Spatial Multi Criteria Analysis to Propose Special Use Zone Planning In Bantimurung Bulusaraung National Park (BBNP), South Sulawesi, Indonesia

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By

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Abstract

The issue of community development inside BBNP has become a main concern in the park management. To prove this issue, an analysis of the relationship between population growth and land cover change is essential. Ministry of Forestry regulates the idea of "Special use zone" in Ministry Decree (Permenhut) No. 56/2006 about Zoning Principles in National Park. Several activities allowed inside a special use zone are protection area, utilization area for people demand, rehabilitation and population growth and carrying capacity monitoring. This research aims to identify and analyze community problem in order to propose special use zone planning using spatial multi criteria analysis in Bantimurung Bulusaraung National Park (BBNP), South Sulawesi, Indonesia. This aims was pursued by conducting 3 parts of analysis which are land cover change analysis, community area mapping and community area spatial planning. Land cover change analysis performed maximum likelihood supervised classification on Landsat-7 TM 2002 and 2009(RGB 542) with overall accuracy 77% and 83% respectively. According to this classification, deforestation area was identified in land cover change analysis which is about 1,974 ha (20%) of study area. The deforestation was then correlated with population growth in study area using linier regression that shows negative significant correlation. Because of relationship between deforestation and population growth, community area mapping was carried out. Three methods (Maximum Likelihood Supervised Classification (MLC), Object Based Classification (OBC) and Visual Interpretation (VI)) were examined to map the land cover of GoeEye 0.4 m resolution (Google Earth) on the selected subset area. The overall accuracy for these 3 classification techniques were 56%, 58% and 86% respectively. Technique with highest accuracy (VI) was used to map the whole study area. The result of land cover map was utilized in community spatial planning. Community spatial planning was performed as land use allocation accomplished using Spatial Multi Criteria Evaluation (SMCE) ILWIS software using biophysical criteria which was defined through literature study and questionnaire distribution. Land cover, slope, soil, rainfall and distance to road, settlement, tourism object, river and flora fauna habitat were selected as considered criteria. Land use allocation resulted protection area in7,439.36 ha (74.88%), rehabilitation area 1,996.38 ha (20.09%) and agriculture area in157.51 ha(1.59%) and non suitable area 341,88 ha(3.4%).

Keywords : *community problem, special use zone, land cover classification, spatial multi criteria evaluation*

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1. Introduction

1.1. Background

1.1.1. Problems in National Park Management

International Union for Conservation Nature (IUCN) defined a national park as large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities (IUCN, 2008). National Parks in Indonesia function as an essential part of the last defense from deforestation (Wiratno, 2002). It underscores the role of the protected areas in preserving genetic resources, safeguarding critical watersheds, and managing ecotourism attractions for the benefit of local populations (Moore and Cifuentes, 1997). Furthermore, protected areas play an important role in conserving tropical diversity and ecosystems (Bruner *et al.*, 2001).

In managing a national park, it is always essential to pay attention to the existence of community settling around or within it. McNeely (1994) stated that “National park as a protected area can also provide valuable services to local communities”. The extension of settlement area can be a threat for ecosystem in national park, because most people living within it have a high dependency on forest resources, since they need land for agriculture, take fuel wood, fruit, and even sometimes, hunt some animals for their meals or collect mushroom or honey bees. Such benefits are often difficult to quantify, and even local people may take them for granted. These activities may lead to land use changes, illegal logging, wildlife habitat fragmentations etc. if it is not well-controlled. However, this problem should be wisely considered by the park management, as Mannigel (2002)concluded that the adjacent area of a national park should also have attention in order to obtain an effective management. In Japan, people continue to live within the park boundaries, and socio-economic activities such as agriculture and forestry take place within the confines of the regulations (NACS-J, 2000).

Protected areas are often established without involving local stakeholders during the process and conflicts arise from different interests of communities nearby(Ghimire and Pimbert, 1997). Furthermore, Wiratno (2002) stated that in Indonesia, the establishment of conservation area, including national park is still accomplished without negotiation with local community. For instance, the foundation of Gunung Merapi National Park in 2004 is protested by community, scientist and NGO’s(Dewi, 2007). It caused community conflict and settlement problems in national parks often become more severe and uncontrolled. Some regulations and policies are usually more concern on the ecosystem and habitat of wildlife in national park, and neglect the influence of human activities. Therefore, this issue needs more studies on how government should manage a national park as protected area by rely on the balance of ecology, economy and social aspects. In Indonesia, community problem in national parks has become an important issue to be dealt with for many years. Some national parks have settlement area, inhabited by communities and already existed before the national park area status had been legalized. In South Sulawesi, the community area inside forest reached approximately 200,941 hectares from 1981-2005(BPKH, 2007). Population and development growth of this community threats the ecosystem of national park if they are not well maintained.

1.1.2. Community Problem in Bantimurung Bulusaraung National Park (BBNP)

Bantimurung Bulusaraung National Park (BBNP) is a new national park, located in Maros Regency, South Sulawesi. It has a large and unique karsts ecosystem, which is mostly covered by tropical forests. Since 2008, BBNP has been going through a process of development of zoning system to its area appropriately. Management Plan of BBNP (2008) mentioned that the park management is still facing many problems, especially dealing with community. There is a settlement located within BBNP area, which has been already there for a long time ago before the national park is founded and it tends to expand by time. This fact is proven by the development of some permanent infrastructures for public services, such as mosque, market, roads and schools(BBNP, 2008). The existence of these public facilities could attract more people to come to this area. Some key commodities like *Kemiri* or Candlenut (*Aleurites moluccana*), Coconut and cocoa grow well in that area and it seems to make people intend to expand their agriculture land because these commodities have high economic value for them. This condition may lead as a threat for ecosystem of BBNP, because it could direct to further deforestation or forest conversion into plantation and settlement. This is against the new rules and activities that the Indonesian Ministry of Forestry is taking to promote REDD strategy for reducing the emission of carbon by deforestation and forest degradation.

1.1.3. The Role of Special Use Zone

Conservation policy in Indonesia has been mostly excluding people and human activity from the 534 protected areas, including 50 national parks, covering a total of 28.2 million hectares(Mulyana *et al.*, 2010). In response to that issue, a concept of establishing a special use zone for community development has been aroused. Law no. 5/1990 defines a national park as an area designated to protect natural ecosystems and managed by the National Park Agency using a zoning management system. The zoning of national parks is regulated further through Ministerial Decree P.56, which is specifically explained as the spatial arrangement of the park in different areas based on each function (ecological, socio-economic and cultural). According to this decree, a special use zone is ‘‘a zone to accommodate local communities that have been residing in the area since before it was designated a national park, or to accommodate public facilities and infrastructure such as telecommunication towers, roads and electricity installations’’. Moreover, activities like protection, rehabilitation and agriculture are allowed to be established within special use zone to support community development. This zone would accommodate people who live within park boundaries or use the land, and would establish collaborative management. However, as of 2010, few national parks are managed collaboratively and even fewer have a designated special use zone. Although codified in law, the design of special use zones remains unspecified(Mulyana *et al.*, 2010).

Special use zone is proposed as an area within a national park where the presence of people and their activities is officially recognized and managed, which can enable simultaneous conservation of the park's resources and development for local people(Mulyana *et al.*, 2010). In addition, Supriyanto (2007) stated that settlement and agricultural land belongs to community could only be legitimated under special use zone, when the location is within national park border. A special use zone is expected to reduce and overcome conflicts between local people and the national park, since it is an area where the needs of people and of the park can be reconciled.

1.1.4. Remote Sensing for Land Cover Classification

Remote sensing nowadays has been developed to help human identifying and analyzing multi-sectoral problems. It usually deals with satellite image processing to extract information about earth surface features (e.g. land covers types). This can be done by interpretation or classification of remotely sensed data. Land cover map can be derived from image classification. As the spatial resolution increases, between-class spectral confusion and within-class spectral variation increases (Mathieu *et al.*, 2007). There are several image classification techniques used for different purposes. They varied based on the image source quality and the aim of classification. Different spatial resolution of images could use different methods or techniques in identification and classification of land cover types to get the best result.

Object-based classification techniques provide new classifier that have the potential for improving the semi-automatic extraction of information (e.g. the well known per-pixel Maximum Likelihood classification) from very high resolution imagery (Benz, 2004). The availability of satellite data with very fine spatial resolution brought a reconsideration of digital methods used for information extraction. Instead of pixels, grouping pixels or so called object oriented techniques offer more suitable analysis to classify satellite data. Compared to conventional pixel-based classification approaches, utilizing only the spectral response, image objects contain additional information, like object texture and shape. Object-oriented classification is suitable even for very high resolution or radar imagery (Xiaoxia *et al.*, 2004). In different study, Huang and Ni (2008) stated that "compared with the middle and low resolution satellite images, the high resolution satellite images have richer spatial but less spectral information". When these images are used for classification and land cover-use extraction, previous study has already shown that the conventional pixel-based statistical methods cannot obtain satisfactory result.

Visual interpretation is also a technique for identifying objects of an image. This is usually applied when dealing with a very high resolution image that we can easily recognize each object and can delineate their borders without difficulty. Because it is done manually, this technique is time consuming and requires specific knowledge of the area of interpretation. Involving knowledge based interpretation is expected to help interpreter in extracting information from the image according to field observation.

1.2. Conceptual Framework

The success and sustainability of a national park is highly depends on its characteristics. BBNP has several values that have to be well protected and maintained. Karsts ecosystem, natural tourism and rare species habitat are most valuable assets of BBNP. As an open-accessed area, external factors like human pressure are likely to affect the park via trans-passing of people through the park which could lead to more problems like disturbance, deforestation and forest degradation. Community development in BBNP is one of main issues concern the park management. As for the community living inside the park, population growth, agriculture land expansion and infrastructure development, are continue to happen before and after the establishment of the national park. Therefore, BBNP needs to respond to this problem with an appropriate zoning management.

Based on the National Law of Indonesia No. 5/1990 about Forestry, the basic management of a national park can be done by applying zoning system. Some types of zoning system are legalized to be established within national park, which are Core Zone, Wilderness Zone, Utilization Zone and Special Use Zone. The last zone is a respond to the dynamic community problem living inside the park and actuated in Ministry of Forestry Regulation No 56/2006 about Zoning Principle in National Park. The designation of special use zone is not yet clarified. Thus, it is required to analyze and propose the design of this zone. Remote sensing and GIS techniques can be used to help this objective. Figure 1 describes the conceptual framework of this research.

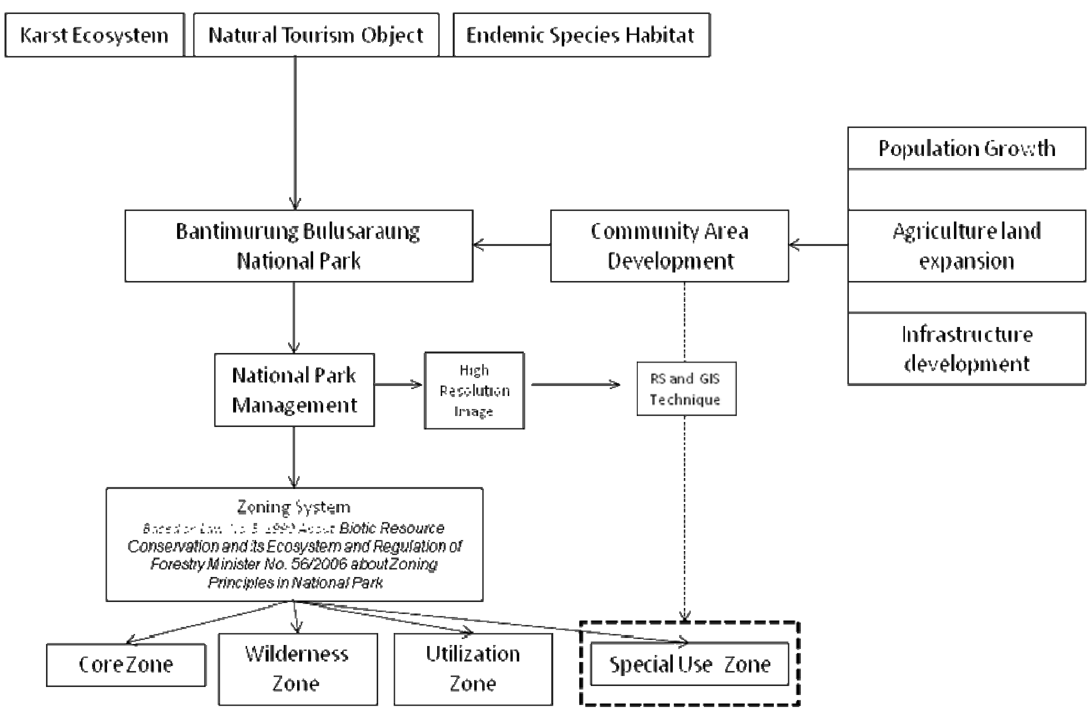


Figure 1. Conceptual framework of the research

1.3. Problem Statement

Currently, the issue of community development inside BBNP has become a main concern in the park management. To prove this issue, an analysis of the relationship between population growth and land cover change is essential. In reality, the community location inside the park are scattered in different separated location or clusters. However, to obtain a better monitoring and management of this community area, an analysis of land use allocation is important. Community area mapping is crucial process to be achieved in order to support a land use planning. By knowing community distribution within study area, suitable land use allocation could be determined, both to help preserving community development and protecting park ecosystem. The utilization of high resolution image can be very helpful to identify the details (e.g. shape, border, size, etc.) of each object, since the position of community's domain like settlement and agriculture area are dispersed. Thus, some remote sensing analysis in terms of image classification was employed to extract information from the data of this research.

Ministry of Forestry regulates the idea of "Special use zone" in Ministry Decree (Permenhut) No. 56/2006 about Zoning Principles in National Park. The term special use zone is actually representing community area, since this regulation mentioned that special use zone could be established for accommodating community life within a national park, which was existed before the park is established. According to the regulation, several activities are allowed inside a community zone. It consists of protection area, utilization area for people demand, rehabilitation and population growth and carrying capacity monitoring. The permission of these activities is due to the aims of special use zones which allows for environmentally friendly and sustainable economic development within the pre-set limits of a national park's conservation goals. Thus, this establishment of this zone will still remains biodiversity conservation, but with secondary purpose which is a sustainable use to enable local users, stakeholders, to maintain or achieve a desirable level of wellbeing. However, as of 2010, few national parks are managed collaboratively and even fewer have a designated special use zone. Although codified in law, the design of special use zones remains unspecified(Mulyana *et al.*, 2010). Therefore, developing criteria for the spatial planning of community zone is an important issue to be considered. The criteria should match with sustainable development aspects. "Sustainable development rests on three pillars, which are society, economy and environment" (UNEP, 2002).

In order to support spatial planning of community zone, the application of Spatial Multiple Criteria Evaluation (SMCE) was carried out. SMCE is a part of spatial multi criteria decision analysis, which consists of procedures involving the utilization of geographical data as the input, combined with decision maker's preference and manipulation of data according to specified decision rules. Furthermore, SMCE is an important tool to produce policy relevant information about spatial decision problems for decision making. A good example of SMCE application is site selection, which is one form of planning and decision models(Sharifi and Retsios, 2004). Site selection process can be performed to obtain suitable land use allocation within Special Use Zone. This method was applied in this research, because in national park management, zoning system is a decision making issue that requires evaluation of multiple land and attributes according to multiple objectives.

Moreover, this technique has been employed to support the specific task of protected area planning(Geneletti and van Duren, 2008).

Geographic Information System analysis was also used in manipulating the data of this research. GIS is a computer-based system that offers a convenient and powerful platform for performing land suitability analysis and allocation (Mendoza, 1997). GIS can also act as problem solving in a decision support system involving the integration of spatially referenced data in a problem solving environment (Hadi, 2008). The combination of GIS and remote sensing can serve as an analytical and predicting tool for planning of aquaculture development and to test the consequence of various development decisions before their use in the landscape (Aguilar-Manjarrez, 1995). Therefore, GIS application can be utilized in spatial analysis for land allocation in community zone of BBNP, referring to thematic spatial data that are already available.

1.4. Research Objectives

1.4.1. General Research Objective

Identify and analyze community problem in order to propose special use zone planning using spatial multi criteria analysis in Bantimurung Bulusaraung National Park (BBNP), South Sulawesi, Indonesia.

1.4.2. Specific Research Objectives:

a. Detect land cover changes and assess the relationship between land cover change and population growth in BBNP.
b. Examine the ability of object-based classification of GeoEye high spatial resolution satellite image to accurately map land cover types in BBNP in comparison to pixel-based (Maximum Likelihood) classification and visual interpretation.
c. Develop biophysical criteria upon which a spatial design for “Special Use Zone” in BBNP could be done, in reference to Ministry of Forestry Decree (*Permenhut)* No. 56/2006 about Zoning Principle in National Park and other literatures.
d. Propose a spatial multi criteria planning for special use zone based on land cover classification and biophysical criteria.

1.5. Research questions

a. How is the land cover change in the study area from 2002-2009?
b. Is there any relationship between land cover change and population growth in BBNP?
c. How accurate is object-based classification compared to pixel based classification and visual interpretation for identifying land cover types in the study area?
d. What are suitable criteria to be used to design a “Special Use Zone” in BBNP?
e. How can spatial multi criteria analysis solve the problem of a land use planning in community zone in BBNP based on biophysical aspect?

2. Concepts and Definition

2.1. National Park Management

National Park (NP) is one form of protected area. Protected area is defined as a large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provides a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities (IUCN, 2008). Specifically, national park is included in category II of six protected area categories according to the International World Conservation Union (IUCN) which functions mainly for conservation and recreation. However, national park management is not only dealing with conservation and recreation but even profound challenges, given widespread conditions of poverty, rapid population growth, and political instability, especially in developing countries(Treves LN *et al.*, 2005; Treves LN and K, 2005). The Indonesian's Law no 9/1990 about Natural Resource and Ecosystem Conservation revealed national park definition as a protected area with its unique ecosystem, managed by zoning system and utilized for research, science exploration, education, supporting tourism and recreation function.

Moreover, one objective of NP based on IUCN guidelines for protected area is to take into account the needs of indigenous people and local communities, including subsistence resource use, in so far as these will not adversely affect the primary management objective. Furthermore, it is explained that one role of NP is to support compatible economic development, mostly through recreation and tourism, that can contribute to local and national economies and in particular to local communities(IUCN, 2008).

2.1.1. Community Problem in National Park

According to the IUCN (1994), protection of biological diversity can be achieved by overcoming obstacles like having a careful understanding of the protected area values, their design, and acceptance of area protection, and indigenous education, conflict situations with local peoples, and management role in sustainable development.

Discussing a national park management is always related to the problems taken part into it. It is proven by various land use and management problems such as deforestation, wildlife poaching, illicit loggings, uncontrolled bush fires, shifting cultivation and over grazing(Bisong, 2009). A case of Faro National Park, Benoue and Bouba-Njida in Cameroon, were also characterized by numerous incidences of conflicts. It happens due to the establishment of NP without involving community knowledge. As the result, many people were under arrest and combat could not be avoided (Njiforti and Tchamba, 1993).

