsevell (2009) who mention that land cover and climate change are the two factors that can influence biodiversity existence. Since the exposure to human influence is considered dominant, climate change factor was not considered in this analysis.

In this analysis, researcher tried to link vulnerability with representativeness, since linking vulnerability and representativeness in conservation action is important (Faith and Walker, 1996). In this assessment, researcher tried to link those two by using landscape uniqueness as criteria. Landscape uniqueness used was not only considered the type of landscape that exist in the LLNP area but also the landscape in the whole area of Sulawesi as one biogeography area. The reason of comparing landscape in LLNP to landscape in Sulawesi region is because landscape in LLNP is one integrated part of the whole important biogeography of Sulawesi. Threat to ecosystem in LLNP will influence the conservation and the existence of landscape in the Sulawesi region and LLNP contains only a limited number of the landscape diversity present in the area.

In assessing vulnerability of biodiversity loss, researcher only concerns with endangered and unique species since those condition is the most critical to be extinct. The use of endangered and unique species as a proxy was follow the concept that introduced by Abbitt *et al.* (2000) that strongly mentioned about the priority to endangered species in the vulnerability and Gaston *et al.* (2002) who mentioned about vulnerability species to disappearance.

Nevertheless, those limitations did not mean that other biodiversity was neglected. The potential biodiversity, which is still not yet explored, were also considered. The forest coverage outside the habitat was also used to represent potentiality of higher biodiversity compare to non forest areas. The forested area express general biodiversity which also vulnerable to be loss if the forest were degraded.

### 5.1.2 Accuracy and reliability of assessment

To discuss vulnerability assessment method, researcher used principle from Li *et al.,* (2009) mentioned accuracy and reliability of the vulnerability analysis depends on some factors: data quality, data processing and weight factors.

#### *5.1.2.1 Data quality*

All criteria chosen should be presented in spatial data type since the next analysis is using spatial analysis in ArcGIS software. But, the lack of information is one of the major obstacles in preparing map for the analysis. The deficiency of information was not only non spatial information (as mention in the previous chapter) but also spatial data.

In this research, one of the biggest problems related to data quality is image availability. Researcher tried to find the most recent imagery, but the Landsat image acquired on 28 September 2002 is the best image that researcher can get for this research.

Another important thing related to data quality is preparing map of population density effect. Since there is no method about how to produce spatial expression of population effect to national park, researcher used assumption “the more dense the human population the farther the potentiality of area being degraded. The potential effect of people to nature was explained in many journals, but the implication of population effect to distance of people in mortifying the nature is not available.

#### *5.1.2.2 Data processing*

As mentioned by Baraldi *et al.* (2005) and Tempfli *et al.* (2009) quantitative accuracy assessment of maps deals with the comparison of a site on a map against reference information for the same study location/site. In this research, the training sample points and points for accuracy assessment were derived from Google Earth images and existing landcover map (give lit ref), without field work. This approach follows the method suggested by Baraldi *et al.* (2005). But errors can be produced, if the reference landcover map had been produced with some error. The error propagation certainly occurs as a result of cumulative error from reference map and error in processing the landcover map. This error was unavoidable. The solution to overcome the problem is by maintaining low level of error produced in each step of processing.

Another issue related to data processing is error that results from map conversion. As mentioned by Tempfli et al., (2009) conversion from vector to raster also produces errors, especially in boundary. This error also unavoidable and in this research, researcher did not investigate further about the error produced.

#### *5.1.2.3 Weighing*

Weighing is an important part in the analysis since the effect of each criterion can be different between one and another. In the beginning, researcher used the Analytical Hierarchy Process (AHP) with pair-wise comparison questionnaire through expert judgment. This method, unfortunately, turn out into a new problem whenever the consistency ratio is more than 0.1 and the expert cannot be re-consulted.

As a solution, researcher tried to modify the weighing method by transforming weighing from AHP into a non parametric ranking method (Friedman test). This method is a solution to overcome the problem. Combining those two methods has not ever been done before. Since ranking method is also one of the method that can be used to asses weight (Malczewski, 1999), researcher believe that this solution is the best way to overcome the weighing problem.

To improved and generate robust weighing result, researcher used Friedman's anova statistical analysis. The statistical test was used to assess weight for each criterion, whether there are a significance differences among criterion or not, when summarizing weight from all expert was made. Another benefit to use statistical analysis in summarizing weight is the statistical analysis can produced confident judgment, since the judgment from experts potentially produce some bias.

In the summary of weight, researcher found out that the agreement among researcher are not too strong which can be seen from the standard deviation of weight produced (see ***Appendix 20, 21 and 22***). Looking through the descriptive analysis, there is only 4 criteria that has reach high agreement (more than 50%), which are: population density (in the vulnerability of landscape diversity loss (8 experts or 57% from total respondent) and vulnerability of forest loss (9 experts or 64%). The second criterion is proximity settlement which most experts (8 experts or 57%) agree to give weight 4 in the vulnerability of forest loss. Proximity to river was also given the lowest rank in the vulnerability of forest loss (8 experts or 57%). Last but not least, physical factors criteria which most experts agree to be the lowest rank in the vulnerability of biodiversity loss.

Lower agreement and standard deviation value mean high bias in the weight judgment. The bias produced potentially caused by some factors, which are:

1. Different interest and background

   Even researcher had selected expert that related to this field of interest, the background and interest based on experts experience are different between one expert to another.

2. Lack of information about study area

   Researcher realized that this research is very dependent to site characteristics. Information about location very much influences the judgment. For example, the area like LLNP, which river is very narrow and high stream, the used of river as accessibility is less favorable.

The bias has been considered, and statistical analysis had been applied as the best alternative solution. From the result, researcher found that there is a significant result, which means that there is a minimum 2 of criteria that statistically give significance difference for all criteria in all vulnerability type assessment. From post hoc test, there are some criteria that significantly different one to another. The criteria that do not give significant result do not mean that the weight becomes useless. The principal of post hoc of Friedman's test is to find the most significant value by comparing criteria in pair. Comparing higher weight criteria with lower one will produce significant result, while comparing identical weight will produce non significant value. Looking to that principle, researcher decided to still use the weight value of all identical weight (non significant criteria) as the weight value of each criterion.

According to the analysis, researcher found that the criteria of population density criteria has the highest weight value for vulnerability of landscape loss and vulnerability to biodiversity loss, while proximity to road is the highest weight value for vulnerability to forest loss. Those findings are support with some literature, for example Kirkland and Ostfeld (1999), Meyer and Turner (1992), Bilsborrow (1992) and Mena et al. (2006) that mention about population is important driven factors that potentially induced nature degradation.

Researcher realized that using population in the vulnerability assessment is not only deal with demography. As mention by Meyer and Turner (1992), there are 4 other categories that potentially causing nature degradation related to human population, which are technology, socio and economic organization, level of economic development and culture. Nevertheless, with limitation of research time and data availability, researcher only used only population density. It can be recommended that adding other factors of human population in vulnerability analysis to get more detail and more comprehensive vulnerability assessment.

## 5.2 Vulnerability

Based on Smit and Wandel (2006) and Adger (2006), concept of vulnerability is interrelated with adaptation, adaptive capacity, resilience, sensitivity and exposure. For this analysis, researcher only concern with vulnerability and exposure and assume that the other aspect *ceteris paribus*.

The degraded areas no longer are a threat to conservation, but the possibility of natural areas to be converted is more serious threat. The conservation action should look for the future challenges and the next opportunities for conservation, which also supported by Jarvis et al. (2010). Vulnerability information gives a clear picture of what and where the LLNP area faces serious threat in the future.

Integrated vulnerability assessment is not a new thing. There are several researches that has been conducted such as : Wang *et al.* (2008) which assess vulnerability in Tibetan Plateau and O'Brien *et al.* (2009) who assess vulnerability based on multiple stressor in the context of sociological field. Füssel (2007) mentioned that integrated vulnerability assessment traditionally only focused on physical stressors (e.g. natural hazards and climate change). But, assessing integrated vulnerability by doing the assessment based on different exposure and different current state (nature response) and then integrate all vulnerability type into one integrated map is a new method. Until now, there is no current literature explaining this method. This research approach or method can be proposed for other vulnerability research.

From the assessment, researcher found some advantages from this method compared to other methods:

1. This method can give clear descriptions about problems (exposure and impact) and reason behind the analysis and also clearer work flow of the analysis.
2. Another type of vulnerability can be added easily if another assessment is needed to enhance or to make the analysis more comprehensive.

Beside the advantages, researcher also found disadvantage: the process takes a longer time, especially in weighing process.

## 5.3 Vulnerability and implication to national park and regional development

This research was conduct in the framework of planning support system (PSS) because this research aims at providing geo-information instruments that that can be used specifically by planners to undertake their professional responsibilities (Geneletti, 2008) after (Brail and Kloosterman, 2001). The most important goal of vulnerability assessment is to provide assistance to the authority and practitioners (Li *et al.*, 2009). By doing vulnerability assessment, conservation organizations can get clear image about "what will become threatened in the next several years" (Jarvis *et al.*, 2010). Reducing vulnerability of environment can be more effective if it is supported by other strategies and plans at various level authority (Smit and Wandel, 2006).

### 5.3.1 Implication to national park authority

Vulnerability information gives information about potential threat in the future, so that the proposed alternative/action that can be taken by the authority tend to be more prevention or mitigation. The tendency to use mitigation action or prevention is also suggested by Van Laake and Sánchez-Azofeifa (2004) .

By looking at the vulnerability map and existing LLNP spatial plan, there are 2 major alternatives that can be proposed for LLNP management, which are:

1. Preventive action

   Implication to LLNP authority is obvious that the high vulnerability area should be watched over more. The high vulnerability area is top priority for LLNP authority to be taking care of The effectiveness of management can be improved by concentrating the focus of management into those areas. Improving resources allocation also another benefit from vulnerability assessment, which is also mentioned by Jarvis *et al*. (2010). This is very important to address the issue about limited resources that happened in LLNP and in other national park in general.

Preventive alternative not only deal with nature and protecting the nature condition, but also encouraging local people who live surround the area to decrease their threat to the forest. But, the authority should pay attention to some situation happened in tropical forest which has been identified by Byron and Arnold (1997) :

- Forest is central to livelihood system,
- Forest product is important supplementary and safety net for local people
- Non-timber forest product should be emphasized as a more important forest product
- Local people need help in exploiting opportunities to increase benefits from forest
- Encouraging non forestry activities for local people

2. Adaptation action

Adaptation action can be taken by revising the LLNP spatial plan and doing reforestation for the area that had been degraded. Nevertheless, LLNP should be careful in revising spatial plan, especially for downgrading the level of management in the area.

Reforestation is needed to restore the natural condition especially in LLNP areas. Besides that reforestation can give more benefit wherever the reforestation is located in the susceptibility to erosion areas. In implementing reforestation, the local people surround the area should be involved and encouraged with benefit that can be yielded from reforestation action.

### 5.3.2 Implication to local/ regional authority

With the concept from Pressey and Taffs (2001), which are conservation action should go to the areas with both high vulnerability (urgent protection needed to avoid destruction) and high irreplaceability (few or no alternatives if destroyed), the policy, regulation and program should be proposed. In this case, planners should consider the condition of nature environment and development and its trade off (Mehaffey *et al.*, 2008).

According to map in the ***Figure 19***, high vulnerability areas are concentrated in the north east, center and southeast of the LLNP area. Those concentrated areas are closed to center of Palolo district, center of Wuasa District and surrounding Lindu and Besoa enclave areas and area surround Katu settlement as well. To those areas, it is suggested that regional authority should take a part in developing program to reduce the stress of local people interaction with the area. On this area, regional authority also suggested to plan the development directed away from national park.

Special attention from regional authority should be given to two areas (Palolo and Wuasa) which are the center of district. The center of district means center of activities. The center of development tends to grow faster than the other area.

## 5.4 Limitation of the research

Researcher was trying to do all the process fairly well, but there are some impediment encountered, which can be explained as:

- Lack of information about location and effect of human activities to nature/conservation areas related to study area is not available. Since this information are very site specific, the use of information that comes from other location can leads to bias in the assessment.
- This assessment has strong result in producing a clear description/ picture of vulnerability of national park. Nevertheless, there was no attention to trend historic data since lack of local historic data. The trend historic data can support the analysis especially to predict future vulnerability.
- As mention by Malczewski (1999) sensitivity analysis is considered necessary when assessing criteria to examine relative contribution to the aggregate susceptibility criteria. But, the analysis was undone since the limitation of time of research.

# VI. Conclusion and Recommendation

## 6.1 Conclusion

A number of criteria that is related with vulnerability to landscape diversity, vulnerability to forest loss and vulnerability to biodiversity loss had been developed. Assessing the criteria with current condition determined each type of vulnerability. With the integration through weighing and overlay process, integrated vulnerability map can be produced. Integrated vulnerability of national park also can give a clear picture about vulnerability area that should get serious attention from the national park authority. The effectiveness and efficiency of management can be improved by focusing the resources into the area.

Integrated vulnerability information is easy to understand. This media can be used to communicate with planner as input for spatial planning process.

The use of GIS and remote sensing brings many advantages in the vulnerability assessment. Combining weight with spatial data by using overlay function in GIS can be done straightforwardly.

Taking the limitations and discussion on the results into consideration (*see **chapter 5***), this thesis shows that all research questions can be answered in a positive sense and it can be concluded therefore that the objectives were met (*see **section 1.3***). This means that the approach presented in this thesis results in (spatial) vulnerability information which can serve as input for local and regional planning purposes.

## 6.2 Recommendations

In this research, researcher used outdated landcover map. To produce more accurate vulnerability map, it is recommended to do the analysis with a more recent landcover map. The problem of cloud cover is a serious limitation for optical remote sensing in the tropics and hence become a major obstacle in producing landcover maps. It is recommended to investigate other remote sensing techniques (like Radar and hyper temporal remote sensing) which potentially circumvent this problem.

Data about biodiversity (status, distribution, population number, etc.) are limitedly found. The situation is the same for data on the (quantitative) relationship/effect between human activity and nature/conservation. It is recommended to do research in those themes in order to fill the gap in data availability.

In this research, researcher limits the vulnerability analysis only to exposure to human activities, while the national park existence also exposed to other factor. To improve the comprehensiveness of vulnerability analysis the other exposure such as climate change and natural disaster can be supplemented in the vulnerability assessment.

Integrated vulnerability assessment that derived from different types of vulnerability is a new method. This method can be applied to assess vulnerability to park in other location.

A number of recommendations for national park and local/regional authority had been produced (*see **section 4.8***). It is hoped that all recommendation are not only outcome of this research but also practically used by the authority.

All outcome of this research, especially integrated vulnerability map and recommendation, will be more efficient if communicated to local and regional planners in combination with a more in depth explanation. Dissemination or even a small short course can be conducted to improve the awareness and capacity of the authority (national park management and local/regional authority).

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# Appendices

## Appendix 1. Data and Material

Basic data that was used in this study include remotely-sensed data from satellites images, spatial data (maps) and non spatial data.

### Imagery

In the analysis, there are several imageries that was used, which is presented in ***Table 1***.

