THESIS

ESTIMATING HABITAT LOSS AND IDENTIFYING REFUGE AREA FOR JAVAN LANGUR (*Tracyphitecus auratus*) AS IMPACT OF MERAPI ERUPTION 2010

Thesis submitted to the Double Degree M.Sc. Programme, Gadjah Mada University and Faculty of Geo-Information Science and Earth Observation, University of Twente
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Abstract

The last 2010 Merapi eruption was a cathastropic event which result a huge damage and causalities. The effect of eruption not only descend to human life but also to wildlife. The estimation of habitat loss and spatial analysis of javan langurs' habitat (*Tracyphitecus auratus*) due to that event has not been known. Concerning the regular eruption of Merapi Volcano it is important to identify refuge areas and to map species at risk as one of conservation efforts to reduce exctintion. The objective of this research is to estimate habitat loss of *Tracyphitecus auratus* in 2010 Merapi eruption caused by pyroclastic and to recognize refuge areas. Maxent models was employed to identify suitable habitat before and after 2010 Merapi eruption using seven enviromental variables: landcover, forest canopy density, slope, elevation, annual temperature, monthly and annual precipitation and 45 numbers of presence points.

Two suitable habitat models of year 2009 and year 2012 were generated from Maxent at a good scale of 30 by 30m. The area under ROC curve (AUC) and True Skill Statistic (TSS) were used to measure the model's accuracy. Model of year 2009 and 2012 result value of AUC 0.976 and 0.977 and value of TSS are 0.721 and 0.723 respectively. Landcover, slope and elevation were the most significant variables. The result shows that habitat loss of javan langur caused by pyroclastic was 148 hectares of medium suitable and categorized as temporary habitat loss. Species at risk map suggested that at least 352 hectares of high suitable habitat will be affected by pyroclastic hazard of VEI=4. The identified refuge areas within national park at eastern and northern flank of the volcano and outside Merapi Volcano National Park that found in Wonodoyo, Suroteleng and Mriyan villages may be the best achieved and we suggested that those potential habitat patches could be designated as reserve habitat.

Key words: *Merapi eruption, habitat loss, suitable habitat modeling, Tracyphitecus auratus, refuge area*

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Yogyakarta, March 2013
Ayun W

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List of Abbreviations

AFJ	: Animal Friend Jogja
AUC	: Area under Receiver Curve
CITES	: *the* Convention on International Trade in Endangered Species
COP	: Centre for Orangutan Protection
DEM	: Digital Elevation Model
GIS	: Geographic Information System IUCN
IUCN	: *the* International Union for Conservation of Nature (IUCN)
JAAN	: Jakarta Animal Aid Network
MVNP	: Merapi Volcano National Park
MAXENT	: Maximum Entrophy
PEDRR	: Partnership for Environment and Disaster Risk Reduction
RMSE	: Root Mean Square Error
SAR	: Search and Rescue
SDM	: Species Distribution Modeling (Models)
SRTM	: Shuttle Radar Topographic Mission
TSS	: True Skill Statistic
VIF	: Variance Inflation Factor

Chapter 1 Introduction

1.1 Background

Located in central part between Yogyakarta Province and Central Java Province, Merapi is the most dynamic and injurious volcano in the world (Voight *et al.*, 2000). It has been recorded that in Merapi modern phase there are more than 53 events as categorized big eruptions occurred since 1786 (Voight *et al.*, 2000 and Camus et al., 2000). Although the activity and hazardous side, Merapi roles as habitat for numerous species and resource base for many people. Concerning the biodiversity of flora and fauna which represent the mountain species of Java, Government of Indonesia established Merapi Volcano as National Park at year 2004. The park provides habitat for musang (*Paradoxurus hermaprodus*), pangolin (*Manis javanica*), squirrel (*Callosciurus notatus*), monkey (*Maccaca fascicularis*), wild boar (*Sus scrofa*), deer (*Muntiacus muntjak)* and at least 99 species of birds survive in this area, included the bird of Indonesia's icon, javan eagle (*Spizaetus bartelsi*) (Anonymus, 2011).

Situated in high population density, Merapi Volcano National Park (MVNP) is facing communities around Merapi Volcano who have been living together and engages daily with the park. They inhabit around the national park, encompass thirty villages in eight districts of four regencies. Their livelihood which very depend on natural resource of park such as sand mining, farming, overgrazing and charcoal making being significant disruption whereas forest in Merapi National Park is the remaining habitat for protected species, the highly distinctive mammals of javan leopard (*Panthera pardus*) and the vulnerable endemic primate species of javan langur (*Tracyphitecus auratus*).

1.1.1 Focus species: *Tracyphitecus auratus*

Tracyphitecus auratus is an important species considering its function on seed propagation and seed dispersal. Listed in The International Union for Conservation of Nature (IUCN) Redlist (Nijman,V and Supriatna, J. 2008) this species is included in Vulnerable condition according to the continued population decline, as an impact of illegal trade, hunting, and degraded habitat. Included in Apendix II The Convention on

International Trade in Endangered Species (CITES) that means the animal is restricted for trade (CITES, 2012), Government of Indonesia has protected this animals with Law of Forestry Minister on Protected Animals number 733 year 1999.

Javan langur is known by various names, such as langur (Sundanesse), lutung (Javanesse), petu hirengan (Balinesse) and ebony leaf monkey (Supriatna and Wahyono, 2000). Systematically classification of javan langur is described as follows:

Taxonomy :	Kingdom: Animalia Phylum : Chordata Class : Mammalia Order : Primates Family : Cercopithecidae Species : *Trachypithecus auratus ssp. auratus*
Redlist category :	Vulnerable based on A2cd criterion
History :	2000 : Endangered
Population trend :	Decreasing Source : Nijman, V. & Supriatna, J. 2008

Figure 1: Javan langur (*Tracyphitecus auratus*) found in Plawangan, Merapi Volcano National Park - April 2012 (credit photo: FOBI, 2012)

Javan langur is diurnal animal meaning that their main activities are in day-light time. In their daily life, javan langurs can move 500-1300 meters and prefer to live in habitat which has abundant trees about 14-16 m heigth (Nursal, 2001). Javan langur need trees not only as food resources but also as sleeping sites and lodge trees. They are included in folivorous or herbivorous or frugivorous species which prefers leaf as their food. Percentages of their food are 46% of leaf, 27% of ripe fruits and 8% of unripe fruits (Wawandono, 2010). The species of food trees are vary but dominantly with puspa (*Schima wallichii*), saninten (*Castanopsis argentea*), kiara (*Ficus sp*), and kuray (*Trema orientalis*) (Wawandono, 2010). They need space about 605,74 m^2 as their core area and 15-23 ha for their home range (Wawandono, 2010).

Kool (1992, 1993) found most of their food consists of protein-rich leaves. The leaves selected for consumption are low fiber. Javan langur has ability to digest the high fiber because it has tanin (Kool 1992). At time the main food is seldom, the immature leaves of teak tree (*Tectona grandis*) substitute as food source for this species (Kool, 1993, 1991). It has eating soil habit which is predicted for searching bacteria to help digest food and minerals (Supriatna and Wahyono, 2000). This animal has body length of 450 mm - 750 mm and the tail length is 410 mm - 750 mm with standard body mass of 7.1 kg. Javan langur will reach adult at the age of 4-5 years and can live up to 20 years (Supriatna and Wahyono, 2000).

The distribution of these species ranges from upland until highland forest (Supriatna and Wahyono, 2000). They can be found in vast type of ecosystem including coastal areas, mangrove, peat swamp forest, dry deciduous, lowland and highland forest (Nijman, 2000). Studied by Nijman between year 1994 and year 2000 javan langur has specific area mostly in mountainous forest area. Below is a map showing geographic distribution of javan langur in Java, Lombok and Bali Island (Figure 2).

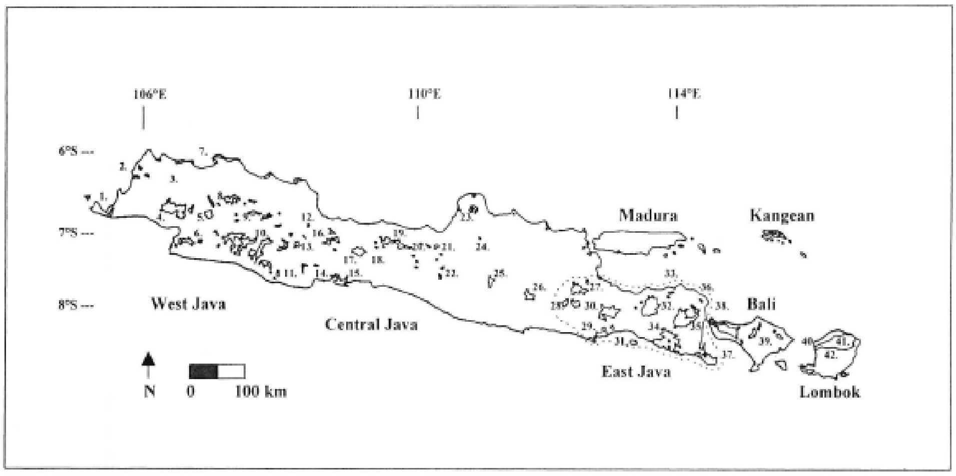


Figure 2: Geographic distribution of Tracyphitecus auratus in Java, Bali and Lombok Island (Source: Nijman, 2000)

1.1.2 The 2010 Merapi eruption

The last Merapi eruption in October-November 2010 made a huge damage and causalities. The pyroclastic of big explosion on 4–5 November damaged abundant empty of rural community outside the higher flank of the volcano and flowed through in an area of 13 km^2 over the river (Surono, Jousset et al. 2012). It generated an ash material that increased to 17 km elevation through with a nues ardente flow that moved 16 km down to the Gendol River lead into Yogyakarta city (Surono, Jousset et al. 2012).

Merapi Volcano eruption characterized by lava dome growth followed by a glowing lava dome (Voight et al., 2000). Pyroclastic flow in Merapi Volcano occurs from the fall down of the lava dome when huge volcanic emission mass are squashed become minor elements and go down to the vertical slope (Takahashi and Tsujimoto, 2000). Thouret, Gupta et al. (2010) argued that pyroclastic flows are hit blends of huge rock pieces and gases which fall down volcanic flanks when quick-tempered outbreaks. They create from whole or part fail of an big explosion column, leaking of volcanic powder from an vigorous crater, and fall down of an dynamic lava ground or surge (Thouret, Gupta et al. 2010).

Newhall et al (2000) suggested that pyroclastic substance from fall down of Merapi column is frequently spread in fairly thin parts delineated by the roughly basin drainage. Vigorous parts able to move repeatedly according to alterations of cavity position otherwise attritio and structurional transforms which impact stumpy areas beside the cauldron border (Newhall et.al, 2000).

The 2010 event was a 100 years period explosion that had a VEI and Me of about 4, triggered a highllighting and all types of earthquakes as recognized in Merapi and produced pyroclastic that slid 16 km along the Gendol River (Surono, Jousset et al. 2012). The estimation of damage caused by 2010 Merapi eruption has been studied by Yulianto, Sofan et al (2012) that results of 133.31 ha for settlements, 92.32 ha for paddy fields, 235.60 ha for dry farming, 570.98 ha for plantations, 380.86 ha for bare land, and 0.12 ha for forest areas. Rapid Damage Assessment using satellite imagery analysis and ground check survey also done by Faculty of Forestry Gadjah Mada University and Merapi Volcano National Park (MVNP) that estimate about 30 percent of area or 2450 ha forest area suffered damage (Anonim, 2011).

Considering the damaged forest area, the effect of eruption not only descends to human life, but also to wildlife. The destructed habitat can indicate the decline population of animals, included javan langur, because the survival of this species is depends on forest cover (Nijman, 2001). However the habitat loss estimation of javan langur has not been done. The term of habitat loss is very different than just forest area loss. It is also a common when we found disingenuous concept of habitat loss which only focuses on loss of vegetation cover (Lindenmayer, 2006). Several parameters in habitat suitability have to be considered since running habitat loss depends on the perceptive why animals react to landscape changes since there are numerous cases of species that have declined when suitable habitat for them had been shirked (Lindenmayer, 2006).

Subarkah (2012) argued that the past event also caused the change of animals distribution included the endemic primate of javan langur (*Tracypithecus auratus*) however mapping the distribution of the species has not been done. As the first official survey, Subarkah (2012) studied the ecology aspect of the species in Merapi National Park. Besides, it also considered on population of javan langur after 2010 Merapi eruption. The study predicted the population density of javan langur in Plawangan and Bibi Hill was 0.87 individual/km² and 5.78 individual/km² respectively. Spatial analysis of habitat and the parameters which significantly influence the distribution of javan langurs in Merapi Volcano National Park have not known yet whereas the relationship between primate occurrence and environmental factors which spatially determined is important for preservation and biodiversity efforts (Guisan and Zimmermann, 2000). To have whole understanding on the distribution patterns of javan langur, it is essential to analys the spatial distribution of species.


Figure 3: *Macaca fascicularis*, one of primate species, found in damaged areas after Merapi eruption 2010 and southern flank area of Merapi volcano after the event (credit photo: Nofria DF and Merapi Volcano NP)

Regarding the vulnerable and endemic status of *Tracyphitecus auratus*, a conservation effort is needed. One of crutial part in preserving species is maintaining its habitat. The term of habitat refers to “the subset of physical environmental factors that allow an animal or a plant to survive and reproduce” (Block and Brennan, 1993 in Lindenmayer, 2006). It is an area which fulfill needs of animals namely water, food and severity (Alikodra, 2002). It has sources and situations that provide home as well as survival and reproduction of species (Hall, et.al. 1997). Beier, et.al 2008 stated that habitat for any species is described according to origin of existence constraints namely foodstuff, cover, nest spots, free from dangers, and correlations among predator species. Bolen and Robinson (1995) differ habitat components into 4 (four) factors namely food, water, space and cover. It is commonly incorrect terms of habitat which defines habitat as a vegetation type (Hall, et.al. 1997) such as a woodland habitat, a riparian habitat, etc.

According to the high risk of Merapi eruption to wildlife, Merapi Volcano National Park as authority does not have a risk map whereas those animals are one of elements at risk. Generating this kind of map is useful as an input in disaster management of wildlife since these species face the risk of volcano hazard which can be a threat for their life.

Approximately, since 1800 once every three years a volcanic catastrophe has occurred in Merapi causing a lot number of settlement and very wide of agriculture land and wooded areas damaged (Voight et.al., 2000). The regularly eruption of Merapi volcano makes a change on its land cover which has direct effect to the habitat of wildlife. Animals will move to avoid the damage environment and to find refuge areas to protect themselves. By definition, refuge area is an area purposed for the protection of wild animals, within that hunting and other threaten activities are either prohibited or strictly controlled (Svancara, Scott et al. 2009). There are many countries have established refuge area system with mission to manage natural resources and to preserve and to restore the flora and faunal resources and wildlife territory (Svancara, Scott et al. 2009). Related to this condition, suitable habitat selection for refuge area is important and critical as a part of management program to prevent wildlife from fatality. For satisfying the all problem stated in background above, modeling habitat before and after the 2010 eruption would be an important approach.

1.2 Species Distribution Models

The term of Species Distribution Models (SDMs) refers to estimation of site suitability based on statistical analyses of associations between presence or absence of species and environmental variables (Elith and Leathwick, 2009). The same terms with SDMs are correlative or statistical models, habitat models or ecological niche models. Prediction of species occurence and models proper habitat have widely helped conservasionist to understand the interaction within ecological (Guisan and Zimmermann, 2000; Guisan and Thuiller, 2005). Modelling habitat suitability supply a tools for evaluation the effect of ecosystem alteration or another habitat change of species distribution (Guisan and Zimmermann 2000). Among numerous habitat models method, Maximum Enthropy (MaxEnt) modeling is very efficient for varifying utilization enviroment and variety dispersions for a multispecies within large type of site (Elith et al, 2006; Baldwin, R 2009). The models produced by MaxEnt have a normal probabilistic explanation, presenting an elastic degree from highest to smallest amount of suitable habitat. (Philips, 2004).

1.3 Research Problem

This research has sense that deal with quantifying part of volcanic eruption affect to wildlife and provide refuge area as one of the solutions. Estimation of habitat loss and its impact to habitat of javan langur due to the last Merapi eruption has not been conducted whereas this data is needed to understand the javan langur's habitat changes that caused by natural damage factors in volcanic eruption.

Conventionally species at risk map only focus on common threat factors such as illegal trade, hunting and land conversion. It is rarely made a species at risk map which focus on volcanic hazard and considering human interaction factor. Improving this kind of map will add references on mapping species at risk.

Due to the trend of widespread area affected by Merapi eruption, we should find the other refuge areas far from Merapi Volcano. There is an alternatives location for this purpose such as forest area outside the park in northern and eastern flank of Merapi. Thus, identifying refuge areas is needed.

1.4 Research Objectives

The study aims main three objectives which concentrate for selecting refuge areas surrounding Merapi Volcano. This main objective can be achieved through three specific objectives as below:

1. To identify areas surrounding Merapi Volcano which suitable for *Tracyphitecus auratus*
2. To estimate habitat loss of javan langur due to the last Merapi eruption in 2010.
3. To generate a risk map for javan langur according to pyroclastic hazard of Merapi eruption.

1.5 Research Questions

To reach three objectives above, these following questions are addressed:

Nr	Objectives	Research Questions
1	To identify areas surrounding Merapi Volcano which suitable for	1. Where areas are suitable for *Tracyphitecus auratus?* 2. What combinations of enviromental parameters

Nr	Objectives	Research Questions
	Tracyphitecus auratus	are most determine the suitable habitat for *Tracyphitecus auratus* at Merapi Volcano National Park? 3. Is there refuge areas for javan langur outside Merapi Volcano National Park be identified by?
2	To estimates habitat loss of javan langur due to the last Merapi eruption in 2010	4. What is the condition of javan langur's habitat after the 2010 Merapi eruption? 5. How much is the loss of javan langur's habitat caused by pyroclastic in 2010 Merapi eruption? 6. Does the natural disaster is the main factor on habitat change of *Tracyphitecus auratus* at Merapi Volcano National Park?
3	To generate a risk map for javan langur according to pyroclastic hazard of Merapi eruption	7. Where areas are risky for javan langur? 8. Where areas surrounding Merapi Volcano are suitable for refuge areas of javan langur?