Indigenous people realize that protection areas could prevent their territories, land resource, cultural assets and sustain their life. It becomes a reason behind the increasing indigenous people's protected areas around the world (IUCN, 2008). Furthermore, IUCN considers the issues of settled populations in national park, replacement and compensation option to be given in order to accommodate community livelihood and change the management approaches in terms of solving community problems. In other words, there is a need to determine the level of relevance and the appropriateness of both conservation and human development. However, the objectives behind the conservation scheme is to conserve natural resources for long-term benefits, while the concern of the inhabitants of protected areas is the need to have a means of livelihood for survival (Bisong, 2009).

2.1.2. Zoning System

Zoning system is a type of national park management which is already worldwide applied in many countries. It is intended to ease the management by dividing areas into several particular functions. The effort to promote environmental protection and improve local lives and livelihoods across protected areas, forces managers to turn into a land-use zoning management. To be ideal, these zoning projects should provide a means of equaling conservation aims and economic development goals across large areas and among diverse stakeholders. Thus, zoning efforts will be effective if it is supported by a legitimate managerial capacity among related stakeholders (Treves LN *et al.*, 2005).
Recently, in Indonesia, three main zones are considered in a national park by the law of Republic Indonesia No. 41/1999 about Forestry, which are Core Zone, Wilderness Zone and Utilization Zone.

2.1.2.1. Community Zone

Regarding to community and social problems occurring within national park management, the establishment of a specific zone to accommodate people’s activity has been evolved. IUCN (2008) specify a Community Conserved Area as natural and modified ecosystems, including significant biodiversity, ecological services and cultural values, voluntarily conserved by indigenous peoples and local and mobile communities through customary laws or other effective means.

In Indonesia, community area has become a big and important issue in the last years. Ministry of Forestry responded to community zone by regulating the possibility of special use zone establishment in Ministry Forestry Decree *(*Permenhut*)* no. 56/2006 about zoning principles in national park. According to that decree, a special use zone is a zone to accommodate local communities that have been residing in the area since before it was designated a national park, or to accommodate public facilities and infrastructure such as telecommunication towers, roads and electricity installations’. Several activities allowed within this area, which are protection, limited exploration to support community livelihood, rehabilitation and monitoring carrying capacity of the area.
Furthermore, Mulyana (2010) added the general principles of that special use zone more specifically, that are:

a. The special use zone is an integral part of the national park, with clear boundaries agreed by all stakeholders and with direct geographical, social, economic or cultural links to the area outside the park.
b. Land and resources within the special use zone remain state land with a conservation function.
c. People may receive rights of use, management or access, but no rights of ownership.
d. Specific rules on who has rights, what rights are given and the responsibilities linked to those rights need to be developed and agreed on by the stakeholders.

e. All use must be environmentally friendly, based on principles of conservation and sustainability.
f. Local rules developed for the special use zones are binding on all people receiving rights to the special use zone.
g. The park agency should exercise its authority in a responsible and accountable manner, collaborating with and respecting other parties.

Some principles are applied to all national parks in Indonesia (for example, land remains state land), but others are to be developed in accordance with the specific needs and conditions of each park.

2.1.3. Spatial Planning in National Park

Spatial planning in national park is required to obtain an effective management, based on land use suitability. It should bring ecology, social and economy consideration to implement a sustainable development. In national park scope, the spatial planning is commonly represented in zoning system, a type of management worldwide. Some considerations of spatial planning in defining protected area according to IUCN (2008) are:

a. the ecological needs of species and ecosystems
b. the threats to the species or ecosystem values
c. the protected area's objectives, existing and proposed international designations and how
d. contribution to landscape, country and global biodiversity conservation efforts
e. developing and implementing a process to assign/review management categories in a country
f. No loss of naturalness, ecosystem function, or species viability.
g. the landscape and seascape when assigning categories
h. Stakeholders matter.
i. Management effectiveness when assigning protected area categories.
j. More restrictive management categories are not always better.
k. Use the categories as a tool for within-protected area planning. Within a single protected area, several zones with different management objectives can be agreed if this helps overall management.
l. Societal benefits of diversifying the category port- folio. Considering a variety of protected area management categories can often improve public perceptions of protected areas and increase their likelihood of success.

2.2. Population Growth and Deforestation

Population pressure, poverty and weak institutional framework have often been suspected as the predominant underlying causes of forest depletion and degradation in developing countries (Gulati and Sharma, 2000). The predominant causes for dwindling forest wealth have been identified as over-exploitation, overgrazing, illegal encroachments, unsustainable practices, forest fires, and an indiscriminate sitting of development projects in the forest areas (GoI, 1999). However, population pressure is always be the underlying cause of overexploitation of the natural resources including forest stock. Possibly, poverty, corruption, weak institutions, and wasteful consumption patterns also combine with the population pressure facilitating depletion and degradation of forest stock having enormous environmental degradation ramifications(Gulati and Sharma, 2000). Protected area, including national park is also suffered from deforestation. The influence of population growth in deforestation was indicated. A study said that human population density has a potentially confounding affect on deforestation in national park. Deforestation is much faster in the densely settled land beyond the national park boundary than sparsely inhabited area (Treves LN and K, 2005).

2.3. Image Classification

2.3.1. Visual Interpretation

Instead of computerized-automated classification, visual interpretation also acts as a powerful method to classify imagery. Manual delineation or digitization somehow is a more accurate and detail work in order to differentiate features based on knowledge of the interpreter of the objects. The ability to recognize objects in aerial and satellite photographs can be explained as follows: from knowledge of a landscape and its depiction, interpretation rules are developed to assign predetermined meanings to certain combinations of image properties, such as color, form, size, texture or context (Donner, 2008).

2.3.2. Pixel Based Classification

Pixel based classification is a very common technique mainly used in image interpretation. It is often called traditional image classification since it is conventionally applied based on per single pixel value. The overall objective of classical image classification procedures is to automatically categorized all pixels in an image into land cover classes or themes(Xiaoxia *et al.*, 2004).

There are three techniques of pixel based classification, consist of supervised, unsupervised and hybrid classification. In this research, supervised classification was used. “In supervised classification, the image analyzed by pixel categorization process using a computer algorithm, resulting in a numerical description of the various land cover types present in a scene. In order to do this, representative sample sites of known cover type, called raining area are used to compile a numerical “interpretation key “ that describes the spectral attributes for each feature type of interest. Each pixel in the data set is then compared numerically to each category in the interpretation key and labeled with the name of the category it looks more like(Matinfar *et al.*, 2007).

Several types of algorithm have been known as the basis of computerized classification in image interpretation. Among the conventional methods of classifying the multispectral imagery, such as parallelepiped, minimum distance to mean, nearest neighbor and Maximum Likelihood Classification (MLC). The latest is the most common used algorithm for pixel-based classification, and it has been shown to give the best results for classification of remotely sensed natural resource data, among the algorithms of parametric classifiers (Ippoliti-Ramilo *et al.*, 2003).

2.3.3. Object Based Classification

Object based classification is one example of development to improve the traditional pixel based classification. The difference of object based classification from the pixel based classification is that object-oriented classification does not operate directly on single pixels, but more grouping many pixels in a certain way by image segmentation according to object characteristics like shape, color, compactness, spectral reflectance etc. Image segmentation is a preliminary step in object-oriented image classification that divides the image into homogeneous, contiguous objects (Yan *et al.*, 2006). Many examples of object-based image classification have attempted to reproduce traditional pixel-based classification techniques, but using the spatial scale of the object instead of the pixel (Aplin and Smith, 2008). Comparing with pixel-based image analysis, object-based image analysis has many advantages (Hay and Castilla, 2006), such as: the way it classifies an image by partitioning it into objects is similar to the way humans comprehend the landscape; image-objects exhibit useful features (shape, texture, context relations with other objects) that single pixels lack; image-objects can be more readily integrated in vector GIS.

In other words, instead of extracting information based on each pixel, object based classification considers the spatial relation of pixels like its neighborhood, similarity in color and shape etc. which forms as a homogenous objects. Thus, it will provide more recognizable and valuable information, for instance in land cover classification. Along with the increase of spatial resolution for satellite images, the spatial information is expected to be more abundant than before. Object based classification utilizes the spatial segmentation procedure prior to the classification (Hay and Castilla, 2006; Cheng *et al.*, 2008)

Many researchers have been applying it to examine the ability of object based classification. One of these is concern environmental field including urban growth and shrub land encroachment (Laliberte *et al.*, 2004; Stow *et al.*, 2008). Furthermore, object-oriented image classification has been successfully used to identify logging and other forest management activities using Landsat ETM+ imagery (Flanders *et al.*, 2003) to map shrub encroachment using QuickBird imagery (Laliberte *et al.*, 2004); to quantify landscape structure using imagery from Landsat ETM+, QuickBird, and aerial photography(Ivits *et al.*, 2005); to map fuel types using Landsat TM and Ikonos imagery (Giakoumakis *et al.*, 2002) and to detect changes in land use from imagery in the German national topographic and cartographic database (Walter, 2004).

2.4. Spatial Multi Criteria Analysis

2.4.1. Spatial Multi Criteria Analysis

“Spatial multicriteria decision analysis is a process that combines and transforms geographical data (the input) into a decision”(Sharifi and Retsios, 2004). This process involves geographical data utilization and usually supported by stakeholders perception in a decision making. Some modifications are also commonly applied to the data according to several rule sets, in order to reach the purpose. Aggregation of geographical data is likely to be done to create one-dimensional values for some proposed alternatives. “The difference with conventional multicriteria decision analysis is the large number of factors necessary to identify and consider, and, the extent of the interrelationships among these factors. These factors make spatial multicriteria decision analysis much more complex and difficult"(Malczewski, 2006)

2.4.2. Spatial Multi Criteria Analysis and GIS for Spatial Planning

GIS and Multi Criteria Decision Making (MCDM) are tools that can support the decision makers in achieving greater effectiveness and efficiency in the spatial decision-making process. The combination of multi-criteria evaluation methods and spatial analysis is referred as Spatial Multiple Criteria Evaluation "SMCE". SMCE is an important way to produce policy relevant information about spatial decision problems to decision makers (Sharifi and Retsios, 2004). Thus, SMCE is usually applied to simplify a complex problem, extract it into more structured problem with each solution and criteria. According to Keeney (1992),"two major approaches can be distinguished: alternative-focused, and value-focused. The alternative-focused approach starts with development of alternative options, proceeds with the specification of values and criteria, then ends with evaluation and recommendation of an option. The value-focused approach on the other hand, considers the values as the fundamental element in the decision analysis. Therefore, it first focuses on the specification of values (value structure), then considering the values, feasible options are developed and evaluated based on the predefined value and criteria structure. This implies that decision alternatives should be generated so that the values specified for a decision situation are best achieved. In other words, the order of thinking is focused on what is desired, rather than on the evaluation of alternatives. In fact alternatives are considered as means to achieve the more fundamental values, rather than being an end. Naturally, in decision problems in which alternative options have to be developed and then evaluated, the value-focused approach can be much more effective".

3. Materials and Methods

3.1. Study Area

3.1.1. Location

Bantimurung Bulusaraung National Park (BBNP) is a new national park that has been founded since October 18th 2004, by Minister of Forestry Decree No. 398/2004. The total area of BBNP is approximately 43.750 Ha, with the total boundary length around 478, 22 km. Geographically, it is located between 119° 34' 17" – 119° 55' 13" longitude and between 4° 42' 49" – 5° 06' 42" latitude. This research was conducted in the southern part of (BBNP), with approximate area of 9.935,6 Ha (Figure 2). It is the main conflict area between community and national park authority, and there is a tendency of community area development because of its proximity to main road (provincial road). Administratively, the area is in Samangki village, Maros Regency, South Sulawesi Province, Indonesia.

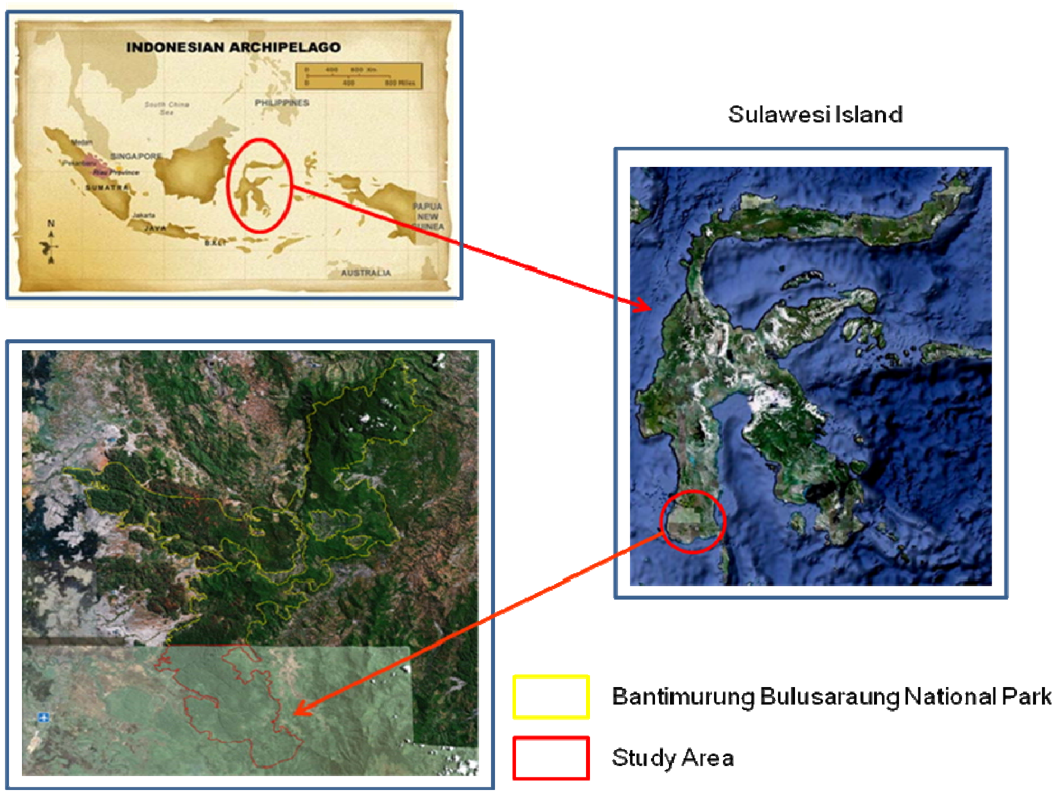


Figure 2. The location of Bantimurung Bulusaraung National Park and the study area

The reason behind the establishment of BBNP is because it has a very unique and endemic karsts ecosystem. It is known as the largest karsts ecosystem in Indonesia, the second in the world after China, and has been proposed as a "*world heritage site*"(BBNP, 2008). This giant karsts ecosystem is forming approximately 400 caves with many different ornaments which attract tourists and researchers to explore their beauty and potency (BBNP, 2008). As a habitat for wildlife, BBNP is also famous as "*the kingdom of butterfly "because* there are 103 species of butterfly living inside the park and also as the habitat of the extinct smallest primate Tarsius (*Tarsius spectrum*)(Figure 3). More potential things in BBNP could be found as waterfalls, natural ponds and rivers and also many key species such as Maccaca Maura (black maccaca), Kuskus Beruang (*Ailurops ursinus*), Kuskus Kecil (*Stigocuscus celebensis*), birds and reptiles.

Figure 3. The main assets of Bantimurung Bulusaraung National Park (Karsts ecosystem, wild butterfly, and smallest primate; Tarsius spectrum). Source : BBNP,2008

3.1.2. Climate

Referring to Schmidt and Fergusson classification(Schmidt and Fergusson, 1951), the climate in southern part of BBNP is categorized as type D, central part as type C and northern part is type B. The rainfall map of BBNP shows four rainfall areas, ranging from 2,250 – 3,750 mm/year. The range of 3,250-3,750 mm/year rainfall covers 75% of karsts area in which there are less human activities because inaccessible condition and 25% spreads in southern part of BBNP which are non-karsts area and relatively flat topography where agricultural land can be easily found. The average monthly rainfall in BBNP is shown in Figure 4.

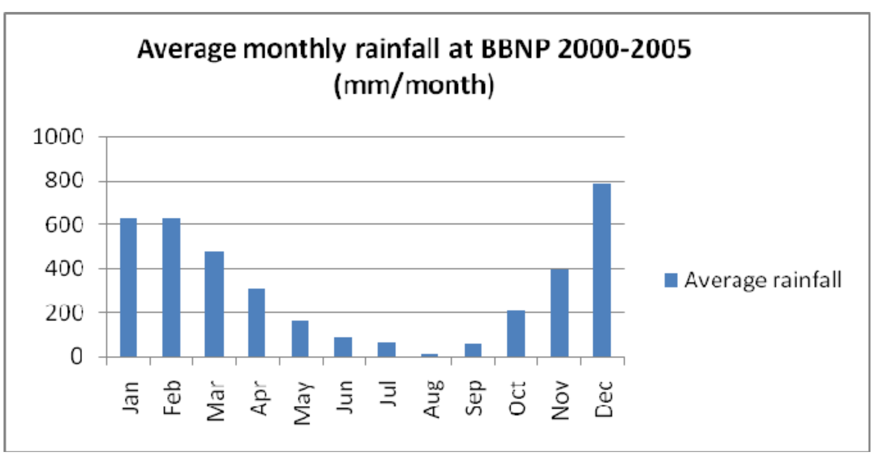


Figure 4. Average monthly rainfall in BBNP 2000-2005 (mm/month).

Temperature level in BBNP ranging from 21.7^{o} C(min) and 34.2^{o} C(max) in 2007. The average monthly temperature in Bantimurung, which is collected from Hassanuddin meteorology station is shown in Figure 5.

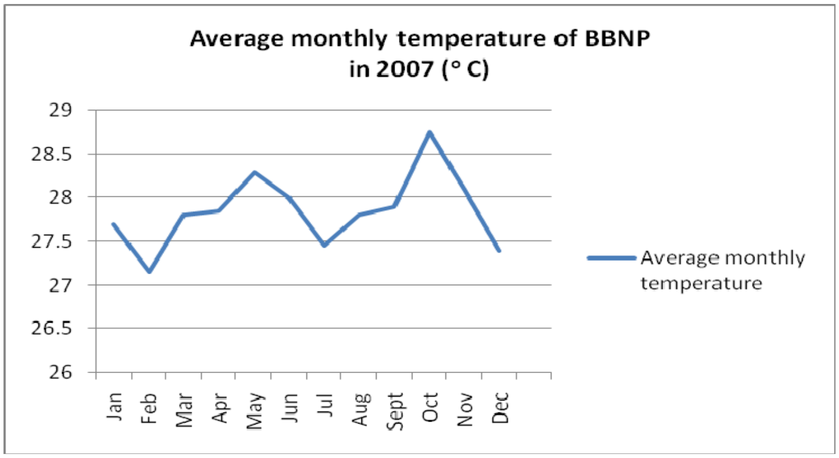


Figure 5.Average monthly temperature in BBNP 2007 (0C)

The monthly relative humidity in BBNP, which is also reported from Hassanuddin meteorology station by month, can be seen in Figure 6.