***Table 1***. List of Imageries used

| Type of Imageries | Resolution | Year | Sources |
|---|---|---|---|
| **Landsat TM-7 2002** | 30 meter | 2008 | http://glovis.usgs.gov/. |
| **SRTM-DEM** | 90 meter | 2008 | www.srtm.dem.usgs.gov |

### Maps

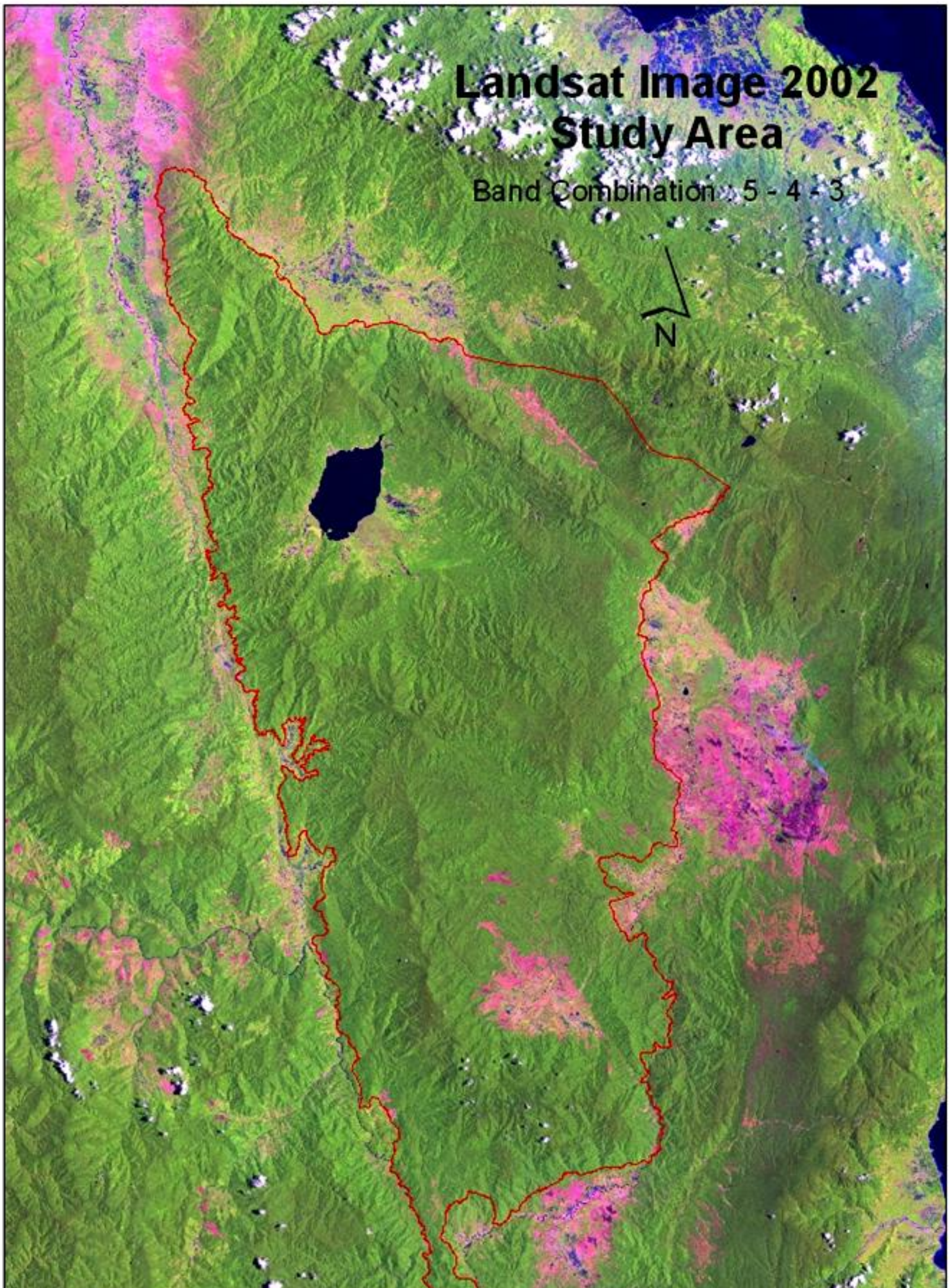
There are several maps which were used in the analysis which also is presented in ***Table 2***.

***Table 2***. List of maps used

| Type of Maps | Year | Sources |
|---|---|---|
| **Road** | 2001 | National Coordinating Agency for survey and mapping (Bakosurtanal) |
| **River** | 2001 | National Coordinating Agency for survey and mapping (Bakosurtanal) |
| **Administrative map** | 2001 | National Coordinating Agency for survey and mapping (Bakosurtanal) |
| **Forest Land Use Plan by Concession (TGHK)** | 1992 | Ministry of forestry |
| **Forest concessionary map** | 2009 | Ministry of forestry |
| **LLNP Map** | 2001 | LLNP Management -TNC |
| **Biodiversity map** | 2004 | LLNP Management-TNC |
| **Vegetation type** | 2004 | LLNP Management-TNC |
| **Existing zoning map of LLNP** | 2004 | LLNP Management-TNC |
| **Soil map** | 2004 | LLNP Management-TNC |
| **Rainfall map** | 2004 | LLNP Management-TNC |
| **Settlement map** | 2001 | LLNP Management-TNC |
| **Forest Health** | 2004 | The Nature Conservancy |

### Non spatial data

Non spatial data that needed for the analysis are: national park management plan and population data.


Landsat Image 2002
Study Area
Band Combination : 5 - 4 - 3
N
Acquisition date : 28 - 9 - 2002
Prijection System : UTM - WGS - 1984

## Appendix 2. Detail explanation of Forest Coverage Density Mapper

Detail explanation is adopted from Rikimaru *et al.* (2002).

**a. Advanced Vegetation index (AVI)**

This model examines the characteristics of chlorophyll-a using a new Advanced Vegetation Index (AVI) which using formula:

**B1-B7: TM Band 1-7 data**

B43=B4-B3 after normalization of the data range.

CASE-a B 43 < 0 AVI= 0

CASE-b B 43 > 0 AVI = ((B 4 +1) **x** (256-B3) **x** B 43)1/3

**b. Bare Soil Index (BI)**

Bare soil index is model to improve the calculation of vegetation index in the area where the vegetation covers less than half of the area. BI is formulated with medium infrared layer. combining those two indices in the analysis can show range from high vegetation conditions to exposed soil conditions. The formula is :

**BI= [(B5+B3)-(B4+B1)] / [(B5+B3) + (B4+B1)] x 100 +100**; 0 < BI <200

**c. Shadow index (SI)**

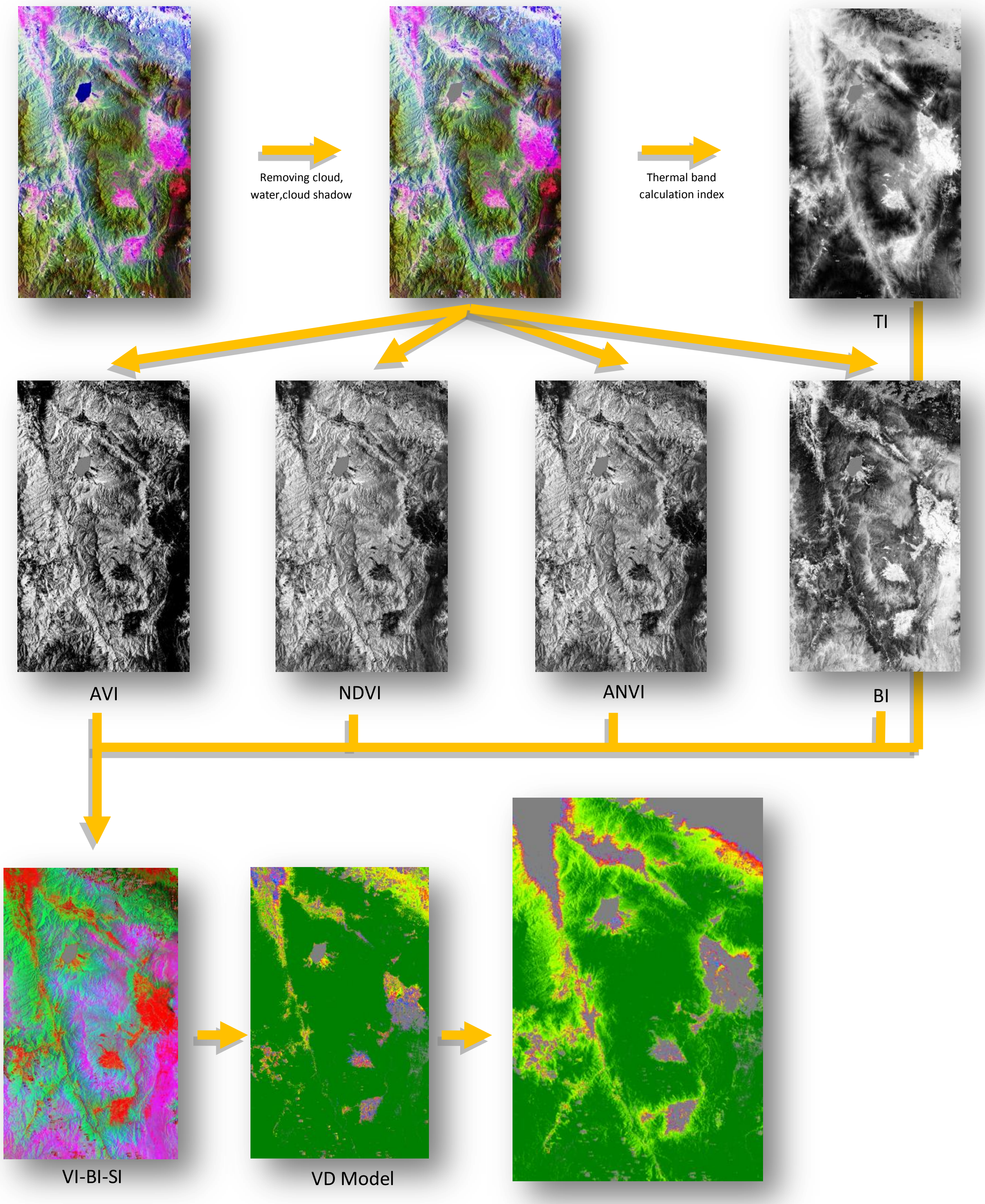
SI is model eliminate shadow characteristics of forest by using spectral information on the forest shadow itself and thermal information on the forest influenced by shadow (the low radiance of visible bands). The formula is presented below.

$$SI = [(256-B1) \times (256-B2) \times (256-B3)]^{1/3}$$

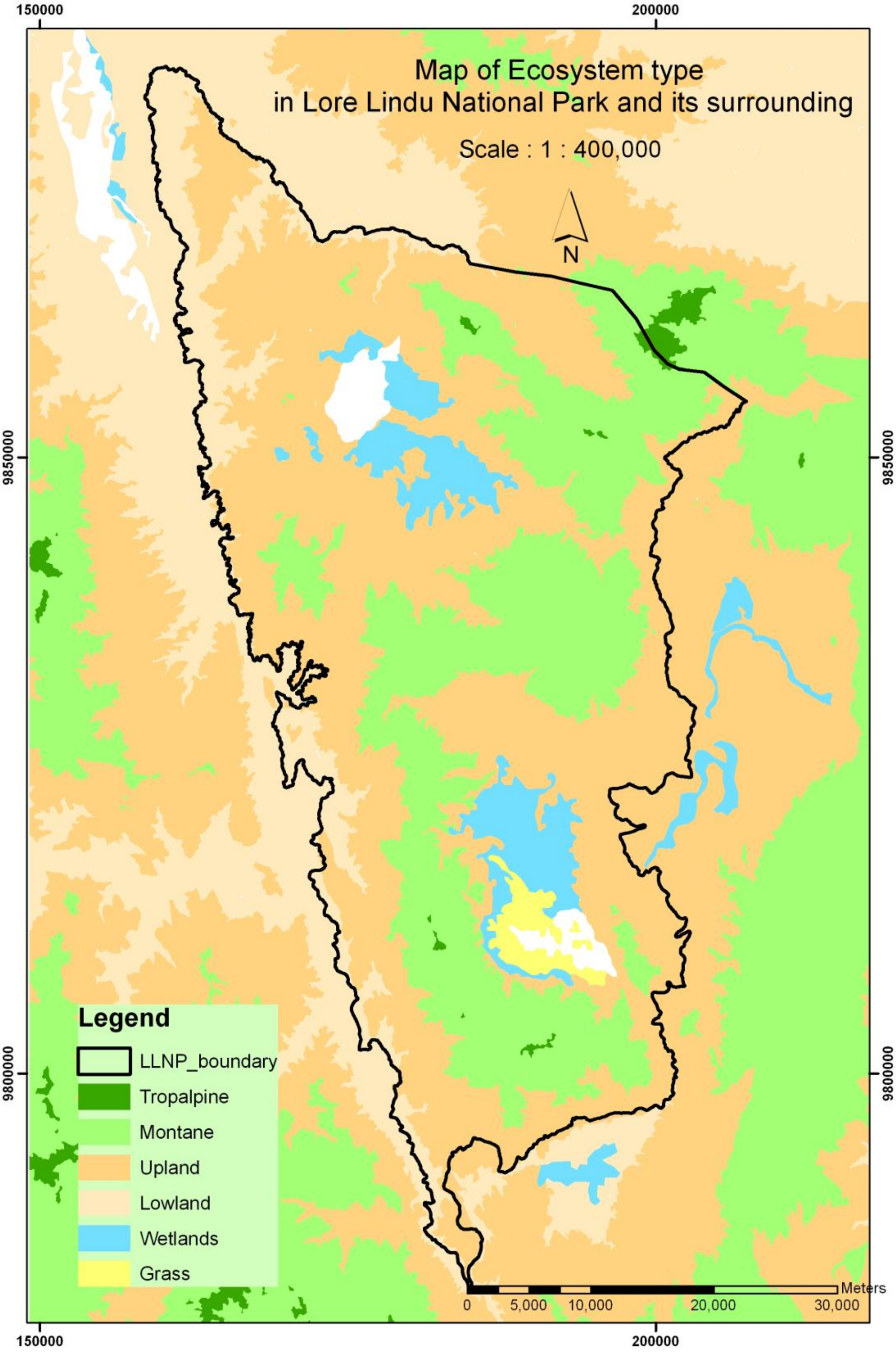
**d. Thermal Index (TI)**

Thermal index is used to calculate the effect from the relatively cool temperature inside a forest, which resulted from “shielding effect” of the forest canopy and calculate evaporation from the leaf surface which mitigates warming. The thermal infrared band of TM data is used for the analysis. For determining the score for each type of percent coverage follows the rule that the higher the percentage the higher the vulnerability.