Table 1: Showing research questions for each objectives of this research

1.6 Hyphothesis

We proposed two hypotheses in this research as follows:

Ho : The pyroclastic of 2010 Merapi eruption did not cause significant habitat loss of javan langur in Merapi Volcano National Park

H1 : The pyroclastic of 2010 Merapi eruption caused significant habitat loss of javan langur in Merapi Volcano National Park

Ho : The all proposed enviromental variables have a significant contribution in determining suitable habitat for *Tracyphitecus auratus*

H1 : Only several enviromental variables have a significant contribution in determining suitable habitat for *Tracyphitecus auratus*

1.7 Benefit of the Research

The estimation of habitat loss of javan langur can provide information related with habitat changes caused by natural disaster. Furthermore, this will be an input in policy and strategy of national park management. The selected suitable habitat can be used for providing refuge areas which is an important effort of conservation in volcanic hazard prone areas. From this research 3 outputs are expected as follows: estimation of habitat loss, a risk map of javan langur, and identified refuge areas.

Chapter 2 Literature Review

2.1 Natural Disasater and Ecosystem

The association between environment and disaster has performs circular and cumulative pattern, which on one side natural disaster result direct and secondary effects to environment (Kreimer and Munasinghe, 1991) as has been studied in Wenchuan earthquake (Du, Chen et al. 2012) and the 2004 Indian ocean tsunami (Chatenoux and Peduzzi, 2007). On the other hand, environment degradation can generate disasters, decrease resilience and release green house gasses that trigger climate change and other forms of disaster (UNEP, 2009). Recently, ecosystem approach similarly or more beneficially in reducing disaster risk than technology or infrasructure based (Rieux, et al, 2006)

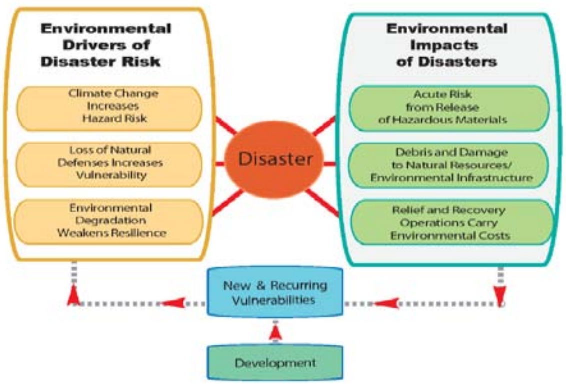


Figure 4: Disaster and environment linkages (source: PEDRR, 2010)

Disasters can have unfavorable influences on the environment and on ecosystems which could have instant to long-term effects on life, health and livelihoods of populations who well-being depend on a given environment or ecosystem (PEDRR, 2010). This could be triggers increase of invasive species and habitat failure (Rieux, et al, 2006). Environmental impacts may incorporate direct damage to natural resources, destruction and fragmentation of wildlife habitat (Kreimer and Munasinghe 1991). The fragmentation and loss of habitat are related to degraded resources, higher isolation and increasing the far-reaching edge effects (Laurence and Bierregaard, 1997). Fragmented landscapes usually experience a net loss of important habitat and largely reduce in connection and core territory (Marshal et.al, 2006). Several research frequently have assumed that species with specific habitat parameters that is great range of teritory, ecological interest and adversion to edges will endure higher from habitat loss, destruction and boundary pressure (Dyke, 2003)

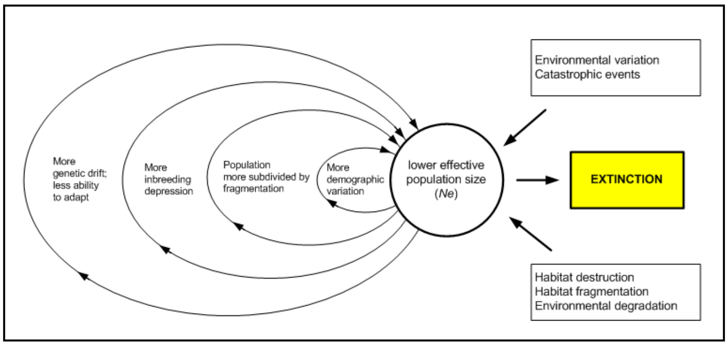


Figure 5: Catastrophic events and the effect to species' population (Primack, 1993).

To determine the consequences of land-use change and catastrophic events like natural disaster on habitats is not straightforward (Leemans, 1999). If a habitat of species is distorted, the instant impact during a life of one species may not be too apparent and the final extinction due to habitat destruction and fragmentation could become clear only after decades and centuries (Tilman et al., 1997 in Leemans, 1999). At the short time, the effect could be in decreasing of population size and variaton in species' demographic (Figure 5)

2.2 Volcanic Hazard

The term of hazard is defined as "a dangerous occurrence, material, or situation which trigger death, hurt or other health impacts, building destruction, failure of occupations and services, community and financial disturbance, or ecological defect" (UNISDR, 2009). As geological hazard, volcanic eruption can produce not only single hazard but numerous hazards in same time. When the dome collapse or explosive eruption occur, volcanic landslides bring a pyroclastic material with temperature can reach 800^0C and speed get to 360 km per hour transverse lower area at along a few kilometres away (Westen, et.al 2009, Sheridan et.al, 2004), and at the similar moment million cubics of ash sprayed on hundred kilometers away.

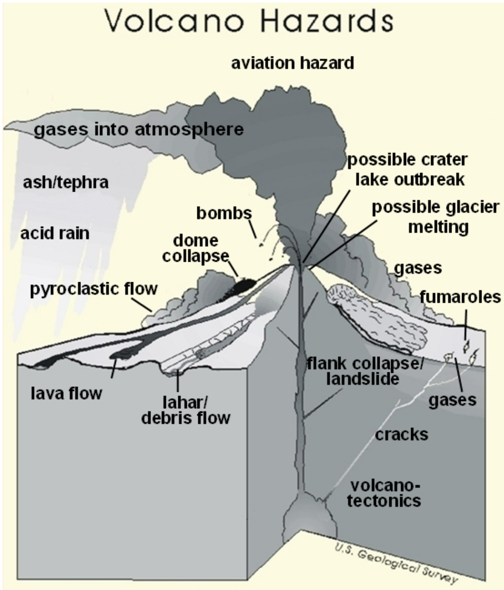


Figure 6: Numerous hazard types in volcanic eruption (source: US Geological Survey in Westen, 2009)

Figure 6 above showing several hazards from volcanic eruption such as ash, gas, lahars, lava flows, pyroclastic flows, and tephra. The most significant causes of disaster during volcanic eruption are corresponded to hazardous cases in several triggering factors and the eruption itself has many types and the duration can vary from few minutes to months or year (USGS, 2012).

Volcanic eruption types differ based on their height of plume and the volume of tephra. Several volcanos have a return period time of eruption which ranging from once in a year until once in thousand years, as well as volume of produced tephra which can achieve up to a thousand billion cubic metres (figure 7).

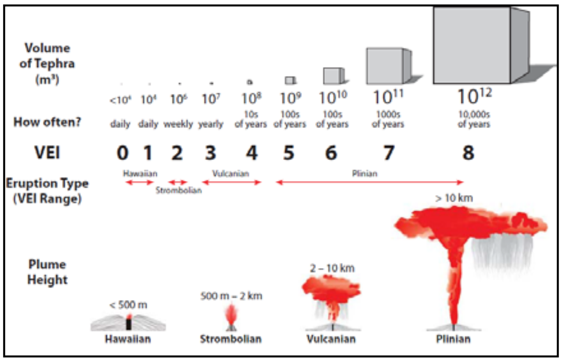


Figure 7: Ilustration of quantitative (source: www.delmarlearning.com)

2.3 GIS in modeling suitable habitat

Remote Sensing and GIS has widely been used in analysis of habitat fragmentation and loss. Habitat fragmentation is clearly seen when viewed from an aerial photograph or satellite imagery (Leeuw, 2000). The applying of remote sensing data for modeling appropriateness of habitat and mapping is powerfully supported by the results of Cousse and Joachim (1999) in the Cevennes National Park and Laffly (1999) in the Jura Mountains as cited in Jacquin, Cheret et al. (2005).

Suitability of land for wildlife reflects its capability in ensuring wildlife sustainability. With its multi-use, satellite imagery can provide quantification of landscapes depending on its resolution and patch size (Kenter, et.al, 2003). The factors influencing precision of suitable habitat map is the fitness of the output to the real condition (Leeuw, 2002). The habitat condition consists of several forest variables can be quite easily produced over large areas using satellite data.

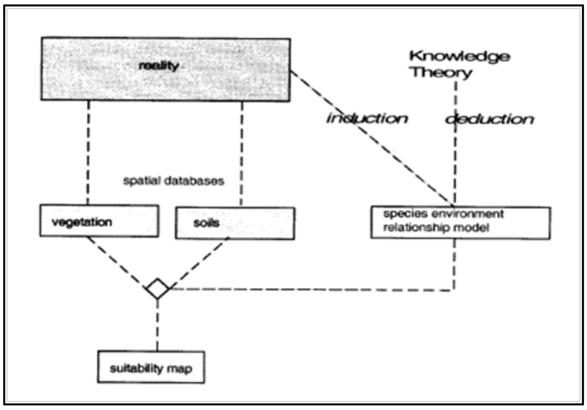


Figure 8: Scheme for GIS based suitability mapping (Source: Leeuw, 2002)

More over, the GIS combined with ecological niche-based modeling approach has established in evaluating the relationships between ecological predictors and species distribution, species diversity, and species habitat suitability the same with estimation of the amount of population (Torres et al, 2010)

2.4 Disaster Management for Wildlife

Adapted from the definition of disaster risk management by UNISDR (2009) disaster management of wildlife is according to comprehensif process involved organizations, concept and operational to apply policies, strategies, enhanced coping capacities to reduce the unpleasant crashs of dangers and the probability of disaster for wildlife. This process is addressed to evade, decrease and remove the bad results of disaster by prevention, mitigation and preparedness

Risk assessment is the first step in conservation of speciest at risk. Referring to Environment Canada (2008) there are several activities related to assessment of species at risk i.e : 1) recognize prospective occurrences of species and ecosystems at risk, 2) carry out proper surveys to verify existence or absence of species and ecosystems at risk, and 3) mitigate potential impacts such as man made building or destructed habitat which can influence species and their ecosystem.

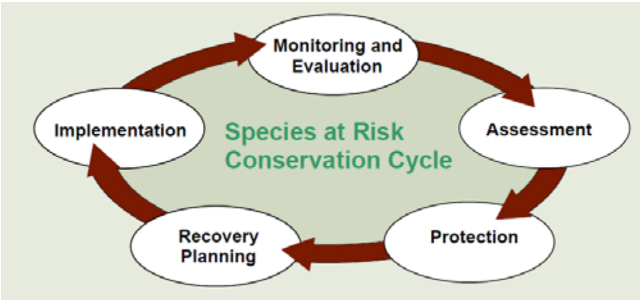


Figure 9: Species at risk conservation cycle (source: Environment Canada, 2008)

Chapter 3 Research Methodology

3.1 Study Area

The study was conducted at Merapi Volcano National Park which located in two provinces, i.e. Yogyakarta and Central Java Province and geographically lied between 110°15'00" - 110°37'30" E and 07°22'33" - 07°52'30" S. Established in 2004 by Decree of the Ministry of Forestry Number 134, this conservation area has mandate to optimize preservation of flora and fauna species and to establish the function of forest in environmental services.

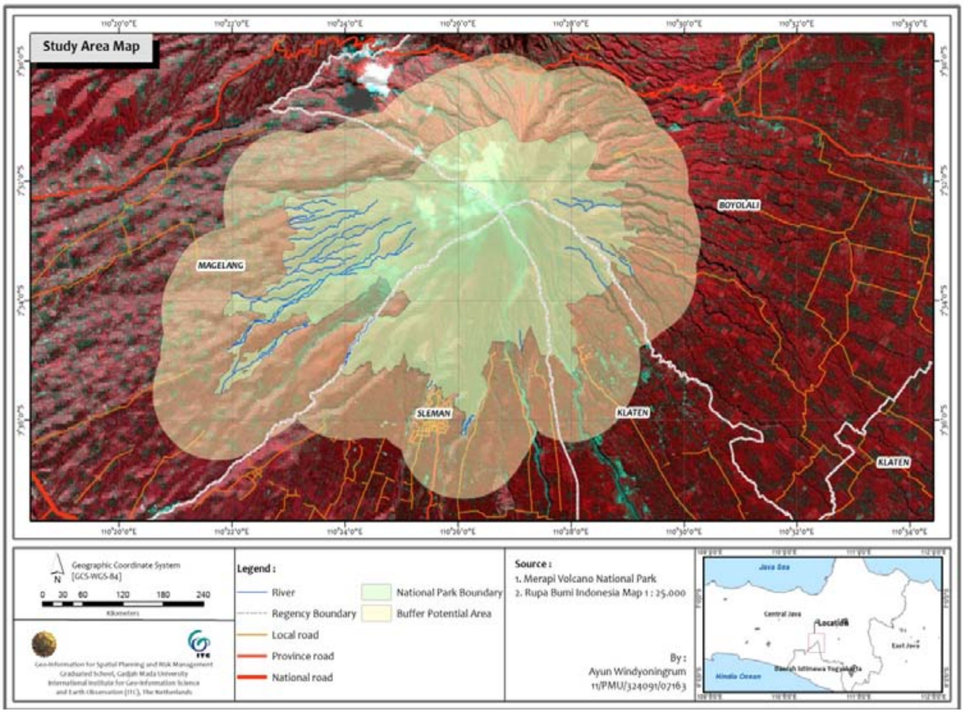


Figure 10: Merapi National Park and its surrondings as study area (Source: data processing, 2012)

Merapi Volcano National Park has area of 6510 ha, divided into 4 zones namely sanctuary zone, wilderness zone, buffer zone and utilization zone. There are four species of vegetation dominating in this area i.e *Pinus mercusii*, *Erythrina lithosperma*, *Schima wallichii and Acacia decurens* (Subarkah, 2012). Annual rainfall ranges from 2500 up to 3400 mm. Rainfall variations along the slopes of Mount Merapi is influenced by orographic rain. Like other tropical monsoon region, variation in temperature and humidity are essentially not flashy. Temperatures range between 20-33^0 C and humidity vary between 80% - 99%.

To identify potential habitat outside Merapi Volcano National Park, we included forest patch near the boundary of national park into the models. The scenario was determined by buffering areas surronding national park within 2 kilometers from major road (see light tone area surronded national park's boundary in figure 10). The distances of 2 kilometers was assumed as the furthest of their daily move in a day which can reach 500-1300 meters (Nursal, 2001)

3.2 Methods

This research focused on estimating loss of habitat and mapping species at risk in volcanic hazard area. There are some important parameters for habitat analysis which should be considered namely forest cover, food, and topography (Roy et.al, 1995). For modeling suitable habitat of javan langur, some environmental parameters were used namely landcover, forest canopy density, precipitation, temperature, slope and altitude.

To achieve main objectives of this research, we build methods in detail way as mentioned in below:

3.2.1 Pre Fieldwork

In this phase, the main activity is collecting data and information related to Javan langur species such as literature review of their habitat, behavior, and diet. Spatial analysis to determine the habitat suitability is concentrated on factors which influence the quality of javan langur's habitat, namely coverage area which correlated with food resources and their moving space, topography, and climatic variables. Besides we collected also data points of langurs sighting from previous research which can be used in models the species distribution.

3.2.2 Fieldwork

Fieldwork was undertaken from mid October until the end of November for about 3 weeks mainly to collect location point of javan langur in Merapi National Park and nearby, its habitat characterics and interview with local people. According to Supriatna, (2000) that javan langur prefers to life in forest which supply leaves as their main food, we conducted survey in several potential areas within Merapi Volcano NP namely Dukun and Srumbung in Magelang Regency, Musuk, Selo, and Cepogo in Boyolali Regency and

Deles in Klaten Regency. In each area we collected data on population and habitat characteristics of javan langur. Apart of gaining information, we visited and discussed with staff and Head of Merapi Volcano National Park about disaster management related to wildlife.

3.3 Suitable Habitat Modelling

There are several statistical modeling instruments that made to relate between species occurence points with ecological parameters to create a species distribution model (SDM) such as GAM, GLM, DOMAIN, GARP, MaxEnt (Guisan and Zimmerman, 2000). These tools generate geographic distributions for a given species based on areas of which has the same ecological condition to entries of species occurence points (Elith et.al, 2006)

We employed MaxEnt as a tools in creating species distribution and modeling suitable habitat concerning its ability to differentiate between suitable and unsuitable habitat using minimum presence only data (Philips et.al,2006). MaxEnt is a universal-principle machine learning method based on a easy and accurate numerical formulation which predict the most uniform distribution (maximum entropy) of case points measured up to environment site offered the restraint obtained from the data, (Philips et al, 2006). This method uses presence-only records as input in environmental layers (Elith et al. 2006) which can be in format of museum records, herbaria, fossil locals or reported sightings.

Philip (2006) stated that principally, maximum entropy models are based on a easy logic: when modeling the unidentified occasions with a statistical form, the single with maximum entropy always ought to be selected. Maxent is the model that constructs large amounts of homogeneous distribution but still correctly suppose the examined facts (Torres et al, 2010). The following formula explains the enthrophy of π which used in Maxent model (Schapire et.al)

$$H(\hat{\pi}) = -\sum_{x \in X} \hat{\pi}(x) \ln \hat{\pi}(x) \qquad (1)$$

Where,

π : the unknown probability distribution above a limited set *x*

x : the set of pixels or points in research region

ln : the natural logarithm.

From the algorithm above, the distribution model defines a non-negative probability π (x) to each point x and these probabilities sum to 1 where the best approximation of π is the probability distribution π (Philips et.al, 2006).

The potential distribution determines where locations are appropriate for supporting species life therefore it is an immense significance of preservation. Philips (2006) argued that Maximum Entrophy models approach can also be employed to guess the species realized distribution such as by eliminating locations where the species is identified to be not present related to degradation and enviromental problems. Several enviromental parameters used in modeling suitable habitat of javan langurs in MVNP are described below:

3.3.1 Precipitation

To have layer of precipitation which will be used in modeling suitable habitat, we made precipitation layers using interpolation method and rainfall data from 9 raingauges. Considering topographic variable in study area, the topo to raster interpolation method was used to have spatial pattern and estimation of annual and monthly precipitation. This method has been used broadly in environmental sciences (Li and Heap, 2011). Firstly, data location points of the 9 raingauges and those values were built in vector layer (shape file type). The second step was preparing layer of the study area boundary as the border of interpolation step. The interpolation stage produced maximum and minimum values which will be then cut or clipped based on the research area. At this step, cell size which produced was still in default type that does not have a size of 30 m, so we used resample tool to change the size of the nearest pixel.

3.3.2 Temperature

The same method as described in making precipitation layer was applied in making temperature layer. We used annual average temperature from only 4 weather station surronding study area since like other place in tropical region there are no crucial differences of temperature value within a year.

3.3.3 Landcover

In model suitable habitat of species, landcover is the most essential aspect which determining its function as food resource, thermal cover, hiding cover and human encroachment (Beier, et.al. 2006). We use Aster imagery resolution 15 m of year 2009 and of year 2012 to visually identify.