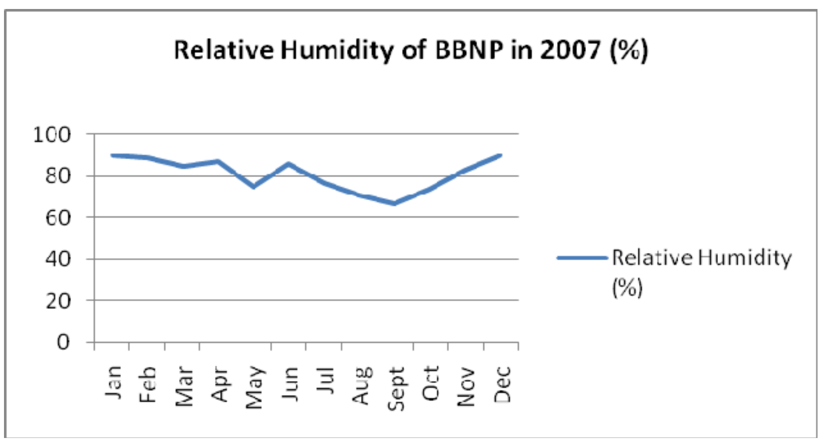


Figure 6. Average monthly relative humidity of BBNP in 2007 (%)

3.1.3. Geology, Geomorphology and Soil

Geological condition in BBNP is composed of sedimentary rocks which are sandstone, clay-rock, and conglomerates. Other types are breccia, basalt, gypsum, andesite, limestone, bioclastic, calcarenit, calsirudite, grabodiorite, basalt-phyroxin and alluvium-sediment. There are two main type of soil in BBNP, which are Rendolls with its high organic matter, mostly located in flat-valley area, in southern part of BBNP and Eutropepts, a part of Inceptisol type, commonly found in steep slope and the peak of karsts.

3.1.4. Topography

The surface condition of BBNP is varied from flat, undulating, hilly and mountain. High mountain area is located in north-east part (Bulusaraung Mountain), with its highest point 1.565 m asl. This side is characterized mostly by high relief topography, very steep slope, sharp and coarse surface. Hilly area covers central part of BBNP, with smooth up to medium relief or texture, medium steep or flat slope and some valley area. The other part in south direction is dominated by flat land with flat-undulating topographic relief and smooth texture. In between of this area are filled by tower karsts (Figure 7).

Figure 7. Landscape of Bantimurung Bulusaraung National Park. Source : BBNP, 2008

3.1.5. Land Cover Type

Table 1 shows land cover types of BBNP surveyed in 1987.

Table 1. Land cover types of BBNP Surveyed in 1987 (RPTN BBNP, 2008)

No.	Land Cover Type	Width (Ha)	%
1.	Primary forest	34,348.89	78.70
2.	Secondary forest	8,105.21	18.57
3.	Clear land	826.34	1.89
4.	Settlement	42.79	0.10
5.	Paddy field	324.02	0.74
	Total	**43,647.26**	**100.00**

Source : Long Term Management Plan (RPTN) of BBNP, 2007

BBNP is covered by tropical vegetation types (RPTN BBNP,2008) which are:
Wanga Palm (*Piqafetta filaris* and *Arenga sp*.), Uru (*Elmerillia* sp.), *Casuarina* sp., *Duabanga moluccana, Eucalyptus deglupta, Agathis philippinensis, Ficus* spp., Bitti (*Vitex cofassus*), Nyatoh (*Palaquium obtusifolium),* Cendrana (*Pterocarpus indicus*), *Sterqulia foetid,* Aren/Sugar Palm (*Arenga pinnata*), Kemiri/Candlenut (*Aleurites moluccana*), Bayur (*Pterospermum celebicum,* Eboni (*Diospyros celebica*), Jabon (*Antocephalus cadamba*) , Nyamplung (*Calophyllum inophyllum*) and many other species.

3.1.6. Socio Economic

Most of population in the study area is Makassar and Bugis tribes. About 80% is indigenous people, while the rest comes from outside area. This population is revealed to be existed in this area since a long time ago, from their ancestor and it is proven by the graveyard located there. In general, the people living around and inside BBNP work in farming or agriculture, trading and raising cattle. Approximately, about 70% of population is working as farmers, who have around 0.5-1 ha agriculture land per family (Parrang, 2008). They cultivate paddy field and plant Kemiri or Candlenut (*Aleurites moluccana)*, cocoa and coconut in their plantation. For livestock nurture, they raise bulls, cow and goats. Other activities are related to forest yield collection such as palm sugar, honey bees, butterflies, fuel wood and furniture wood.

3.2. Materials

3.2.1. Data

Table 2 shows the data that will be used in this research work.

Table 2. Available data for this research

No	Type of data	Date	Source	Remarks
a.	**Satellite imageries**			
1.	Geoeye	30-4-2009	Google Earth	0.4 m spatial resolution
2.	Landsat ETM 2002	12-9-2002	www.glovis.usgs.gov	30 m resolution
3.	Landsat ETM 2009	02-11-2009	www.glovis.usgs.gov	30 m resolution
b.	**Maps**			
2.	River map	2008	Topographic map	1:50.000
3.	Road map	2008	Topographic map	1:50.000
4.	Rainfall map	2008	Maros Statistical Agency	1:50.000
5.	Soil type map	16-06-2008	Topographic map	1:50.000
6.	Administrative map	2008	Maros Statistical Agency	shapefile
7.	Tourism Object map	16-06-2008	Topographic map	1:50.000
8.	Flora fauna map	16-06-2008	Topographic map	1:50.000
9.	Land cover map	2002	BBNP	shapefile
11.	DEM	2008	SRTM South Sulawesi	90m spatial resolution
c.	**Other data**			
1.	Demographic data	2006-2008	Maros Statistical Agency	
2.	Strategic plan of BBNP	2007-2009	BBNP authority	document
3.	Long Term Management Plan	2008-2027	BBNP authority	document

3.2.2. Software

Several software are used in this research such as ArGIS 9.3, ERDAS IMAGINE 10, ILWIS 3.7 and ECognition 8 Developer.

3.3. Methods

Overall method of this research consists of 3 parts analysis, which is shown in Figure 8 below.

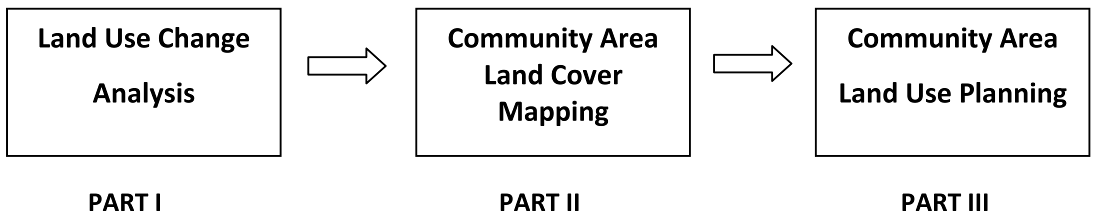


Figure 8. Research general framework

3.3.1. PART I: Land Use Change Analysis

This analysis compared land cover of two images of study area in 2002 and 2009. Detailed flowchart of this part of method is shown in Figure 3.8. The maximum likelihood supervised classification using ERDAS Imagine 9 was applied on both Landsat-7 TM image (30 m resolution) acquired on 12 September 2002 and 02 November 2009, with band combination RGB 542 *(see appendix 1.).* The classification divided objects into 2 classes, forest and non forest to detect deforestation and reforestation area in that period. Looking at the two images, 2002 image was cloud free, while 2009 image has some cloudy areas. To equalize the area of classification, cloudy area subtraction was applied for image 2002, using correspondent cloud area in 2009. The classification result was then overlaid to detect the change area using raster calculator in spatial analysis in ArcGIS software. The overlaid two images generated a land use change image, consisting deforestation, reforestation and no change classes. From this calculation, the area of changes was generated in pixel number and then converted to hectare. The result of this part was become the basis of the next analysis, which is community area mapping to detect the distribution of community activities. After acquiring deforestation area, regression analysis was then run to assess the relationship between deforestation and population growth. In this analysis, deforestation was represented by forest cover change in 2002-2009 and it was correlated to population growth in 2002-2009 within 3 villages located inside study area. Forest cover area in 2002-2009 was produced based on deforestation rate, calculated using Puyravaud (2003) formula. The relationship between forest cover and population growth was described based on R^2 value from regression analysis using SPSS 16 software.

Land use change analysis followed the flowchart in Figure 9.

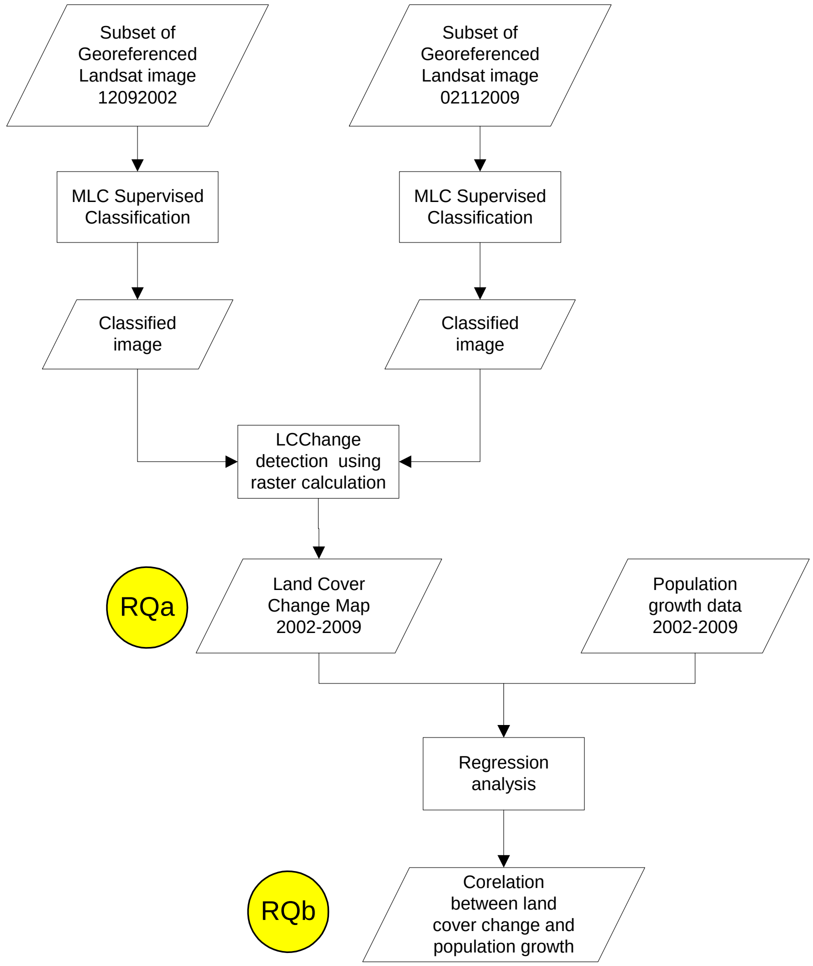


Figure 9. The flowchart of land cover change analysis

3.3.2. PART II: Community Area Land Cover Mapping

This part is addressed to classify the land cover types in the study area based on GeoEye image (acquired on 30 April 2009), which is downloaded from Google Earth. For this research, GeoEye image was used because this image can be downloaded easily from Google earth and it is free. Fortunately, this image has a high spatial resolution which is 0.4 m, which means objects can be easily distinguished. This high spatial resolution is required because this research want to map community existence inside BBNP which is formed as settlement, paddy field and dryland plantation. The location of those community objects is relatively scattered or not clustered, so, it is need to differentiate each single objects using high spatial resolution image to get detail information.

The classification techniques used were Supervised Maximum Likelihood Classification (MLC), Object Based Classification (OBC) and visual interpretation (knowledge based delineation). In order to run the classification and test the accuracy of the output (land cover maps) of these three techniques effectively, training and test samples were selected from different land cover types within the study area. A subset area was selected, which was assumed to represent all cover type classes within the study area (Figure 10). Consequently, the mentioned samples were selected from the subset area to do the classification and interpretation process. Technique having the highest accuracy on the cropped area was used to classify the whole study area.

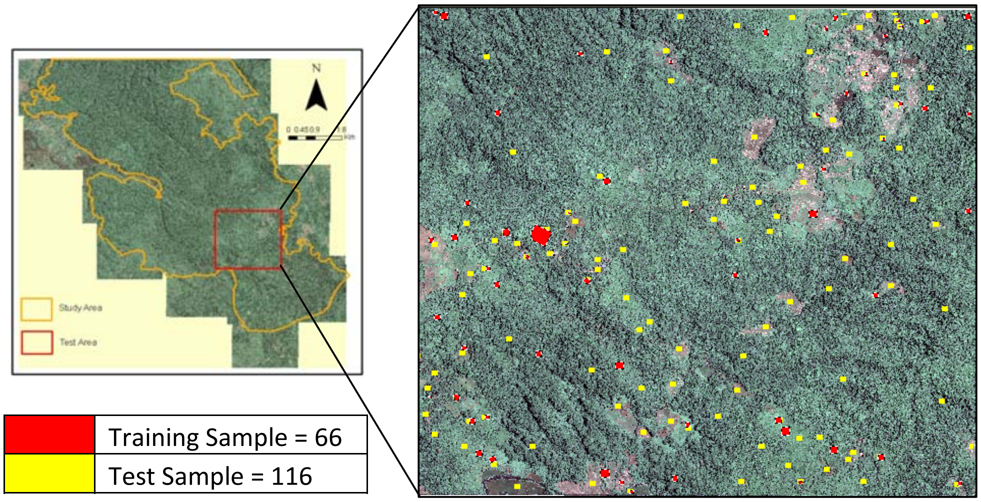


Figure 10 . Sub-set area used to run the classification and interpretation of different land cover types.

The process of land cover mapping of the community area is illustrated in Figure 11.

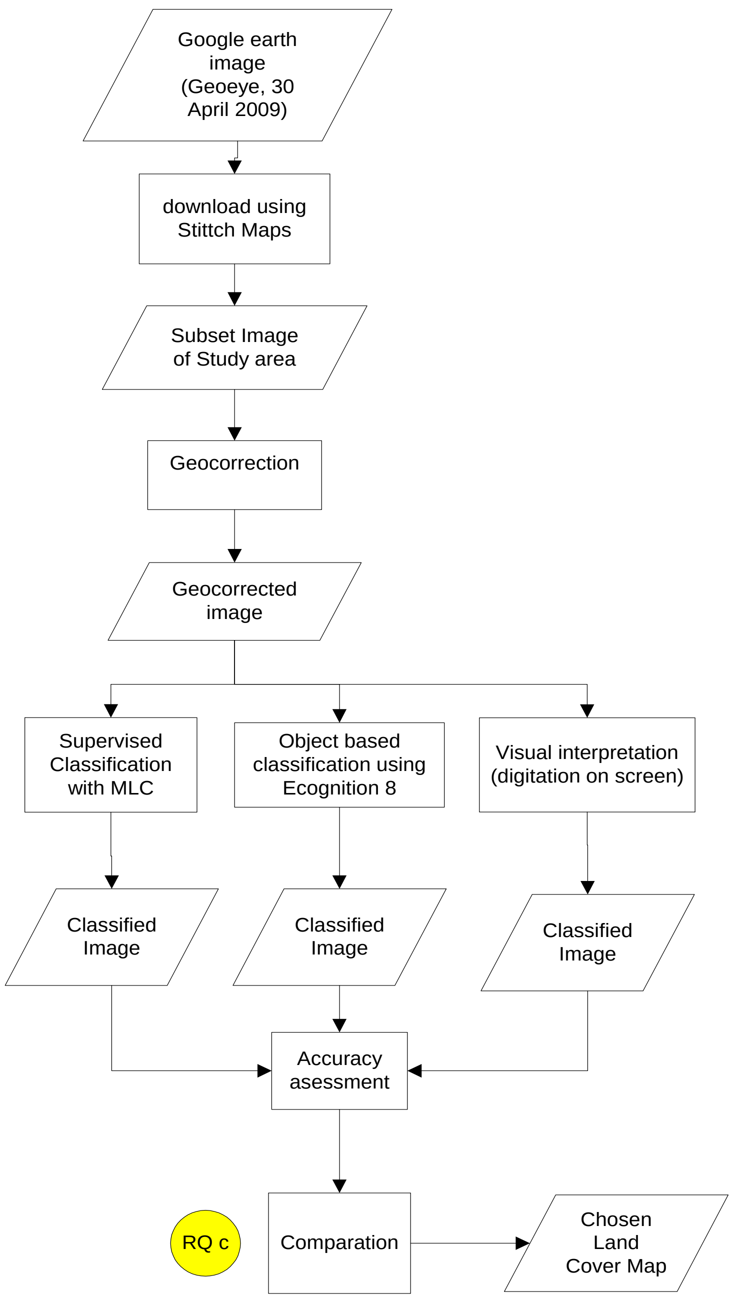


Figure 11. The flowchart of land cover mapping process of community area.

a. Maximum Likelihood Classifier (MLC) Supervised Classification

This method classifies pixel by checking its Euclidean distance to class center, looking at the shape and the orientation of defined (supervised) training samples in feature space(Fauzi, 2001).It works based on the highest probability in statistical parameter to define which class a pixel belongs to. ERDAS Imagine was used to apply this method.

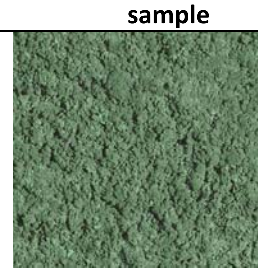
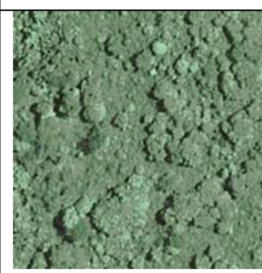
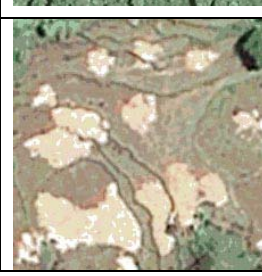
b. Object Based Classification

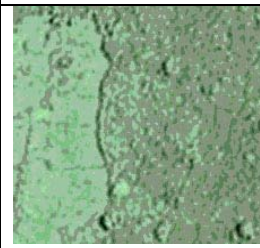
The main different of this method compare to MLC supervised classification is on the basis of classification. This method uses nearest neighborhood classifier to differentiate classes based on segmented object from groups of pixels. In this step, Ecoqnition 8 software was employed to run the classification. Specifically, the classification was applied on Quick Map Mode, with the setting of scale parameter (SP) 25, shape 0.2 and color 0.7. Scale parameter represents the homogeneity level of object segment, means the higher the scale the more homogeny the grouped object. The color and shape value refer to the basis of segmentation. The higher value between color and shape will be the priority basis in segmentation than the other. These values were chosen as the final setting after several iterations and it resulted the most appropriate segment in grouping pixels based on different object (houses, trees, paddy field etc).

c. Visual Interpretation

The visual classification was done by manual delineation of specified objects on GeoEye image (30 April 2009), downloaded from Google Earth. The object delineation of the image was completed using ArcGIS software according to the specification of each class which is provided in Table 3.

Table 3. Class description for land cover visual interpretation on Google Earth image

No	Cover type	Description	Google earth image sample
1	**Intact Forest**	Forest with relatively dense tree canopy. The tree canopy even overlapped each other. It is located quite far from settlement	
2	**Degraded forest**	Visually, this class is shown by forest which less canopy density, some trees are already exploited. It is usually located close to settlement, paddy field or dryland plantation which is easily accessed.	
3	**Paddy field**	Object with relatively unique shape, brown/light green color and elongated line pattern.	