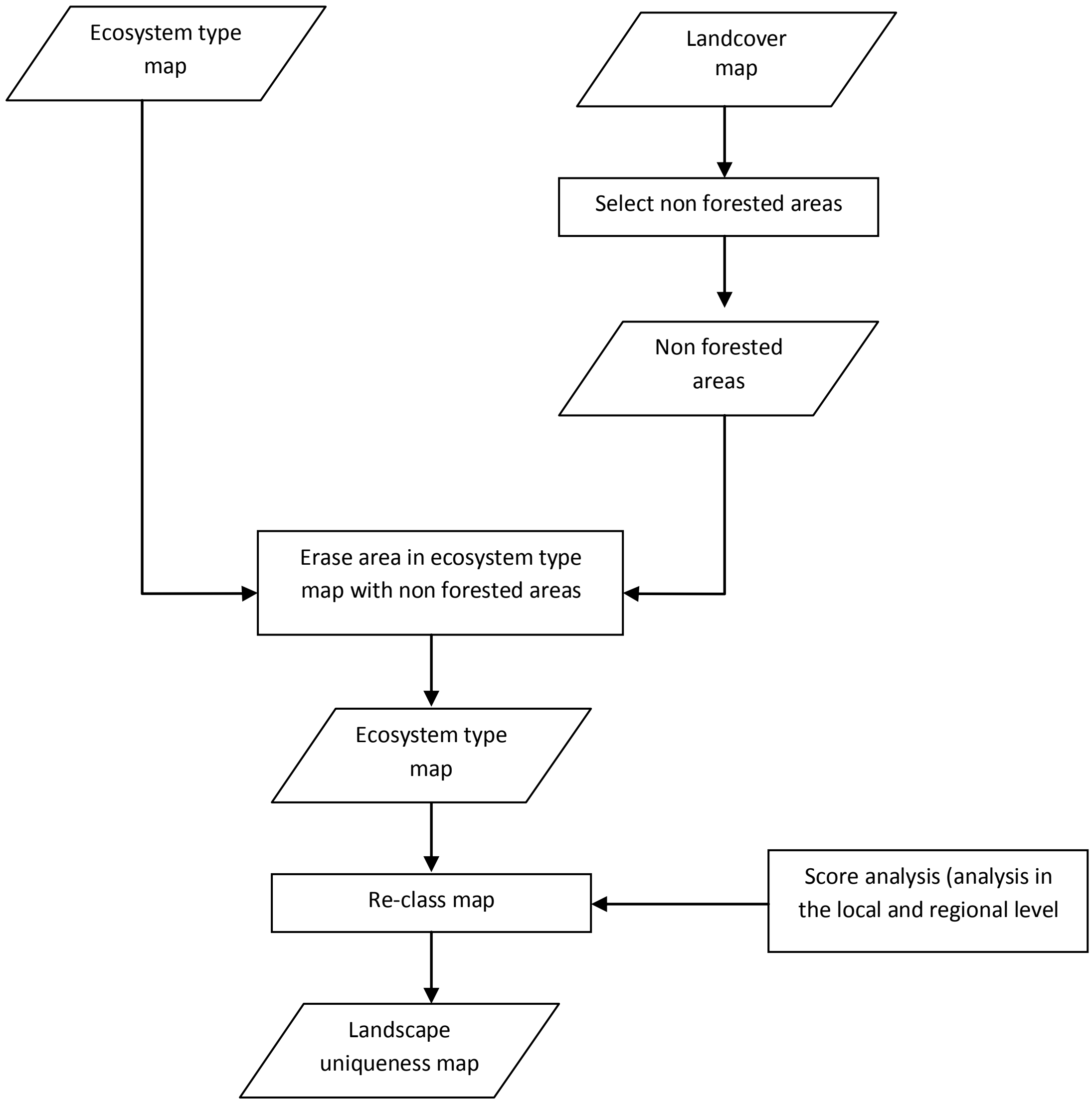
## Appendix 3. Process of determining forest resources estimation through Forest Cover Density Mapper



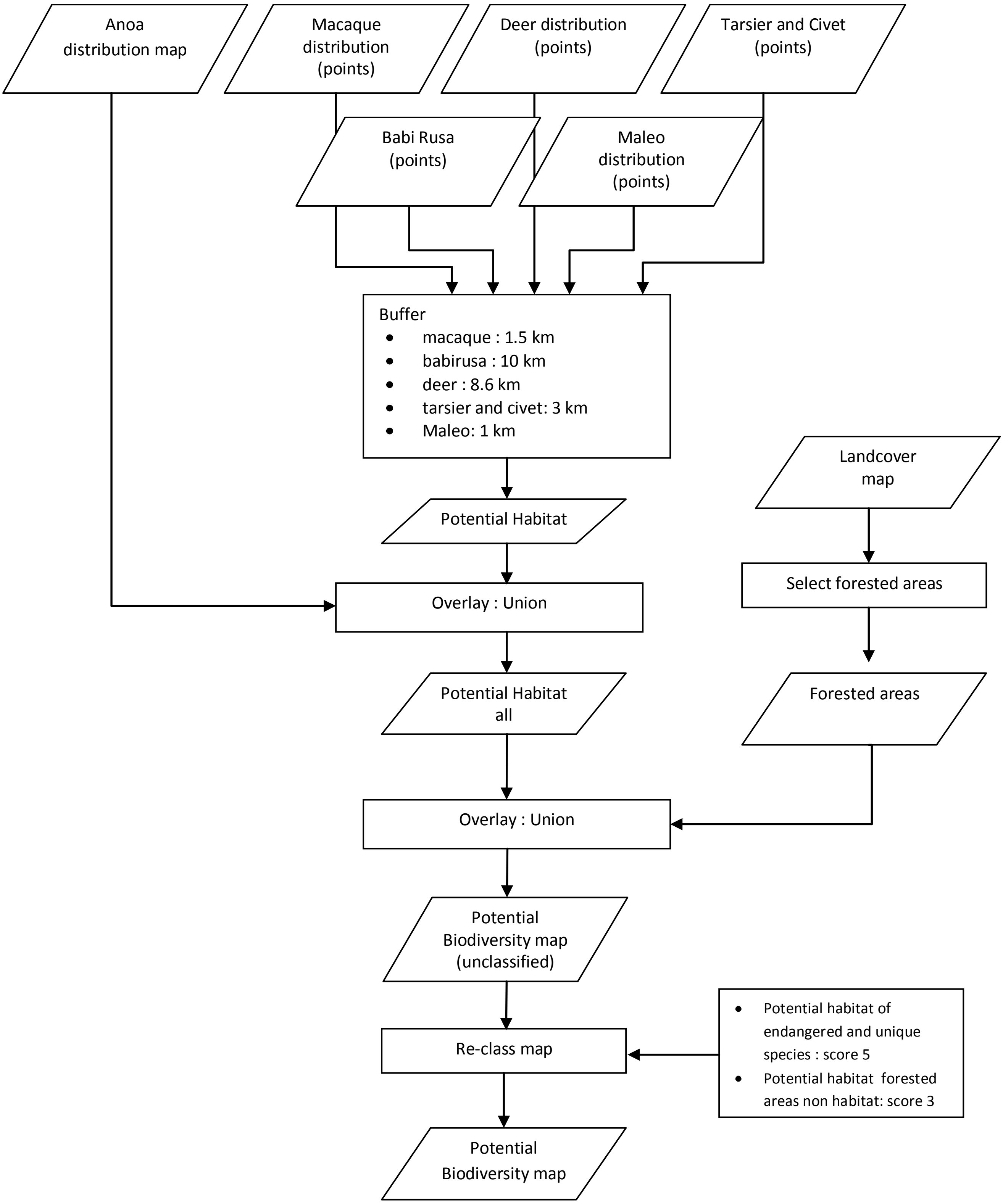
## Appendix 4. Map of types of Ecosystem in Lore Lindu National Park



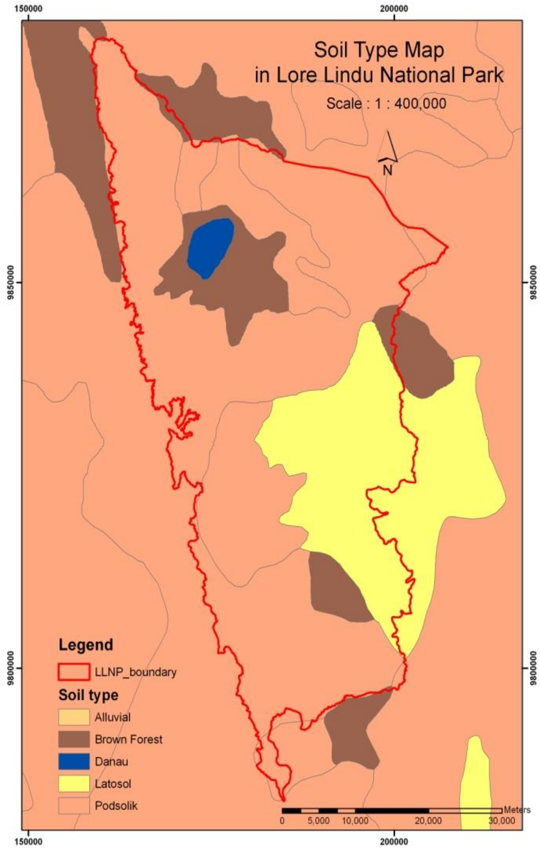
## Appendix 5. Process to derive landscape uniqueness map

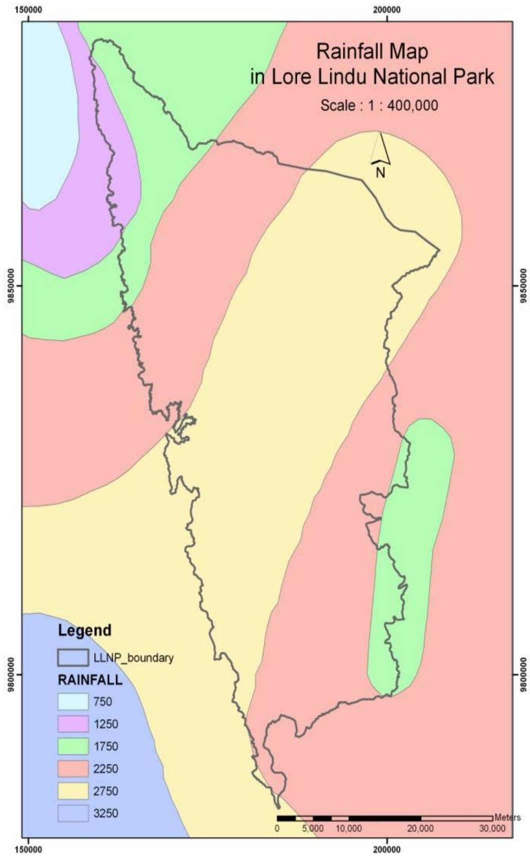


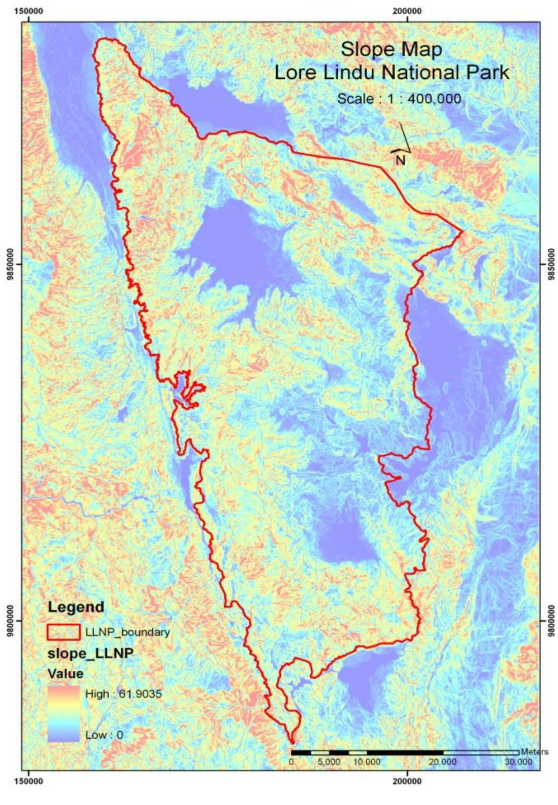
## Appendix 6. Detail process to derive biodiversity map



## Appendix 7. Physical factors map (Soil type, Rainfall and Slope)



## Appendix 8. Population number per village

| No. | Village name | Population number (pupils) | No. | Village name | Population number (pupils) |
|---|---|---|---|---|---|
| 1 | Tuare | 468 | 31 | Mataue | 523 |
| 2 | Tomehipi | 317 | 32 | Kaduwaa | 940 |
| 3 | Kageroa | 339 | 33 | Bolapapu | 3,094 |
| 4 | Lengkeka | 693 | 34 | Wuasa | 2,426 |
| 5 | Kolori | 532 | 35 | Watumaeta | 1,371 |
| 6 | Lelio | 331 | 36 | Puroo | 867 |
| 7 | Moa | 397 | 37 | Sedoa | 632 |
| 8 | Lempe | 283 | 38 | Langko | 739 |
| 9 | Doda | 772 | 39 | Salua | 949 |
| 10 | Hanggira | 1,115 | 40 | Tuwa | 1,163 |
| 11 | Bariri | 654 | 41 | Tomado | 2,021 |
| 12 | Pili Makujawa | 374 | 42 | Anca | 654 |
| 13 | Lempelero | 817 | 43 | Omu | 1,372 |
| 14 | Torire | 332 | 44 | Simoro | 665 |
| 15 | Gimpu | 697 | 45 | Pakuli | 3,252 |
| 16 | Tomua | 717 | 46 | Pandere | 2,258 |
| 17 | Tompi Bugis | 493 | 47 | Kamarora A | 2,018 |
| 18 | Rompo | 399 | 48 | Kamarora B | 1,268 |
| 19 | Lawua | 1,571 | 49 | Tongoa | 1,452 |
| 20 | Salutome | 715 | 50 | Kadidia | 597 |
| 21 | Watukilo | 644 | 51 | Kalawara | 1,688 |
| 22 | Betue | 271 | 52 | Rahmat | 2,892 |
| 23 | Katu | 279 | 53 | Lambara | 1,215 |
| 24 | O'o Perese | 859 | 54 | Sintuwu | 1,256 |
| 25 | Watutau | 685 | 55 | Sibalaya Selatan | 685 |
| 26 | Siliwanga | 677 | 56 | Sibalaya Utara | 3,397 |
| 27 | Toro | 2,105 | 57 | Bobo | 1,050 |
| 28 | Wanga | 344 | 58 | Sibowi | 3,397 |
| 29 | Dodolo | 323 | 59 | Baku Bakulu | 900 |
| 30 | Sungku | 841 | 60 | Sidondo I | 4,708 |
| | | | 61 | Sigimpu | 782 |

# *Appendix 9*. Questionnaire

**Pair-wise comparison questionnaire for expert judgment**

Research title: Vulnerability Assessment of National Park as Approach to Integrate Regional Development
*(case study Lore Lindu National Park, Central Sulawesi, Indonesia)*

Researcher: Eru N. Dahlan (Student on NRM Department, Faculty of ITC, University of Twente)

Name of Expert : ……………………………………………………………….

***Short description of the research***

*The objective of this research is to assess the vulnerability of Lore Lindu National Park (LLNP) as input for integration of nature conservation (central government) and socio-economic development (regional authority) at regional level. Based on LLNP management aims (LLNP Management Plan 2004), three vulnerability types were identified, which are: (1) Vulnerability to landscape diversity loss; (2) Vulnerability to forest loss and (3) Vulnerability to biodiversity loss.*

*For each vulnerability type the criteria determining vulnerability were identified, e.g. areas closer to a road are considered to be more vulnerable than areas further away. In order to derive the relative importance of the criteria for vulnerability assessment, a weighing through an expert judgment for all criteria was chosen. This questionnaire was designed to obtain the expert judgment of the criteria.*

***Instruction to fill the questionnaire***

*Mark your opinion about the relative importance of the criteria given on the two sides of the scales, refer the scoring pattern:*

LHS Middle RHS

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Criterion "A" | 9<br>Absolutely important | 7<br>Very strongly important | 5<br>Strongly important | 3<br>Slightly important | 1<br>Equally important | 3<br>Slightly important | 5<br>Strongly important | 7<br>Very strongly important | 9<br>Absolutely important | Criterion "B" |

If criterion 'A' is more important compare to criteria B, use left hand side (LHS) of the scale. The higher the number of the criteria, the higher the level of importance of criterion compare to the opposite criterion.