MaxEnt can predict suitable habitat using both continous and categorical data such as landcover types. We reclassified landcover and land use types into nominal data as summarized below:

Table 2: the reclassification of landcover and landuse

Land cover and Land use	Reclassified class
Dry farm land	1
Settlement	2
Shurb land	3
Bare land	4
Grass	5
Mixed forest	6
Pine forest	7
Damaged pine forest	8

3.3.4 Forest Canopy Density

According to Nijman (2010) that the species is very depend on forest cover and aboreal species we proposed the density of forest canopy and landcover as as one of environmental layers in predicting suitable habitat for javan langur in Merapi Volcano National Park. As the valuable parameter, forest canopy density can represent the forest ability to support animals' life. It indicates the growth and quality of forest (Rikimaru, et.al., 2002).

3.3.4.1 Landsat ETM + Gap Filling

The landsat images used for Forest Canopy Density Mapping were Landsat ETM + acqusition on 31 July 2009 and 13 Juni 2012 of path 120/row 065. Those images included in level L1T briefly means that the images had been corrected. The Level 1T (L1T) data invention presents normal radiometric precision, geometric correctness by including ground control points and occupying a Digital Elevation Model (DEM) for topographic precision. The accuracy of geodetic measure of the product depends on the precision of the ground control points and the pixel size of the DEM used (NASA,2013)

Image used in this research were Landsat ETM+SLC off data. These image refers to all Landsat 7 images collected after May 31, 2003 when the Scan Line Corrector (SLC) was stop working (USGS, 2012) . These images have holes, however still functional and keep the similar radiometric and geometric rectifications as previous images accumulated before SLC failure (USGS, 2012). We used Frame and Fill software to fill gaps in

Landsat ETM+ year 2012 and patched it with other images which have the same period time.

3.3.4.2 Forest Canopy Density Mapping

Employed FCD mapper version 2.2, the FCD model consist of bio-material fact modeling and analysis utilizing data derived from four indices: Advanced Vegetation Index (AVI), Bare Soil Index (BI), Shadow Index or Scaled Shadow Index (SI, SSI) and Thermal Index (TI).

The Forest Canopy Density Model combines data from the four indices. The correlation between forest conditions and the four indices (Vegetation Index, Bare soil Index, Shadow Index and Thermal Index) is ilustrated in Figure 11. Vegetation index responses all vegetation items such as the forest and the grassland and Advanced vegetation index AVI correlates with vegetation quantity which balanced with NDVI. Shadow index rises if the forest density enhance, Thermal index enhances as the vegetation quantity rises, while bare soil index enhances as the bare soil exposure degrees of ground rises and these index values are calculated for every pixel (ITTO, JOFCA. 2003)

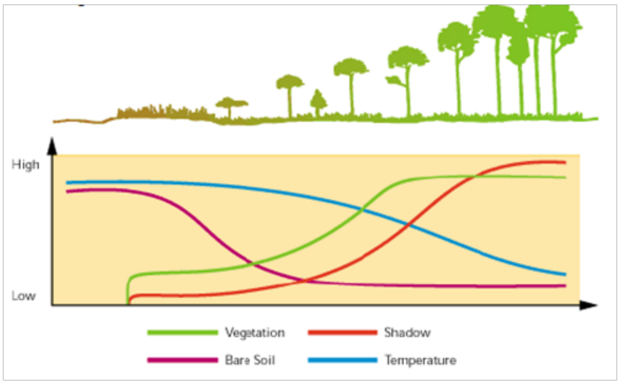


Figure 11: Ilustration of canopy density mapping concept (Source: Jamalabad and Abkar, no year)

The concept of canopy density mapping can be determined by this formula:

$$\mathbf{FCD= (VD \times SSI +1)^{1/2} -1} \qquad (2)$$

Where,

VD : Vegetation Cover Density (%) for each pixel

SSI : Scaled Shadow Index (%) for each pixel

FCD : Forest Canopy Density (%) for each pixel

3.3.5 Elevation

Topographic variables is widely used as spatial predictor in species distribution models (Guisan and Zimmermann 2000). As mountanious area, Merapi Volcano National Park has variety of altitude. To have elevation data we retrieved DEM data from Shuttle Radar Topographic Mapping (http://srtm.csi.cgiar.org/.) which has pixel size of 90 m and we resampled into 30 m pixel size using nearest neighbor method. SRTM has the same data structure as other grid data format which consists of cells that each of them has a representative value of height and can be properly used for small scale local study area (Mukherjee, Joshi et al. 2013)

3.3.6 Slope

The free access and wide utility of DEM SRTM by generating topographic variables have been applied in ecological modelling (Wise, 2007). DEMs commonly have coarse resolution for generating steep slope and lower zones but it contribute too little impact on the resulted topographic factor (Shafique, van der Meijde et al. 2011). We calculated slope degrees from elevation data using 3D analyst tool in ArcGIS 9.3

3.4 Primate Occurence

In models suitable habitat using Maxent method, species presence data is vital data that being basis in predicts distribution of π (Schapire, no year). According to Elith (2006) that presence points of species can be in form of herbaria, museum collection, fossil locals, and reported sightings or incidental records, we collected data of javan langurs' occurence by applying some method which commonly used in primate survei.

The location points of javan langur in Merapi National Park collected during fieldwork and secondary data. To reduce duplication of records between datasets, we omitted a number of adjacent points.

3.4.1.1 Fixed Points Count survey

It is commonly used for large areas but limited time. By notice the sounds of animals calling, it can be estimated the density of populations in certain area and a good prediction of species presence (Brockelman WY, Srikosamatara S. 1993).

3.4.1.2 Dung or Feces survey

This method has widely been applied in animals' survei. In primate survei, feses can be used as a sign of species occurences (Kuhl, Ancrenaz et.al, 2011). Even dung and decay rate can be used as a factor in calculating species population (Kühl *et al.* 2007).

3.4.1.3 Photo survey

Due to time limit, a number of presence data in this study were collected throughout a photograph survey done by several volunteers who familiar with primate survey. It is able and very useful for designing systematic forecasting of the possible distribution of a target species.(Kadoya, Ishii et al. 2009).

3.4.1.4 Secondary Data

The first survey of langur in MVNP which done by Subarkah (2012) was useful in collecting presence data and it contributes 19 points in this research. We were also supported data from Merapi Volcano National Park for about 6 presence points.

3.5 Preparing Environmental Layers

The all enviromental parameter layers with their values of various variables were converted to ascii raster grid format as asked by Maxent software. These background layers which made using boundary of the study area should have the same number of columns, rows and pixel size when the raster data were converted into a format of ASCII or txt type file. At previous step the cell size might not same. It was due to the clip that resulted in a difference of about one or two columns or rows. Therefore recalculation was done to match the value on the grid of the same size. The first step was to make a grid with a size of 30 x 30 m with a vector format covering the study area. We then converted raster data (e.g temperature layer) to the point of the tool in the form of raster-to-point, resulting in a point with a certain value which will be joined with the grid that was created earlier. At this stage, a single grid will calculate the average value in it and to get the value of a single pixel. The last step is to change the results of the join vector data into raster data with the option of cellsize was 30 meters. The all layers were converted into txt format to produce the same number of columns, rows, and pixel size. To have enviromental layers with same projection as presence point's data in geographic projection systems, we converted all layers from UTM projection system to geographical system. The final number of column is 701, rows: 500, xll corner: 110.34292054506 yll corner: -7.6232015360381, and cell size is 0.00027201673932971.

Another important input in modelling suitable habitat using Maxent software is presence points of javan langur that written in **csv** type file which contain species name, longitude and latitude coordinate of their location.

3.6 Habitat Analysis

To have picture of habitat's condition after 2010 Merapi eruption several parameters of habitat quality should be measured. The vegetations within sampling plots size 20 m by 20 m were identified. Area selected as sampling plots were near nested tree or food resources of javan langur

3.7 Data Analysis

Attained in the fieldwork, we had data in the form of species occurrence location and had been georeferenced which determines where the javan langur species has been observed. Besides, there were data of environmental variables, such as average rainfall, average temperature, elevation, slope, forest cover density, and landcover types. We also validated two parameters used in research namely Forest Canopy Density and landcover identification as described below:

3.7.1 Forest Canopy Density Validation

Percentage values of canopy density generated from FCD Mapper were validated with result of density estimation which obtained from fieldwork. We employed statistical analysis of the root mean square error, which described below:

$$\boldsymbol{RMSErrors} = \sqrt{\frac{\sum_{i=1}^{n}(\hat{y}_i - y_i)^2}{n}} \qquad (4)$$

Where,

y_1 : observed canopy density values

y_2 : measured canopy density values

n : number of sampling plots

3.7.2 Accuracy Assessment of Landcover Classification

To assess the accuracy between land uses in the modeled land-use map and the authentic land-use map, usually based on a pixel by pixel evaluation. The methods which most widely used for this assessment is the Kappa coefficient of agreement (Cohen, 1960) in (van Vliet, Bregt et al. 2011). The formula of Kappa is described below:

$$\hat{K} = \frac{\text{observed accuracy - chance agreement}}{\text{1 - chance agreement}} \quad (3)$$

Or can be written in mathematical

$$\hat{K} = \frac{N \sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r} (x_{i+} * x_{+i})}{N^2 - \sum_{i=1}^{r} (x_{i+} * x_{+i})}, \quad (4)$$

Where,

r : the amount of rows in the matrix,

x_{ii} : the amount of observations in row i and column i,

x_{i+} *and* x_{+i} : the marginal totals of row i and column i, respectively, and

N : the total number of observations

3.7.3 Model Accuracy using AUC and TSS

A model should be measured its accuracy since the accuracy show the quality of the model (Fielding and Bell, 1997). To test the acuracy of resulted models, we observed AUC value and TSS. The purpose of AUC to estimate the predictive accuracy of models has widely been used (Lobo et.al, 2008). AUC is the area under ROC curve which present a single measure of overall accuracy and an illustration of the model’s discrimination ability which not rely on a certain threshold (Fielding and Bell, 1997). Hijmans and Elith (2013) stated that AUC determines the value of rank-link and in fair data, a high AUC indicates that sites with high index value susceptible to be areas of known presence and areas with lower index values are likely to be areas where the species is not known to be present (absent or a random point). Models that has value of AUC 0.5-0.6 = no discrimination; 0.6-0.7 = discrimination; 0.7-0.8 = suitable; 0.8-0.9 = admirable; and 0.9-1.0 = excellent (Phillips et al., 2006).

The use of AUC only as accuracy of model performance was critized since it based on a single threshold-independent of prevalence which can occupy wide niches, therefore the predicted area are larger than scarce species (Allouche et.al,2006). It is recomended for using True Skill Statistic (TSS) as one measure of model's accuracy. The formula of TSS is described below :

$$TSS = (sensitivity + specificity) - 1 \quad (5)$$

Where, sensitivity is the amount of observed occurences that are correctly predicted, while specificity is quantity of observed absences that correctly predicted (Allouche et.al, 2006). Sensitivity is quantification of ommision errors while specificity is quantification of commission errors (Allouche et.al, 2006). According to Pearson et.al (2007) we used the 10 percentile training presence logistic threshold as threshold number. As mentioned in Jones, et.al (2010) TSS value less than 0.2 can be assigned as not good, between 0-2 and 0.6 is fair, and greater than 0.6 is good.

3.7.4 Multicollinearity Test

The main constraint of previous modelling practices is supposedly related to the failure to recognize and integrate the interactions between enviromental variables (Austin 2002). Several method were applied to select enviromental variables such as deviance reduction as measured with the x2 statistic, stepwise regression, shrinkage rules, or collinearity test (Guisan, Edwards Jr et al. 2002). Multicollinearity is a data problem which determines the linear corelation among two or more variables and might be a root somber complexity with the trustworthiness of the approximations of the model parameters (Alin 2010). We selected the collinearity test using variance inflation factor (VIF) which can detect collinearity (Guisan, Edwards Jr et al. 2002) among parameter estimates. The VIF formula is described below:

$$VIF_j = \frac{1}{1 - R_j^2} \quad (6)$$

Where,

R^2_j : coefficient of determination resulted by regressing the j^{th} predictor on the remaining predictors.

To detect multicollinearity problem between continous variables we calculated the Variance inflation factor (VIF) using linear regression in SPSS 17.0 statistical programme. The calculation is firstly made using all the predictor variables and then eliminating the variables that generate VIF greater than 10. Recalculation was done again with the new reduced list of predictors and the process continues until all enviromental variables have VIF less than 10. The high value of VIF more than 10 indicates that collinearity occurs between one or more variables used.

3.7.5 A Jackknife test for most influence variables

To find out the significance of enviromental variables we completed jackknife test. This method dropping the least important variable from the full model then a new model was made with remaining variables (Baldwin, 2009). All feasible combinations of variables were modeled and then ranked concerning the AUC scores, the model with high parsimonious was selected according to its simplicity and least variables (Baldwin, 2009)

3.8 Pyroclastic of 2010 Merapi Eruption

The area damaged by pyroclastic had been studied by (Cronin, Lube et al.) who mapped pyroclastic density current (PDC) deposits using high resolution image (Ikonos and GeoEye1) and validated the density by measuring thickness of PDC in the field. The 2010 eruption produced larger PDC deposit and greater volumes than previous Merapi eruption (Cronin, Lube et al.).The major stream of pyroclastic density current influenced on south western and southeastern section of the summit which coverage area of 24.5 km^2 mainly on Kali Gendol while little PDCs found in Kali Senowo, Kali Krasak and Kali Boyong (Cronin, Lube et al.). Figure below shows the distribution of pyroclastic density current of 2010 Merapi eruption.

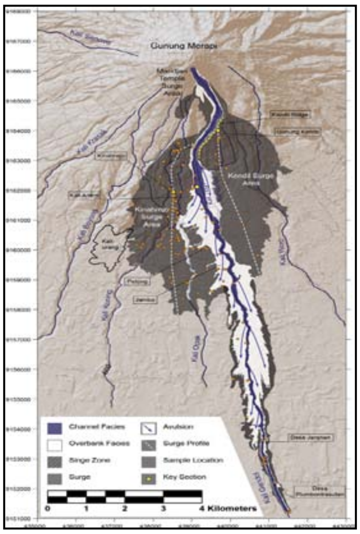


Figure 12:The distribution of pyroclastic of 2010 Merapi eruption (source: Cronin, Lube et al.)

To be used as triggering factor on habitat loss, we should consider the effect of pyroclastic to trees. This had been studied by Kelfoun, Legros et al. (2000) who described three categories of damaged trees namely "(1) *Singed trees* with dried leaves but no broken branches (2) *Broken trees* with stripped leaves and broken branches or trunks and (3) *Blown-down trees* (or downed-trees) with trunks either uprooted or snapped off at ground level". Level of damaged on trees is very depend on steepnees of slope. The more steep of slope is the greater of damaged trees since steep slope can induce collision and fragementation which can increase mechanical energy of the pyroclastic (Kelfoun, Legros et al. 2000).

3.9 Mapping Species at Risk

A "species at risk" is any plant or animal in danger of extinction caused by natural factors or of disappearing from its habitat according to human activities such as illegal trade, land conversion and deforestation (IUCN, 2012). In general, species at risk map is a map contain amount number of species at risk which sometimes also include the Redlist category from IUCN (International Union for Conservation Nature)

According to the definition of risk by UN-ISDR, risk is "the probability of harmful consequences, or expected losses included enviromental damaged resulting from interactions between (natural, human-induced or man-made) hazards and vulnerable conditions". Risk can be presented theoretically on the following basic formula (UN-ISDR, 2009):

$$\textbf{\textit{Risk = Hazard x Vulnerability}} \qquad (7)$$

We generated species at risk according to pyroclastic hazard of Merapi eruption with vulnerability and hazard as described below:

3.9.1 Vulnerability

We can define vulnerability in many terms and viewpoints. It is the degree of loss sensitivity of the system and factor or root causes of vulnerability (PEDRR, 2010). Westen (2010) argued that environmental vulnerability is the prospective impact of event to environment. According to the theory of ecological vulnerability defined by De Lang et.al (2009) in Lahr et.al (2010) potential exposure and sensitivity habitat of species can be assigned as vulnerability in mapping species at risk.

Since the object of this research is langurs that very mobile animals we defined the elements which can be measured i.e elements related to its suitable habitat. We are not too bothered on the species or their homerange itself since they most likely will go away when the volcano become active and will return back if suitable habitat for them has been restored.

Concerning that vulnerability of *Tracyphitecus auratus* in facing pyroclastic hazard very depend on habitat quality, we proposed suitable habitat, distance to settlement and accessibility of habitat as the main factor in defining vulnerable habitat. We analysed the vulnerability of habitat by identifying accessibility of habitat and distance to settlement. We mapped road within the park using Quickbird imagery of year 2006 and counted the road density using line density tools in ArcGIS. We also concerning on vulnerability of habitat due to potential encouragement by measured habitat distance to settlement using euclidean distance tools.

3.9.1.1 Distance to settlement

The euclidean distance tools has been widely used in detecting pattern of species movement (Conner and Plowman 2001) and habitat selection and connectivity (Nikolakaki 2004). We calculated distance of habitat to settlement based on interpretation result of Aster imagery of year 2012 which could inform the last location of settlement areas.

3.9.1.2 Accessibility within national park

To determine the degree of accessibility of habitat by human interaction, we calculated road density using line density tools in ArcGIS. Since map of road which presented in base map (Rupa Bumi Indonesia Map) did not reflect the current condition of accessibility within the park, we identified footpaths using Quickbird imagery of year 2006.

3.9.2 Pyroclastic Hazard Map

Accepted as the primary cause of devastation and losses in volcanic event (Costa, 1984), lahars produce pyroclastic that should be assessed and recognized its potential hazard. Volcanic hazard assessment at Merapi can be made through on restructured the history of eruption, by considering eruptive manners and scenarios, and on existing models and prelude mathematical modeling (Thouret, Lavigne et al. 2000). One result of the volcanic eruption of Merapi in 2010 was morphological changes in the peak of Merapi Volcano increasingly open to the southeastern – southern flank. The next Merapi eruption after 2010 event was deliberated by Darmawan (2012) which predicting the pyroclastic hazard using several scenarios of eruption index from level 1 up to 4 (VEI 1-4). Eruption index ranging from 1 up to 4 were used based on the history of Merapi eruption that has frequent eruptions range 1 to 4. He has compared the pyroclastic distribution based on ground check validation, on SPOT 5 imagery and on GeoEye imageries. He suggested that Titan2D can properly map the flow of pyroclastic material that has bomb coarse up to fine sand size, but it can not model pyroclastic sand material or surges which are very smooth size (Darmawan, 2012). Thus, using Titan 2D the research modeled the pyroclastic hazard after 2010 eruption from one million up to 60 million cubic meters of pyroclastic.