4	**Settlement**	This class is indicated by rectangular roof of settlements which some are clustered and many others are scattered in different places, usually next to paddy field or dryland plantation.	
5	**Dryland plantation**	It has similar with other vegetated area color, but with rough texture and more regular crop pattern.	
6	**Cleared land**	It means areas that have flat, smooth texture with light green color and without trees on its surface.	

3.3.3. PART III: Community Area Land Use Planning

3.3.3.1. Multi Criteria Analysis for Land Use Allocation

This analysis is intended to configure land use allocation in study area by involving spatial and thematic data. Land use allocation was proposed for designation of special use zone. ILWIS 3.6 Spatial Multi Criteria Evaluation (SMCE) was applied to help site selection process according to defined objectives and alternatives.

The flowchart of analysis is illustrated in Figure 12, which can be explained as follows:
The main objective of this part of the analysis is to produce a land use allocation map based on suitability value for defined alternatives. Furthermore, this main objective was divided into three sub-objectives which represent three types of area allowed to be established within a special use zone based on Ministry of Forestry regulation (Permenhut) no. 56 about Zoning Principal in National Park. These three areas are protection, rehabilitation and community development area. Within study area, community development area is represented by agriculture area. These three area site selection were determined in different criteria tree using ILWIS SMCE software to obtain suitability value. The development for each criterion was the next step, which only relies on biophysical aspect and generated based on literature reviews and stakeholder preferences throughout questionnaire distribution. Several raster maps from available thematic data were used to create suitability map refer to each alternative function (protection, rehabilitation and agriculture). The next process was standardization of different criterion to equalize different value from input maps. Weighing for each

criterion was defined by several stakeholders who concern to national park management through questionnaires distribution. Weighted summation was run after that to calculate the total value of each criterion in constructing the three areas. The final output of each criteria tree is a suitability map for protection, rehabilitation and agriculture area. At the last part, the three suitability map was split into suitable and non suitable area based on each suitability value. Then, the suitable area for each function (protection, rehabilitation and agriculture) will be merged to create a land use allocation map to propose spatial plan for special use zone. The final result of this process is a composite index map in which each pixel indicates value for certain suitable area.

Figure 12 illustrates the whole steps applied in spatial multicriteria analysis using ILWIS SMCE 3.7 software.

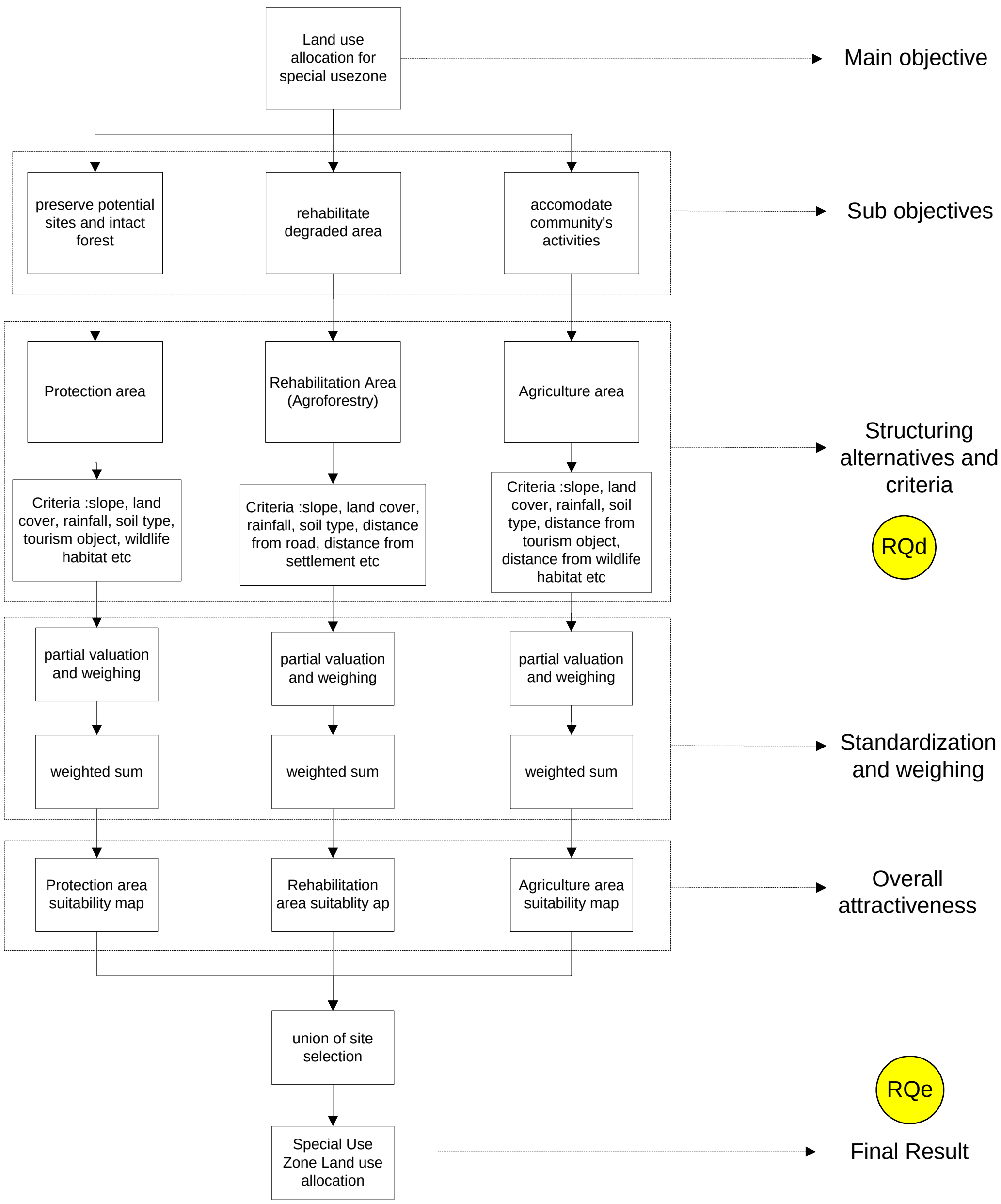


Figure 12. The flowchart of spatial planning of community area. (Partly after Sharifi, 2004).

4. Result

4.1. Land Cover Change Analysis

4.1.1. Land Cover Map 2002 and 2009

This analysis aimed to detect deforestation and assess its rate in the study area. Therefore, classification only divided classes into two, forest and non forest. Land cover map 2002 and 2009 was generated based on image classification using Supervised Classification (Maximum Likelihood Classifier) in ERDAS Imagine software. The images used for the classifications were from Landsat -7 TM, acquired on 12 September 2002 and 2 November 2009. The results of the two classifications are in Figure 13 and 14.

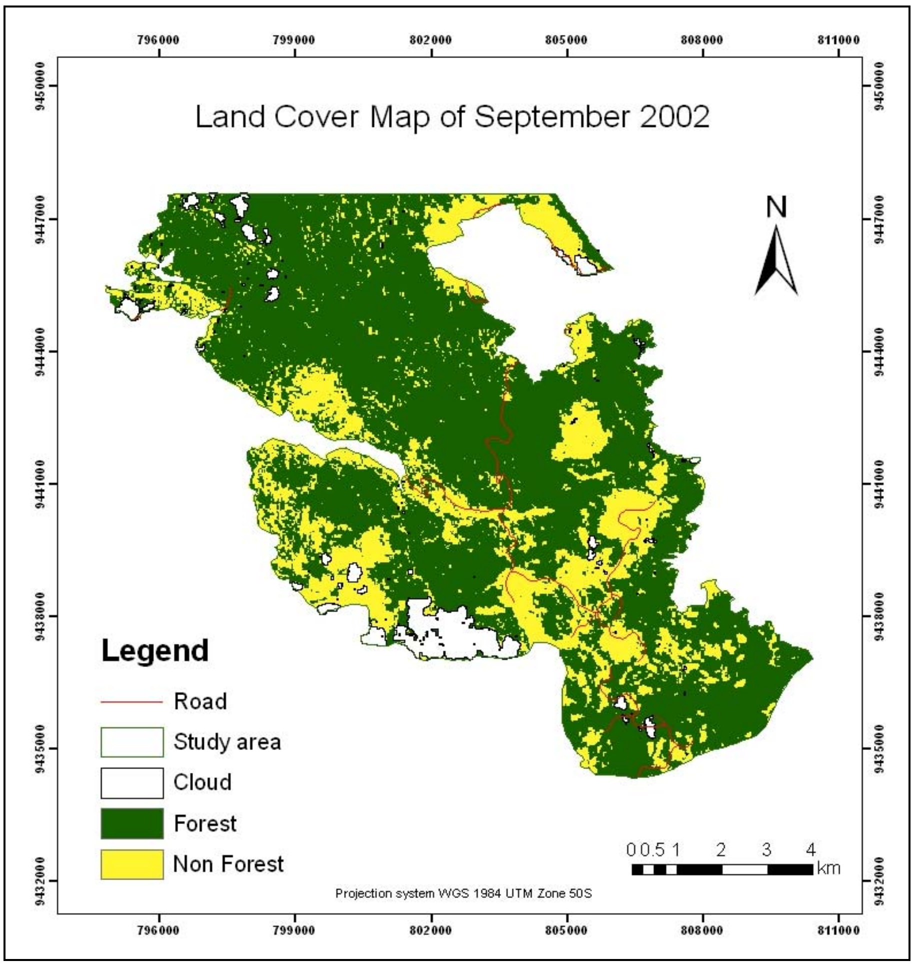


Figure 13. Land cover map of 2002

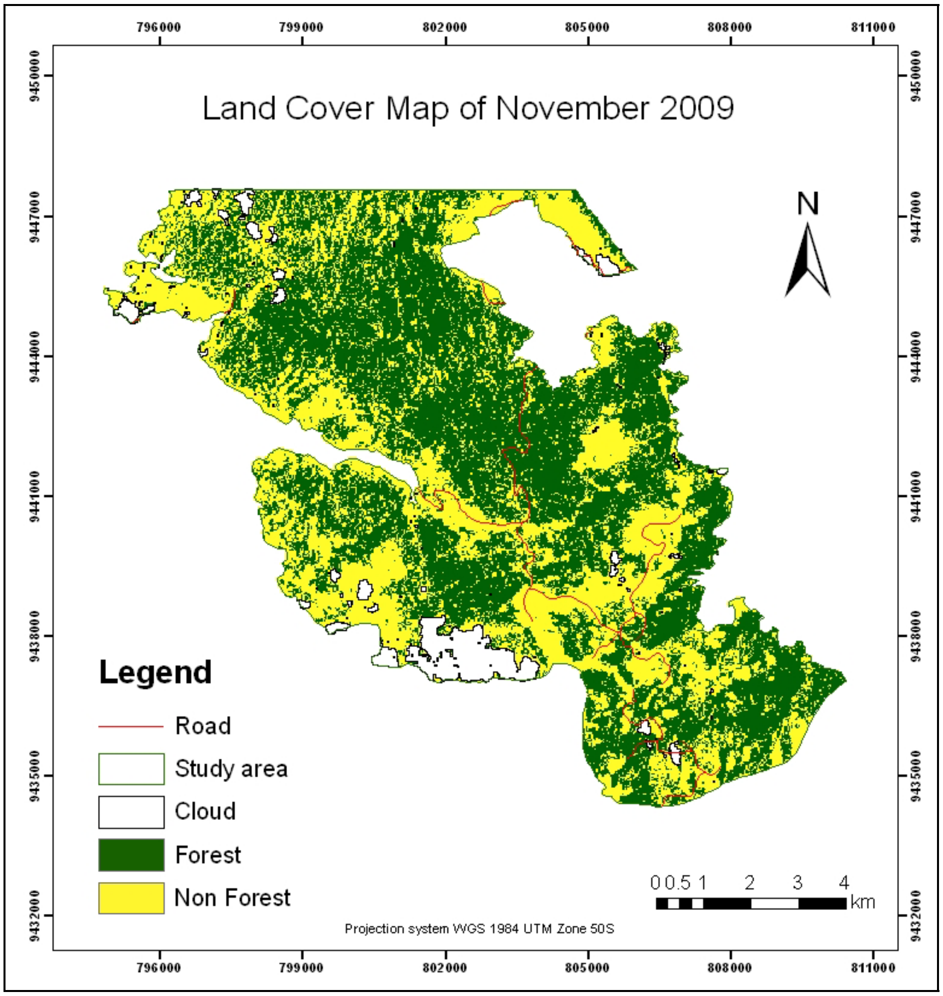


Figure 14. Land cover map of 2009

Figures 13 and 14 show the land cover condition of study area in both 2002 and 2009. Landsat-7 TM image of 2002 is cloud free, while the image of 2009 has cloud cover of 4.05 percent or an area of 406.91 ha. To equalize land cover change, identical area of clouds on 2009 image was masked from the image of 2002. The overall land cover area of 2002 and 2009 are indicated as Table 4 below.

Table 4. Comparison of land cover area in 2002 and 2009

Land cover	**Area (Ha)**			
	2002	**%**	**2009**	**%**
Forest	7119.09	70.81	5455.35	54.26
Non forest	2528.37	25.15	4192.11	41.69
Cloud	406.91	4.05	406.91	4.05
Total	10.054,37	100	10.054,37	100

Graphically, land cover change in 2002 and 2009 can be seen in the Figure 15.

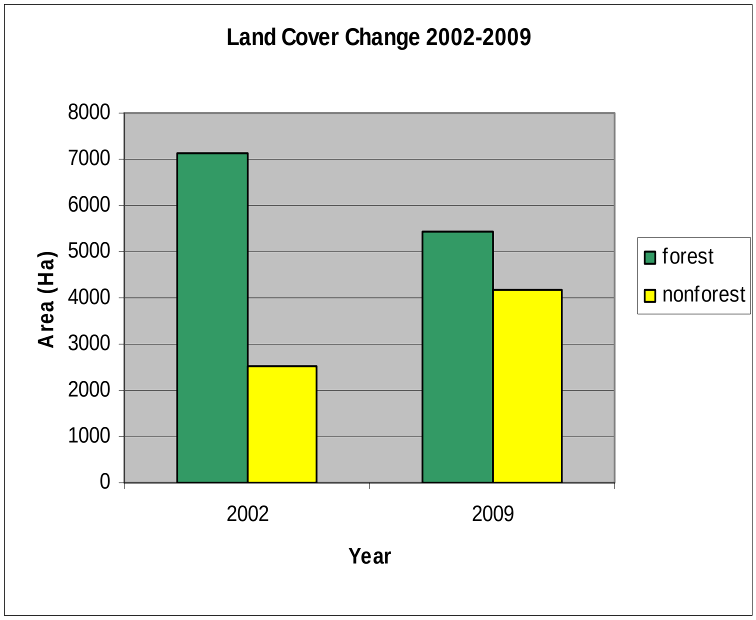


Figure 15. Land cover change in 2002 and 2009

Table 4 and Figure 15 show the change of forest and non forest area. In seven years (i.e. 2002 to 2009) forest area decreased from 7119.09 ha (70.81%) to 5455.35 ha (54.26%). On the other hand, non forest areas increased from 2528.37ha (25.15%) to 4192.11 ha (41.69%).

4.1.2. Accuracy Assessment

The accuracy assessment for 2002 image was done using the test samples of land cover map 2002 developed by Forest Mapping Agency of Sulawesi, while for 2009 image, test sample were selected from 0.4 meter high resolution Geoeye, 30 April 2009(Google Earth date of access). The first source was used as reference because it is a product of in charge institution related to forest area mapping, which is made based on Landsat image interpretation combined with field observation data. The second source was employed because it has high resolution image that can show a quite detail and easily recognized objects.

a. Land Cover Classification 2002 Accuracy

   Accuracy assessment for both Landsat images in 2002 and 2009 was performed as error matrix and overall accuracy. For Landsat image 2002, error matrix and overall accuracy are presented in Table 5 and Table 6.

Table 5. Error matrix for land cover map 2002

Classified Data	Unclassified	Forest	Non Forest	Row Total
Unclassified	1	0	0	1
Forest	0	46	21	67
Non Forest	0	3	37	40
Total	**1**	**49**	**58**	**108**

Table 6. Total accuracy assessment for land cover of 2002

Class Name	Reference Total	Classified Total	No. of correct	Producer's Accuracy	User's Accuracy
Unclassified	1	1	1	---	---
Forest	49	67	46	93.88%	68.66%
Non_forest	58	40	37	63.79%	92.50%
Total	108	108	84		
Overall Classification Accuracy = 77.78%					

b. Land Cover classification 2009 Accuracy

Accuracy assessment for Landsat image 2009 classification was performed in error matrix (table 7) and overall accuracy (Table 8).

Table 7. Error matrix for land cover map of 2009

Classified Data	Unclassified	Forest	Non_forest	Cloud	Row Total
Unclassified	1	0	0	0	1
Forest	0	19	8	0	27
Non_forest	0	4	67	0	71
Cloud	0	0	5	0	5
Total	**1**	**23**	**80**	**0**	**104**

Table 8. Total accuracy assessment for land cover of 2009

Class Name	Reference Total	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	1	1	1	---	---
Forest	23	27	19	82.61%	70.37%
Non forest	80	71	67	83.75%	94.37%
Cloud	0	5	0	---	---
Totals	104	104	87		
Overall Classification Accuracy = **83.65%**					

4.1.3. Land Cover Change 2002-2009

The land cover change map below was generated using raster calculator function in ArcGIS by overlaying the two land cover map sof 2002 and 2009. Cloud subtractions were applied for both images to equalize the total area. Finally, the overlaid map divided classes into 2 types of changes which are deforestation and reforestation based on forest and non-forest cover types, as shown in Figure 16 below:

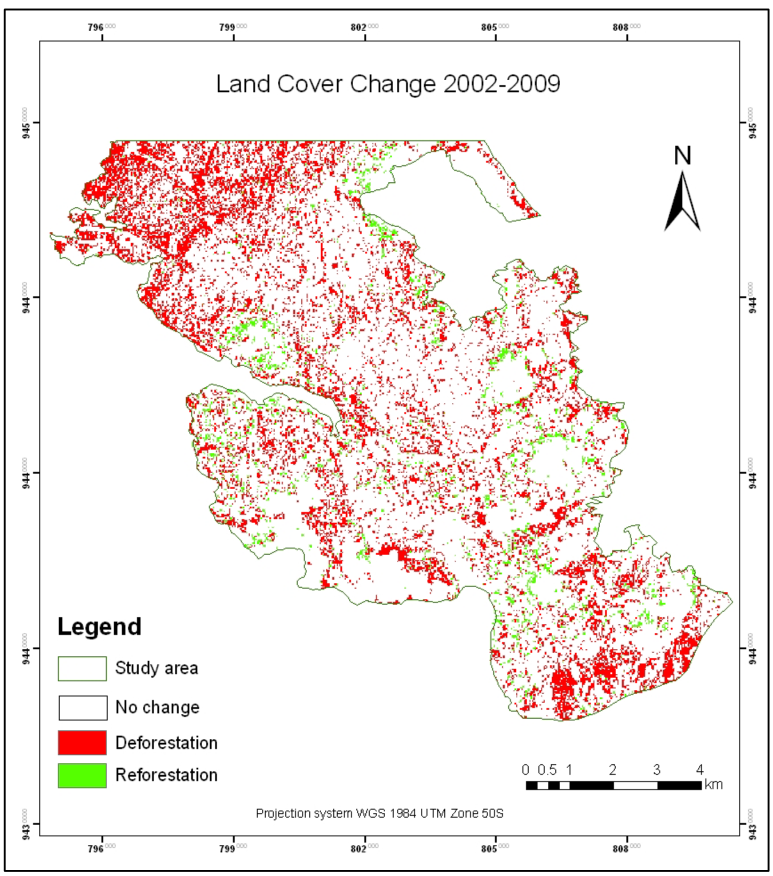


Figure 16. Land cover change map 2002 – 2009

The changes in the study area from forest to non forest classes produce the overall area as shown in Table 9.