If criterion 'B' is more important, use right hand side (RHS) of the scale.

If criterion 'A' and 'B' are equally important, put tick mark on the center portion (Middle)/ score 1 of the scale.

**Example :**

To assess **preferences of people in choosing a car,** which criterion is more important:
Model or price

Model ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ Price
9 7 5 3 1 3 5 7 9

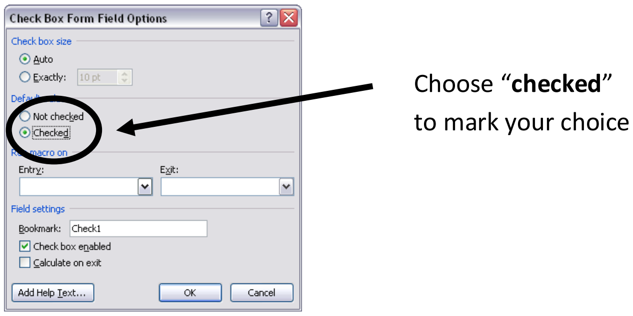
If you think that price is strongly important compare to model, tick number 5 on the right hand side as described:

Model ☐ ☐ ☐ ☐ ☐ ☐ ☒ ☐ ☐ Price
9 7 5 3 1 3 5 7 9

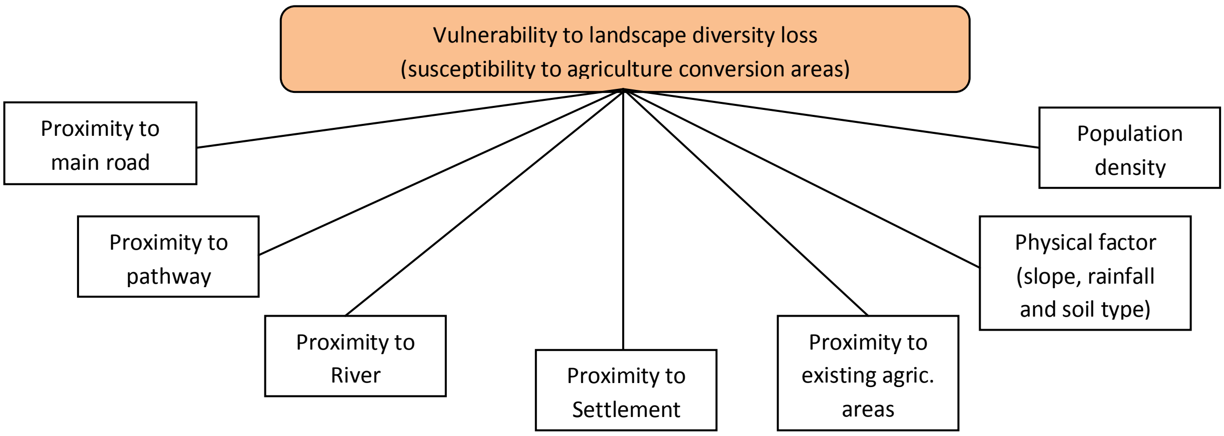
But, if you think that model is equally important compare to price or you don't agree with the comparison, tick number 1 as described:

Model ☐ ☐ ☐ ☐ ☒ ☐ ☐ ☐ ☐ Price
9 7 5 3 1 3 5 7 9

*Please put the tick mark in the box of your choice by **double clicking** the grey box and choose "**checked**" in the **check box form field options** as describe in the figure below.*




## A. Assessing weight of criteria to asses vulnerability to landscape diversity loss




Note :

- *Proximity to road, river and settlement are expressed as the Euclidean distance in km from the features*
- *Proximity to agriculture is expressed as the Euclidean distance from the outer boundary of the area*
- *Physical factors refers to suitability for agriculture expressed in soil type, slope (%) and rainfall (mm/year)*
- *Population density is population size per km$^2$*

In order to assess weight of criteria to assess **"vulnerability to landscape loss"** in terms of "**susceptibility to landscape conversion into agricultural areas"**, which criterion is more important:

1. Proximity to road or proximity to pathway

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to road | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to pathway |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

2. Proximity to road or proximity to settlement

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to road | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to settlement |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

3. Proximity to road or proximity to river

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to road | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to river |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

4. Proximity to road or proximity to existing agriculture

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to road | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to existing agriculture |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

5. Proximity to road or physical factors (slope, soil type and rainfall)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to road | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | physical factors (slope, soil type and rainfall) |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

6. Proximity to road or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to road | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

7. Proximity to pathway or proximity to settlement

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to road | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to settlement |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

8. Proximity to pathway or proximity to river

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to pathway | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to river |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

9. Proximity to pathway or proximity to existing agriculture

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to pathway | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to existing agriculture |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

10. Proximity to pathway or physical factors (slope, soil type and rainfall)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to pathway | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | physical factors (slope, soil type and rainfall) |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

11. Proximity to pathway or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to pathway | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

12. Proximity to settlement or proximity to river

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to settlement | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to river |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

13. Proximity to settlement or proximity to existing agriculture

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to settlement | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to existing agriculture |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

14. Proximity to settlement or physical factors (slope, soil type and rainfall)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to settlement | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | physical factors (slope, soil type and rainfall) |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

15. Proximity to settlement or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to settlement | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

16. Proximity to river or proximity to existing agriculture

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to river | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to existing agriculture |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

17. Proximity to river or physical factors (slope, soil type and rainfall)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to river | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | physical factors (slope, soil type and rainfall) |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

18. Proximity to river or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to river | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

19. Proximity to existing agriculture or physical factors (slope, soil type and rainfall)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to existing agriculture | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | physical factors (slope, soil type and rainfall) |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

20. Proximity to existing agriculture or population density

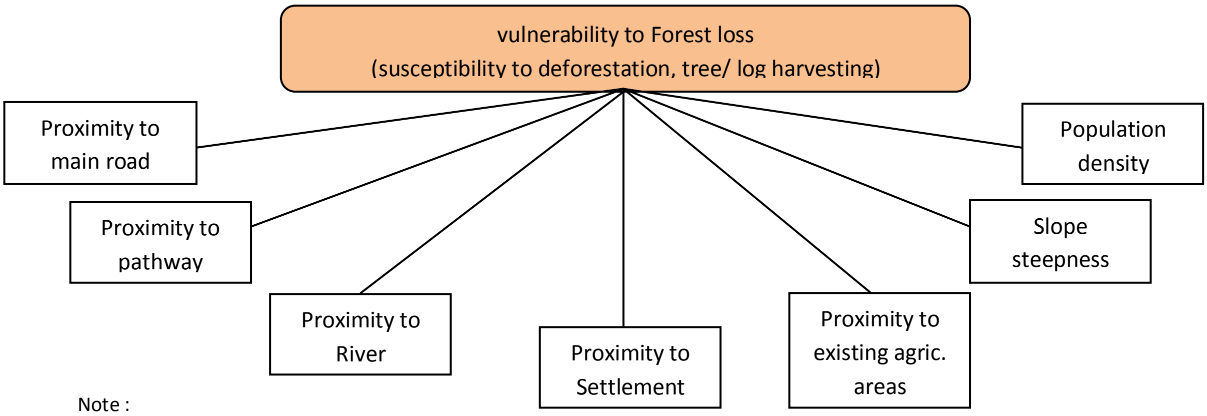
| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to existing | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |

agriculture 9 7 5 3 1 3 5 7 9

21. Physical factors (slope, soil type and rainfall) or population density

Physical factors (slope, soil type and rainfall) ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ population density
9 7 5 3 1 3 5 7 9

**B. Assessing weight of criteria to asses vulnerability to forest loss**




Note :

- *Proximity to main road, pathway, river and settlement are expressed as the Euclidean distance in km from the features*
- *Proximity to agriculture is expressed as the Euclidean distance from the outer boundary of the area*
- *Slope steepness is expressed in percent (%)*
- *Population density is population size per km$^2$*

In order to assess weight of criteria to assess **"vulnerability to forest loss"** in terms of "**susceptibility to illegal tree/ log harvesting"**, which criterion is more important:

1. Proximity to road or proximity to pathway

   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to pathway
   9 7 5 3 1 3 5 7 9

2. Proximity to road or proximity to settlement

   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to settlement
   9 7 5 3 1 3 5 7 9

3. Proximity to road or proximity to river

   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to river
   9 7 5 3 1 3 5 7 9

4. Proximity to road or proximity to existing agriculture

   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to existing agriculture
   9 7 5 3 1 3 5 7 9

5. Proximity to road or slope steepness

   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ slope steepness
   9 7 5 3 1 3 5 7 9

6. Proximity to road or population density

   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ population density
   9 7 5 3 1 3 5 7 9

7. Proximity to pathway or proximity to settlement

   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to settlement
   9 7 5 3 1 3 5 7 9

8. Proximity to pathway or proximity to river

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to pathway | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to river |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

9. Proximity to pathway or proximity to existing agriculture

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to pathway | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to existing agriculture |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

10. Proximity to pathway or slope steepness

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to pathway | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | slope steepness |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

11. Proximity to pathway or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to pathway | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

12. Proximity to settlement or proximity to river

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to settlement | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to river |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

13. Proximity to settlement or proximity to existing agriculture

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to settlement | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to existing agriculture |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

14. Proximity to settlement or steepness

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to settlement | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | slope steepness |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

15. Proximity to settlement or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to settlement | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

16. Proximity to river or proximity to existing agriculture

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to river | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | proximity to existing agriculture |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

17. Proximity to river or slope steepness

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to river | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | slope steepness |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

18. Proximity to river or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to river | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

19. Proximity to existing agriculture or slope steepness

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to existing agriculture | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | slope steepness |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

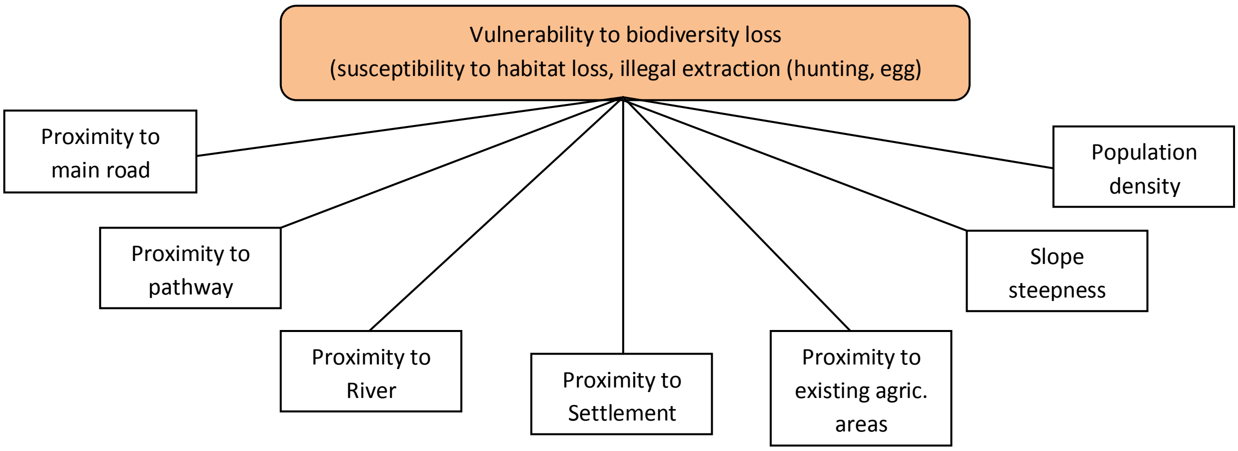
20. Proximity to existing agriculture or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Proximity to existing agriculture | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

21. Slope steepness or population density

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Slope steepness | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | population density |
| | 9 | 7 | 5 | 3 | 1 | 3 | 5 | 7 | 9 | |

**Assessing weight of criteria to asses vulnerability to biodiversity loss**




Note :

- *Proximity to road, river and settlement are expressed as the Euclidean distance in km from the features*
- *Proximity to agriculture is expressed as the Euclidean distance from the outer boundary of the area*
- *Slope steepness is expressed in percent (%)*
- *Population density is population size per km$^2$*

In order to assess weight of criteria to assess **"vulnerability to biodiversity loss"** in terms of "**susceptibility to illegal extraction (e.g.: hunting and egg collection)"**, which criterion is more important:

1. Proximity to road or proximity to pathway
   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to pathway
   9 7 5 3 1 3 5 7 9
2. Proximity to road or proximity to settlement
   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to settlement
   9 7 5 3 1 3 5 7 9
3. Proximity to road or proximity to river
   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to river
   9 7 5 3 1 3 5 7 9
4. Proximity to road or proximity to existing agriculture
   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to existing agriculture
   9 7 5 3 1 3 5 7 9
5. Proximity to road or slope steepness
   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ slope steepness
   9 7 5 3 1 3 5 7 9
6. Proximity to road or population density
   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ population density
   9 7 5 3 1 3 5 7 9
7. Proximity to pathway or proximity to settlement
   Proximity to road ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to settlement
   9 7 5 3 1 3 5 7 9
8. Proximity to pathway or proximity to river
   Proximity to pathway ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to river
   9 7 5 3 1 3 5 7 9
9. Proximity to pathway or proximity to existing agriculture
   Proximity to pathway ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to existing

9 7 5 3 1 3 5 7 9 agriculture

10. Proximity to pathway or slope steepness
Proximity to pathway ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ slope steepness
9 7 5 3 1 3 5 7 9

11. Proximity to pathway or population density
Proximity to pathway ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ population density
9 7 5 3 1 3 5 7 9

12. Proximity to settlement or proximity to river
Proximity to settlement ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to river
9 7 5 3 1 3 5 7 9

13. Proximity to settlement or proximity to existing agriculture
Proximity to settlement ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to existing agriculture
9 7 5 3 1 3 5 7 9

14. Proximity to settlement or slope steepness
Proximity to settlement ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ slope steepness
9 7 5 3 1 3 5 7 9

15. Proximity to settlement or population density
Proximity to settlement ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ population density
9 7 5 3 1 3 5 7 9

16. Proximity to river or proximity to existing agriculture
Proximity to river ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ proximity to existing agriculture
9 7 5 3 1 3 5 7 9

17. Proximity to river or slope steepness
Proximity to river ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ slope steepness
9 7 5 3 1 3 5 7 9