Table 3: Four scenarios of the next eruption after 2010 event

Index Volume of Ejecta (Newhall, 1982)	Volume	Model	Historical Events at last 100 years (Voight et.al, 2000)	Hazard Prediction using Titan 2D
VEI 1	$10^4 – 10^6$ m^3	10^6 m^3	1915, 1918, 1922, 1924, 1932, 1957, 1971.	The furthest distance of avalanches with a volume of less than 1 million m^3 will reach 3.2 km from the peak of Merapi Volcano. The area affected about 125 acres. The maximum thickness of sediment will reach 4-8 m and located in the valley of Kendil hill.
VEI 2	1-10x10^6 m^3	4x10^6 m^3	14 times	The area affected due to pyroclastic of VEI 2 is 391.79 acres with a maximum sediment thickness reaches 4-8 m in the valley of Kendil Hill and Opak upstream. The furthest distance of avalanches up to 7 km from the peak of Merapi Volcano.
VEI 3	10-100x10^6 m^3	42x10^6 m^3	1930 and 1961.	Pyroclastic can reach on distance of 11 km from the summit. The area affected is 818.5 hectares.
VEI 4	>100x10^6m^3	60x10^6 m^3	1872-1873 and 2010	The pyroclastic with a volume of 60 million m^3 can reach in distance of 16.5 km from the peak of Merapi. It is possible that volume more than 100 million m^3 can reach more than 20 km from the summit of Merapi volcano. The damaged area can totally reach 3.559 acres

(source: Darmawan, 2012)

Since this map was the recent pyroclastic hazard map after 2010 event and available at the time of this research with proper scale which meet our needs, we used this map as hazard map in mapping species at risk althoughi it should be noted that this pyroclastic hazard map has not been validated.

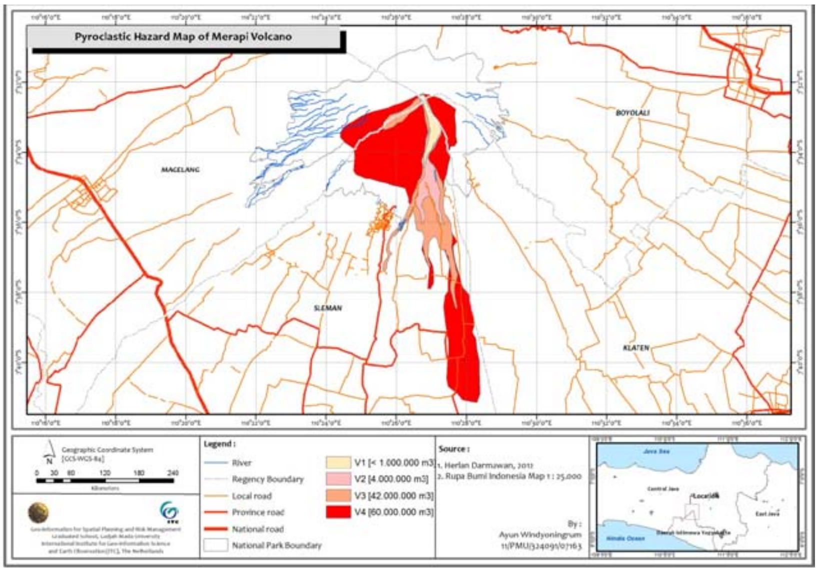


Figure 13: Pyroclastic Hazard Map (Source: Darmawan, 2012)

The eruption with VEI =1 and VEI=2 are most frequently arised in recent 100 year and have the same characteristics which often through the bottom of drainage and produce maximum thickness of sediment about 4-8 m in the valley of Kendil Hill and Opak upstream, we assumed these type as scenario 1 and given a value of 1, while VEI=3 is 2 and VEI=4 which huge eruption was given score value of 3. The 3 (three) scenarios of pyroclastic hazard was described in this following table :

Table 4: Scoring of Hazard Level

Scenarios	Hazard Level	Score Value
VEI 1 and VEI 2	Low	1
VEI 3	Medium	2
VEI 4	High	3

Pyroclastic hazard map (Darmawan, 2012) was properly cut off regarding boundary of national park and reclassified as shown in this following map:

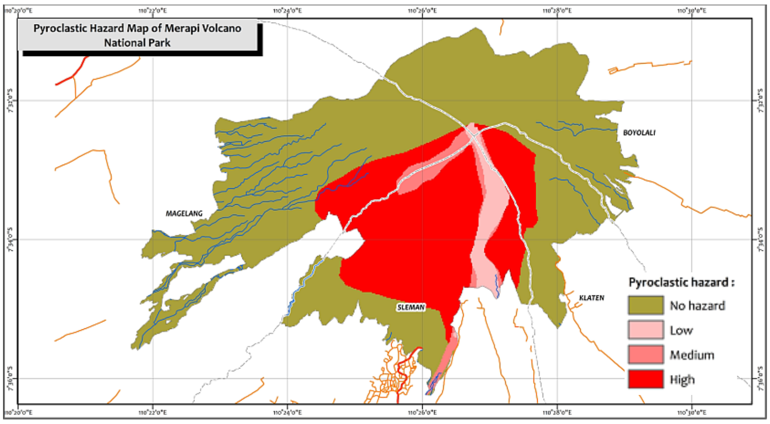


Figure 14: Pyroclastic hazard map of Merapi Volcano NP (source: Darmawan, 2012)

Weighted overlay technique based on scoring method was applied to have species at risk map. Assuming that pyroclastic hazard is the main factor in forest coverage change, the pyroclastic hazard was given score of 70% while vulnerability was given score 30%.

3.10 Refuge Area Identification

We determined refuge areas for javan langur as follow: 1) refuge area outside the park: to generate this site we included area within 2 kilometers from major road surronding the boundary of MVNP into Maxent model. It has been studied that MaxEnt can successfully predict the occurrence of species in unsurveyed areas which could be an approach on resolving of conservative distribution (Bidinger et.al, 2012). We proposed 2 kilometers assuming on daily move of langurs which ranging 500-1300 meters (Nursal, 2010). 2) Overlying existing habitat with map of Merapi eruption during 1911 – 2010 and 3) The refuge points: we collected also information of refuge spots during 2010 eruption by interviewing local people and participatory mapping.

3.11 Research Approach

Combining literature review, satellite imagery and data fieldwork, this research is designed in appropriate way as below:

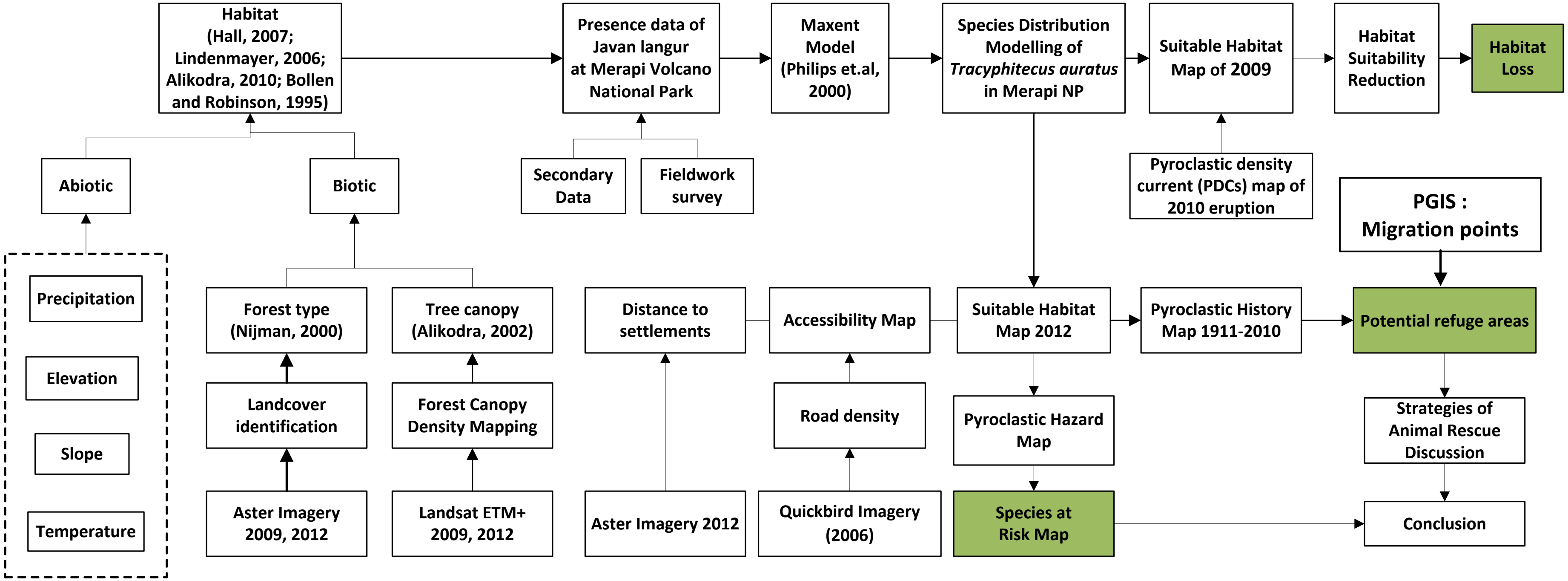


Figure 15: Flowchart showing research framework (Source: data processing, 2012)

3.12 Raw Materials

List below showing materials used in this research as follows:

Table 5: Detail materials used in this research

Materials	Description	Spatial resolution; year	Source
ASTER imagery	Landcover	15 m; 7 July 2009 and 13 June 2012	Faculty of Forestry, Gadjah Mada University and LPDAAC through RSG Laboratory, ITC-Faculty of Geo-Science and Earth Observation, University of Twente.
Landsat ETM+ imagery Path/Row120/65	Forest Canopy Density	30 m; 31 July, 27 October 2009 and 1 September , 13 June 2012	http://glovis.usgs.gov/
Quickbird Image	Road density	60 cm; 2006	National Land Agency
Pyroclastic Map of 2010	Area damaged in northern flank of Merapi Volcano	Scale 1: 100,000	Cronin, Lube et al.
Pyroclastic Hazard Map	The future hazard predicted	Scale 1:100,000; 2012	Darmawan (2012)
Historical map of Merapi eruption	The previous damaged area	2009	BPPTK
Rainfall data	Annual and monthly rainfall	2002-2011	SABO Office and Meteorological, Climatological and Geophysical Office
Temperature data	Mean temperature	2002-2011	Meteorological, Climatological and Geophysical Agency and Adisucipto International Airport, Yogyakarta
DEM	Elevation and Slope	90 m; 2000	http://srtm.csi.cgiar.org
Base Map	Road and river network	scale 1:25.000	Rupa Bumi Indonesia Map sheet Kaliurang

3.13 Tools and Software

To gain the objectives we use several tools for collecting data in fieldwork such as binokuler, ring finder, GPS Garmin CS76X, and camera while software used to analyze and to present data were ArcGIS 9.3, MaxEnt 3.3.3k, Forest Canopy Density Mapper Ver.2, ENVI Version 4.5, SPSS 17.0, Frame and Fill, and Microsoft Excel.

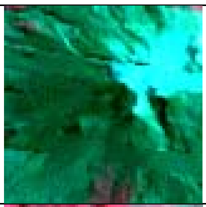
Chapter 4 Results

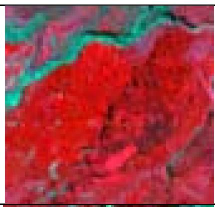
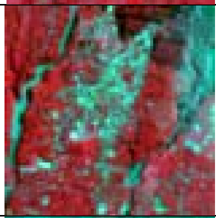
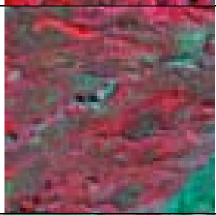
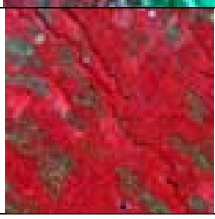
A conservation of species can be effectively attained by understanding the relations between the animal and its environment (Estes et al., 2008). To select suitable habitat of javan langur in study area, we employed Maxent software which requires a set of environmental layers and presence data. To obtain selected environmental factors that affect habitat suitability of javan langur, we chose biotic parameters comprise landcover type and forest canopy density, and abiotic parameters which consist of annual and monthly rainfall, temperature, slope and elevation. Each of parameters is described below:

4.1 Land cover and Land Use Identification

We used Aster imagery of year 2009 and 2012 to generate land cover and land use map. As the guidelines in visual interpretation seven elements of keys interpretation should be considered are tone, texture, shape, size, pattern, site and association (Bakker, Wim H. et.al, 2004). Aster imagery recorded on 13 June 2012 was delivered from LPDAAC (The Land Processes Distributed Active Archive Center) through RSG Laboratory, ITC-Faculty of Geo-Science and Earth Observation, University of Twente. Using visual interpretation, eight types of landcover and land use were indentified inside and outside the national park. To have clear differences among several landcover, Aster imagery with resolution 15 m of year 2009 and 2012 were identified using false colour composites (see Table 6 below).

Table 6: Visual interpretation key of Aster imagery

Land cover/land use	Composite 321	Key interpretation
Barren land		Dark and light cyan color, smooth texture, and associated with peak of mountain
Mixed forest		Dark red colour with rough texture, and associated in steep slope or upper slope

Land cover/land use	Composite 321	Key interpretation
Pine forest		Light red, reguler pattern, moderate smooth texture, and associated in steep slope or upper slope.
Settlement area		Light cyan, reguler pattern, and ssociated with drainage pattern or dry farm land.
Grass land		Light red near to magenta, very smooth texture, and associated with bareland and pine forest
Damaged pine forest		Dark magenta, smooth texture but roughter than grass, associated with pine forest
Shurb land		Lighter red than grass, smooth texture, and associated with mixed forest and bareland
Dry farm land		Red, smoother texture than forest, associated with settlement and drainage pattern.

4.1.1 Land Cover Classification

Figure 16 shows landcover of year 2012 and 2009 of MVNP. The widest area within national park is mix forest for about 2537.28 hectares or 36.96%, while 22.29% and 17% of the park are barren land and shrub land respectively. There is a decrease number on mixed forest during year 2009 until 2012. About 498 hectares area of mixed forest has reduced, in contrast with barren land that rapidly increase as many as 472.95 hectares (Table 7)

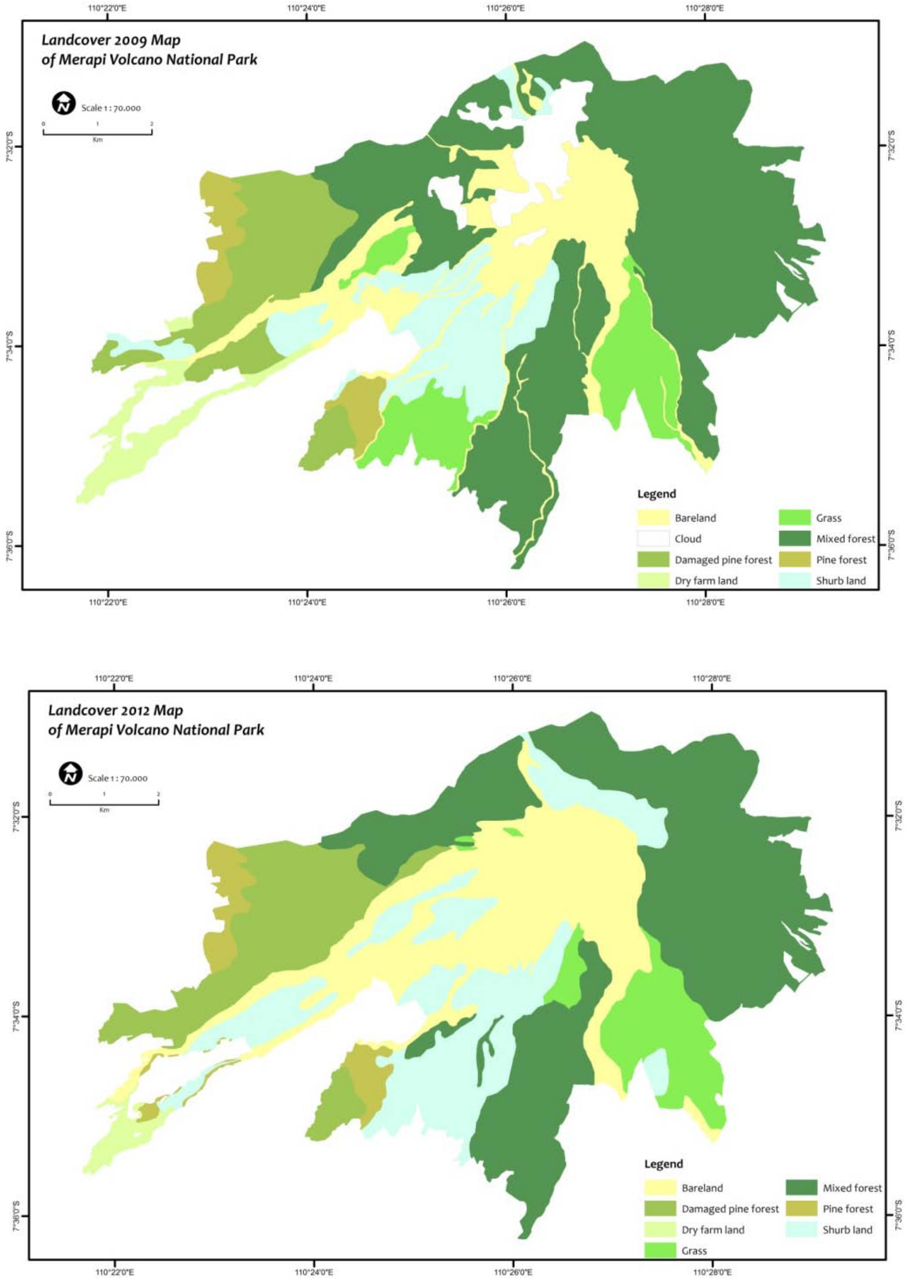


Figure 16: Landcover Map of year 2009 and 2012 (Source: data processing, 2012)

Although it was known as conservation areas, we found dry farm land within the park. It was found mainly in western flank of the mountain and administratively included in Magelang Regency. Besides barren land, grassland and shurbland also increase as many 7% and 17% respectively.