Table 9. Land cover change area detection from 2002-2009

Changes	Pixel	Area (Ha)	%
Deforestation	21939	1,974.51	20.45
Reforestation	3453	310.77	3.22
No Change	81802	7,362.18	76.31
Total	**107194**	**9647.46**	**100**

Deforestation is detected larger than reforestation according to land cover change analysis, shown in Table 4.6. The total area deforested in the period of 2002-2009 is 1,974.51 ha (20%) while reforestation is only 310.77 ha (3.22%). About 7,362.18 ha (76.31%) area is remain the same or no change.

4.1.4. Relationship between Land Cover Change and Population

The relationship between land cover changes and population can prove that deforestation rate is correlated with population growth, especially in the village located within study area.

4.1.4.1. Deforestation Rate (2002-2009)

It is calculated according to Puyravaud (2003) equation as follow:

$$R = 1/(t2-t1) \times \ln(A2/A1)$$

R : Deforestation rate (*to ease the next calculation, this value was converted in %)*
t2 and t1: year, A2 and A1 : forest cover in t2 and t1 respectively

The deforestation rate result was based on the calculation for the period of 2002-2009 **is 0.04 or 4 %.** The rate was then used to calculate forest cover area for the period of 2002 - 2009. Forest cover within study area in 2002-2009 as the calculation result based on deforestation rate is indicated in Table 10.

Table 10. Annual forest cover for the period 2002-2009

Year	Forest (ha)
2002	7119.09
2003	6834.326
2004	6560.953
2005	6298.515
2006	6046.575
2007	5804.712
2008	5572.523
2009	5455.35

4.1.4.2. Population Growth

The calculated population growth was derived from the population data of three villages located within and around the study area. It is indicated in the Table 11. These three villages were selected to be correlated with land cover change because of their location and accessibility to national park, which is supported by road network.

Table 11. Population of three villages in and around BBNP for the period 2002-2009

Year	Population of village			Total
	Samangki	Sambueja	Jenetasa	
2002	4284	4031	3486	11800
2003	4333	4089	3486	11907
2004	4382	4148	3536	12066
2005	4407	4209	3587	12203
2006	4474	4272	3641	12387
2007	4534	4333	3691	12558
2008	4585	4395	3744	12725
2009	4651	4458	3797	12906

The three villages considered in this relation are located within BBNP border, which can be illustrated in Figure 17 below.

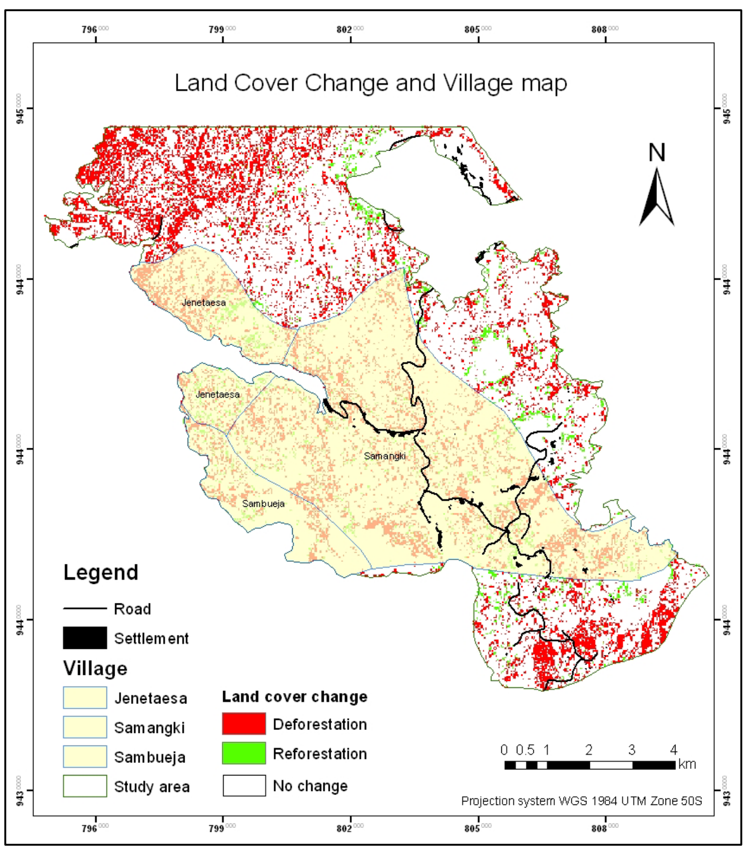


Figure 17. Land cover changes in relation to the three villages in and around BBNP

4.1.4.3. Regression analysis

Regression analysis was applied to assess the relationship between deforestation and population growth. The analysis was run using SPSS 16 and the result is shown in Table 12.

Table 12. Regression analysis result of population growth and deforestation

Variable X	Variable Y	R Square	t calc	t table	Conclusion
population	forest cover	0.98	17.6	2.132	t calc > t table = negative correlation (significant)

The result implies that there is a significant correlation between deforestation and population growth since the R Square is 0.98 and calculated t is larger than tabulated one (with df=4 and confidence level of 95% or α=0.05). The relationship is negative between the remaining forest cover and population growth (Figure 18). As population increases, forest cover decreases. In other words, more population causes the more deforestation. Graphically, this relation can be found in Figure 18.

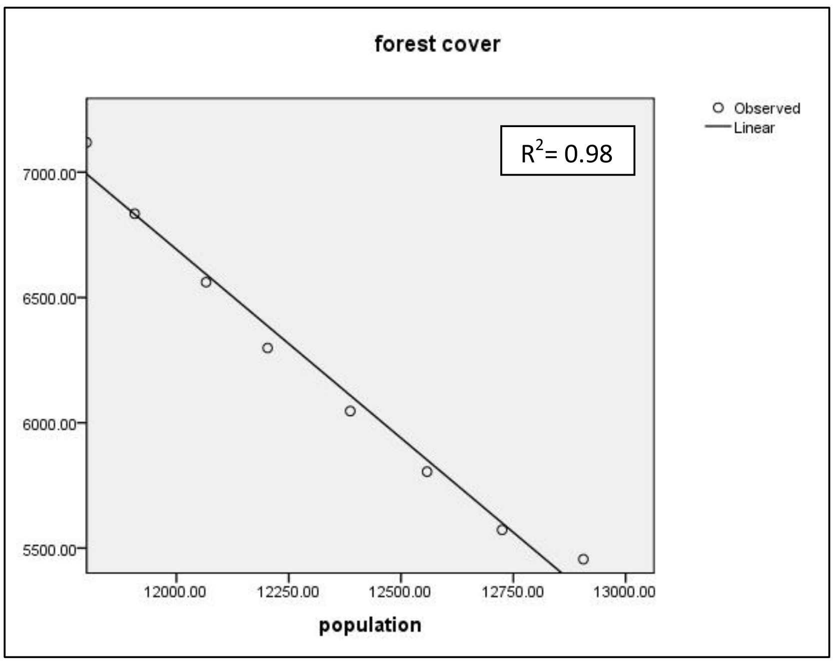


Figure 18. Relationship between population growth and remaining forest cover

4.2. Community Area Land Cover Mapping

In this part of the research, supervised maximum likelihood classification, object based classification (i.e. eCognition 8) and visual interpretation were applied to the GeoEye high resolution of 13 April 2009(Google Earth, accessed on 29 March 2010). These three methods techniques run on selected subset area of the whole study area as shown in the Figure 19.

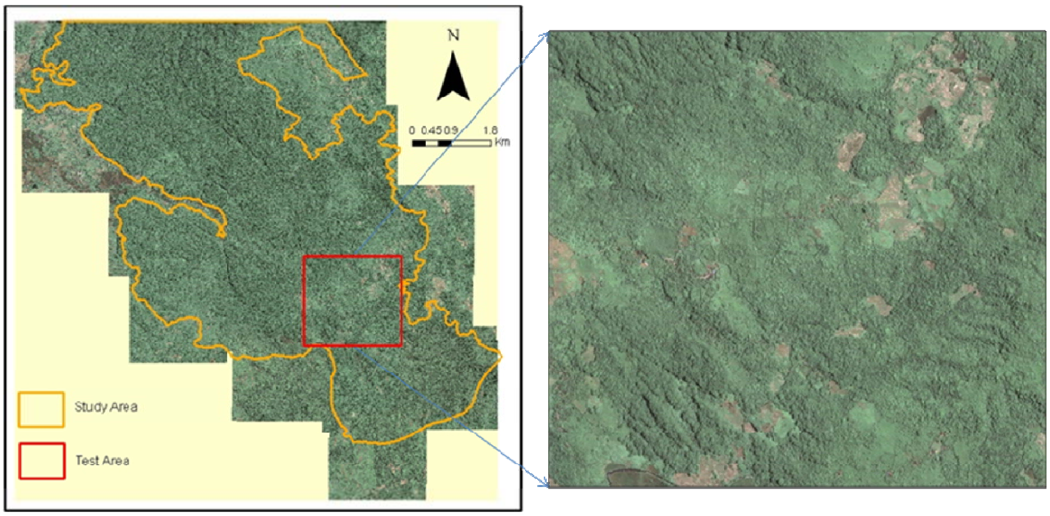
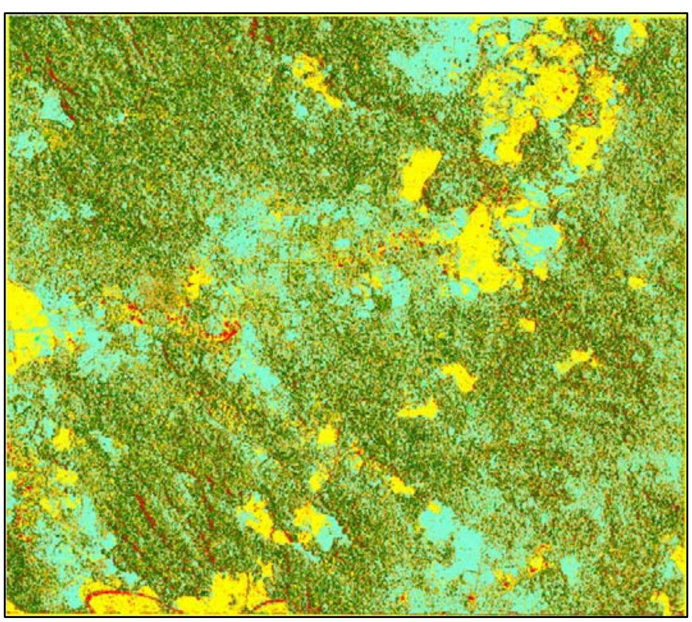


Figure 19. Selected subset area to apply supervised maximum Likelihood and object based classification.

4.2.1. Supervised Maximum Likelihood Classification (MLC)

This classification used independent groups of training samples and test samples. Test samples were collected from the field by national park staff members on April 2010. The result of classification is shown in Figure 20 while the accuracy assessments are shown in Tables 14 and 15.



Color	Class Name
	Intact forest
	Degraded forest
	Paddy field
	Settlement
	Dry land plantation
	Cleared land

Figure 20. Object based classification result on the selected subset area

Accuracy assessment

The accuracy assessment for supervised classification result was presented based on error matrix shown in Table 13 and overall accuracy in Table 14.

Table 13. Error matrix of the results of the supervised classification map of the selected sub-set

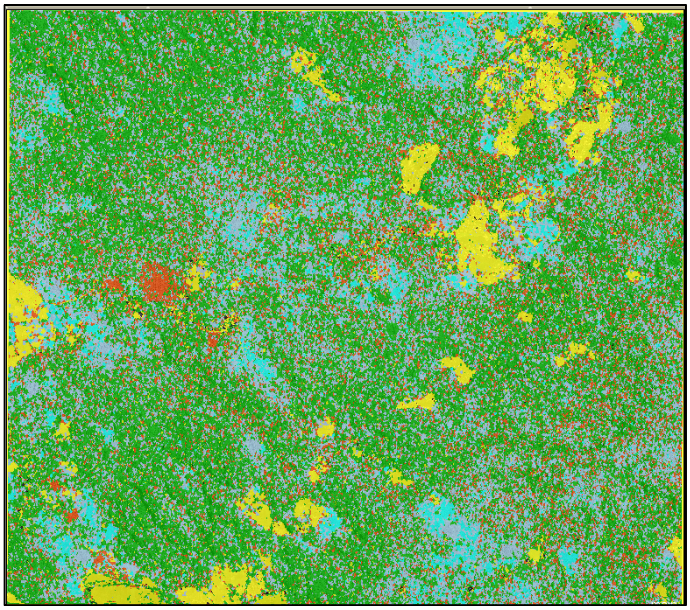
Classified Data	unclassified	inforest	degforest	paddy	settlement	dryland	clearedland	Row Total
Unclassified	1	0	0	0	0	0	14	15
Intact forest	0	6	5	0	0	1	0	12
Degraded forest	0	0	0	0	0	0	0	0
Paddy field	0	2	0	28	0	2	0	32
Settlement	0	1	0	0	29	0	0	30
Dryland plantation	0	3	5	1	0	2	0	11
Cleared land	0	4	6	1	0	5	0	16
Column Total	**1**	**16**	**16**	**30**	**29**	**10**	**14**	**116**

Table 14. Overall classification accuracy of the supervised classification map of the selected subset

Class Name	Reference Totals	Classified Totals	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	1	15	1	---	---
Intact forest	16	12	6	37.50%	50.00%
Degraded forest	16	0	0	---	---
Paddy field	30	32	28	93.33%	87.50%
Settlement	29	30	29	100.00%	96.67%
Dryland plantation	10	11	2	20.00%	18.18%
Cleared land	14	16	0	0.00%	0.00%
Total	116	116	66		
Overall Classification Accuracy = 56.90%					

4.2.2. Object Based Classification

Figure 21 illustrates land cover classification result using eCognition 8 software for selected subset area



Color	Class Name
	Intact forest
	Degraded forest
	Paddy field
	Settlement
	Dry land plantation
	Cleared land

Figure 21. Object based classification result on the selected subset area

Accuracy assessment of this classification was indicated as an error matrix and overall accuracy shown in Table 15 and Table 16.

Table 15. Error matrix of the results of the object base classification map of the selected subset

Classified data	**Unclassified**	**Cleared land**	**Degraded forest**	**Dryland plantation**	**Intact forest**	**Paddy field**	**Settlement**	**Row Total**
Unclassified	1	0	0	0	0	0	0	1
Intact forest	0	1	10	1	8	1	12	33
Degraded forest	0	1	4	1	3	1	1	11
Settlement	0	0	0	0	0	0	9	9
Paddy field	0	0	0	0	0	27	5	32
Dryland plantation	0	0	2	8	4	1	2	17
Cleared land	0	12	0	0	1	0	0	13
Column Total	**1**	**14**	**16**	**10**	**16**	**30**	**29**	**116**

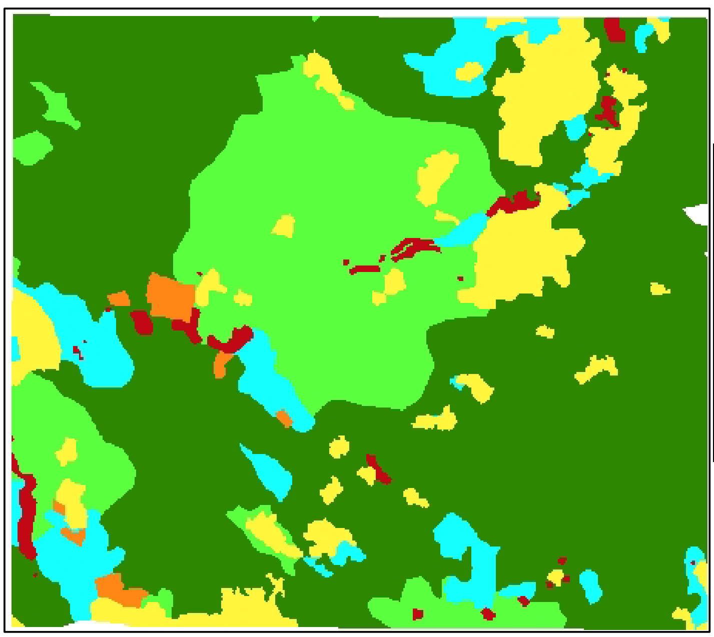
Table 16. Overall classification accuracy of the object base classification map of the selected subset

Class name	**Reference total**	**Classified total**	**Number correct**	**Producers accuracy**	**Users accuracy**
Unclassified	1	1	1	100%	100%
Intact forest	16	33	8	50.00%	24.24%
Degraded forest	16	11	4	25.00%	36.36%
Paddy field	30	32	27	90.00%	84.38%
Settlement	29	9	9	31.03%	100.00%
Dryland plantation	10	17	8	80.00%	47.06%
Cleared land	14	13	12	85.71%	92.31%
Total	116	116	68		
Overal accuracy = 58.62 %					

4.2.3. Visual Interpretation

The visual interpretation was done by manual delineation of specific objects on GeoEye image of 30 April 2009(Google Earth, accessed on 29 March 2010). Object delineation of the image was following the description of each class which is provided in methodology chapters (Table 3).

The delineation result of selected area is shown in Figure 22.



Color	**Class Name**
	Intact forest
	Degraded forest
	Paddy field
	Settlement
	Dry land plantation
	Cleared land

Figure 22. Visual interpretation classification result of the selected subset area.

The accuracy assessment for this classification technique is presented in error matrix of selected subset (Table 17) and overall accuracy in Table 18.

Table 17. Error matrix of the results of the visual interpretation map of the selected subset

Classified data	Unclassified	Intact forest	Degraded forest	Paddy field	Settlement	Dryland plantation	Cleared land	Row Total
Unclassified	1	0	0	0	0	0	0	1
Intact forest	0	16	10	0	0	0	0	26
Degraded forest	0	0	5	0	0	2	1	8
Paddy field	0	0	0	30	0	0	1	31
Settlement	0	0	1	0	29	0	0	30
Dryland plantation	0	0	0	0	0	7	0	7
Cleared land	0	0	0	0	0	1	12	13
Column total	**1**	**16**	**16**	**30**	**29**	**10**	**14**	**116**

Table 18. Overall classification accuracy of visual interpretation map of the selected subset

Class name	Reference total	Classified total	Number correct	Producers accuracy	Users accuracy
Unclassified	1	1	1	100%	100%
Intact forest	16	26	16	100.00%	62%
Degraded forest	16	8	5	31.25%	63%
Paddy field	30	31	30	100.00%	97%
Settlement	29	30	29	100.00%	97%
Dryland plantation	10	7	7	70.00%	100%
Cleared land	14	13	12	85.71%	92%
Total	116	116	68		
Overall accuracy =86.2 %					

Because of having the highest accuracy result, visual interpretation was chosen as the technique to map land cover/land use within the whole study area. According to the description of each class in Table 3, the result of visual interpretation (manual delineation) is performed in Figure 23.