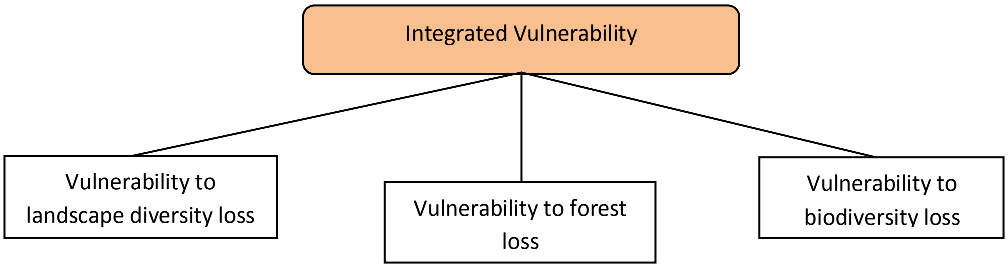
18. Proximity to river or population density
Proximity to river ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ population density
9 7 5 3 1 3 5 7 9

19. Proximity to existing agriculture or slope steepness
Proximity to existing agriculture ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ slope steepness
9 7 5 3 1 3 5 7 9

20. Proximity to existing agriculture or population density
Proximity to existing agriculture ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ population density
9 7 5 3 1 3 5 7 9

21. Slope steepness or population density
Slope steepness ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ population density
9 7 5 3 1 3 5 7 9

**C. Integrating all vulnerability type assessment**




In order to assess the integrated vulnerability, which type of vulnerability is more important:

a. Vulnerability to landscape diversity loss or vulnerability to biodiversity loss

| Vulnerability to landscape diversity loss | ☐ 9 | ☐ 7 | ☐ 5 | ☐ 3 | ☐ 1 | ☐ 3 | ☐ 5 | ☐ 7 | ☐ 9 | Vulnerability to biodiversity loss |
|---|---|---|---|---|---|---|---|---|---|---|

b. Vulnerability to landscape diversity loss or vulnerability to forest loss

| Vulnerability to landscape diversity loss | ☐ 9 | ☐ 7 | ☐ 5 | ☐ 3 | ☐ 1 | ☐ 3 | ☐ 5 | ☐ 7 | ☐ 9 | Vulnerability to forest loss |
|---|---|---|---|---|---|---|---|---|---|---|

c. Vulnerability to biodiversity loss or vulnerability to forest loss

| Vulnerability to biodiversity loss | ☐ 9 | ☐ 7 | ☐ 5 | ☐ 3 | ☐ 1 | ☐ 3 | ☐ 5 | ☐ 7 | ☐ 9 | Vulnerability to forest loss |
|---|---|---|---|---|---|---|---|---|---|---|

**------Thank you very much for your participation in this research ------**

## *Appendix 10*. Criteria investigation for vulnerability to landscape loss

| No | Landscape type | Exposure | Intensity | Impact | Criteria |
|---|---|---|---|---|---|
| **1** | Lowland forest ecosystem | Human activities related to agriculture and forest utilization | ∞ | Change in landcover | LULC |
| | | | | Conversion to agricultural fields | Landscape uniqueness |
| | | | | Conversion to grass land | Proximity to agriculture |
| | | | | | Proximity to settlement |
| | | | | | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Slope |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | | | | Population number |
| | | Climate change | discrete | Change in landcover | LULC |
| | | | | | Landscape uniqueness |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | | | | Population number |
| **2** | Lower montane forest ecosystem | Human activities related to agriculture and forest utilization | ∞ | Change in landcover | LULC |
| | | | discrete | Conversion to agricultural fields | Landscape uniqueness |
| | | | | Conversion to grass land | Proximity to agriculture |
| | | | | Exotic species invassion | Proximity to settlement |
| | | | | Fragmentation | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Slope |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | Climate change | discrete | Change in landcover | LULC |
| | | | | | Landscape uniqueness |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | | | | Population number |
| **3** | Upper montane forest ecosystem | Human activities related to agriculture and forest utilization | ∞ | Change in landcover | LULC |
| | | | discrete | Conversion to agricultural fields | Landscape uniqueness |
| | | | | Conversion to grass land | Proximity to agriculture |
| | | | | | Proximity to |

| No | Landscape type | Exposure | Intensity | Impact | Criteria |
|---|---|---|---|---|---|
| | | | | | settlement |
| | | | | | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Slope |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | Climate change | discrete | Change in landcover | LULC |
| | | | | Landslide | Landscape uniqueness |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | | | | Population number |
| **4** | Cloud forest ecosystem | Human activities related to agriculture and forest utilization | ∞ | Change in landcover | LULC |
| | | | discrete | Conversion to agricultural fields | Landscape uniqueness |
| | | | | Conversion to grass land | Proximity to agriculture |
| | | | | Exotic species invassion | Proximity to settlement |
| | | | | Fragmentation | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Slope |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | Climate change | discrete | Change in landcover | LULC |
| | | | | | Landscape uniqueness |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | | | | Population number |
| **5** | Savana and Grass land ecosystem | Human activities related to agriculture and forest utilization | ∞ | Change in landcover | LULC |
| | | | discrete | Conversion to agricultural fields | Landscape uniqueness |
| | | | | | Proximity to agriculture |
| | | | | | Proximity to settlement |
| | | | | | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Slope |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | Climate change | discrete | Change in landcover | LULC |
| | | | | Drought | Landscape uniqueness |
| | | | | Erosion | Geology |

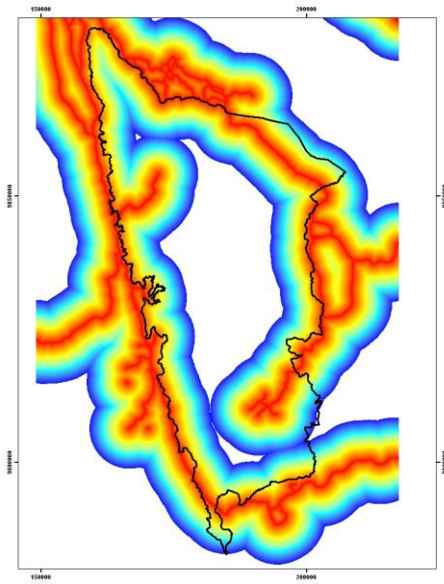
| No | Landscape type | Exposure | Intensity | Impact | Criteria |
|---|---|---|---|---|---|
| | | | | | Soil type |
| | | | | | Rainfall |
| **6** | Swamp forest ecosystem | Human activities related to agriculture and forest utilization | ∞ | Change in landcover | LULC |
| | | | discrete | Conversion to agricultural fields | Landscape uniqueness |
| | | | | Sucession | Proximity to agriculture |
| | | | | | Proximity to settlement |
| | | | | | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Slope |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | Climate change | discrete | Change in landcover | LULC |
| | | | | Drought | Landscape uniqueness |
| | | | | Erosion | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | | | | Population number |
| **7** | Lake ecosystem | Human activities related to agriculture and forest utilization | ∞ | Change in landcover | LULC |
| | | | discrete | Conversion to agricultural fields | Landscape uniqueness |
| | | | | Sucession | Proximity to agriculture |
| | | | | Pollution | Proximity to settlement |
| | | | | | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Slope |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | Climate change | discrete | Change in landcover | LULC |
| | | | | water level decreasing | Landscape uniqueness |
| | | | | | Geology |
| | | | | | Soil type |
| | | | | | Rainfall |
| | | | | | Temperature |
| | | | | | Population number |

## Appendix 11. Major forest types on the island of Sulawesi adopted from Cannon *et al.* (2007) and Whitten et al., (1987) and comparison to produce landscape uniqueness score

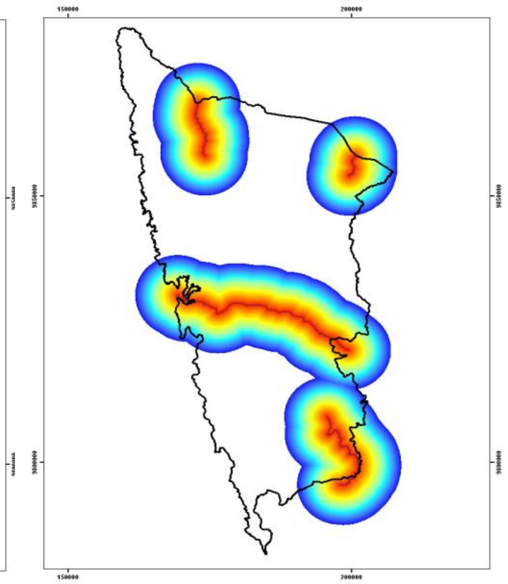
| No | Forest type | Vegetation type | Total Area in Sulawesi (ha) | Total Percentage in Sulawesi | Total Area in LLNP (ha) | Total Percentage compare to Sulawesi | compare to sulawesi (rank) | Compare to total (rank) | Total rank |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Mangrove | Mangrove Forest | 76,264 | 0.41 | 0 | | | | |
| **2** | Wetlands | Swamp forest | 568,643 | 3.05 | 21,110 | 3.71% | 5 | 4 | 9 |
| **3** | Karst | Lowland forest | 149,996 | 0.81 | 0 | | | | |
| **4** | Lowland alluvium | Lowland forest | 1,512,201 | 8.12 | 6,095 | 0.07% | 2 | 2 | 4 |
| **5** | Lowland intermediate | | 5,712,661 | 30.67 | | | | | |
| **6** | Lowland limestone | | 1,199,129 | 6.44 | | | | | |
| **7** | Lowland mafic | | 537,446 | 2.89 | | | | | |
| **8** | Hill alluvium | Lower montane | 39,919 | 0.21 | 119,679 | 1.59% | 3 | 5 | 8 |
| **9** | Hill limestone | | 583,432 | 3.13 | | | | | |
| **10** | Hill intermediate | | 3,124,860 | 16.78 | | | | | |
| **11** | Hill mafic | | 650,385 | 3.49 | | | | | |
| **12** | Upland limestone | | 353,074 | 1.9 | | | | | |
| **13** | Upland intermediate | | 2,450,343 | 13.16 | | | | | |
| **14** | Upland mafic | | 311,061 | 1.67 | | | | | |
| **15** | Montane limestone | Upper montane | 65,647 | 0.35 | 476 | 0.04% | 1 | 1 | 2 |
| **16** | Montane mafic | | 73,155 | 0.39 | | | | | |
| **17** | Montane intermediate | | 1,055,281 | 5.67 | | | | | |
| **18** | Tropalpine | Sub alpine | 161,767 | 0.87 | 5,854 | 3.62% | 4 | 3 | 7 |
| | **Total** | | **18,625,264** | **100** | | | | | |

***) based on Whitten et. al. (1987) after Van Stenis (1950) and Whitmore (1984)**

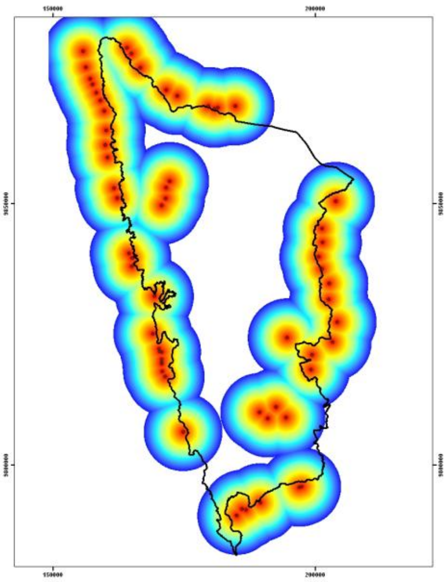
## ***Appendix 12*. Proximity criteria maps**