Table 7: Showing landcover changes during 2009-2012 in Merapi Volcano NP

Landcover	2009		2012		Change (ha)
	Area (ha)	Percentage	Area (ha)	Percentage	
Mixed forest	2,902.59	44.6	2,404.53	36.96	-498.06
Barren land	977.49	15.0	1,450.44	22.29	472.95
Shurb land	672.93	10.3	1,106.01	17.00	433.08
Dry farm land	216.45	3.3	83.34	1.28	-133.11
Damaged pine forest	683.19	10.5	779.31	11.98	96.12
Pine forest	210.06	3.2	222.75	3.42	12.69
Grass	556.56	8.6	460.17	7.07	-96.39
Cloud	287.19	4.4	0	0	0
Total	6,506.46	100	6,506.55	100	

Ground check validation was done during fieldwork on collecting presence data of javan langurs. Kappa test shows result of 0.736 with over all accuracy is 82.143 and producer accuracy is 83.871.

4.2 Forest Canopy Density

Mapping forest canopy density using FCD mapper was fairly easy as guided in tutorial document. There are nine (9) major processes namely noise reduction, AVI, BI, SI, TI, vegetation density, SSI, multi VD model, and FCD (ITTO, 2003).

The processes which almost close to canopy ilustration were Scaled Shadow Index (figure 17). In this process the VI, SI and BI were changed into Green-Red-Blue composite and displayed in false colour images. According to Rikimaru 2002 that the area of high density forest is displayed in the cyan, the area in grass, agricultural crops and equal is displayed in the green and bare soil is displayed in the red, we found significant changes of area covered by forest between year 2009 and 2012. The greatest change was in southern channel of Merapi which directly passed by pyroclastic flow (see figure 17)

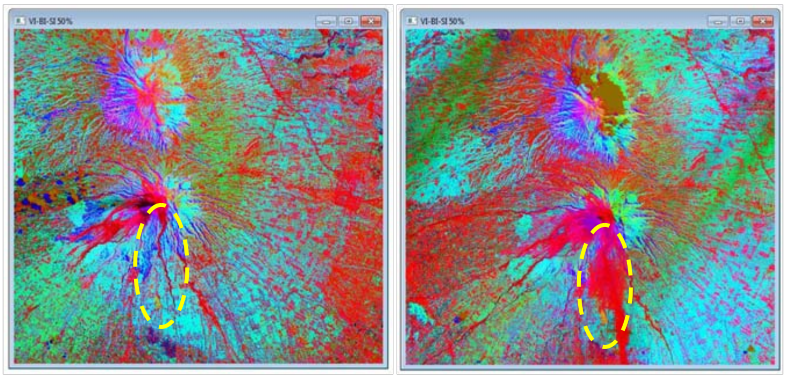


Figure 17: Significant change from cyan colour to red color in several channel of Merapi showing area changes from forest to bare soil (Source: data processing, 2012)

The crutial step was cluster selection which classifying results of SSI process into forest and non forest. We used first false colour images (figure 18) as guidance in deliniating those clusters, red colour as forest and cyan colour as non forest. Automatically, FCD mapper will generate the cluster calculation and continue with -model multi vegetation density- process.

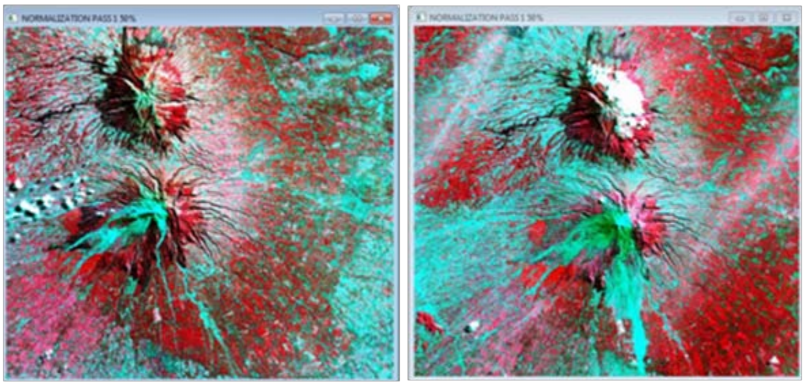


Figure 18: False colour of Landsat ETM+ images of 2009 (left) and 2012 (right) in 432 composite used as guidance in cluster selection process

The last step of FCD mapping was FCD process. It give image of how dense the canopy within study area. We reclassified into 11 class contain percentage of canopy density ranging for 0-98 percent. Class of 0-1 percent can be interpreted close to pure barren land which no trees or few trees inside; while the highest class which is 90-99 percent means that the area has a very dense canopy.

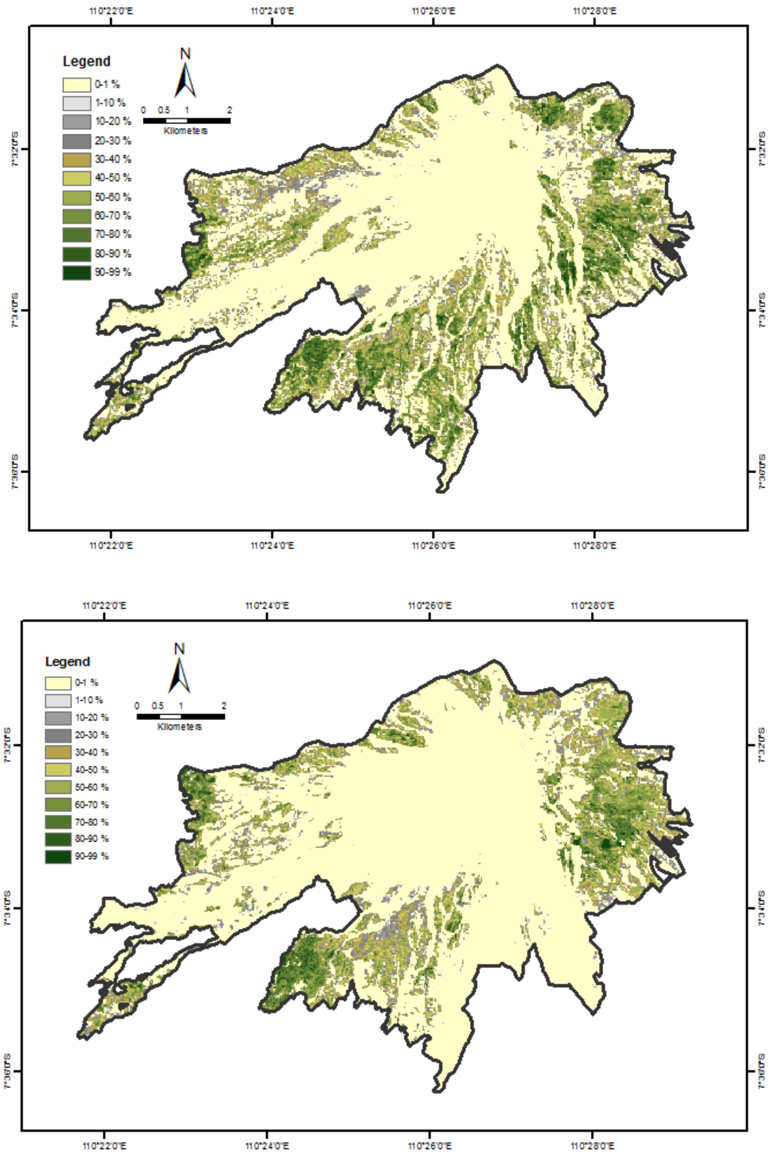


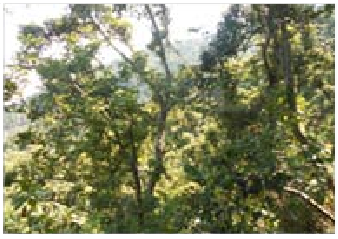
Figure 19: Canopy density of 2009 (above) and of 2012 (below) (Source: data processing, 2012)

Based on use of Landsat ETM+ imagery, Forest Canopy Density has a pixel size of 30 x 30 meters or 900 square meters in field. It could be interpreted that FCD value of 40% means that in of this pixel we can have canopy coverage 40 percent of totally 900 square meters area in the field. Figure 19 at below side shows the recent canopy density in Merapi Volcano National Park. Extracted from Landsat ETM+ which acquired on 13 June 2012, FCD value of 2012 at study area has a decline in canopy area. The reduction not only occurs in southern channel which directly passed by pyroclastic flow, but also in western flank of the park. Compared with FCD value of year 2009 in year 2012 the barren land which has no canopy also increased surrounding the top of mountain. South and southwest flank experience more pyroclastic flow than the other flank since the beginning of this century which made a huge bare land with less tree canopy (Kelfoun, Legros et al. 2000).

Pine forest (12%)

Community forest (21%)

Casuarina forest (54%)



Mixed forest (87%)

Figure 20: Canopy densities in several forest types

4.2.1 Validation

To validate the result of FCD mapper, we measured the canopy density in 40 sampling plots which then were compared with the density of canopy index from FCD mapper. RMS error value was 12.848. It means that there is 12.848 percent of error between observed estimation and result of FCD mapper. The level of agreement (R^2) was 0.7938 as showed in graphic below (see figure 26). It can be interpreted that there is a strong correlation between observed value and estimated value of FCD. According to this reasonable value, it can be concluded that FCD value generated from FCD mapper can be used in modeling suitable habitat of javan langur.

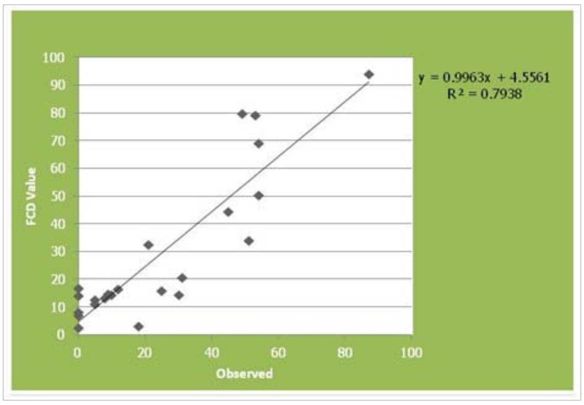


Figure 21: Graphic of R^2 between observed and estimated value of FCD

4.3 Elevation

Beier (2006) argued that elevation is a determinant of land cover. It also affects the thermal environment of an animal, the amount of precipitation, and the form of precipitation (Beier, 2006). Elevation data for modeling suitable habitat was derived from SRTM data (http://srtm.csi.cgiar.org) with resolution of 90 m and was resampled into pixel size of 30m using nearest neighbor method in spatial analyst tools in ArcGIS. Variation of altitude in Merapi Volcano National Park ranges between 609.9 up to 2907.5 meters.

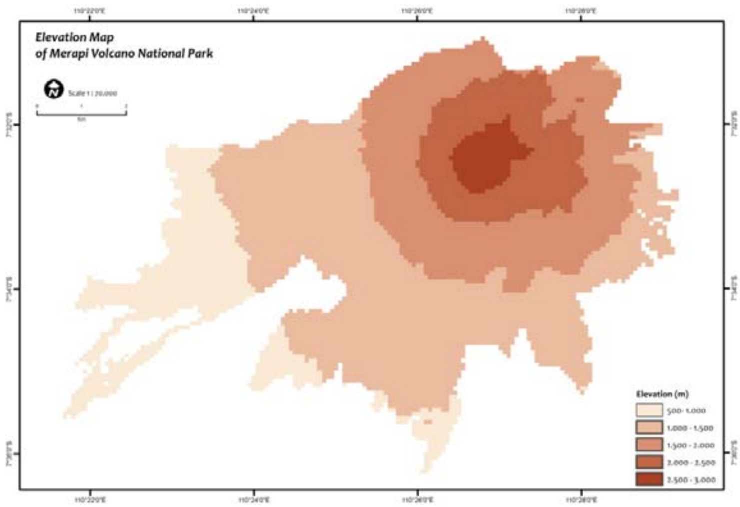


Figure 22: Elevation variety in Merapi National Park

4.4 Slope

Often referred as stratovolcano, Merapi has spesific conical shape which makes this area has many steep slopes. Using elevation data we calculated slope angle. The slope data was classified into degree unit, ranging from 0.48 degree until 54.17 degree. Most of steep slope lies in eastern flank of Merapi and its summit. (Figure 23)

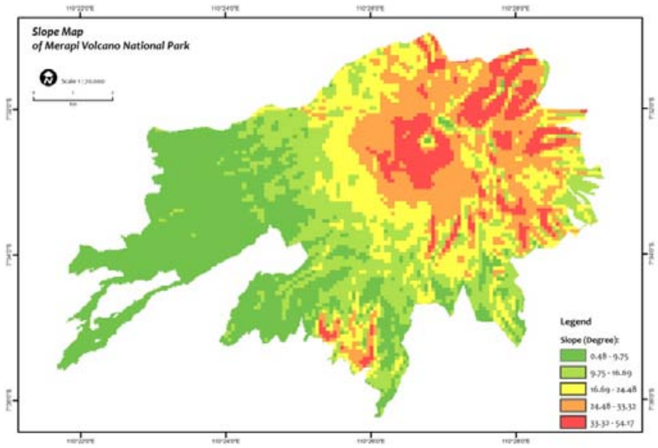


Figure 23: Slope Map of Merapi Volcano National Park

Using presence data of *Tracyphitecus auratus* and topographic variables we made boxplot diagram to ilustrate location of the species in MVNP. Javan langur can mostly be found in elevation between 1300 and 1900 meters above sea level and slope between 23^0 until 28^0. In boxplot of slope distribution we found 6 points of occurence data that out of normal distribution in slope range of 5^0 – 15^0.

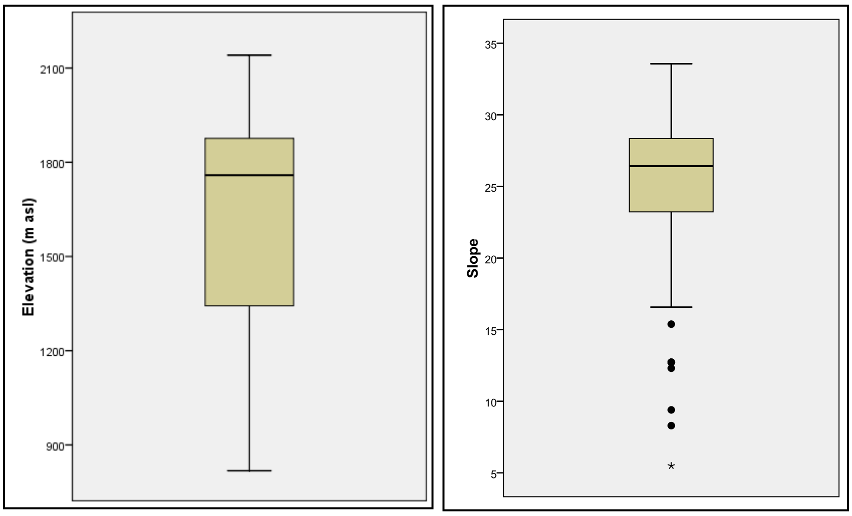


Figure 24: Boxplot diagram show elevation and slope point where mostly found *Tracyphitecus auratus*

4.5 Precipitation

We selected two data of climatic variables namely precipitation and temperature. Rainfall data during year 2002-2011 were obtained from 9 raingauges near Merapi Volcano namely Babadan, Ngepos, Pakem, Argomulyo, Musuk, Cepogo, Selo, Deles, and Gunung Maron raingauge.

Analysis on rainfall data for the duration of 2002-2011 from 9 raingauges in study area shows that there are no large differences on pattern of dry season and wet season. During January-April and October-December are wet season, while dry season occurs during May to September (see figure 25). Raingauges in Ngepos, Magelang has the highest average monthly rainfall amount of 290.83 mm while Musuk in Boyolali Regency experiences the lowest rainfall of 196.83 mm

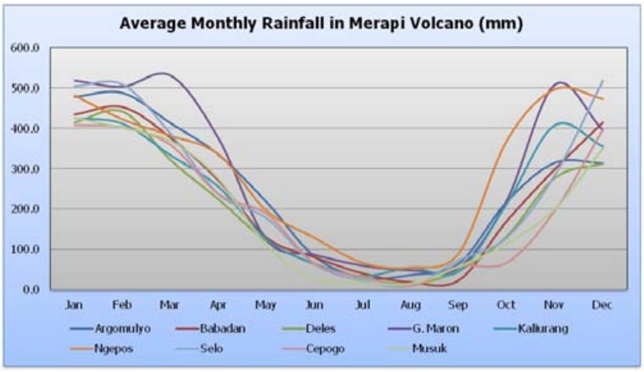


Figure 25: Average Monthly Rainfall (Source: data processing, 2012)

4.5.1 Annual Rainfall

Annual precipitation in Merapi Volcano National Park ranging from 2361 mm up to 3491 mm. Map below (figure 26) presents the area in southwestern flank experienced more rainfall while in the eastern flank near Boyolali Regency experienced less rain. This difference is clearly seen during observation, where the people in eastern slope of Merapi experience water problem, while they who are in southwestern slope do not. This variation gives influence on livelihood of local people. In western flank farmer plant vegetables crops and rice, while in eastern and norteastern flank is mainly tobacco and corn which need less water.

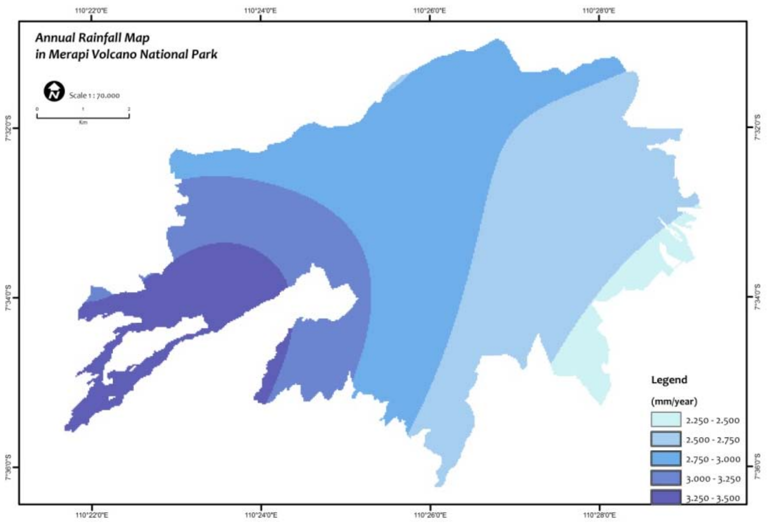


Figure 26: Annual Rainfall Map in Merapi Volcano National Park

4.6 Temperature

Temperature data were derived from Meteorological, Climatological and Geophysical Office near the study area: Kaliurang, Magelang, Boyolali and Adisucipto International Airport Yogyakarta during year 2002 – 2012. The coolest average temperature is 24.79 celcius degree in southwestern flank, and the hotest area is located in northern flank which has average temperature of 25.62 celcius degree (figure 27)

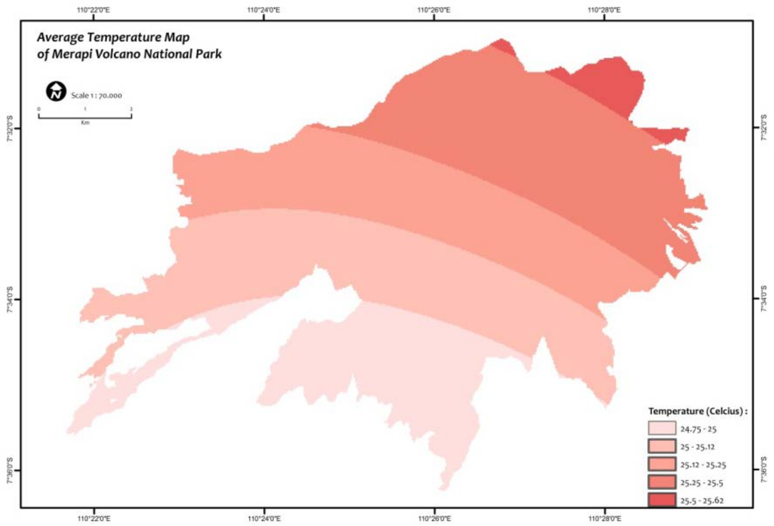


Figure 27: Average Temperature Map in Merapi Volcano National Park

Seven enviromental parameters mentioned above will be used in selecting suitable habitat of javan langur. Table 8 below presents the summary of environmental parameters used in models suitable habitat.