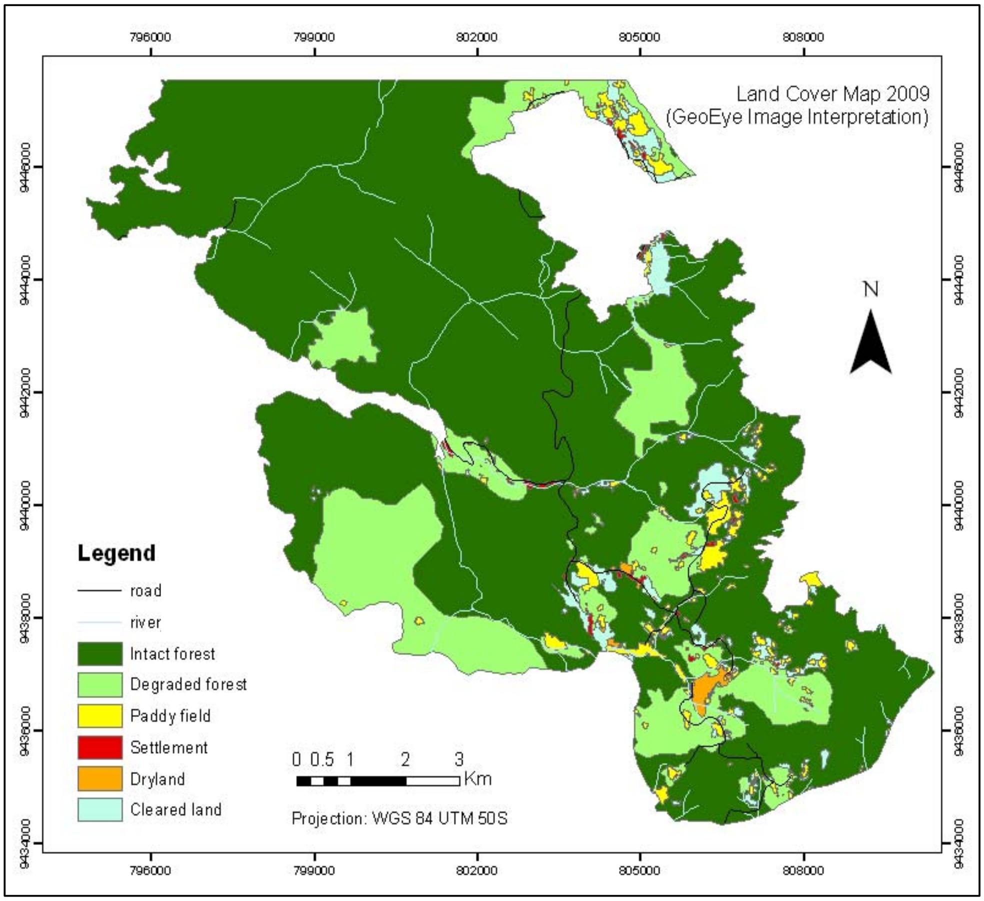


Figure 23 Land cover map based on visual interpretation of GeoEye of 30 April 2009

The overall area and percentage of each land cover type can be found in the Table 19.

Table 19. Land cover types area and percentage resulted from the visual interpretation of GeoEye image.

Class	Area (ha)	Percentage
Intact forest	7604.511	76.54
Degraded Forest	1743.292	17.54
Paddy field	260.130	2.62
Settlement	33.411	0.34
Dryland plantation	35.278	0.36
Cleared land	259.020	2.61
Total	**9935.642**	**100**

4.3. Community area spatial planning

4.3.1. Spatial Multi Criteria Analysis

According to literature review and questionnaire distribution, several biophysical criteria were obtained as the basis of suitability map production. The description of criteria to define suitable area for protection, rehabilitation and agriculture area using SMCE ILWIS 3.6 is shown in Table 20 below.

Table 20. Criteria description for land use allocation

<table>
<tr><th>Objective</th><th>Sub Objectives</th><th>Alternatives</th><th>Criteria</th><th>Group</th><th>Weight (%)</th></tr>
<tr><td rowspan="18">Land use allocation within Special Use Zone</td><td rowspan="7">Find suitable area for protection</td><td rowspan="7">Protection area</td><td>within intact forest</td><td>Constraint</td><td></td></tr>
<tr><td>within slope > 40%</td><td>Slope</td><td>40</td></tr>
<tr><td>within rainfall > 3000 mm/year</td><td>Rainfall</td><td>10</td></tr>
<tr><td>distance from tourism object 0-500m</td><td rowspan="4">Distance</td><td rowspan="4">50</td></tr>
<tr><td>distance to habitat 0-1000m</td></tr>
<tr><td>distance to river0-200m</td></tr>
<tr><td>distance to settlement >2000m</td></tr>
<tr><td rowspan="5">Find suitable area for rehabilitation</td><td rowspan="5">Rehabilitation area</td><td>within degraded forest and cleared land</td><td>Constraint</td><td></td></tr>
<tr><td>within slope <40%</td><td>Slope</td><td>60</td></tr>
<tr><td>distance to road 0-1000m</td><td rowspan="3">Distance</td><td rowspan="3">40</td></tr>
<tr><td>distance to river > 200m</td></tr>
<tr><td>distance to settlement max 2000m</td></tr>
<tr><td rowspan="7">Find suitable area for agriculture</td><td rowspan="7">Agriculture area</td><td>within paddyfield, settlement, dryland and cleared land</td><td>Constraint</td><td></td></tr>
<tr><td>Soil : fluvaquent, eutropept,humitropept and tropohumult. (Haryadi, 2009)</td><td>Constraint</td><td></td></tr>
<tr><td>Slope <40%</td><td>Slope</td><td>60</td></tr>
<tr><td>distance from tourism object >500m</td><td rowspan="4">Distance</td><td rowspan="4">40</td></tr>
<tr><td>distance to habitat >1000m</td></tr>
<tr><td>distance to river >200m</td></tr>
<tr><td>distance to settlement</td></tr>
</table>

Each criterion map used in this analysis was generated using ILWIS 3.7 software. Land cover map used the result of visual interpretation in analysis Part II. Soil map, rainfall map and slope map were obtained from available data. All distance maps (to road, settlement, river, tourism objects and flora fauna habitat) were created using Euclidean Distance function. These all input maps can be found in appendix 2.

4.3.1.1. Suitability Map

Suitability map resulted from defined criteria and weight is illustrated in Figure 24.

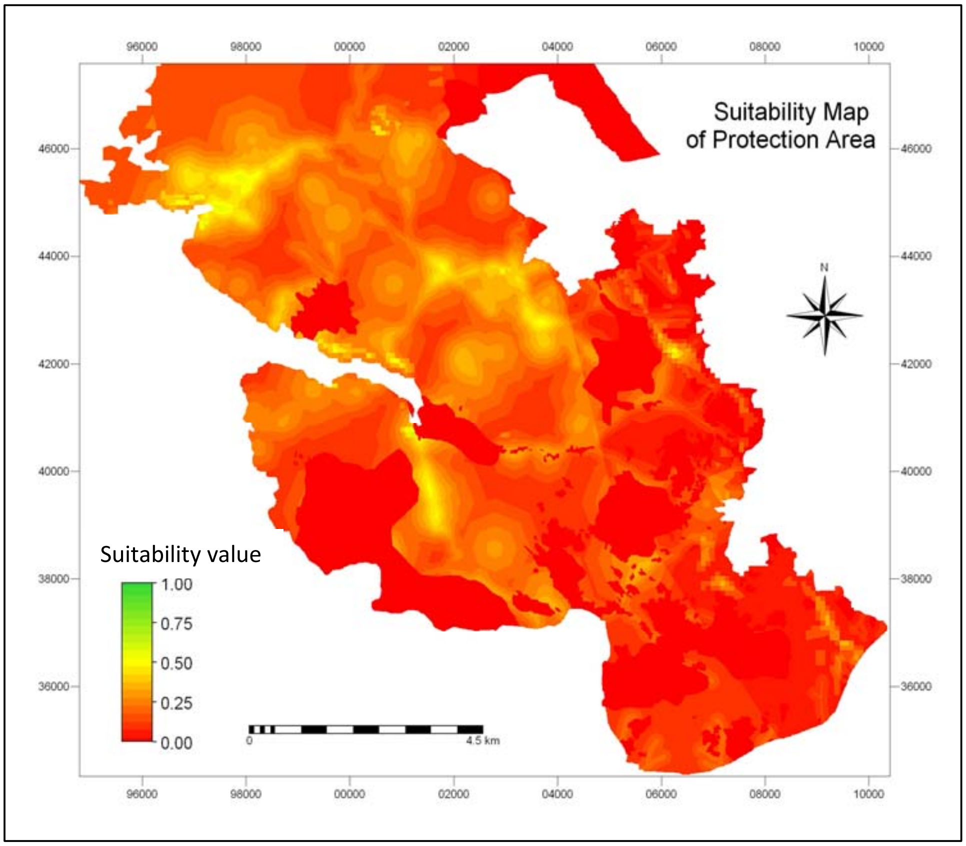


Figure 24. Suitability map of protection area

The suitability value of protection area is actually ranging from 0 – 0.64. It covers almost the whole study area since I refer to intact forest, the largest land cover type.

a. Rehabilitation Area

Suitability map for rehabilitation is shown in Figure 25.

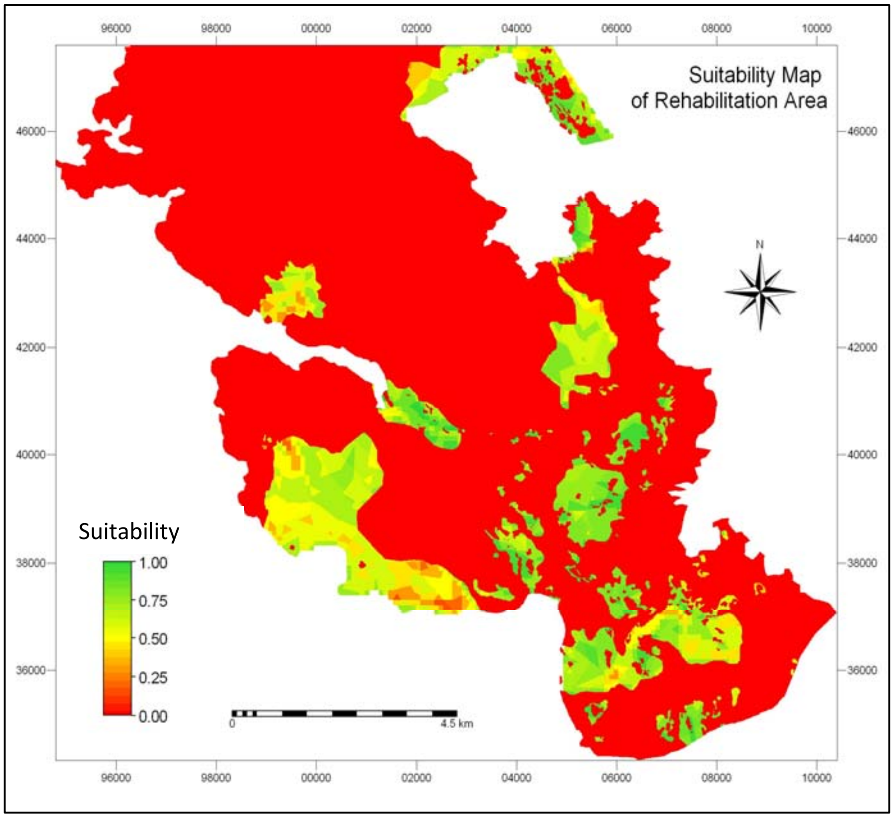


Figure 25. Suitability map of rehabilitation area

The value of suitability on rehabilitation area is ranging from 0 – 1. It means that there is value which is very suitable for rehabilitation activity, and also value which is not suitable at all to be rehabilitated. This suitability area is situated in scattered location, which has high value of rehabilitation criteria.

b. Agriculture Area

Suitability map for agriculture can be found in Figure 26.

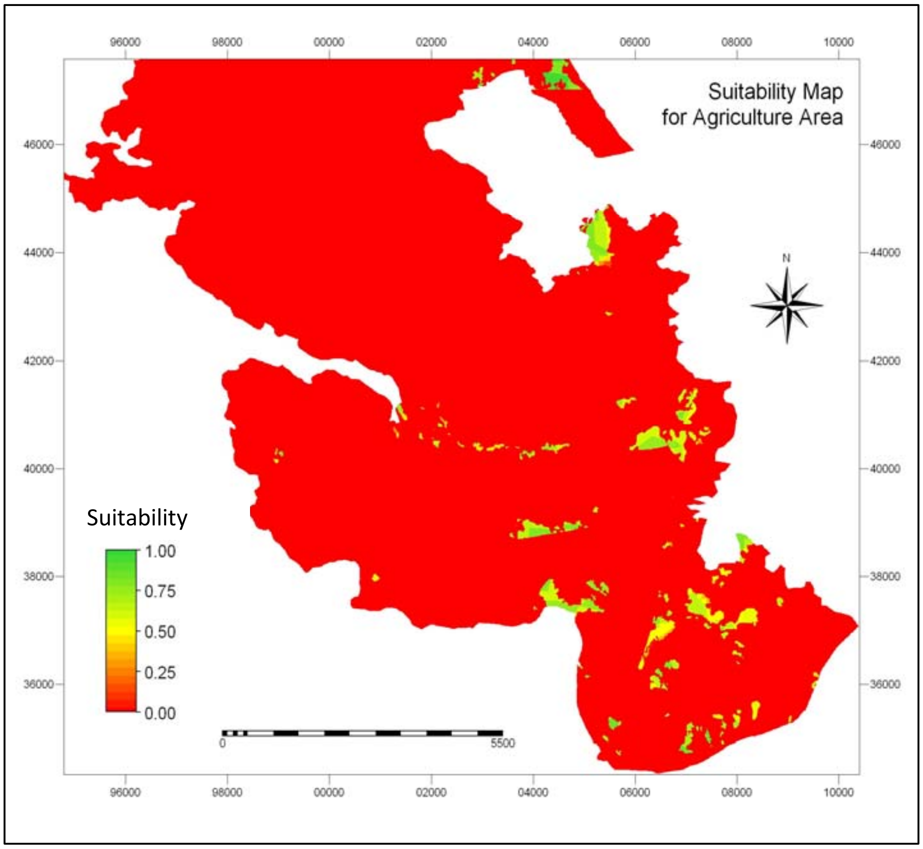


Figure 26. Suitability map of agriculture area

This suitability map combined community activity cover type, which are settlement, paddy field, dry land plantation and cleared land. But with additional criteria such as slope and distance, it became a quite small area, distributed mainly close to settlement area. The value is ranging from 0 -1. In order to present the overall land use allocation for proposed special use zone, the 3 suitability maps for protection, rehabilitation and agriculture area, were then intersected. The suitability maps were divided into suitable and not suitable classes, by considering area with suitability value more than 0 as suitable areas and with 0 value as non suitable areas. The suitable area shows the possibility to use the area as a certain function, even though the suitability value is low. Meanwhile, the non suitable area can be considered as other function. Figure 27 below presents the land allocation suitability map for proposed special use zone in BBNP. Area A represents suitable area for protection, B is suitable for rehabilitation, C is suitable for agriculture and nonsuit is the area which is not suitable for any function.

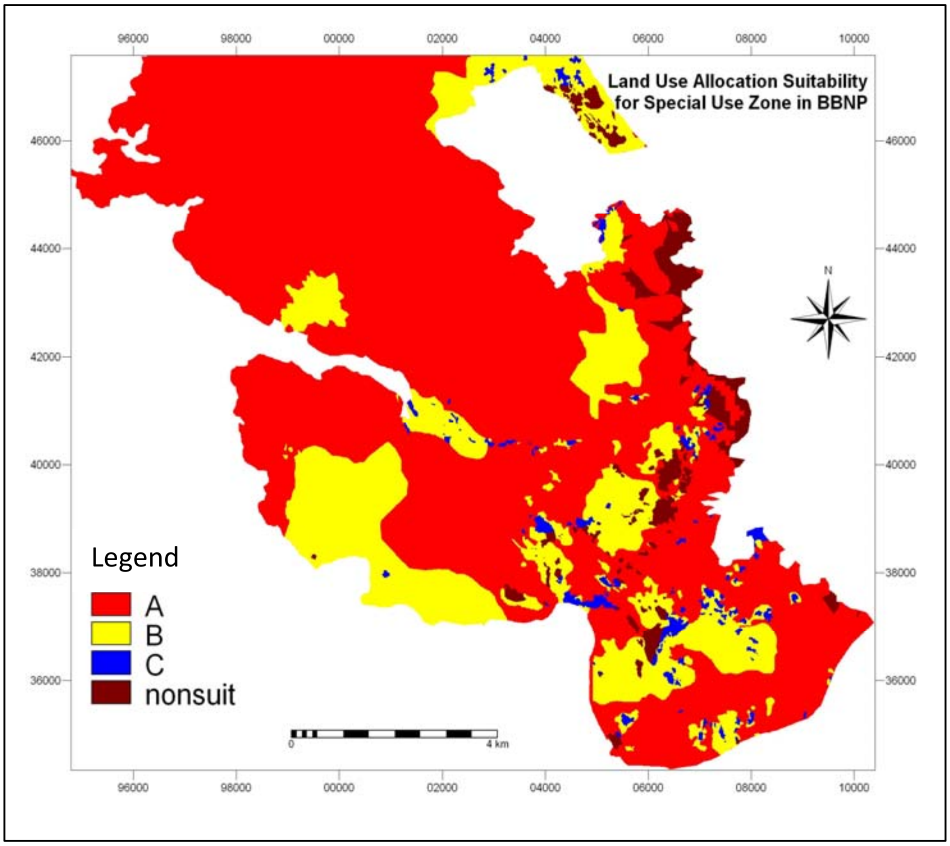


Figure 27. Land use allocation suitability for special use zone in BBNP

The overall area of protection, rehabilitation and agriculture land use allocation can be found as Table 21.

Table 21. The overall area of land use allocation for special use zone in BBNP

No	Allocation	No. of pixel	Area (m2)	Area (ha)	Percentage
1	Protection area	743936	74393600	7439.36	74.88
2	Rehabilitation area	199638	19963800	1996.38	20.09
3	Agriculture area	15751	1575100	157.51	1.59
4	not suitable (value = 0)	34188	3418800	341.88	3.44
	Total	993513	99351300	9935.13	100.00

From all land use allocation type, protection has the largest area, which is 7,439.36 ha or 74.88%, followed by rehabilitation area, 1,996.38 ha or 20.09%. Agriculture has the smallest area with 157.51 ha or.1.59%. There is a non suitable area with 341, 88 ha (3.4%), found on the map. This area represents the area with suitability value 0 from all allocation type (protection, rehabilitation and agriculture). The total area is 9935.13 ha which is smaller than total study are derived from GeoEye visual interpretation which is 9935.64 ha. This slight difference happened because of conversion from shapefile input maps to raster maps as the output with pixel size 10 meter.