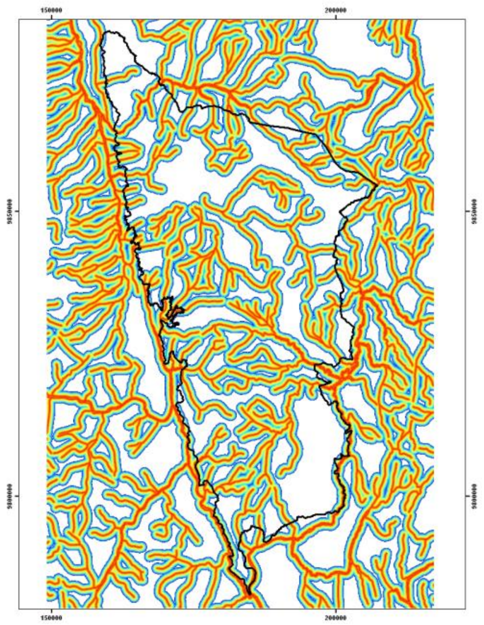
Proximity to road map



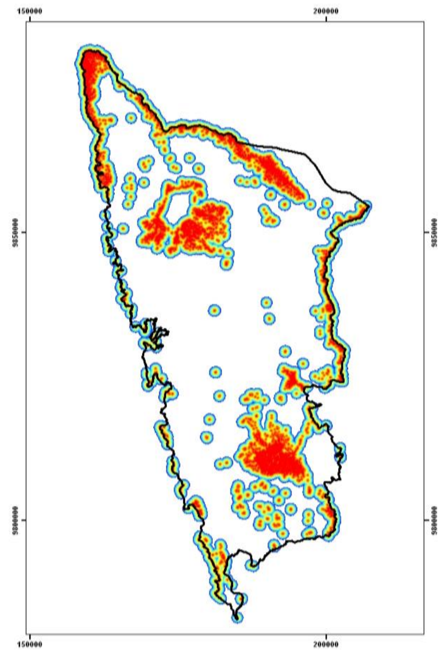
Proximity to pathway map



Proximity to village map

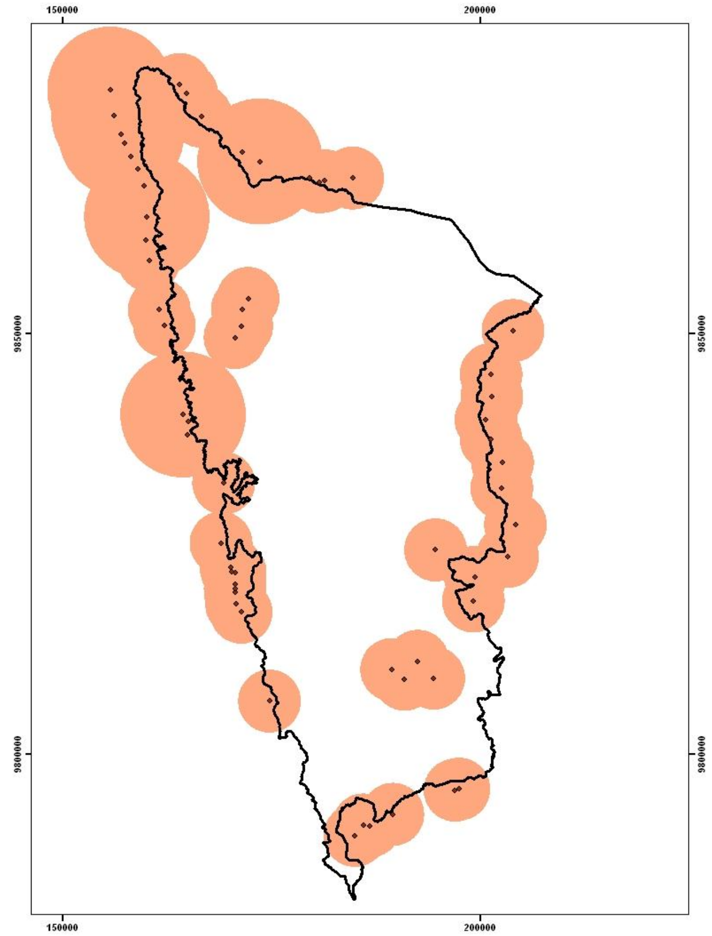


Proximity to river map



Proximity to agriculture map

## Appendix 13. Population density map




Map of Population Effect

## Appendix 14. Criteria investigation for vulnerability to biodiversity loss

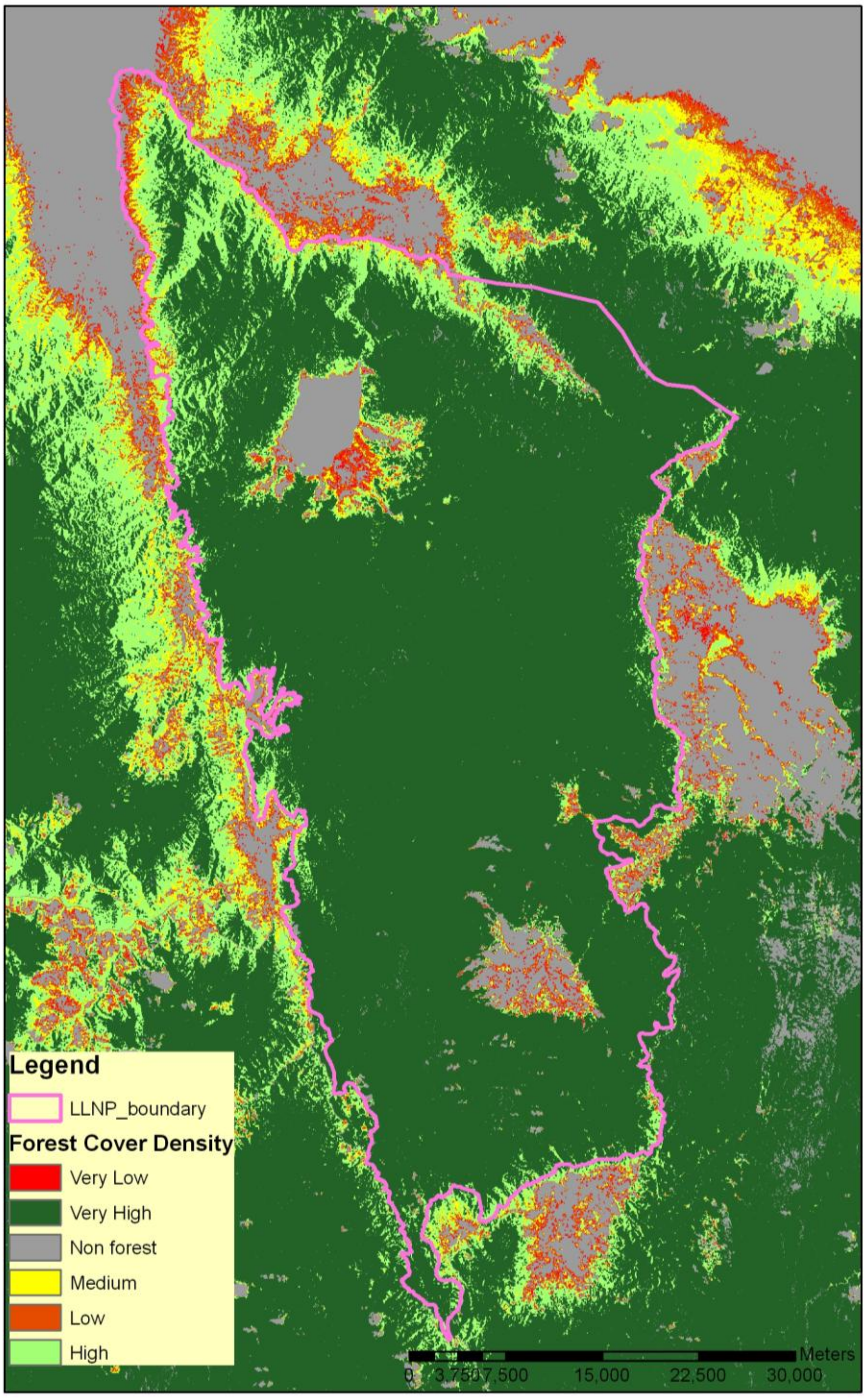
| No | Biodiversity type | Exposure | Intensity | Impact | Criteria |
|---|---|---|---|---|---|
| **1** | Fauna | Human activities related to agriculture | ∞ | Decreasing quantity and quality of endangered species habitat | Endangered Species distribution |
| | | | | Fragmentation | Specific species habitat (proximity) |
| | | | | Change in landcover | Umbrella species home range |
| | | | | | Accessibility (proximity to road, settlement, river) |
| | | | | | |
| | | Human activities related to egg collection and animal hunting | ∞ | Decreasing in number of population | Endangered Species distribution |
| | | | | | Specific species habitat (proximity) |
| | | | | | Umbrella species home range |
| | | | | | Accessibility (proximity to road, settlement, river) |
| | | | | | |
| **2** | Flora | Human activities related to agriculture | ∞ | Decreasing quantity and quality of biodiversity | Umbrella species home range |
| | | | | Exotic species invasion | Accessibility (proximity to road, settlement, river) |
| | | | | Fragmentation | |
| | | | | Change in landcover | |

## Appendix 15. Criteria investigation for vulnerability of forest loss

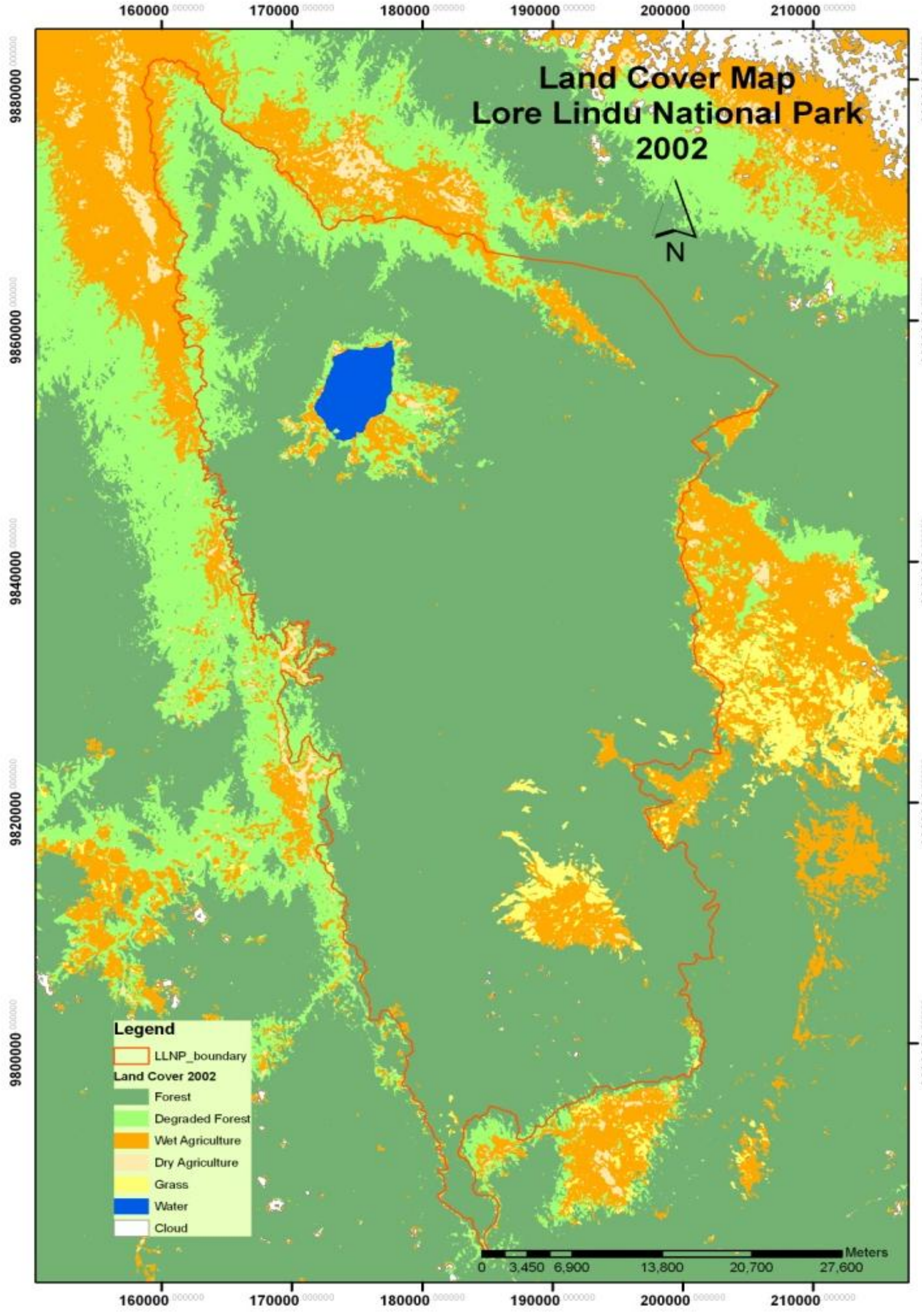
| No | Forest resources | Exposure | Intensity | Impact | Criteria |
|---|---|---|---|---|---|
| **1** | Tangible forest resources | Human activities related illegal tree harvesting | ∞ | Change in landcover | Proximity to settlement |
| | | | | Capability forest ecosystem services decreasing | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Population number |
| | | | | | Proximity to river |
| | | | | | |
| | | | | | |
| **2** | Intangible forest product | Human activities related to agriculture | ∞ | Change in landcover | Proximity to settlement |
| | | | | Capability forest ecosystem services decreasing | Proximity to road |
| | | | | | Proximity to river |
| | | | | | Population number |
| | | | | | |
| | | | | | |

## Appendix 16. Forest resources estimation resulted from Forest Cover Density Mapper

**Forest Resources Estimation
resulted from Forest Cover Density Mapper**



## Appendix 17. Land cover map 2002



## Appendix 18. Accuracy Assessment result

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : f:/research_eru/imageries/le71140612002271sgs00/class_
User Name : Eru N. Dahlan
Date : Mon May 31 03:45:36 2010

ACCURACY TOTALS

| Class Name | Reference Totals | Classified Totals | Number Correct | Producers Accuracy |
|---|---|---|---|---|
| No data | 0 | 0 | 0 | --- |
| Forest | 37 | 38 | 35 | 94.59% |
| Dry Agriculture | 14 | 23 | 11 | 78.57% |
| Wet Agriculture | 14 | 5 | 5 | 35.71% |
| Clouds | 0 | 0 | 0 | --- |
| Water | 5 | 5 | 5 | 100.00% |
| Grass | 10 | 6 | 6 | 60.00% |
| Degraded Forest | 18 | 21 | 16 | 88.89% |
| Totals | 98 | 98 | 78 | |

Overall Classification Accuracy = 79.59%

----- End of Accuracy Totals -----

# Appendix 19. The weight result from expert judgment

## Weight of Vulnerability of landscape diversity loss resulted from AHP

| No | Expert | Prox to Road | Prox to pathway | Prox to Settlement | Prox to River | Prox to existing agric | Physical factors | Population density | In-consistency |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Expert 1 | 0.301 | 0.027 | 0.228 | 0.065 | 0.080 | 0.042 | 0.257 | 0.324 |
| 2 | Expert 2 | 0.231 | 0.097 | 0.205 | 0.033 | 0.137 | 0.036 | 0.261 | 0.497 |
| 3 | Expert 3 | 0.120 | 0.069 | 0.266 | 0.020 | 0.084 | 0.019 | 0.421 | 0.289 |
| 4 | Expert 4 | 0.146 | 0.019 | 0.153 | 0.043 | 0.047 | 0.096 | 0.495 | 0.290 |
| 5 | Expert 5 | 0.038 | 0.112 | 0.152 | 0.038 | 0.299 | 0.142 | 0.219 | 0.334 |
| 6 | Expert 6 | 0.162 | 0.050 | 0.256 | 0.043 | 0.132 | 0.037 | 0.322 | 0.258 |
| 7 | Expert 7 | 0.047 | 0.036 | 0.192 | 0.158 | 0.214 | 0.254 | 0.098 | 0.154 |
| 8 | Expert 8 | 0.074 | 0.034 | 0.196 | 0.024 | 0.211 | 0.213 | 0.247 | 0.316 |
| 9 | Expert 9 | 0.284 | 0.155 | 0.210 | 0.133 | 0.048 | 0.065 | 0.104 | 0.129 |
| 10 | Expert 10 | 0.238 | 0.108 | 0.203 | 0.042 | 0.174 | 0.108 | 0.127 | 0.184 |
| 11 | Expert 11 | 0.103 | 0.030 | 0.231 | 0.039 | 0.220 | 0.022 | 0.356 | 0.279 |
| 12 | Expert 12 | 0.142 | 0.024 | 0.095 | 0.019 | 0.137 | 0.427 | 0.155 | 0.253 |
| 13 | Expert 13 | 0.301 | 0.041 | 0.175 | 0.036 | 0.113 | 0.022 | 0.312 | 0.142 |
| 14 | Expert 14 | 0.089 | 0.062 | 0.180 | 0.028 | 0.185 | 0.027 | 0.430 | 0.200 |
|  | Total | 1.744 | 0.738 | 2.293 | 0.639 | 1.646 | 1.034 | 2.907 |  |
|  | Average | 0.159 | 0.067 | 0.208 | 0.058 | 0.150 | 0.094 | 0.264 |  |

## Weight of Vulnerability of forest loss result from AHP

| No | Expert | Prox to Road | Prox to pathway | Prox to Settlement | Prox to River | Prox to existing agric | Physical factors | Population density | In-consistency |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Expert 1 | 0.323 | 0.185 | 0.170 | 0.027 | 0.070 | 0.033 | 0.192 | 0.363 |
| **2** | Expert 2 | 0.479 | 0.078 | 0.110 | 0.030 | 0.115 | 0.031 | 0.158 | 0.289 |
| **3** | Expert 3 | 0.363 | 0.150 | 0.070 | 0.206 | 0.033 | 0.145 | 0.034 | 0.113 |
| **4** | Expert 4 | 0.218 | 0.264 | 0.047 | 0.027 | 0.029 | 0.298 | 0.117 | 0.217 |
| **5** | Expert 5 | 0.059 | 0.133 | 0.303 | 0.045 | 0.106 | 0.042 | 0.311 | 0.132 |
| **6** | Expert 6 | 0.162 | 0.050 | 0.256 | 0.043 | 0.132 | 0.037 | 0.322 | 0.258 |
| **7** | Expert 7 | 0.231 | 0.063 | 0.149 | 0.149 | 0.204 | 0.028 | 0.175 | 0.130 |
| **8** | Expert 8 | 0.465 | 0.248 | 0.062 | 0.117 | 0.032 | 0.026 | 0.049 | 0.089 |
| **9** | Expert 9 | 0.446 | 0.171 | 0.114 | 0.143 | 0.043 | 0.027 | 0.056 | 0.091 |
| **10** | Expert 10 | 0.529 | 0.154 | 0.118 | 0.046 | 0.221 | 0.063 | 0.086 | 0.190 |
| **11** | Expert 11 | 0.335 | 0.043 | 0.107 | 0.028 | 0.233 | 0.031 | 0.222 | 0.227 |
| **12** | Expert 12 | 0.131 | 0.024 | 0.109 | 0.016 | 0.077 | 0.465 | 0.179 | 0.201 |
| **13** | Expert 13 | 0.373 | 0.035 | 0.084 | 0.026 | 0.084 | 0.156 | 0.241 | 0.125 |
| **14** | Expert 14 | 0.186 | 0.126 | 0.104 | 0.039 | 0.082 | 0.072 | 0.392 | 0.301 |
| | Total | 3.608 | 1.542 | 1.506 | 0.861 | 1.218 | 0.759 | 1.722 | |
| | Average | 0.328 | 0.140 | 0.137 | 0.078 | 0.111 | 0.069 | 0.157 | |