Table 8: Summary of environmental parameters used in the models

Variable	Range	Description
Elevation	609.9 - 2907.5	Elevation above sea level
Slope	0.48 – 54.17	Slope angle in degrees
Temperature	24.79 – 25.62	Average temperature in celcius degree
Annual rainfall	2388.56 – 3512.02	Average annual rainfall in mm
Monthly rainfall	199.11- 292.66	Average monthly rainfall in mm
Forest Canopy Density	0 – 99	Percentage of forest canopy density
Landcover and Landuse	1-8	Reclassification of each landcover types

This following table showing characteristic of each variables used in modeling suitable habitat of *Tracyphitecus auratus* in Merapi Volcano National Park.

Table 9: Identity of Enviromental variables (source: data processing, 2012)

Variables	Code	Data types	Numerical precision
Train or test data set	Tracyphitecus auratus	Factor	--
X coordinate in Geographic Coordinate	x	Numeric	--
Y coordinate in Geographic Coordinate	y	Numeric	--
Altitude	elev	Continous	1m
Slope	slope	Continous	1^0
Annual mean rainfall	ann	Continous	1 mm
Monthly mean rainfall	monthly	Continous	1 mm
Annual mean temperature	temp	Continous	1^0 C
Value of FCD index	fcd	Continous	0.01
LULC types (with 8 classes)	landcover	Categorical	--

4.7 Presence Data

During fieldwork 2 points of feses and 5 points of reported sighting were collected. The all points meanly located in area up than 1300 meters above sea level.

Table 10: Presence points of javan langur in Merapi Volcano National Park (Source: fieldwork and secondary data, 2012)

Evidences of presence points	Number of points	Number of species
Recorded sighting	38	210
Incidental	5	-
Feses	2	-
Total	45	210

Figure below shows pictures of javan langurs' feses found in mixed forest at Deles, Klaten and Srumbung, Magelang. To make sure that those dung are langur feces, we compared them with picture presented in (van Nijboer, Clauss et al. 2007)

a b c

Figure 28: Feses found in mixed forest at Deles, Klaten (a) and Srumbung, Magelang (b) at 1600 msl compared with images of dung in article of van Nijboer, Clauss et al. 2007.

Incidental sighting were obtained by asking local people where they had found langurs and rechecking the information by visiting the locations. We included the points although we didn't meet the species only if the site has potency as habitat for instance that it was dominated by resource food of langur.

Figure 29: Fieldwork activities and incidental sighting point in Magelang

Often found in valleys with steep slope, javan langur in Merapi Volcano National Park chose an inaccessible area for people. They inhabit at the top of canopy. According to Subarkah, Wawandono et.al (2011) javan langur used crown canopy as their main activities such as feeding, resting and sleeping although during observation we found one activity of langur that was not in tree canopy. They likely looking something in the ground looking for insects as their alternative food resources (Kool, 1993)

As their main food resources, dadap (*Erythrina lithosperma)* and pasang *(Lithocarpus sundaicus)* also serve as nesting trees. These trees are very old and big. Javan langur live in a group consists of 5-7 individu and easily found during morning time when they are eating. On day time, they dwell in trees and hard to be observed because their black coloured bodies are similar to the color of tree log.

Figure 30: Groups of javan langur species was seen within mix forest in Tegalmulyo (a, c), Rogobelah (b) and Gunung Bibi (d) (Source: fieldwork, 2012)

The point's data which collected were organized in their species' name; longitude and latitude coordinate and were saved as comma dilimited or .csv file format. All presence data were randomly divided into training points and test points as much as 32 points and 13 points respectively.

4.8 Multicollinearity test for Enviromental Variables

At the first calculation, monthly_precipitation variable had value of VIF more than 10 that indicates collinearity. After we excluded monthly_precipitation variable the VIF of remaining variables were less than 10. The VIF of continous variables are described below:

Table 11: Result of Multicollinearity Test

Enviromental variable	VIF value
Annual precipitation	1.987
Elevation	7.165
Slope	7.395
Annual temperature	1.858
Forest canopy density 2009	1.292
Forest canopy density 2012	1.225

Based on result of multicollinearity we included variable of annual precipitation, elevation, slope, annual temperature, and forest canopy density as predictor in modeling suitable habitat of *Tracyphitecus auratus.*

4.9 Suitable Habitat Models Performance

We employed MaxEnt version 3.3.3k to identify suitable habitat for *Tracyphitecus auratus* in study area. MaxEnt creates a uninterrupted species distribution map where the value of each pixel of the modeled area represents a probability of presence of the species study and their suitable habitat. (Howard and Sergio, 2012). Based on result of multicollinearity test as described in previous section, we only used 6 enviromental layers: annual temperature, annual precipitation, landcover, slope, elevation, and forest canopy density. Obtained in .asc type data, we mapped using raster calculater in spatial analyst tools and changed into raster data format. Figure below showing models output from Maxent of year 2009 and year 2012 (figure 31). The heat colors show location with good predicted circumstances.

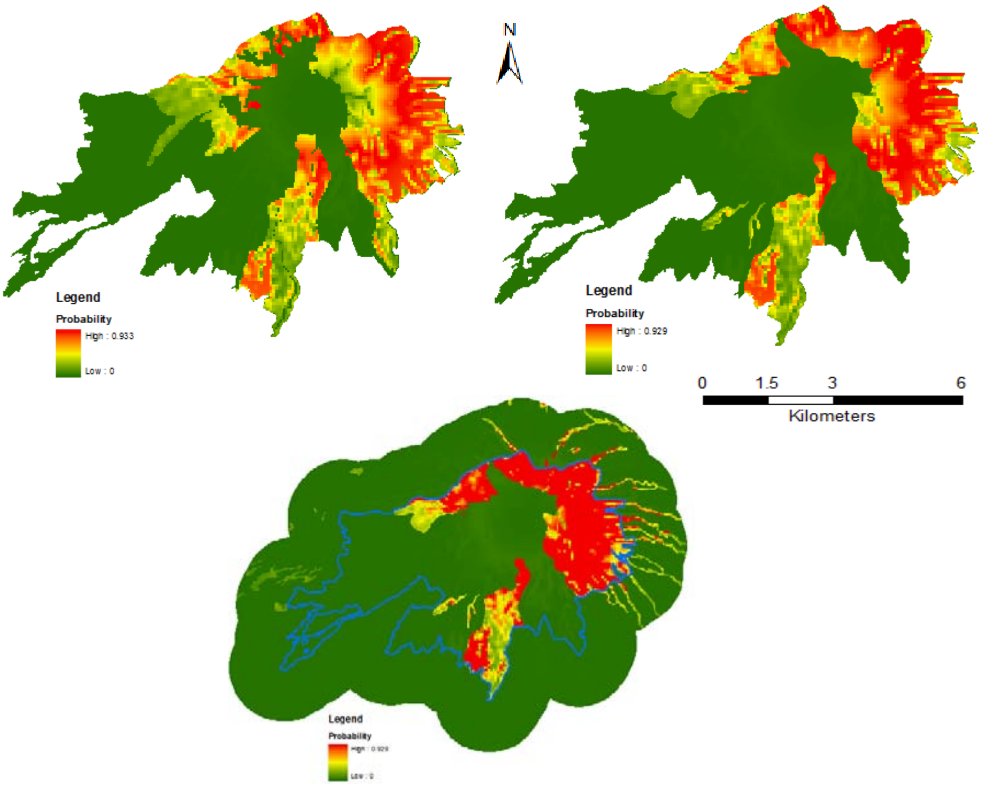


Figure 31: Model performs of the year 2009 (left side) of year 2012 (right side) and of year 2012 which included additional area (below). Warmer colours be a sign of suitable habitat for *Tracyphitecus auratus*

Spatial pattern of habitat in model of year 2009 and 2012 has a significant change, with the largest change occured on west and southwest flank of study area. The model of year 2009 has more red and yellow colour than model of year 2012. We can see also that there were wide opened areas leading to western and southern flank. These areas will be analysed as habitat loss.

4.9.1 Model accuracy and variables most matter

Each model of the year 2009 and 2012 is split into training and test data which randomly selected as much as 70 percent and 30 percent respectively. Area under Curve (AUC) show good values for both model of year 2009 and of year 2012. True Skill Statistic result value more than 0.6 as measured good model (see Table 12)

Table 12: Analysis of model accuracy

Accuracy parameter	2009	2012
Training AUC	0.976	0.977
Sensitivity	0.769	0.769
Specificity	0.952	0.953
TSS	0.721	0.723

The high value of specificity and therefore low sensitivity can be explained that the model can correctly predict the absences and can be certainly anywhere mapped as presence really does have the species (Freeman and Moisen, 2008). Figure 32 below presents that all presence points was succesfully mapped in the models. The more points are the higher value of probability.

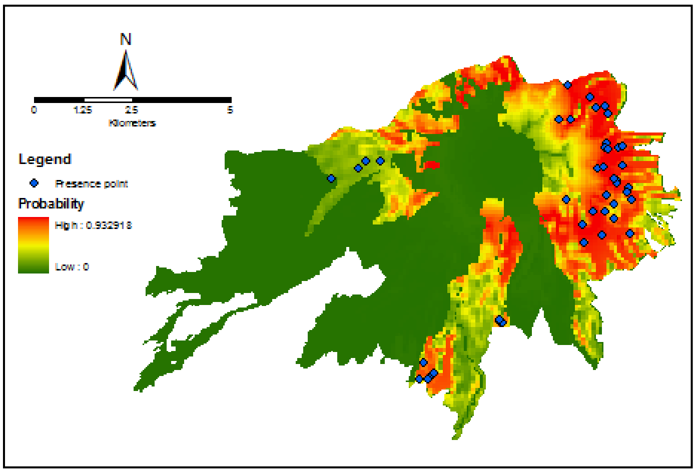
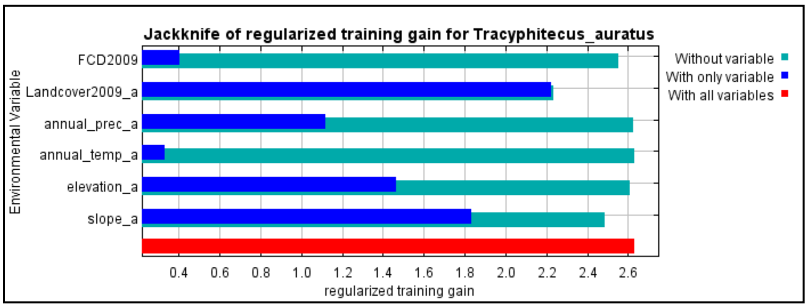


Figure 32: Distribution of presence point compared with suitable habitat from Maxent model of year 2009

The MaxEnt also generates 3 jacknife plots namely jackknife of regularized training gain, jackknife of test gain, and jackknife of AUC. The first jackknife reflects the importance of each variable in training model while the second jackknife plot shows effective variable in test data. The last jackknife of AUC determines the most important single variable for predicting distribution of species when test data and training data are divided (Philips, 2006)

Jackknife of regularized training gain (figure 33) below showing environmental variables and their influence in modeling suitable habitat of *Tracyphitecus auratus*.



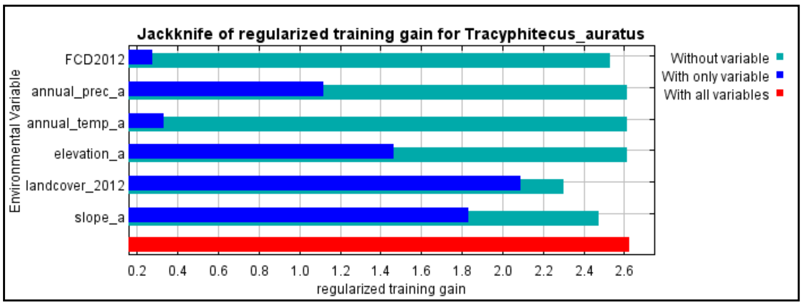


Figure 33: Jacknife result of model year 2009 (up side) and 2012 (downside) using all variables: landcover, annual precipitation, annual temperature, forest canopy density, slope and elevation.

Jackknife plots above show that landcover is the most valuable. Lack of this variable in models will cause the training gain at the least one. In contrast, annual temperature variable does not give significant contribution. Without this variables the models still have a great training gain. By reducing annual temperature variable, the model of year 2012 has increased accuracy value of AUC (Table 13). Employing this method, we selected most important variables.

Table 13: Result of Stepwise Maxent

Nr	Enviromental variables	AUC	
		2009	2012
1	Landcover, Slope, Elevation, annual precipitation, forest canopy density, annual temperature	0.936	0.826
2	Landcover, Slope, Elevation, annual precipitation, forest canopy density,	0.936	0.927
3	Landcover, Slope, Elevation, annual precipitation,	0.941	0.932
4	Landcover, Slope, Elevation	0.946	0.938
5	Landcover, Slope	0.939	0.933

Model number 4 which consists of landcover, slope and elevation has the highest value of AUC among others models. According to Baldwin (2009) this most parsimonous model with high value of AUC was selected as the best model. The basic concept of habitat suitability modelling is classifying the degree to that each cell is suitable for the species (Hirzel et al., 2002). Employed model number 4, figure 34 below showing result of Maxent models of year 2009 and of year 2012 which equally classified into three classes of suitability based on value index: 0.-0.3 is low suitable, 0.3-0.6 is medium suitable, and >0.6 is high suitable.

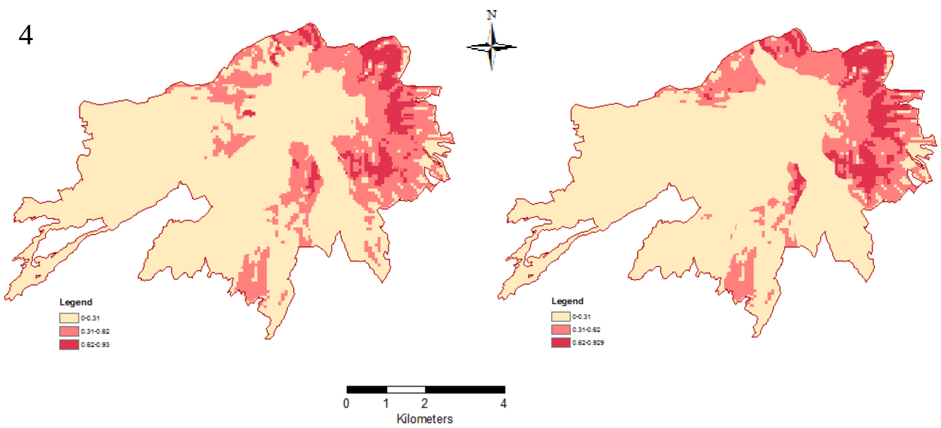


Figure 34: Classified suitable habitat of *Tracyphitecus auratus*

4.10 Habitat Loss

Habitat loss and fragmentation are related with fewer resources, bigger isolation, and more intense and far-reaching edge effects (Laurance & Bierregaard, 1997). Detecting loss of habitat will be a starting point in conservation attempt. In this research loss of habitat caused by pyroclastic in volcanic eruption were done by calculating suitable habitat of javan langur which directly passed by pyroclastic flow of 2010 eruption. We used suitable habitat map of year 2009 which overlaid by pyroclastic map of 2010 Merapi eruption (Cronin, Lube et al.). The intersection of this area made it possible to calculate habitat loss.

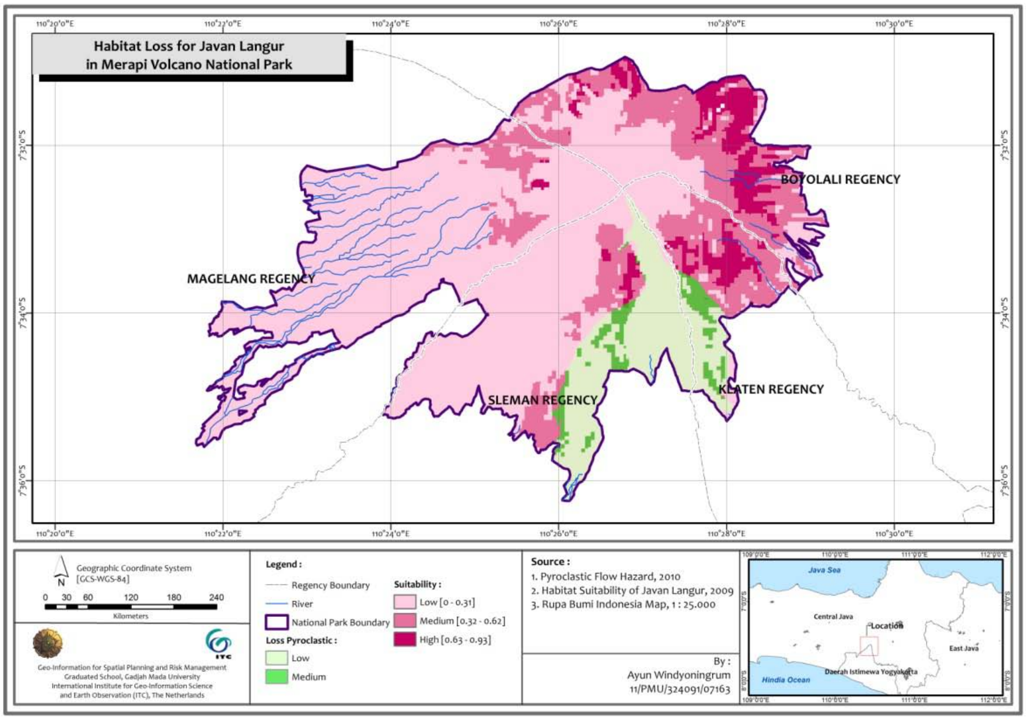


Figure 35: Habitat Loss map caused by pyroclastic of 2010 Merapi eruption

Estimation of loss considers both pyroclastic flow and surges since pyroclastic which has been successfully mapped by (Cronin, Lube et al.). Pyroclastic is the main factor which responsible for a large proportion of volcanic damage and loss (Kelfoun, Legros et al. 2000). We found during fieldwork that pyroclastic can totally damage trees and remained destructed area while observation in forest which not directly affected by pyroclastic showing that forest can fastly restore and growth. We measured the damaged habitat as temporary habitat loss since according to Lindenmayer (2006) that area can not provide suitable conditions for Tracyphitecus auratus for certain time after the destruction. Figure 35 above shows that pyroclastic also cause far-reaching between small habitat patches in part of Plawangan Hill in Sleman Regency and solid habitat patches in Deles, Klaten Regency. Table below shows that about 148 hectares of moderate suitable habitat has disappeared.