5. Discussion

5.1. Land Cover Change Analysis

5.1.1. Population and Deforestation

According to land cover change analysis result, it was found that deforestation within study area is larger than reforestation in the period of 2002-2009. The total area deforested in the period of 2002-2009 is 1,974ha (20%) while reforestation is only 310 ha (3.22%). About 7,362 ha (76.31%) area is remain the same or no change. Deforested areas are distributed almost in whole area. However, the main concentration of deforestation is located mainly near settlement and road network. Some deforestation area is indicated due to misclassification, which is probably caused by the spectral variability and similarity which cause confusion in classification. It is confirmed by the user's accuracy for forest class resulted from the classifications which are 68.66 % (2002) and 70.37 % (2009). This means that some forest areas in the field are classified as non forest area, since its brownish green color is similar with non forest area color (*see appendix 1*).

The next result is about the relationship of forest cover and population growth explained by regression analysis. The result indicated a strong negative correlation between these two variables, shown by the R square 0.98, which means that the more population could decrease forest cover area. However, this result cannot directly describe that population growth is the only cause of deforestation. It must be supported with other facts and field data. Unfortunately, there are no sufficient evidence/field data to prove this relationship like the total land expansion per year, land ownership and land ownership map etc. Therefore, in order to explain the relationship, some aspects described below could direct to the possibility of land expansion by community.

According to the report of long term management plan of BBNP and from local government, deforestation is mainly caused by the community activity. This is because of agricultural land expansion of the community to plant local commodity like Kemiri/candlenut, cocoa and vanilla, which has a quite high economic value than other products. Another problem is identified to be a driver of agriculture expansion. Educational level of the population within study area is relatively low, indicated by number of student which is only 19.07%. More than 55% of the population is illiterate (RPTN BBNP, 2008). This fact confirms the possibility of land expansion in national park can be high because most of the people are with low education. Consequently, they only depend on agricultural activity, without any other options for job, which required a certain educational level.

Moreover, other activities show the dependency of community on forest products, such as brown sugar production, honeybee collection, butterflies hunting, and fuel wood collection. Shifting cultivation is a common system done by community because of open-access to forest land and close to their village. Furthermore, there is no clear information or demarcation about the national park borders. This shifting cultivation system is still implemented until now, as their ancestors inherited to the community, and is also believed to be the main driver in deforestation or land encroachment (BBNP, 2008)Figure 28 illustrate the vulnerability area of encroachment within study area. This map is obtained from BBNP office, based on image interpretation and field observation since 2007.

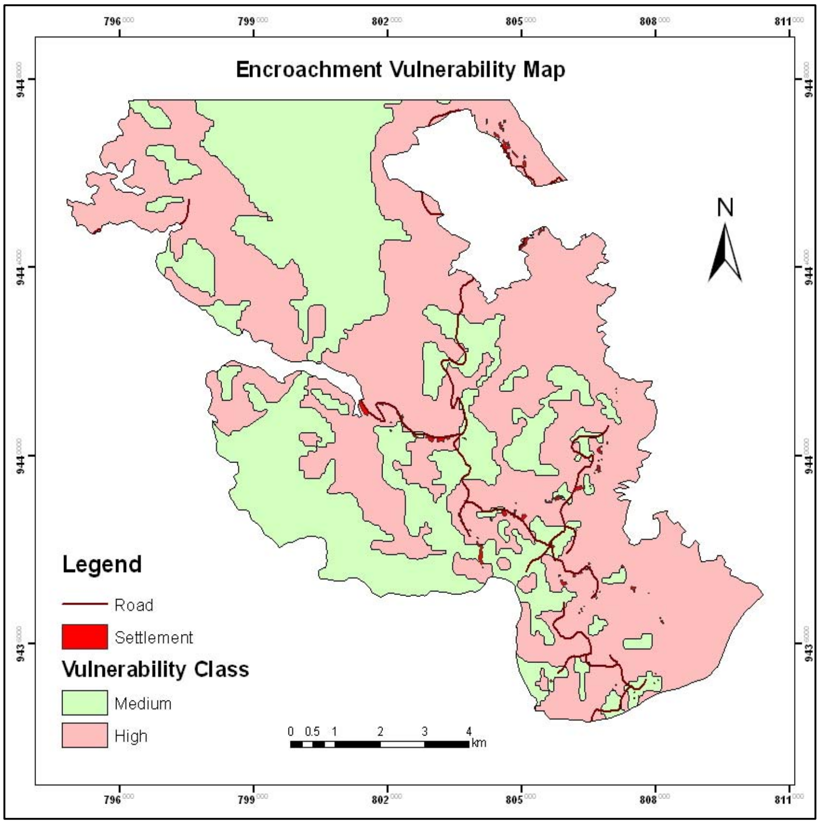


Figure 28. Encroachment vulnerability map within study area. Source : BBNP, 2008

The map indicates the high encroachment vulnerability area is mainly located close to the road as the main access and the existing settlement. Infrastructure development which is appointed by existing mosque, traditional market and school also contribute to community development (BBNP, 2008). More people are likely to settle within the area because of these supporting facilities or infrastructures.

5.1.2. Human Pressure on Agriculture Land

Human pressure is the main factor of the increasing demand for land. The relationship between population growth and deforestation rate can be used as an indicator of human pressure on land. Principally, it deals with the demand for agricultural land to fulfill human needs. To measure the human pressure on agricultural land in study area, Sumarwoto formula about human pressure on land (TP) can be used to detect the need for agricultural land to support people's life subsistence (Sumarwoto, 2004)This formula can be written as follow:

$$TP = \frac{Z.(1-\alpha)\, f.Po.(1+r)^t}{(LT)}$$

Where,

TP = human pressure on agricultural land
Z = Minimum agricultural land required to support people's life (ha/person/year)
a = non-agricultural income proportion (%)
f = percentage of farmer in a village (%)
Po = total population in initial year (baseline)
r = Population growth rate (%)
t = time interval
LT = total agriculture area within a village

The indication of TP value can be described as:
TP = 1 means that the available agricultural land is sufficient to support people's life
TP <1 means that the available agriculture land is more than sufficient to support people's life.
TP >1 means that the available agriculture land is not sufficient to support people's life.
Z value one variable in TP formula, can be calculated by following equation (Sumarwoto,2001):

$$Z = \frac{(0.5\,LSI_2 + 0.5\,LST + 0.76\,LLK}{(LSI + LST + LLK)}$$

LSI = irrigated paddy field area
LST = non-irrigated paddy field area
LLK = dry agriculture area

These formulas were applied to calculate the TP factor on three villages (Jenetaesa, Sambueja and Samangki) located within the study area. It used the 5 years period of 2003-2007 for the calculation. The input data and calculation result of human pressure on land formula can be found in Tables 22 and 23.

Table 22. Z value (calculated using data of 2007)

Village	LSI	LST	LLK	Z
Samangki	179	69	411	0.66
Sambueja	108.96	100	125	0.60
Jenetasa	84	199	84	0.56

Source : calculation and Maros Statistical Agency

Table 23. TP value (calculated based on 2003-2007 data)

Village	Z	a (%)	f (%)	Po(2003)	r (%)	t(2003-2007)	LT (Ha)	TP (2007)
Samangki	0.66	0.3	0.7	4284	0.0113	5	422.15	3.483
Sambueja	0.60	0.42	0.67	4031	0.0144	5	317.92	3.161
Jenetasa	0.56	0.2	0.7	3486	0.0142	5	447	2.622

Source: data calculation and Maros Statistical Agency

Table 24 shows TP value > 1 for all villages. It means that available agriculture land in study area is not sufficient to fulfill people needs to support their life. In other words, people are likely to expand the agriculture land to fulfill their demand. However, this condition may lead to the possibility of forest exploitation or conversion to agriculture area since forest is an open accessed area and it is easily reached by people living within or around it. Furthermore, there is no clear boundary which separates forest which would give it a status. In this case, the border of national park cannot be clearly recognized by community, and it could result in land occupation for agricultural activities.

Nevertheless, this indicator could not directly used to justify the relation between population growth and deforestation in study area, but rather indicating the possibility of forest conversion into agriculture area due to human pressure on land. This possibility can be supported by the present of people living in the three villages in the study area in which approximately 70-80% of them are working as farmers (Parrang, 2008).

5.2. Community Area Mapping

5.2.1. Comparison of Pixel Based and Object Based Classification

Most of the researches support the profound or the robustness of object based classification. By removing the possibility of misclassifying individual pixels, object-based classification can be markedly more accurate than pixel-based classification (Aplin and Smith, 2008). Object-oriented classification approach allows a superior differentiation of basic land use/land cover types and the multi-resolution segmentation method applied appears to be very effective in extracting the segments required for the classification of land features (Rahman and Saha, 2008).

However, the ability of object based classification still shows some weaknesses, which can be a consideration in selecting classification method. Despite many advances, object-oriented methods are still computationally intensive and the improvement in classification accuracy over traditional methods is not always clear (Platt and Rapoza, 2008).

Hay and Castilla (2006) provided some comments on the strengths and weaknesses of object based image analysis, which are:

Strengths:

- Object texture, shape and contextual relationships with other objects are more useful to assist recognition than individual pixel algorithms.
- Image objects are more easily integrated into vector GIS than pixel classifications.

Weaknesses:

- A poor appreciation and hence implementation of hierarchical relationships between objects at different scales and resolutions
- Results are variable based on chosen algorithms and variation of image attributes such as pixel depth.
- Processing time for large images (e.g. aerial photographs) can be extreme and requires parallel processing for efficiency(Hay and Castilla, 2006).

One study found that object-oriented methods yield similar classification accuracy to traditional methods, but that segmentation of pixels into objects made the classification more "map-like" by reducing the number of small disconnected patches (Wilhauck, 2000).

GeoEye image was downloaded from Google Earth to be classified using pixel based and object based classification for this research. In the end of the classification, the accuracy of both methods was calculated. As the result shows, the accuracy of those two methods did not show significant difference. The overall classification accuracy was low which is 56.90 % for pixel based and 58.62 % for object based classification.

In pixel based classification, the lowest user's accuracy was found in cleared land class, which is 0 %. It might be caused by the similar spectral appearance between cleared land and other classes. As mentioned in the confusion matrix, cleared land was misclassified as intact forest, degraded forest and paddy field. The GeoEye image was taken on 30 April 2009, which might be in the end of rainy season, thus objects containing vegetation reflects similar green reflectance. The second lowest class is dryland plantations, which refer to the plantations having regular pattern on the image, with user's accuracy only 18.18%. In color, the appearance of this class is also similar with other vegetated area. Therefore, most of dryland plantations were misclassified as intact forest, degraded forest and paddy field.

For object based classification, the lowest user's accuracy fell in intact forest followed by degraded forest with 24.24 % and 36.36% respectively. Most of intact forest area was misclassified as degraded forest and settlement. It is because dominantly the green color of intact forest from the image creates confusion with the green of degraded forest. While the misclassification as settlement, were likely to occur because of the shadow of the trees in intact forest similar with the color of settlement roof. The similar condition also happened in degraded forest class with the small number of classified sample, some of it was misclassified as intact forest, which has similar reflected color.

According to the comparison, it is indicated that in this case, using simple set of ECognition Quick Map mode on GeoEye image (Google Earth download), object classification could not significantly improve the classification result. The reasons behind this could be because of:

a. Characteristics of study area with high resolution (0.4 meter) causing high variation of spectral appearance, which resulted in some confusion in object differentiation.
b. In object segmentation, somehow it is difficult to achieve precise segment that can separate objects clearly, for example houses and trees. Some overlap objects in one segment can also create confusion in classification.
c. As the image is a downloaded image from Google Earth, it does not have original band, or it is a Jpg image with only standard RGB band. The band combination cannot be modified easily to obtain a certain object appearance, such as generating NDVI to easily separate vegetation class, etc.
d. The lack of supporting thematic data available, which can be used to differentiate objects.

This issue is supported by a study mentioned that to improve the accuracy of object based classification, object-based information can be integrated with other spatial data in vector-based geographical information system (GIS) environments and used widely in spatial analysis (Benz *et al.* 2004,(Walter, 2004)).

5.2.2. Visual Interpretation Classification

In the end of community area mapping exercise, visual interpretation was *chosen* to be used for land cover mapping. The reason is because both automatic classification technique, pixel based and object have resulted in low accuracy (56% and 58%), while visual interpretation had higher accuracy which is 86 %. To get more detail information about land cover within study area, visual interpretation was done by manual delineation on the objects according to field knowledge and the clear appearance of the image because it has 0.4 m resolution.

Unlike digital analysis of the images, a human interpreter in visual interpretation does not interpret the image pixel by pixel, but more aggregating information related to various basic image-features of unknown objects along with his scientific knowledge, general knowledge of the phenomena as well as experience of doing classification. Furthermore, as a consequence, the interpretation result for land use and land cover produced by a well-trained human interpreter is often less crude than the same obtained using digital techniques. Thus, the process of visual interpretation of wide variety of remotely sensed data is a complex intuitive process of combining evidential information from different sources and subjecting such information to an expert's knowledge, experience and heuristics at each levels namely detection, identification, analysis, recognition and classification of the process(Prasad *et al.*, 2002). Object oriented techniques are somehow superior to the traditional pixel based methods, but still inferior to human interpretation (Bruce, 2008).

Although automated classification is widely recognized for its statistical validation, visual interpretation has more potential users. It is due to the lack of resources to provide expensive software and remote sensing training. Visual interpretation could be an efficient and effective way in classification. Beside the benefit of using low-cost software, it also requires analyst knowledge of the study area in terms of spectral response of the image (Puig *et al.*, 2002)

In tropical region, land use and land cover patterns tend to be heterogeneous, especially deforested landscapes that have several variations of the tree canopy density, regrowth, and other land uses. It could hinder the identification of useful training areas for digital supervised classifications. Using visual interpretation, the confusion in object heterogeneity come from small patches or mixture of land cover can be overcome by generalizing the fragmented area in to a certain class (Puig after De Grandi et.al, 1998).

5.3. Special Use Zone Planning

5.3.1. Criteria Development and Justification

General principles of zoning system is applied to all national parks in Indonesia (for example, land remains state land), but especially for special use zone, is to be developed in accordance with the specific needs and conditions of each park. Field experience shows that potential areas for special use zones differ from park to park. It depends on the problem characteristics of each location. Different case, different community and different culture require different management. Thus, the definition and criteria for designating a special use zone should be adjusted to local needs and conditions. In other words, because of the unique and specific problem characterizing a national park management, the design of zoning should be site specific.

To determine if a special use zone can be established, it requires that all stakeholders agree to a set of criteria, including those for conservation and sustainable development. Criteria may be considering the aspect of environmental (health of the ecosystem), economic (acceptable level of wellbeing for the local people), social (equity among groups), cultural (cultural integrity and identity) and political (fair and equitable decision making)(Mulyana, et.al, 2010).

This research only considered the biophysical aspect to determine land use allocation within special use zone. The lack of social economic data caused the socio-economic deliberation could not be established. Repressive action of forest ranger from national park authority has created a severe conflict with community. It caused a high resistance on community to share information both about the relationship of their daily life with forest exploration and their social economy activity to foreigner. Therefore, analysis from social economy point of view could not be accomplished in this research.

Development and justification for each criterion in this analysis was obtained from literature reviews and stakeholder preferences through questionnaire distribution. These all criteria were to be selected in order to fulfill the land use allocation requirement proposed to be set up within special use zone. Protection, rehabilitation and agriculture areas are alternative land uses allowed to be established within special use zone regarding to Ministry of Forestry (MoF) Regulation No. 56/2006.

Finally, land cover, soil type, slope, rainfall, distance to road, distance to settlement, distance to river, distance to tourism object and distance to flora fauna habitat were selected as criteria for the three alternative areas. Presidential Decree of Indonesia No. 32/1990 about Protection Area Management determined the criteria for protection function are the area with slope more than 40%, rainfall more than 3000mm/year or more than 20mm/day, and in the range of 0-100 m along river. Furthermore, Directorate General of Land Rehabilitation and Social Forestry Regulation no 167/2004 concerning Principles of Degraded Land (RLPS, MoF) regulated the specification of rehabilitated area criteria consist of degraded land and mainly within slope 0-40%. Soil type is considered as a criterion for agriculture area based on Ministry of Public Work Regulation No. 41/2007 about Principle of Technical Criteria for Public Work. The proximity or distance to tourism object, flora fauna habitat, road, river and settlement criteria were selected and weighted according to stakeholder preferences, because this issue is highly depends on the local condition where the problem occur. The stakeholders involved in this process were national park authority, community key person, university, local government and NGO which are concern in national park management.

5.3.2. Land Use Allocation

In the first step, spatial multi criteria analysis proposed the suitability map for each alternative based on selected biophysical criteria. The suitability value for each alternative area ranges from 0-1. Moreover, this suitability maps were divided into suitable area and non suitable area. To equal the division of these two classes for protection, rehabilitation and agriculture, the area with suitability value more than 0 (value >0) was consider as suitable area and value 0 (value =0) as non suitable area. It is because area with suitability value more than 0 still have a potency to be selected as a certain function (protection, rehabilitation or agriculture), while 0 value does not show any suitability.

The combination of suitable and non suitable area on each function performed land use allocation in whole study area. About 7,439 ha (74.88 %) was selected as suitable for protection area. It covers mostly on intact forest area, which is reasonable because this protection area is intended to strictly prevent intact forest from land use conversion and any exploitation. The conservation value on this area should be highly protected to preserve the original ecosystem. Rehabilitation area has suitable area of 1996 ha (20.09%) which covers degraded forest and cleared land. The allocation for rehabilitation area is intended to recover the degraded area which is represented by degraded forest and cleared land. Suitable area for agriculture is 157 ha (1.59%), covering settlement, paddy field, dryland plantation, which are mainly the properties of community. It is aimed to care for community right on their ownership. The remaining area (341 ha or 3.4%) is considered as not suitable for any function because it has suitability value 0. In the future, this non suitable area can be defined and utilized for a certain function that might be give advantages both to national park or community under agreement and throughout appropriate decision. It could also be an extended area for defined function (protection, rehabilitation or agriculture) based on national park policy.

This result shows that national park can still preserve the main function as protection area but also consider rehabilitation and agriculture area to accommodate community development. Protection area will be the area which strictly cannot be exploited or changed from its natural condition. On the other area, national park will allow community to expand their activity within agriculture and rehabilitation area. Agriculture area can serve for pure agriculture system representing community properties, but rehabilitation area will provide land for social forestry system (agroforestry), where people can plant crops under the rehabilitated trees (Directorate General RLPS-MoF, 2004). Many rehabilitation programs have been held by Ministry of Forestry to restore forest function and also to foster community welfare by intensively involving them in the program (BBNP, 2008). Furthermore, because this analysis only refer to biophysical aspect, the remaining non suitable area can be considered to be a certain function according to decision making which more rely on other aspect like social-economy, cultural and policy.

At this time, BBNP is still pursuing zoning arrangement. This land use allocation maps can be a consideration in accomplishing zoning system in BBNP. Not directly a final consideration, but will be better if it is followed by another analysis according to more comprehensive aspect like social economy, cultural and political. It is highly required that zoning system result will be legalized and legitimated by many stakeholders related to national park management and also regional development context.