## Weight of Vulnerability of biodiversity loss resulted from AHP

| No | Expert | Prox to Road | Prox to pathway | Prox to Settlement | Prox to River | Prox to existing agric | Physical factors | Population density | In-consistency |
|---|---|---|---|---|---|---|---|---|---|
| **1** | Expert 1 | 0.319 | 0.151 | 0.233 | 0.021 | 0.110 | 0.023 | 0.144 | 0.370 |
| **2** | Expert 2 | 0.180 | 0.122 | 0.161 | 0.046 | 0.226 | 0.052 | 0.213 | 0.447 |
| **3** | Expert 3 | 0.080 | 0.088 | 0.298 | 0.025 | 0.200 | 0.024 | 0.284 | 0.309 |
| **4** | Expert 4 | 0.114 | 0.048 | 0.233 | 0.024 | 0.188 | 0.022 | 0.370 | 0.290 |
| **5** | Expert 5 | 0.059 | 0.133 | 0.303 | 0.045 | 0.106 | 0.042 | 0.311 | 0.132 |
| **6** | Expert 6 | 0.062 | 0.122 | 0.106 | 0.066 | 0.210 | 0.058 | 0.376 | 0.501 |
| **7** | Expert 7 | 0.071 | 0.354 | 0.131 | 0.030 | 0.141 | 0.141 | 0.018 | 0.847 |
| **8** | Expert 8 | 0.045 | 0.265 | 0.246 | 0.077 | 0.182 | 0.042 | 0.143 | 0.115 |
| **9** | Expert 9 | 0.374 | 0.149 | 0.126 | 0.162 | 0.069 | 0.040 | 0.080 | 0.171 |
| **10** | Expert 10 | 0.325 | 0.174 | 0.127 | 0.049 | 0.238 | 0.093 | 0.068 | 0.182 |
| **11** | Expert 11 | 0.091 | 0.036 | 0.213 | 0.037 | 0.284 | 0.020 | 0.320 | 0.458 |
| **12** | Expert 12 | 0.100 | 0.100 | 0.115 | 0.027 | 0.105 | 0.169 | 0.384 | 0.342 |
| **13** | Expert 13 | 0.300 | 0.120 | 0.139 | 0.034 | 0.064 | 0.064 | 0.279 | 0.097 |
| **14** | Expert 14 | 0.163 | 0.140 | 0.211 | 0.042 | 0.090 | 0.025 | 0.329 | 0.221 |
| | Total | 1.720 | 1.641 | 2.177 | 0.584 | 1.954 | 0.556 | 2.326 | |
| | Average | 0.156 | 0.149 | 0.198 | 0.053 | 0.178 | 0.051 | 0.211 | |

## Appendix 20. The weight converted to rank

### Weight of Vulnerability of landscape diversity loss resulted from standardized into ranking

| No | Expert | Prox to Road | Prox to pathway | Prox to Settlement | Prox to River | Prox to existing agric | Physical factors | Population density |
|---|---|---|---|---|---|---|---|---|
| **1** | Expert 1 | 7 | 1 | 5 | 3 | 4 | 2 | 6 |
| **2** | Expert 2 | 6 | 3 | 5 | 1 | 4 | 2 | 7 |
| **3** | Expert 3 | 5 | 3 | 6 | 2 | 4 | 1 | 7 |
| **4** | Expert 4 | 5 | 1 | 6 | 2 | 3 | 4 | 7 |
| **5** | Expert 5 | 1.5 | 3 | 5 | 1.5 | 7 | 4 | 6 |
| **6** | Expert 6 | 5 | 3 | 6 | 2 | 4 | 1 | 7 |
| **7** | Expert 7 | 2 | 1 | 5 | 4 | 6 | 7 | 3 |
| **8** | Expert 8 | 3 | 2 | 4 | 1 | 5 | 6 | 7 |
| **9** | Expert 9 | 7 | 5 | 6 | 4 | 1 | 2 | 3 |
| **10** | Expert 10 | 7 | 2.5 | 6 | 1 | 5 | 2.5 | 4 |
| **11** | Expert 11 | 4 | 2 | 6 | 3 | 5 | 1 | 7 |
| **12** | Expert 12 | 5 | 2 | 3 | 1 | 4 | 7 | 6 |
| **13** | Expert 13 | 6 | 3 | 5 | 2 | 4 | 1 | 7 |
| **14** | Expert 14 | 4 | 3 | 5 | 2 | 6 | 1 | 7 |
| | Total | 63 | 31 | 68 | 28 | 56 | 40 | 77 |
| | Average | 4.82 | 2.46 | 5.21 | 2.11 | 4.43 | 2.96 | 6.00 |

**Weight of Vulnerability of forest loss resulted from standardized into ranking**

| No | Expert | Prox to Road | Prox to pathway | Prox to Settlement | Prox to River | Prox to existing agric | Physical factors | Population density |
|---|---|---|---|---|---|---|---|---|
| **1** | Expert 1 | 7 | 5 | 4 | 1 | 3 | 2 | 6 |
| **2** | Expert 2 | 7 | 3 | 4 | 1 | 5 | 2 | 6 |
| **3** | Expert 3 | 7 | 5 | 3 | 6 | 1 | 4 | 2 |
| **4** | Expert 4 | 5 | 6 | 3 | 1 | 2 | 7 | 4 |
| **5** | Expert 5 | 3 | 5 | 6 | 2 | 4 | 1 | 7 |
| **6** | Expert 6 | 5 | 3 | 6 | 2 | 4 | 1 | 7 |
| **7** | Expert 7 | 7 | 2 | 3 | 3 | 6 | 1 | 5 |
| **8** | Expert 8 | 7 | 6 | 4 | 5 | 2 | 1 | 3 |
| **9** | Expert 9 | 7 | 6 | 4 | 5 | 2 | 1 | 3 |
| **10** | Expert 10 | 7 | 5 | 4 | 1 | 6 | 2 | 3 |
| **11** | Expert 11 | 7 | 3 | 4 | 1 | 6 | 2 | 5 |
| **12** | Expert 12 | 5 | 2 | 4 | 1 | 3 | 7 | 6 |
| **13** | Expert 13 | 7 | 2 | 3 | 1 | 3 | 5 | 6 |
| **14** | Expert 14 | 6 | 5 | 4 | 1 | 3 | 2 | 7 |
| | Total | 81 | 53 | 52 | 30 | 47 | 36 | 63 |
| | Average | 6.23 | 4.08 | 4.00 | 2.31 | 3.62 | 2.77 | 4.85 |

**Weight of Vulnerability of biodiversity loss resulted from standardized into ranking**

| No | Expert | Prox to Road | Prox to pathway | Prox to Settlement | Prox to River | Prox to existing agric | Physical factors | Population density |
|---|---|---|---|---|---|---|---|---|
| **1** | Expert 1 | 7 | 5 | 4 | 1 | 3 | 2 | 6 |
| **2** | Expert 2 | 7 | 3 | 4 | 1 | 5 | 2 | 6 |
| **3** | Expert 3 | 7 | 5 | 3 | 6 | 1 | 4 | 2 |
| **4** | Expert 4 | 5 | 6 | 3 | 1 | 2 | 7 | 4 |
| **5** | Expert 5 | 3 | 5 | 6 | 2 | 4 | 1 | 7 |
| **6** | Expert 6 | 5 | 3 | 6 | 2 | 4 | 1 | 7 |
| **7** | Expert 7 | 7 | 2 | 3 | 3 | 6 | 1 | 5 |
| **8** | Expert 8 | 7 | 6 | 4 | 5 | 2 | 1 | 3 |
| **9** | Expert 9 | 7 | 6 | 4 | 5 | 2 | 1 | 3 |
| **10** | Expert 10 | 7 | 5 | 4 | 1 | 6 | 2 | 3 |
| **11** | Expert 11 | 7 | 3 | 4 | 1 | 6 | 2 | 5 |
| **12** | Expert 12 | 5 | 2 | 4 | 1 | 3 | 7 | 6 |
| **13** | Expert 13 | 7 | 2 | 3 | 1 | 3 | 5 | 6 |
| **14** | Expert 14 | 6 | 5 | 4 | 1 | 3 | 2 | 7 |
| | Total | 81 | 53 | 52 | 30 | 47 | 36 | 63 |
| | Average | 6.23 | 4.08 | 4.00 | 2.31 | 3.62 | 2.77 | 4.85 |

## Appendix 21. Result of testing criteria of vulnerability of landscape loss

The result from The Friedman Test using R Software

Ho: There are no differences in weight between criteria
H1: There are, at least one criterion, difference from the other criteria

a. Descriptive statistic

**Descriptive Statistics**

| | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Prox to Road | 14 | 4.82 | 1.772 | 2 | 7 |
| Prox to pathway | 14 | 2.46 | 1.082 | 1 | 5 |
| Prox to Settlement | 14 | 5.21 | .893 | 3 | 6 |
| Prox to River | 14 | 2.11 | 1.041 | 1 | 4 |
| Prox to existing agric | 14 | 4.43 | 1.453 | 1 | 7 |
| Physical factors | 14 | 2.96 | 2.257 | 1 | 7 |
| Population density | 14 | 6.00 | 1.519 | 3 | 7 |

Table of Frequency of Vulnerability of Landscape Diversity Loss

| Criteria | Rank | | | | | | | Number of experts |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Prox to Road | | 2 | 1 | 2 | 4 | 2 | 3 | 14 |
| Prox to pathway | 3 | 4 | 6 | | 1 | | | 14 |
| Prox to Settlement | | | 1 | 1 | 6 | 6 | | 14 |
| Prox to River | 5 | 5 | 2 | 2 | | | | 14 |
| Prox to existing agric | 1 | | 1 | 6 | 3 | 2 | 1 | 14 |
| Physical factors | 5 | 4 | | 2 | | 1 | 2 | 14 |
| Population density | | | 2 | 1 | | 3 | 8 | 14 |

b. Friedman Test result

> friedman.test.with.post.hoc( Rank ~ Criterium | Expert, d)
Loading required package: coin
Loading required package: survival
Loading required package: splines
Loading required package: mvtnorm
Loading required package: modeltools
Loading required package: stats4
Loading required package: multcomp
Loading required package: colorspace
$Friedman.Test

Asymptotic General Independence Test

data:  Rank by
Criterium (Physical factors, Population density, Prox to existing agric, Prox to pathway, Prox to River, Prox to Road, Prox to Settlement)
stratified by Expert
maxT = 4.727, p-value = 4.469e-05

$PostHoc.Test

Population density - Physical factors 3.707127e-03
Prox to existing agric - Physical factors 5.519063e-01
Prox to pathway - Physical factors 9.964436e-01
Prox to River - Physical factors 9.526727e-01
Prox to Road - Physical factors 2.779398e-01
Prox to Settlement - Physical factors 8.466705e-02
Prox to existing agric - Population density 4.630460e-01
Prox to pathway - Population density 3.105546e-04
Prox to River - Population density 3.919281e-05
Prox to Road - Population density 7.520784e-01
Prox to Settlement - Population density 9.618202e-01
Prox to pathway - Prox to existing agric 1.950654e-01
Prox to River - Prox to existing agric 7.520724e-02
Prox to Road - Prox to existing agric 9.994692e-01
Prox to Settlement - Prox to existing agric 9.618279e-01
Prox to River - Prox to pathway 9.997111e-01
Prox to Road - Prox to pathway 6.650999e-02
Prox to Settlement - Prox to pathway 1.344204e-02
Prox to Road - Prox to River 2.068918e-02
Prox to Settlement - Prox to River 3.251831e-03
Prox to Settlement - Prox to Road 9.984971e-01

$Friedman.Test

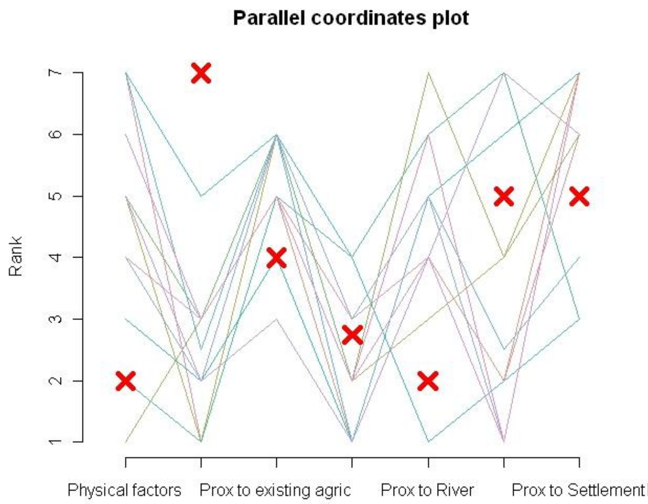
Asymptotic General Independence Test

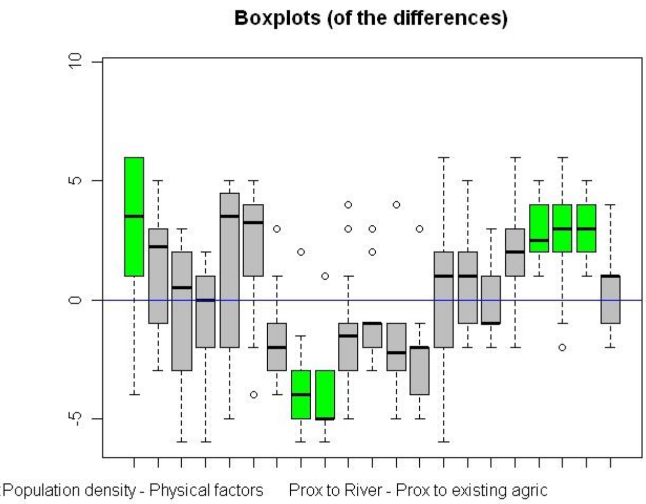
data:  Rank by
Criterium (Physical factors, Population density, Prox to existing agric, Prox to pathway, Prox to River, Prox to Road, Prox to Settlement)
stratified by Expert
maxT = 4.727, p-value = 5.176e-05

$PostHoc.Test

Population density - Physical factors 3.707127e-03
Prox to existing agric - Physical factors 5.519063e-01
Prox to pathway - Physical factors 9.964436e-01
Prox to River - Physical factors 9.526727e-01
Prox to Road - Physical factors 2.779398e-01
Prox to Settlement - Physical factors 8.466705e-02
Prox to existing agric - Population density 4.630460e-01

| | |
|---|---|
| Prox to pathway - Population density | 3.105546e-04 |
| Prox to River - Population density | 3.919281e-05 |
| Prox to Road - Population density | 7.520784e-01 |
| Prox to Settlement - Population density | 9.618202e-01 |
| Prox to pathway - Prox to existing agric | 1.950654e-01 |
| Prox to River - Prox to existing agric | 7.520724e-02 |
| Prox to Road - Prox to existing agric | 9.994692e-01 |
| Prox to Settlement - Prox to existing agric | 9.618279e-01 |
| Prox to River - Prox to pathway | 9.997111e-01 |
| Prox to Road - Prox to pathway | 6.650999e-02 |
| Prox to Settlement - Prox to pathway | 1.344204e-02 |
| Prox to Road - Prox to River | 2.068918e-02 |
| Prox to Settlement - Prox to River | 3.251831e-03 |
| Prox to Settlement - Prox to Road | 9.984971e-01 |