Table 14: Loss of habitat caused by pyroclastic flow of 2010 Merapi eruption

Suitability Class	Total of loss area (ha)
Low	742.178
Medium	148.008
High	-

Outside the loss caused by pyroclastic, we should take into account the loss resulted by land cover change. Comparing suitable habitat of year 2009 and 2012 (see figure 36), during that 4 years there was a large numerous suitable area decline caused by landcover change. About 126 hectares of high suitable habitat and around 333.598 hectares of medium suitable has changed (see table 15)

Table 15: Habitat Change during 2009-2012

Changes of Habitat Suitability	Total of area (ha)
High suitable to Low suitable	36.683
High suitable to Medium suitable	90.126
Medium suitable to Low suitable	333.598

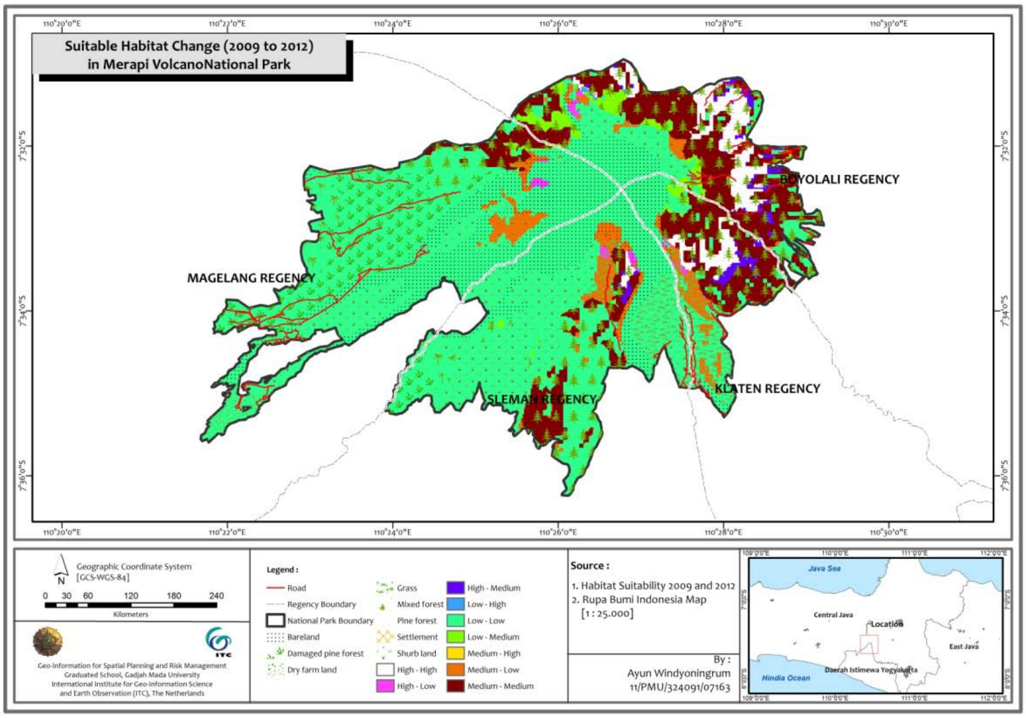


Figure 36: Suitability Habitat Change from year 2009 to 2012

The pattern of habitat change can be detected by overlying suitable habitat map of year 2009 and year 2012. From this method we can assign the area which experience high loss or degradation of habitat quality. Figure 36 shows that high suitable patches which become low suitable was occured near the summit and close to area of pyroclastic flow (see pink colour area), but the high suitable patches that change to medium suitable are found in areas which far from the summit and near the park's boundary (see dark blue colour area). It can be assumed that the human intrusion have influence on habitat change since that condition occurs close to the footpaths.

The trend of suitability change as mentioned above occurs in area surronding road network within the park. The analysis on width and pattern of habitat change of *Tracyphitecus auratus* in Merapi Volcano National Park can be a sign that habitat loss resulted by a catastrophic event such as volcanic eruption is less than that caused by continuous processes of human influences. This remark also found in study done by Finkelstein, Wolf et al. (2010) and Zheng, etl.al (2012). One thing has to be concerned about habitat change is that it can trigger accessibility into conservation area (Eigenbrod, et.al. 2008) besides the risk of disappear species.

4.11 Refuge Areas

Model of 2012 shows that the widest suitable habitat is laid in eastern flank of study area which forms a big habitat patch, while a smaller one occurs in Plawangan Hill. Maxent also identified potential distribution areas which is enviromentally has same condition with observed presence location and can be used to identify suitable sites for reintroduction of a species (Pearson, 2007). Although in medium suitable level, we suggested areas near Wonodoyo, Suroteleng and Mriyan village as refuge area outside Merapi Volcano National Park (see Figure 37)

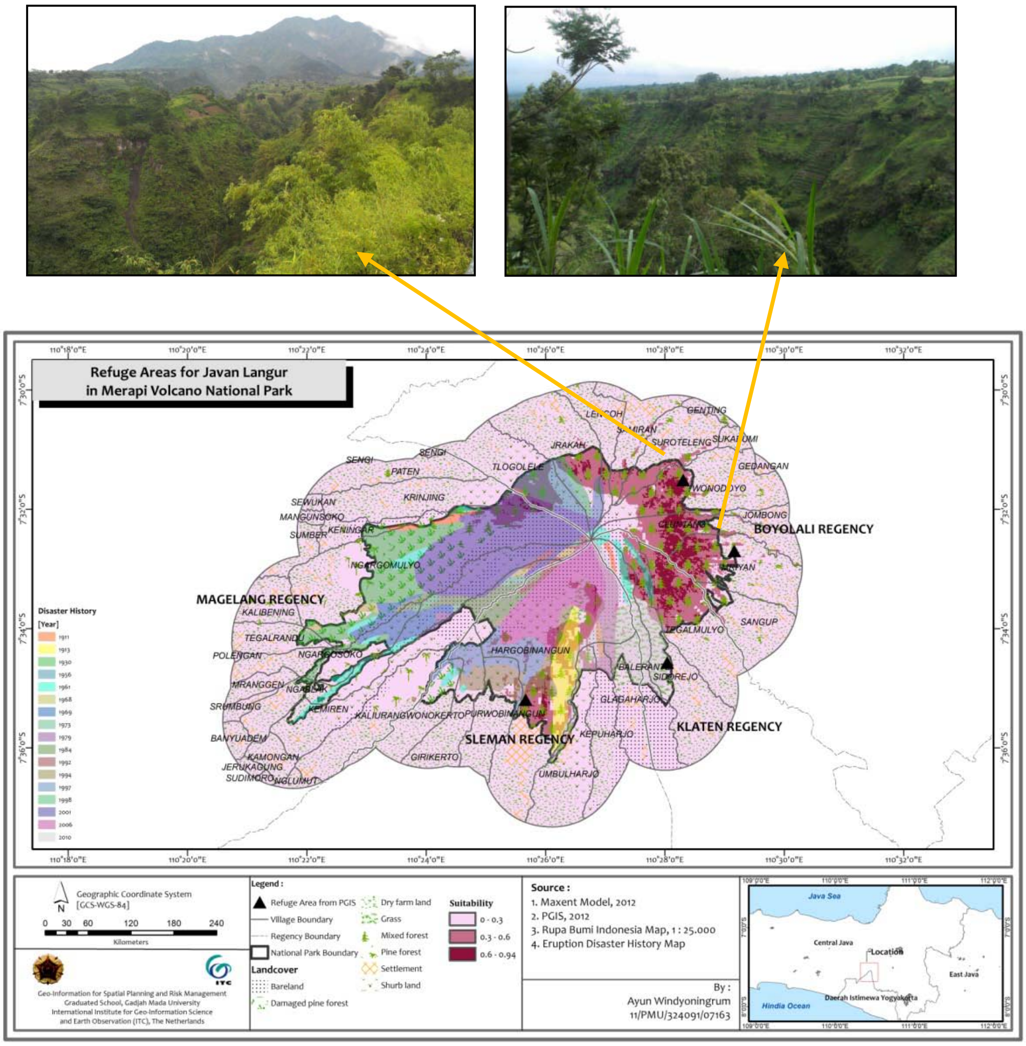


Figure 37: Refuge areas shown in maroon and black red colour. The black triangles are migration points of langurs in 2010 eruption (Source: data processing, 2013)

By overlying historical map of Merapi eruption from year 1911 until the recent event of 2010 we can identify the habitat which rarely experience pyroclastic. During the recent hundred years, the big habitat patch from Deles in Klaten Regency until Rogobelah in Boyolali Regency is never directly exposured by pyroclastic of Merapi eruption.

Throughout fieldwork we also collected data about animal migration during 2010 event by Participatory GIS in Focus Group Discussion and by interviewing local people. Focus Group Discussion held on 23 January 2013 contributed in mapping location of refuge points of wildlife during 2010 Merapi eruption (figure 38).

Figure 38: PGIS in office of MVNP and collecting info of wildlife migration during Merapi 2010 eruption from local people (source: fieldwork, 2012)

About 20 participants consist of volunteers and forest rangers involved in discussion to identify refuge spot and to arrange animal rescue programme. From this method, we collected 4 points of refuge areas in several villages namely Kaliurang, Deles and Musuk villages (see black triangle symbol in figure 37). The refuge points of langurs in the last eruption presented that the species escaped and run down from the mountain.

4.12 Species at Risk Map

Combining definiton of species at risk and definition of risk itself, we developed species at risk map with concerning on habitat of species. As one element at risk, javan langur lives in Merapi Volcano National Park is facing a natural disaster which tend to be regularly event (Voight, Constantine et al. 2000). The species at risk was assessed based on vulnerability of species habitat and potential pyroclastic hazard. Vulnerability analysis was generated based on the suitable habitat and homerange of javan langurs. Hazard and vulnerability are elements of risk and are related by the relationship: hazard × vulnerability = risk (Blong, 1996).

4.12.1 Vulnerability Map

The ecological properties of species are often used to verify sensitivity or vulnerability of species to hazard exposure (Lahr, et al, 2010). Employing euclidean distance, we calculated distance of habitat to settlement as one of habitat's vulnerability parameter. This following map shows that Merapi Volcano NP has been enclosed with settlement.

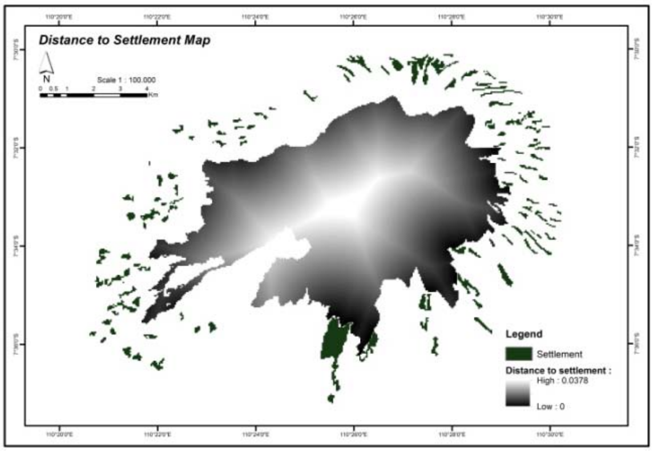


Figure 39: Distance habitat to settlement map

We also proposed accessibility of habitat as paramater to determine vulnerability of habitat. With the resolution of 60 cm Quickbird imagery of year 2006 provided a clear visualization of roads and footpaths within the park. A long and regular pattern of road was lied in western flank which has production forest of pine. Meanwhile short and irregular footpaths were mostly found in eastern and northeastern flank (figure 40)

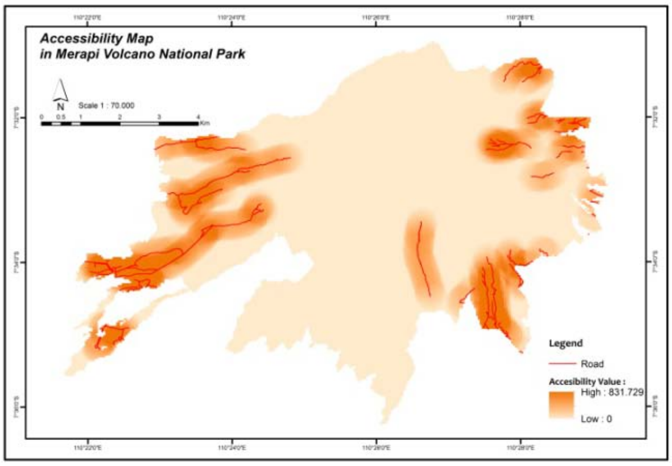


Figure 40 Accessibility of habitat within Merapi Volcano NP

Using three factors of vulnerability we proposed a classification of vulnerability as follow:

Table 16: Classified vulnerability of habitat

Suitability Habitat Class	Distance to settlement (kilometer)	Accessibility Index	Vulnerability Level	Score value
Low	2.5 – 3.78	277.243	Low	1
Medium	1.25 – 2.5	554.486	Medium	2
High	0 – 1.25	831.729	High	3

High suitable habitat can be assigned as high density of species, therefore we proposed high suitable habitat as high vulnerable habitat. Appliying weighted overlay method, we generated habitat vulnerability map of javan langur in Merapi Volcano National Park (figure 41). This method defines some criterias more importance than others (Hailegebriel, 2007 and Zelalem, 2007) in (Walke, Obi Reddy et al. 2012). Suitable habitat that reflects population density of species was given score of 40% while both accessibility and distance to settlements that reflect human encouragement were given score of 30%. This following figure shows habitat vulnerability map.

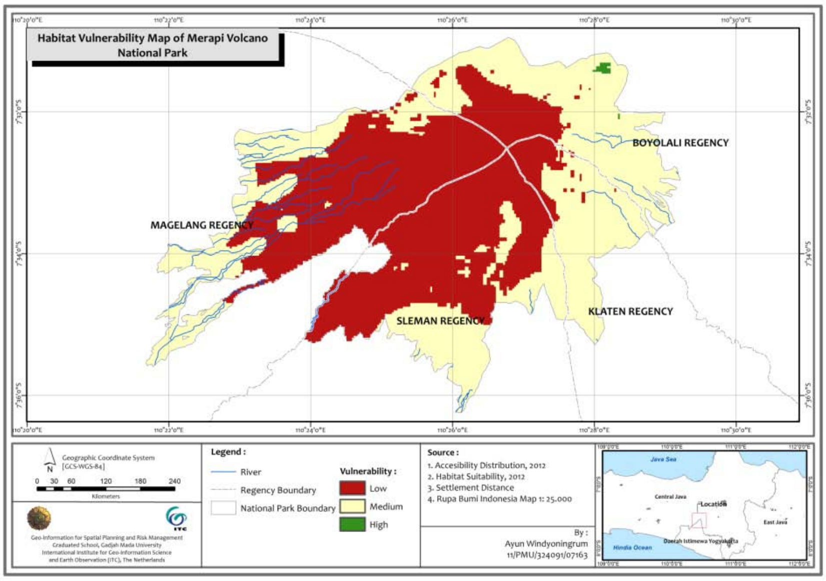


Figure 41: Classified suitable habitat and habitat accesibility map as elements at risk

Adapted from Alberico, Lirer et al. (2008) the intersection between habitat vulnerability and pyroclastic hazard map results a species at rik map (figure 42) which showing habitat of langur that tends to be exposured by pyroclastic hazard. Using three scenarios of eruption, the high risk area was only generated in third scenarios when VEI 4 occurs. In areas which have low risk of pyroclastic hazard it can not be concluded that those areas have no risk at all. We should consider another factor which potential to disturb habitat of langurs, namely human intrusion, which will be more discussed in the last chapter.

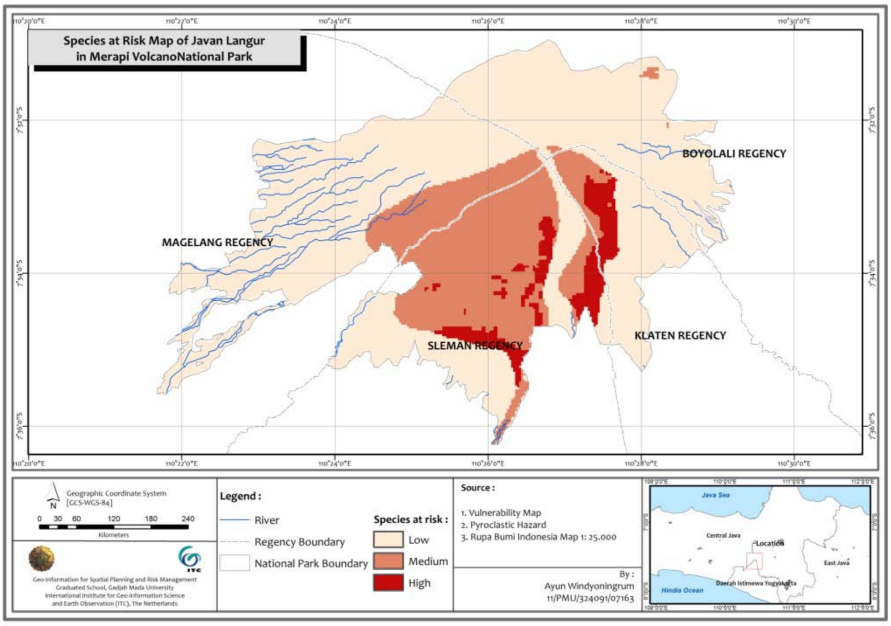


Figure 42: Species at Risk Map of Tracyphitecus auratus at Merapi Volcano NP

Species at risk results about 1548.37 hectares of habitat was in vulnerable condition while 352.73 hectares was in high risk (table 17). The high class of risk means that this area has high hazard and high vulnerability, which can be defined as width of high suitable habitat with high road density and close to settlement. It was found mainly in Deles, Klaten Regency and at Plawangan, Sleman Regency at right and left side of Kali Gendol.