5.4. Limitation of the Research

This research has several limitations, especially related to data availability, including:

a. The lacks of reference data from ground check to measure the classification accuracy in land cover change analysis on Landsat-7 TM 2002 and 2009. In this case, available land cover map and Google Earth image were used as reference.
b. The reference data for accuracy assessment of GeoEye image classification were collected from the field by other persons. It is assumed to be reliable and acceptable to be used in classification accuracy measurement.
c. The lack of thematic data to support land cover classification using object based analysis on GeoEye image (Google Earth). Therefore, the classification was only applied using Simple Map Mode instead of Rule Set Mode in eCognition 8 software. Utilizing some thematic map such as a detail DEM/DSM, LIDAR in Rule Set Mode can probably help to improve classification result.
d. The lack of socio – economic data of study area makes the spatial multi criteria analysis only construct the land use allocation based on biophysical aspect. In the case of special use zone, socio-economic and cultural aspect should also be considered.

6. Conclusion and Recommendation

6.1. Conclusions

This part answer each research question based on the overall analysis.

a. How is the land cover change in the study area from 2002-2009?

Land cover change analysis generated 3 classes within study area which are deforestation, reforestation and no change area. In seven years (i.e. 2002 t0 2009) forest area decreased from 7119ha (70%) to 5455 ha (54%). On the other hand, non forest areas increased from 2528ha (25%) to 4192 ha (41%). Around 7,362 ha (76%) area is remained the same or no change.

b. Is there any relationship between land cover change and population growth in BBNP?

There is a significant correlation between deforestation and population growth since the R Square is 0.98 and calculated t is larger than tabulated one (with df=4 and confidence level of 95% or α=0.05). The relationship is negative between the remaining forest cover and population growth. As population increases, forest cover decreases. In other words, more population causes the more deforestation.

c. How accurate is object-based classification compared to pixel based classification for identifying land cover types in the study area?

Object based classification has a slightly better accuracy (58 %) compared to pixel based classification (56 %) in land cover type identification within study area using GeoEye image (downloaded from Google Earth). Therefore, object based classification cannot significantly improve classification result of GeoEye image (Google Earth download). Visual interpretation improves the classification with a result of 86% classification accuracy.

d. What are suitable biophysical criteria to be used to design a "Special Use Zone" in BBNP?

According to literature reviews and questionnaire distribution to gain stakeholder preferences, there are several biophysical criteria considered in designing special use zone which are: land cover, soil type, slope, rainfall, distance to road, distance to settlement, distance to river, distance to tourism object and distance to flora fauna habitat.

e. How can spatial multi criteria analysis solve the problem of a land use planning in community zone in BBNP based on biophysical aspect?

SMCA allocates 3 main land uses based on function within the study area which are: protection, rehabilitation and agriculture area according to the Ministry of Forestry Regulation no. 56/2006 concerning Zoning Principles in National Park. The allocation for protection is 7,439ha (75%), rehabilitation area 1,996ha (20%) and agriculture has the smallest area with 157ha (2%). About 341ha (3%) is considered as non-suitable area, which is not suitable for the 3 types of land use allocation.

6.2. Recommendations

a. The classification of Google Earth Image using thematic data such as DSM, LIDAR etc. for setting the rule in object based classification might improve the accuracy.

b. Further spatial multi criteria analysis considering socio-economic, cultural and policy aspect are preferable to be done in achieving the appropriate design of special use zone within national park.

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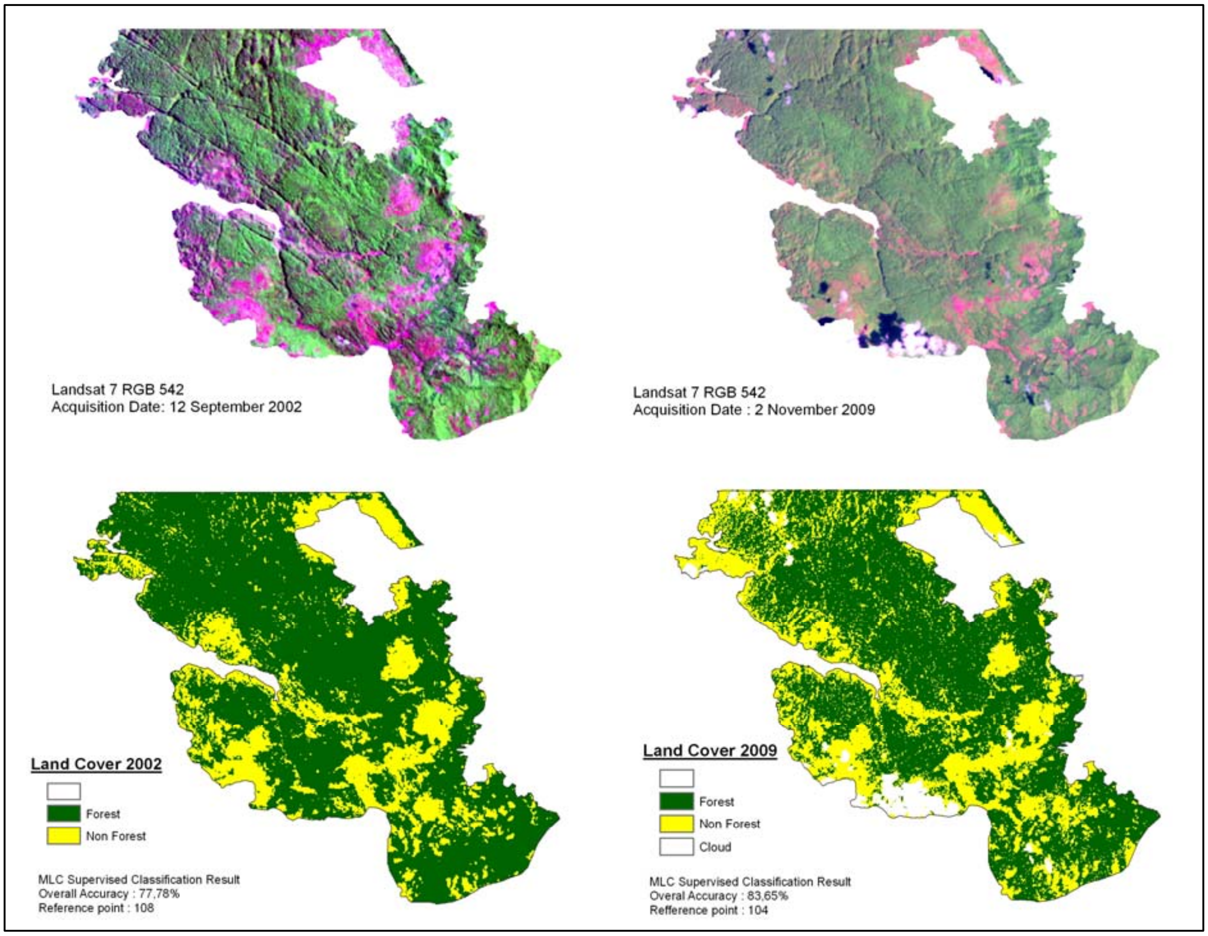
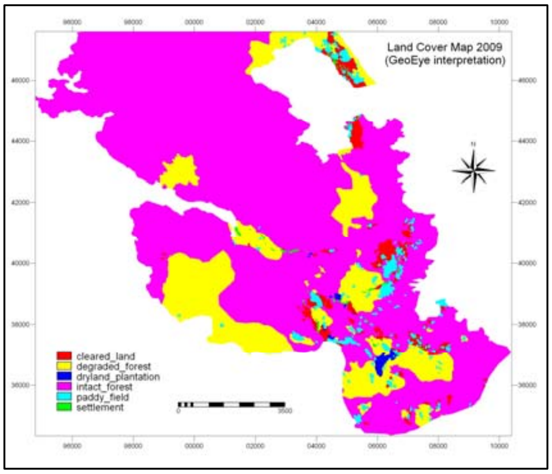
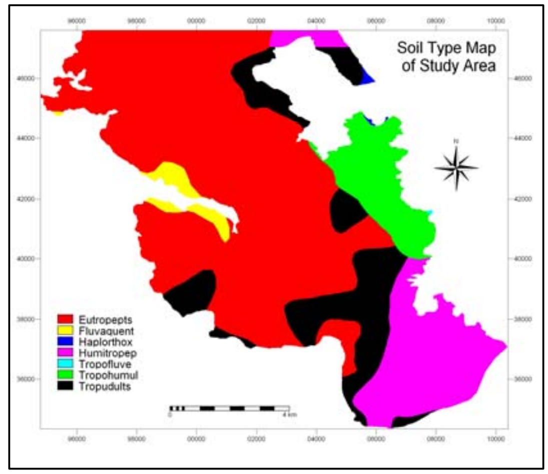
Appendices

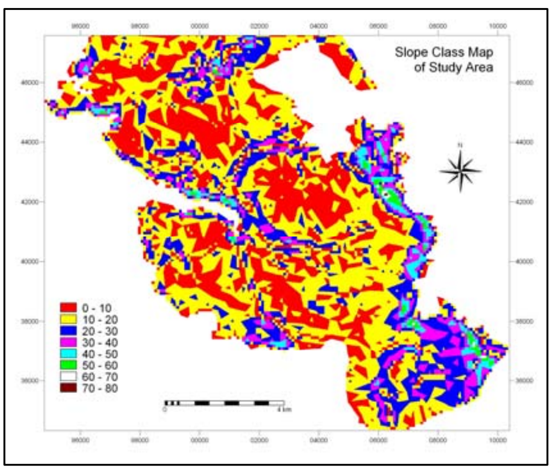
Appendix 1. Landsat-7 TM 2002 and 2009 images and classification result for Land Cover Analysis

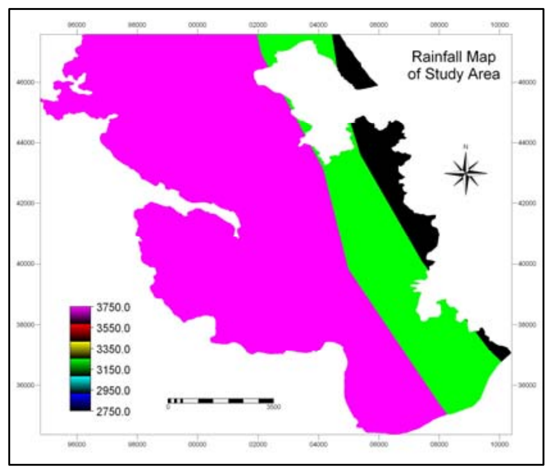


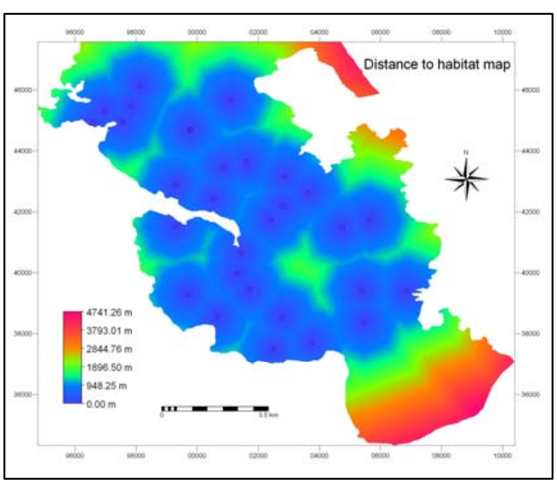
Appendix 2. Criterion input maps for SMCE ILWIS

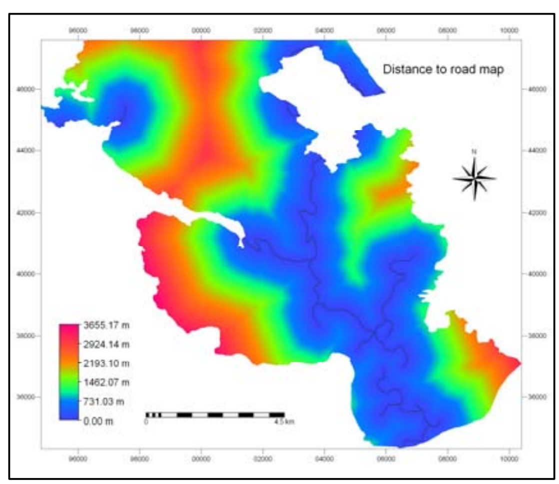


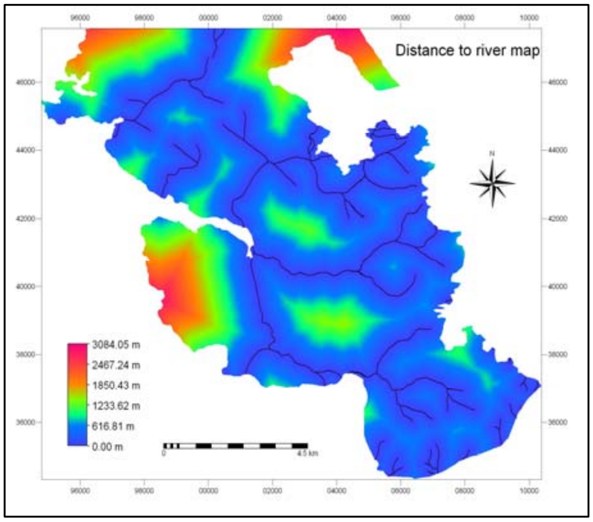


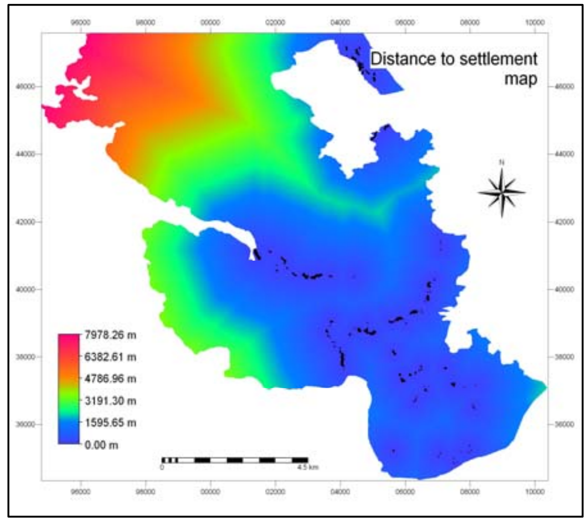


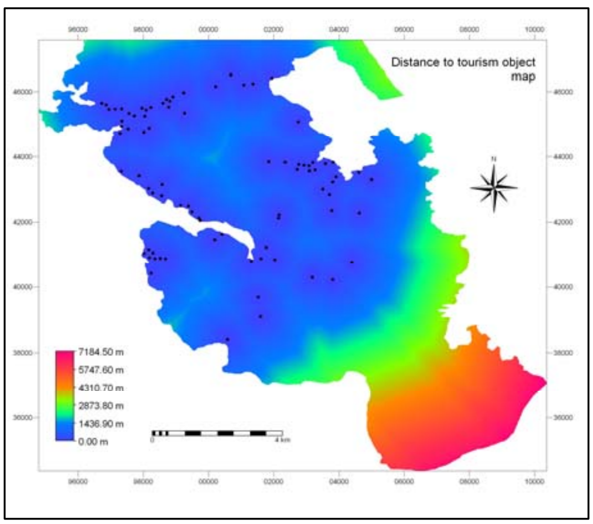







Distance to river map
3084.05 m
2467.24 m
1850.43 m
1233.62 m
616.81 m
0.00 m


Distance to settlement map
7978.26 m
6382.61 m
4786.96 m
3191.30 m
1595.65 m
0.00 m


Distance to tourism object map
7184.50 m
5747.60 m
4310.70 m
2873.80 m
1436.90 m
0.00 m

Appendix 3. Questionnaire for weighing process on SMCE criteria

SMCE Questionnaire for Special Use Zone Spatial Planning

Name of Interviewer:
Date of Interview:
Introduction
Bantimurung Bulusaraung National Park (BBNP) management is constructing a zoning system in order to effectively manage the park. Due to the community problem happened in line with its management, BBNP considers proposing a special use zone based on Permenhut No. 56/2006. This research tries to study the most appropriate land use suitability planning inside the special use zone by proposing 3 alternative areas which are allowed by the regulation. These three areas are protection, rehabilitation and agriculture.

This questionnaire will be used to obtain stakeholder perspectives related to the criteria for each area and the weight of each criterion.

The selected stakeholders as respondents are defined based on the relation or authority to the national park management. They are BBNP management, community key persons, local forestry agency, NGO's, academic representatives, district management, local tourism agency and other related institution.

Respondent identity

1. Name :
2. Age :
3. Job :
4. Institution :

Criteria and Weight for 3 areas in Special Use Zone

1. **Protection Area:** this refers to area which will be protected or prohibited to be exploited or converted, and its values or uniqueness has to be preserved.
   a. Please choose criteria that can be used in designing Protection Area inside community zone. The choice could be more than one, all or even you can add in others row..
      1. Land cover
      2. Soil type
      3. Slope
      4. Rainfall
      5. Tourism objects
      6. Flora and fauna existence
      7. Others (could be more than one):……………………………………………………………………………………………
   b. Please give a certain weight (put in order) for each criterion above using nominal value with the total is 100.

No.	Criterion	Weight (%)	Reason/Remarks
1.	Land Cover		
2.	Soil type		
3.	Slope		
4.	Rainfall		
5.	Tourism objects		
6.	Flora fauna		
7.	Others :………….		
Total		**100**	

2. **Rehabilitation Area**: this refers to area that has been accessed or exploited or degraded that needs to be rehabilitated/restored/ improved due to its sustainability and its functions.
   a. Please choose criteria that can be used in designing Rehabilitation Area inside community zone. The choice could be more than one, all or even you can add in others row..

(Check or circle the number)

1. Land cover
2. Soil type
3. Slope
4. Rainfall
5. Distance to road (proximity)
6. Distance to settlement (proximity)
7. Distance to river (proximity)
8. Others (could be more than one):………………………………………………………………………………

b. Please give a certain weight (put in order) for each criterion above using nominal value with the total is 100.

No.	**Criterion**	**Weight (%)**	**Reason/Remarks**
1.	Land Cover		
2.	Soil type		
3.	Slope		
4.	Rainfall		
5.	Distance to road		
6.	Distance to settlement		
7.	Distance to river		
8.	Others :……………		
Total		**100**	

3. **Agriculture area:** this refers to areas that are already exploited and possible to be exploited in a certain suitability criteria. This area is purposed to accommodate community land demand due to their development.
   a. Please choose criteria that can be used in designing Agriculture Area inside community zone. The choice could be more than one, all or even you can add in others row..
   (Check or circle the number)
   1. Land cover
   2. Soil type
   3. Slope
   4. Rainfall
   5. Distance to Tourism objects
   6. Distance to protected flora and fauna habitat
   7. Distance to settlement
   8. Others (could be more than one):………………………………………………………………………………

   b. Please give a certain weight (put in order) for each criterion above using nominal value with the total is 100.

No.	**Criterion**	**Weight (%)**	**Reason/Remarks**
1.	Land Cover		
2.	Soil type		
3.	Slope		
4.	Rainfall		
5.	Distance to tourism objects		
6.	Distance to protected flora and fauna		
7.	Distance to settlement		
8.	Others:……………..		
Total		**100**	

Other alternatives for community area design

Please share briefly if you have another alternative design or what should be considered in designing community zone.

Answer:

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