## Appendix 22. Result of testing criteria of vulnerability of forest loss

The result from The Friedman Test using R Software

Ho: There are no differences in weight between criteria
H1: There are, at least one criterion, difference from the other criteria

a. Descriptive statistic

**Descriptive Statistics**

| | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Prox to Road | 14 | 6.21 | 1.251 | 3 | 7 |
| Prox to pathway | 14 | 4.14 | 1.562 | 2 | 6 |
| Prox to Settlement | 14 | 4.00 | .961 | 3 | 6 |
| Prox to River | 14 | 2.21 | 1.805 | 1 | 6 |
| Prox to existing agric | 14 | 3.57 | 1.651 | 1 | 6 |
| Physical factors | 14 | 2.71 | 2.164 | 1 | 7 |
| Population density | 14 | 5.00 | 1.710 | 2 | 7 |

Table of Frequency Vulnerability of Forest Loss

| Criteria | Rank | | | | | | | Number of experts |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Prox to Road | | | 1 | | 3 | 1 | 9 | 14 |
| Prox to pathway | | 3 | 3 | | 5 | 3 | | 14 |
| Prox to Settlement | | | 4 | 8 | | 2 | | 14 |
| Prox to River | 8 | 2 | 1 | | 2 | 1 | | 14 |
| Prox to existing agric | 1 | 3 | 4 | 2 | 1 | 3 | | 14 |
| Physical factors | 5 | 5 | | 1 | 1 | | 2 | 14 |
| Population density | | 1 | 3 | 1 | 2 | 4 | 3 | 14 |

b. Friedman Statistic test

```
> friedman.test.with.post.hoc( Rank ~ Criterium | Expert, d)
Loading required package: coin
Loading required package: survival
Loading required package: splines
Loading required package: mvtnorm
Loading required package: modeltools
Loading required package: stats4
Loading required package: multcomp
Loading required package: colorspace
$Friedman.Test

        Asymptotic General Independence Test

data:  Rank by
```

Criterium (Physical factors, Population density, Prox to existing agric, Prox to pathway, Prox to River, Prox to Road, Prox to Settlement)
stratified by Expert
maxT = 4.8614, p-value = 2.78e-05

$PostHoc.Test

Population density - Physical factors 7.493654e-02
Prox to existing agric - Physical factors 9.298256e-01
Prox to pathway - Physical factors 5.805882e-01
Prox to River - Physical factors 9.976346e-01
Prox to Road - Physical factors 2.976049e-04
Prox to Settlement - Physical factors 6.400966e-01
Prox to existing agric - Population density 6.105106e-01
Prox to pathway - Population density 9.419484e-01
Prox to River - Population density 1.323362e-02
Prox to Road - Population density 7.515399e-01
Prox to Settlement - Population density 9.161708e-01
Prox to pathway - Prox to existing agric 9.947836e-01
Prox to River - Prox to existing agric 6.400397e-01
Prox to Road - Prox to existing agric 2.354848e-02
Prox to Settlement - Prox to existing agric 9.976348e-01
Prox to River - Prox to pathway 2.337938e-01
Prox to Road - Prox to pathway 1.449440e-01
Prox to Settlement - Prox to pathway 1.000000e+00
Prox to Road - Prox to River 2.002825e-05
Prox to Settlement - Prox to River 2.772947e-01
Prox to Settlement - Prox to Road 1.180434e-01
$Friedman.Test

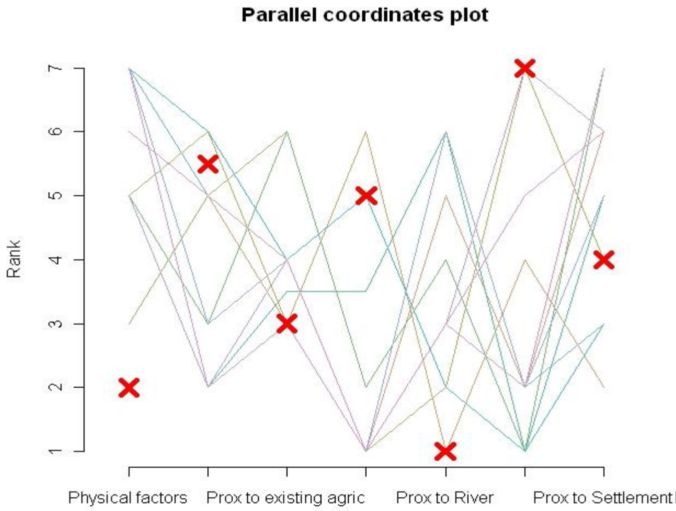
Asymptotic General Independence Test

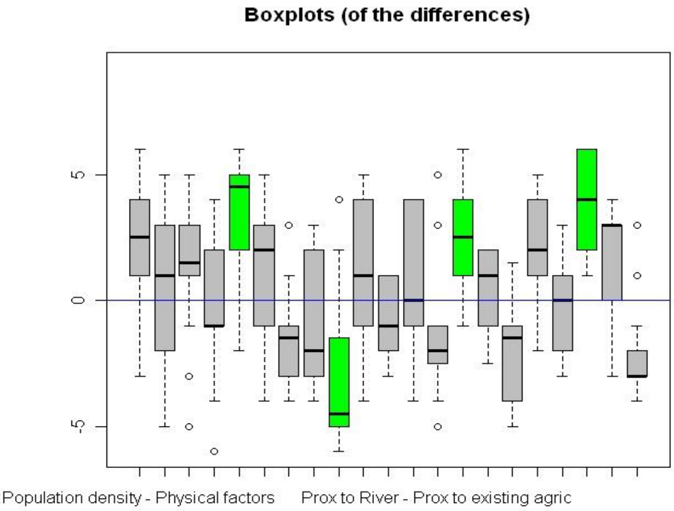
data: Rank by
Criterium (Physical factors, Population density, Prox to existing agric, Prox to pathway, Prox to River, Prox to Road, Prox to Settlement)
stratified by Expert
maxT = 4.8614, p-value = 1.775e-05

$PostHoc.Test

Population density - Physical factors 7.493654e-02
Prox to existing agric - Physical factors 9.298256e-01
Prox to pathway - Physical factors 5.805882e-01
Prox to River - Physical factors 9.976346e-01
Prox to Road - Physical factors 2.976049e-04
Prox to Settlement - Physical factors 6.400966e-01
Prox to existing agric - Population density 6.105106e-01
Prox to pathway - Population density 9.419484e-01
Prox to River - Population density 1.323362e-02
Prox to Road - Population density 7.515399e-01
Prox to Settlement - Population density 9.161708e-01

| | |
|---|---|
| Prox to pathway - Prox to existing agric | 9.947836e-01 |
| Prox to River - Prox to existing agric | 6.400397e-01 |
| Prox to Road - Prox to existing agric | 2.354848e-02 |
| Prox to Settlement - Prox to existing agric | 9.976348e-01 |
| Prox to River - Prox to pathway | 2.337938e-01 |
| Prox to Road - Prox to pathway | 1.449440e-01 |
| Prox to Settlement - Prox to pathway | 1.000000e+00 |
| Prox to Road - Prox to River | 2.002825e-05 |
| Prox to Settlement - Prox to River | 2.772947e-01 |
| Prox to Settlement - Prox to Road | 1.180434e-01 |



# Appendix 23. Result of testing criteria of vulnerability of biodiversity loss

The result from The Friedman Test using R Software

Ho: There are no differences in weight between criteria
H1: There are, at least one criterion, difference from the other criteria

a. Descriptive Analysis

**Descriptive Statistics**

| | N | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Prox to Road | 14 | 4.393 | 1.9432 | 2.0 | 7.0 |
| Prox to pathway | 14 | 4.393 | 1.4959 | 2.0 | 7.0 |
| Prox to Settlement | 14 | 5.14 | 1.027 | 4 | 7 |
| Prox to River | 14 | 2.14 | 1.351 | 1 | 6 |
| Prox to existing agric | 14 | 4.57 | 1.453 | 2 | 7 |
| Physical factors | 14 | 2.00 | 1.617 | 1 | 6 |
| Population density | 14 | 5.29 | 2.091 | 1 | 7 |

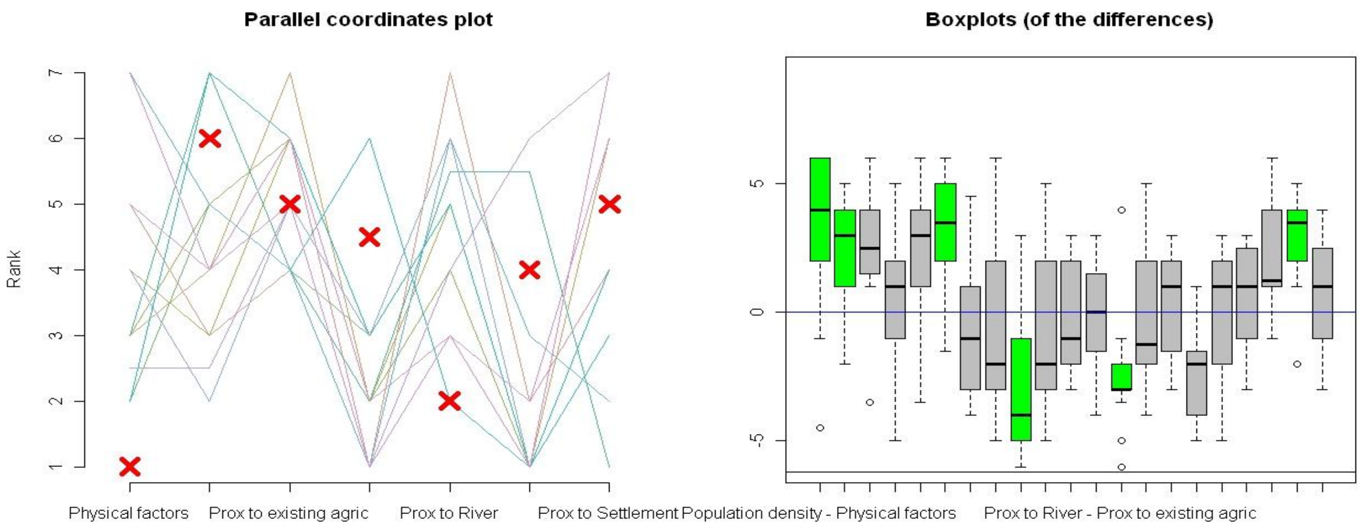
Table of Frequency Vulnerability of Biodiversity Loss

| Criteria | Rank | | | | | | | Number of experts |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Prox to Road | | 3 | 3 | 2 | 2 | | 4 | 14 |
| Prox to pathway | | 2 | 2 | 3 | 5 | | 2 | 14 |
| Prox to Settlement | | | | 5 | 3 | 5 | 1 | 14 |
| Prox to River | 5 | 5 | 3 | | | 1 | | 14 |
| Prox to existing agric | | 1 | 3 | 2 | 4 | 3 | 1 | 14 |
| Physical factors | 8 | 3 | 1 | | 1 | 1 | | 14 |
| Population density | 1 | 1 | 1 | 2 | | 3 | 6 | 14 |

```
> friedman.test.with.post.hoc( Rank ~ Criterium | Expert, d)
Loading required package: coin
Loading required package: survival
Loading required package: splines
Loading required package: mvtnorm
Loading required package: modeltools
Loading required package: stats4
Loading required package: multcomp
Loading required package: colorspace
$Friedman.Test

        Asymptotic General Independence Test
```

```
data:  Rank by
       Criterium (Physical factors, Population density, Prox to existing agric, Prox to pathway, Prox to
River, Prox to Road, Prox to Settlement)
       stratified by Expert
maxT = 3.9855, p-value = 0.001304

$PostHoc.Test

Population density - Physical factors      0.001305886
Prox to existing agric - Physical factors  0.026700150
Prox to pathway - Physical factors         0.058782776
Prox to River - Physical factors           0.999999566
Prox to Road - Physical factors            0.059021145
Prox to Settlement - Physical factors      0.002622246
Prox to existing agric - Population density 0.981661019
Prox to pathway - Population density       0.929820075
Prox to River - Population density         0.002320548
Prox to Road - Population density          0.929824892
Prox to Settlement - Population density    0.999997579
Prox to pathway - Prox to existing agric   0.999973134
Prox to River - Prox to existing agric     0.040361062
Prox to Road - Prox to existing agric      0.999973126
Prox to Settlement - Prox to existing agric 0.994778417
Prox to River - Prox to pathway            0.084056823
Prox to Road - Prox to pathway             1.000000000
Prox to Settlement - Prox to pathway       0.969536947
Prox to Road - Prox to River               0.084278357
Prox to Settlement - Prox to River         0.004454434
Prox to Settlement - Prox to Road          0.969546954
$Friedman.Test

       Asymptotic General Independence Test

data:  Rank by
       Criterium (Physical factors, Population density, Prox to existing agric, Prox to pathway, Prox to
River, Prox to Road, Prox to Settlement)
       stratified by Expert
maxT = 3.9855, p-value = 0.001209

$PostHoc.Test

Population density - Physical factors      0.001305886
Prox to existing agric - Physical factors  0.026700150
Prox to pathway - Physical factors         0.058782776
Prox to River - Physical factors           0.999999566
Prox to Road - Physical factors            0.059021145
Prox to Settlement - Physical factors      0.002622246
Prox to existing agric - Population density 0.981661019
Prox to pathway - Population density       0.929820075
Prox to River - Population density         0.002320548
```

Prox to Road - Population density 0.929824892
Prox to Settlement - Population density 0.999997579
Prox to pathway - Prox to existing agric 0.999973134
Prox to River - Prox to existing agric 0.040361062
Prox to Road - Prox to existing agric 0.999973126
Prox to Settlement - Prox to existing agric 0.994778417
Prox to River - Prox to pathway 0.084056823
Prox to Road - Prox to pathway 1.000000000
Prox to Settlement - Prox to pathway 0.969536947
Prox to Road - Prox to River 0.084278357
Prox to Settlement - Prox to River 0.004454434
Prox to Settlement - Prox to Road 0.969546954



## Appendix 24. Result of testing weight of integrated vulnerability

The result from The Friedman Test using R Software

Ho: There are no differences in weight between each type of vulnerability
H1: There are differences in weight among type of vulnerability

```
> friedman.test.with.post.hoc( Rank ~ Criterium | Expert, d)
Loading required package: coin
Loading required package: survival
Loading required package: splines
Loading required package: mvtnorm
Loading required package: modeltools
Loading required package: stats4
Loading required package: multcomp
Loading required package: colorspace
[1] "The results where not significant, There is no need for a post hoc test"

        Asymptotic General Independence Test

data:  Rank by
        Criterium (VBL, VFL, VLDL)
        stratified by Expert
maxT = 0.8729, p-value = 0.6574
```

**Conclusion:** Retain Ho since p-value > α, where α = 0.05

## Appendix 25. Map of LLNP Spatial Plan