Table 17: Risk Level and Risk Area

Vulnerability Level	Hazard Scenario	Risk Assessment	Habitat at risk (hectares)
1	VEI = 1 VEI = 2	Low Risk	4471.06
2	VEI = 3	Vulnerable	1584.37
3	VEI = 4	High Risk	352.73

The high riskof habitat was generated from hazard scenario of VEI = 4 which has return period of 100 years. It was predicted that this scenario will produce pyroclastic with a volume of 60 million m^3 and can reach in distance of 16.5 km from the peak of Merapi (Darmawan, 2012).

Chapter 5 Discussion

5.1 Suitable Habitat Models

Potetial habitats of *Tracyphitecus auratus* in Merapi Volcano National Park with high suitable class were distributed in mixed forest at high elevation and steep slope, which occupying for only 7.7 percent of total area or about 493.92 ha, while medium suitable is covering 18.4 percent of total area or about 1180.17 ha. The Maxent also suggested that there were potential refuge areas in medium suitable outside national park namely at Wonodoyo, Suroteleng and Mriyan village, in Boyolali Regency.

Since the modelling was designed to identify potential distribution or suitable and unsuitable habitat, following Pearson (2007) we evaluated performance of the model based only on the model's capability to forecast observed presences data, thus we employed AUC and TSS as indicator of models performance. The models were highly discriminative with test AUC of model 2009 and 2012 = 0.946 and 0.938 respectively, signing that *Tracyphitecus auratus* taken a greatly detailed landcover niche. The performance of both models in general also excellent if we consider the training AUC that were 0.976 and 0.977 respectively. Selecting the models which simple but give high value of AUC is important, since we found that difference value of AUC will result difference width and pattern of suitable habitat.

Both models of year 2009 and of year 2012 landcover is the most important variable in determining suitable habitat of langur. For attention, all of the langurs were found in mixed forest of the park which provides food for langurs. Slope and elevation as topographic factor also contribute since langurs prefer to live in remote area. These natural factors allow them far from human interactions.

Our study suggested that incidental sighting gained from local people should be rechecked before used as presence points especially in study area that had changed. Four of five incidental points we got from local people are usefull to determine suitable habitat before disaster event. Farmers in Dukun villages said that they often saw langurs near Kali Lamat before 2010 eruption.

5.2 Pyroclastic Hazard and Habitat Loss

Estimation of habitat loss caused by pyroclatic in 2010 Merapi eruption results about 148 hectares of medium suitable has been lost. Observation during fieldwork performs that damaged habitat was overgrown with *Accacia decurens*. A noticeable habitat change was seen at Deles, Klaten. We found small patches dominated by *Acacia decurens* which close to mixed forest that not directly affected by pyroclastic. The loss caused by pyroclastic can be measured as temporary habitat loss, since the habitat can be restored although it needs quite long time, like phenomena found on floods or forest fire disaster. Figure (36) shows that after the 2010 event, a small habitat patch remained in Plawangan, Sleman Regency while a big habitat patch found from Tegalmulyo, Klaten to Jrakah, Boyolali Regency.

Above the number of habitat loss caused by pyroclastic, we should consider the effect of pyroclastic flow which shape isolation on habitat patches and reduce connectivity between langur's population in southern and eastern flank of Merapi Volcano NP. Those are common problem found in declined forest (Hanski, 1998) however the decreasing habitat linkage such as found in this research area can reduce the population density and survival chance (Fahrig 1998).

Change of suitability habitat that found far from the summit of Merapi, in areas which never experience pyroclastic and near the detected road can be assumed that anthropogenic factor contributes on that degradation. It has been established from previous study that frequently, changes in land use have various impacts on ecological processes and humans are the major drivers of landscape change (Vitousek et al., 1997; Sala et al, 2000).

5.3 Habitat analysis after the 2010 eruption

During 2010 eruption event, all forest in Merapi Volcano National Park was covered by ash with different tickness spatially. A few days after the eruption of 5 November 2010, people who returned from the evacuation to their homes saw some animals had been in forest and ate some plants that still covered by volcanic ash. Even though they were found in bad condition but it can be an indication that forest area affected volcanic ash still remains a habitat for primates. Fortunately, there was sufficient rain occurs after big eruption of 5 November 2010 (Damby, Horwell et al.) which reducing the thickness of ashfall and could trigger forest immediately serve as habitat for animals.

Two years after, the forest has turned green. Except forest area which damaged by pyroclastic flow, lots of areas have become green and provided habitat for wildlife. The forest in national park is mainly covered by higher temperate broad-leaved species, particularly pine and *Schima wallichi*, the mountain flora of java. Pine forest is a former production forest before national park was established.

Figure 43: Two dominant forest types in Merapi Volcano National Park (Source: fieldwork, 2012)

As floristic animals, the javan langur consumes leaves, flowers, fruit, and insect larvae (Kool, 1993). To have picture of the habitat, in primate study several parameters of habitat quality was measured. The vegetations within sampling plot size 20 m by 20 m were identified. Areas selected as sampling plots were near nested tree or food resources of javan langur. The variety of food resources for this species in Merapi National Park consists of:

Table 18: Abundance of food resources for javan langur within sampling plot

Local name	Species	Nr	Density	Relative Density
Dadap	*Erythrina lithosperma*	15	0.0375	30.61
Sowo	*Engelhardia spicata*	6	0.015	12.24
Pasang	*Lithocarpus sundaicus*	10	0.025	20.41
Pakpong	*Schefflera sp*	5	0.0125	10.20
Urang-urang	*Debregasia longifolia*	3	0.0075	6.12
Ketupok	*Codiaeum variegatum*	10	0.025	20.41
Total		49	0.1225	100

The diet behaviour of javan langur which mainly consumes leaves is expected to explain their ability to quickly adapt to the condition of the forest which was not good enough on the days after eruption. The forest turned green fast and became the source of their food. This is a contrast compared with primates that predominantly consume fruits and usually more vulnerable in facing changes of habitat (Boyle and Smith, 2010)

Figure below presents abundance of trees as food resources for javan langur in mixed forest at Gunung Bibi, Boyolali.

Figure 44: *Erythrina llithosperma* (dadap in local name) and *Lithocarpus sundaicus* (pasang in local name) as the main food resources of javan langur (Source: fieldwork, 2012)

Field validation at area that was estimated as habitat loss was done near Gendol River which directly affected by pyroclastic flow. We found a large area dominated by invasive plant species of *Acacia decurens*. A quick observation resulted that acacia bloomed at pole size. The weak branches character of acacia which seen in this area was not suitable for langur. Moreover there was not found food trees for the monkeys (see figure 45)

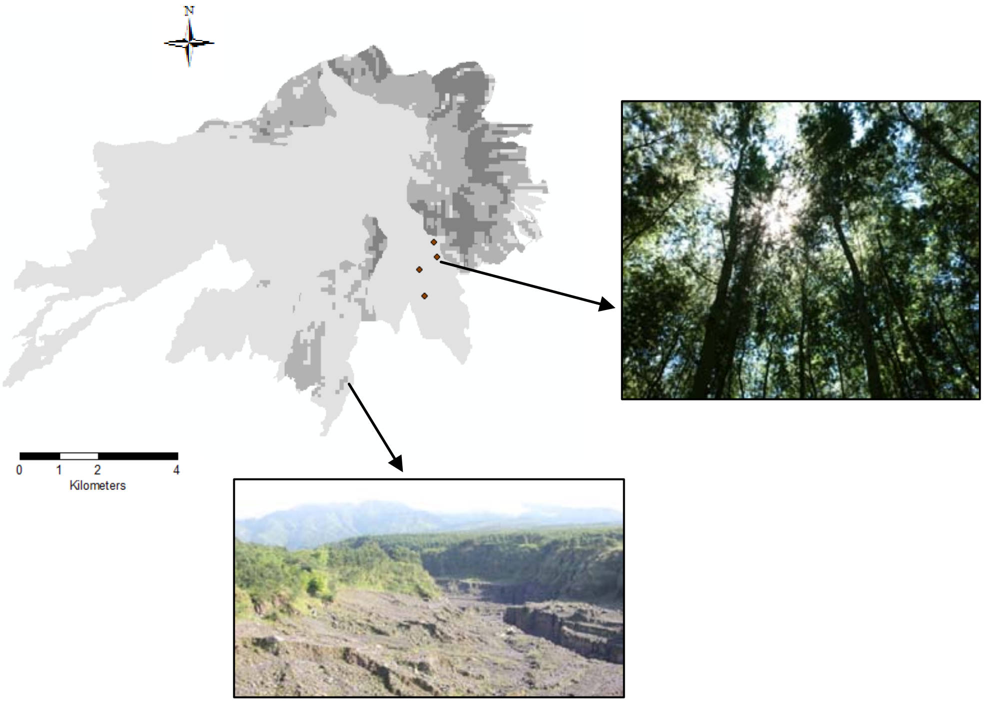


Figure 45: Field validation at habitat which had been directly affected by pyroclastic. It has been regrowth with *Acacia decurens* (source: fieldwork, 2012)

5.4 Habitat Threats

Conservation of habitat is the most crutial way of biodiversity protection (Beier, et.al. 2006). Saving habitat is similar with preventing the species extinction. Occurs in almost all countries, forest as main habitat of species is facing rapid rate of landuse change into agriculture and others man made building.

That change also occurs in Merapi Volcano National Park. Livelihood of community near the park is highly depending on its natural resources. The foremost economic activities which directly disturb habitat of javan langur are coal making and grassing. Based on interview with farmer who used to made coal inside national park, every week he need to cut 2-3 trees. Grassing activity is done for feeding their cows (see figure 46). Especially in dry season, people will go more inside into the forest to fetch grass which sometimes makes damaged on saplings trees. They will also cut down trees that closing forest floor so that the grass can grow lush. Making charcoal flare on the southern slopes, while grassland is countered in the east and west slopes of national park

Figure 46: Over grassing and coal making as habitat threat of javan langurs (Source: fieldwork, 2012)

The fertile land around Merapi volcano drives the very intense farming, even at steep slopes that very close to the park's boundary (figure 47). This cause the large and quality of forest continues to shrink.

Agriculture | Tobacco plantation

Figure 47: Livelihood resources of local people in Merapi (Source: fieldwork, 2012)

During fieldwork we sometimes met with illegal bird hunters, but so far local people stated that they are rarely meet javan langur seekers. We found also an interesting fact related to langurs. People in Kinahrejo, Sleman Regency have belief that if they found langur goes down to their village with a spesific sound, a disaster event is believed will be happen. This could be an early warning system for local people, but at 2010 event there were no people in Kinahrejo saw langurs entering their villages.

Local people said that they have no problem with the exixtence of langurs. It is different if we compare with *Macaca fascicularis*, another primate species in MVNP. The large population of this species and their diet which mostly consist of fruits cause a conflict between species and local people. Farmers have to protect their farmland to avoid destruction done by Maccaca (see figure 48) and evict the macaques from their land but do not kill them.

Figure 48: Farmers near Merapi forest protect their farming land using net to prevent Macaca take out the harvest

This describes the circumstances that they do not directly interfere of animals' life, but it seems they do not understand that their livelihood activity by entering MVNP can threaten animals' life.

5.5 Implication for Animals Rescue Programme

As a part of disaster management for wildlife, animals rescue programme was important for reducing fatalities of animals. Interview with local people and volunteers who had joined animals rescue programme on the 2010 event results several action that should be done. Realizing that the refuge areas outside MVNP are very limited, a right programme is important to take.

Several farmers who cultivate their land near national park were asked to obtain the information about animals' migration during Merapi 2010 eruption. The interview was given to people lives in Dukun, Srumbung, Deles, Musuk and Cepogo district. Most of them said that they did not found groups of javan langur which migrated before big eruption, but other species like deer and *Macaca fascicularis*. Only farmers in Musuk, Boyolali Regency and farmers in Deles, Klaten Regency who stated that they saw langurs down to near their villages.

Volunteers who joined in animals rescue programme argued that the major difficulty in rescuing animals was the forest areas that mainly close to Merapi volcano which very danger.They should be with the SAR team and military since it was announced that during 2010 event, Merapi Volcano National Park was closed from October 25, 2010 when the warning status was raised from Level III to Level IV. During phase after the big eruption some wildlife interest groups did rescue activities. They were from the COP (Centre for Orangutan Protection), JAAN (Jakarta Animal Aid Network), AFJ (Animal Friend Jogja). They worked every day with rescue teams from Merapi National Park. They found 60-70 monkeys in Tlogo Putri and fed them.

Learning from the past, Focus Group Discussion recommended several rescue programmes that should be taken:

5.5.1 Food supply

Actually people who live in lower slope of Merapi Volcano have already concern to animals. A few days after the big eruption, on 12 November 2010 in the village of Keputran, Deles, Klaten Regency people entered their village and tried to feed the wild animals that found in their surrounding villages. People bought fruits in market using their own money and give them to monkeys. Even when people got food support from donors, they immediately took up the food area near forest for feeding the monkeys.

Figure 49: Animal rescue by volunteers during Merapi 2010 eruption (Source: www.merapi.combine.co.id)

Every morning Joint team fed the long-tailed macaque in Kaliurang and other parts of the slopes of Merapi for about a month. On 2 December, 2010, a small team of volunteers climbed the mountain to feed animals by carrying yam, carrots, and peanuts as food for the monkey.

To reduce conflict between animals and people, government is expected to give compensation if any wildlife consumes livestock which belongs to local people. Basically, animals will avoid settlement areas, they enter villages only when their habitat is destroyed and they can not find food resources for surviving. When their natural habitat is changes and it is not allowed to live, there is no other option for these animals in addition to seeking a safer area until conditions recover. We have to supply food in spot areas where wildlife is seen passing without caught them to the cage that sometimes make them stressful. For langgur spesies, supplying food can be done through plantation of local species as their food in surrounding national park's border, such as *Lithocarpus sundaicus*, *Erythrina lithosperma*, and *Engelhardia spicata.*

5.5.2 Captive breeding

It can not be avoided that sometimes rescuing animals should be taken by captive breeding. This could be a good option when we found pain animals. Captive breeding has risk for wild animals which caught and caged because wildlife are experiencing stress, injuries, illnesses and behavioral changes that are not normal and even cause death. Sending wildlife to zoo are costly since appropriate animal welfare standards will take a high cost such as for production of standarized cage which resemble with their natural condition. The captive breeding is also risky related to the behavior change of wild animals into domestic animals, and would complicate efforts when we want to release them back to their previous habitat.

5.5.3 Herding to a safe forest

Herding or evacuating wildlife to a safe forest area is a wise choice that should be prioritized in rescuing programme. This could be success if we give attention to the existing condition of their habitat. The most important thing to maintain the existence of wildlife in MVNP is by conserving their natural habitat since MVNP faces human encroachment as the main risk. The refuge areas should be noticed and protected since those sites are expected as shelter for wildlife when the eruption occured.

In conclusion, the forum suggested that preservation of the natural ecosystem at MVNP is not only to support food chain of wldlife but this could encourage the presence of wildlife included *Tracyphitecus auratus which* in turn can also help as "early warning system" for local people. The wildlife behavior may be a marker of natural shocks that must be addressed by local people.

Chapter 6 Conclusion and Recommendation

This research was carried out to estimate habitat loss of *Tracyphitecus auratus* caused by pyroclastic flow in the 2010 Merapi eruption and to identify refuge areas for the species as one effort in disaster management of wildlife. Modelling appropriate habitat is one of meaningfull steps in this study. By knowing areas which suitable for species we can make a right programe to reduce threats and risks. As the main findings of this research, estimation loss and identification the potential habitat can become a starting point in conservation of species at risk. Regarding that the high suitable habitat of *Tracyphitecus auratus* in Merapi Volcano National Park only found inside the park, understanding threats dan protecting the forest have to be taken. These following number describe conclusions of this research:

6.1 Conclusions

1. This research demonstrated the ability of Maxent models to determine the suitable habitat and most matter environmental variables. Spatial predictors which important in modeling suitable habitat of *Tracyphitecus auratus* in Merapi Volcano NP of year 2009 and 2012 are landcover, slope and elevation.
2. Suitable habitat for *Tracyphitecus auratus* after the 2010 eruption found in solid habitat patches at eastern to northern flank, from Tegalmulyo in Klaten Regency to Jrakah and Tlogolele in Boyolali Regency, while a small suitable habitat patch was found in Plawangan, Sleman Regency. Totally there are 493.92 hectares of high suitable and 1180.17 hectares of medium suitable or 7.7 percent and 18.4 percent of total area respectively.
3. By overlying between pyroclastic map and suitable habitat map before eruption it is strongly revealed that there was a temporary habitat loss of *Tracyphitecus auratus* at the 2010 Merapi eruption. The calcultion result about 148 hectares of medium suitable has been lost. Concerning that the loss is not permanent, thus the habitat loss can be included as temporary habitat loss. The finding also shows that natural disaster is less affected to habitat than landcover change which triggered by human intrusion.

4. By including the area as far as 2 km from major road around TNGM, Maxent model indicates potential refuge areas for Javan langur outside TNGM. Refuge areas identified in the form of small patches that were around Wonodoyo, Suroteleng and Mriyan villages in Boyolali Regency.
5. Species at risk map created by intersectioning vulnerable habitat with pyroclastic hazard map shows that the hazard scenario 1 (VEI 1 and VEI 2) were not encountered both medium and suitable habitat at risk, while in scenario 2 (VEI 3) was found that about 1584 hectares of habitat is moderate risk, and in scenario 3 (VEI 4) was found around 352.73 hectares of habitat is included in high risk.
6. From the group discusion, multi-stakeholder efforts to protect habitat and mitigate of wildlife migration to secure animals during Merapi eruption are crutial among others for reducing fatalities of wildlife. Conservation of the natural ecosystem at MVNP is not only to support food chain of wildlife but this could encourage the presence of wildlife included *Tracyphitecus auratus* which in turn can also help as "early warning system" for local people. The wildlife behavior may be a marker of natural shocks that must be addressed by local people.

6.2 Recommendation

1. The accuracy of landcover interpretation is very influence on this modeling suitable habitat since landcover is the most important factor. The use of high resolution imagery and reliable ground check would improve the accuracy of forest identification, especially in discriminating between mixed forest and dense high shurb areas.
2. The exatitude of species at risk map, which include potential components that affect the vulnerability of habitat, will raise if it also involves hazard maps that have been validated
3. The vulnerability of habitat which only employed distance to settlement and road density has confirmed where and how risky the habitat is. However it is noteable to mention that other parameters such as population viability analysis (which can determine quantitative number of species' population) will be incorporated when creating a risk map. Also the use of recent high resolution imagery will provide the useful road density parameter.

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