THESIS

MAPPING OF POSSIBLE CORRIDORS FOR JAVAN LEOPARD (*Panthera pardus ssp. melas*) BETWEEN GUNUNG MERAPI AND GUNUNG MERBABU NATIONAL PARKS, INDONESIA

Thesis submitted to the Double Degree M.Sc. Programme,
Gadjah Mada University and Faculty of Geo-Information Science and Earth Observation, University of Twente in partial fulfilment of the requirement for the degree of Master of Science in Geo-Information for Spatial Planning and Disaster Risk Management

By:
Andhika Chandra Ariyanto
UGM: 13/357438/PMU/08070
ITC: s6013570

Supervisor:

1. **Prof. Dr. Hartono, DEA., DESS. (UGM)**
2. **Dr. A.G. (Bert) Toxopeus (ITC)**

GRADUATE SCHOOL
GADJAH MADA UNIVERSITY
FACULTY OF GEO-INFORMATION AND EARTH OBSERVATION
UNIVERSITY OF TWENTE
2015

DISCLAIMER

This document describes work undertaken as part of a programme of study at the Double Degree International Programme of Geo-Information for Spatial Planning and Disaster Risk Management, a Joint Education Programme between Faculty of Geo-Information Science and Earth Observation, University of Twente, the Netherlands and Gadjah Mada University, Indonesia. All views and options therein remain the sole responsibility of the author, and do not necessarily represent those of the institute.

Author,

Andhika Chandra Ariyanto

ABSTRACT

Javan Leopard (*Panthera pardus spp. melas*) as the remain big cat species in Java Island after the extinction of Javan Tiger in 1980s has been detected occupying the area of Gunung Merapi and Gunung Merbabu National Parks. Its population is threatened by habitat loss, fragmentation habitat, volcanic and wildfire hazard. Unfortunately, the distribution of this species have not been identified. In addition, since those habitats are separated by a main road and highly populated settlements, the research about corridors for the leopards also have not been conducted yet.

Considering the facts above, the main objective of this research is to predict and map the possible corridor for Javan Leopard between Gunung Merapi and Gunung Merbabu NPs landscape by using remote sensing and GIS approach. In order to achieve that, Species Distribution Modelling (MaxEnt) was demonstrated to predict the leopards' distribution and Least Cost Path was applied to figure out the possible paths which connect those two NPs.

By using presence-only data of Javan Leopard occurrences, 16 observation points alongside several environmental variables which consist of prey, landcover, NDVI, distance to river, settlement, road/path, elevation, slope, rainfall (annual, maximum, minimum), temperature (maximum, minimum) were deployed into MaxEnt programme. Remotely sensed imagery of Landsat 8 and ArcGIS software were used to the analysis process. The results showed that the total presence of leopards' distribution was 4,233 ha while 70% of it located within the area of NPs. Landcover, prey distribution, rainfall (maximum and minimum), minimum temperature and NDVI become the most important variables in this model. Meanwhile, least cost path revealed the most likely possible corridor in 6 km route. It characterized by relatively secure track from settlement areas and enough cover along the route. Applying minimum width for strip corridor (1,000 feet), this possible path intersected 6 ha of settlement, 18 ha of farm and 102 ha of agriculture areas of Boyolali District. Become *the matrix* for Merapi-Merbabu landscape, it plays an important role in creating a corridor to connect those national parks. Moreover, either natural hazards or isolated population issues are plausible to be addressed by developing the corridor.

Keywords: *Javan Leopard, Gunung Merapi NP, Gunung Merbabu NP, Species Distribution Modelling, MaxEnt, Least Cost Path, Corridor*

ACKNOWLEDGEMENTS

All the praises and thanks be to Allah SWT, the Lord of the 'Alamin, as His blesses so I can finish my MSc research.

I also would like to express my thanks to all who have supported me in pursuing Master degree. To my first supervisor Prof. Dr. Hartono, DEA., DESS for his outstanding guidance to accomplish this thesis and to my second supervisor Dr. A.G. (Bert) Toxopeus for his brilliant idea and insight for my research and for introducing me to the magnificent of MaxEnt.

To all ITC members of stuff for their assistance during the MSc course, thanks to Prof. Dr. V.G. Jetten and Dr. H.M.A. (Harald) van der Werff for the critics and suggestions to my thesis proposal, Ir. B.G.C.M. Krol for his warm greetings, his solutions for any problems and all his kindness during my stay in Enschede, Dr. Norman Kerle for the precious peer to peer review session, David G. Rossiter for his wise suggestions related to my research and Dr. Thomas Groen who introduces me to species distribution modelling field.

To GMU board: Prof. Dr. H.A. Sudibyakto, M.S., Prof. Dr.rer.nat. Junun Sartohadi, Msc for their trust and support for me in completing this research, Mbak Indri and Mas Wawan who have assisted me along this course.

To BAPPENAS and NESO who have given this valuable opportunity for me to join this MSc course in GMU and ITC. To Kerinci Seblat National Park authority as its permit and help for me to level up my degree.

I also would like to express my thanks to Gunung Merapi NP authority: Director of GMNP (Ir. Edy Sutiyarto), Mas Nurpana Sulaksono, Mas Asep Nia, Mbak Widya, Pak Suharyana and his member of stuff in Resort-Cangkringan (Ari Nurwijayanto, Nur Anifah, Nurul Hikamiyah, Siswanto), Mas Bangun, Pak Ngatijo, and to Gunung Merbabu NP authority: Director of GMbNP (Ir. Wisnu Wibowo, MM), Pak San Andre Jatmiko, Mas Saeful, Mbak Krtistina Dewi, Jarot Wahyudi, Pak Amat, Astekita Ardi, Fadel and Pak Jupri for their supports during my research period. My gratitude also goes to the members of stuff of Boyolali District especially Pak Kusumo and Bu Diana for the spatial planning data.

To Geo-Info batch 9 (Bappenasers): Uda Aththaar, Mas Budi, Mbak Novia, Uda Febri, Kusnadi, Pipit, Ardhi, Imam and my *partner in crime* Arief thanks for the valuable moment during EAP and MSc course. The other Geo-info batch 9: Listyo, Tiwi, Eko, Muslimin, Hogy, Taufik, Mbak Angga, Dwi, Asti, Bayu, Azmi, Dewa, Novita, Irene and Ahdi thanks for this friendship.

My special thanks also goes to Hero Marhaento, Ayun Windyoningrum, Subyantoro Tri Pradopo, Sa'duddin for the fruitful discussions on my thesis topic and Eddy Dwi Atmaja for the leopard data.

For the remote discussion pertaining Javan Leopard, many thanks to Didik Raharyono, Anton Ario, Hariyawan A Wahyudi, Oki Hadian, Ali Imron and Agung Nugroho. To ITC mates, the MaxEnt'ers: Xuan, Vella and Nyasha, I really appreciate for their assistance in directing me how to deal with MaxEnt.

Finally, my deep appreciation to my parents for their prayers, my brother and sister for their supports, and the most importantly to my *better half* Sarah Arlina and my *little princes* Gendhis Syafiqa Arliyanto for their affections.

Yogyakarta, April 2015
Andhika Chandra Ariyanto

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASCII	: American Standard Code for Information Interchange
a. s. l	: above sea level
AUC	: Area Under receiver operating Characteristic
BPPTK	: Balai Penyelidikan dan Pengembangan Teknologi Kegunungapian (Volcanics Technology Research and Development)
BRT	: Bossted Regression Trees
CITES	: Convention on International Trade in Endangered Species of Wild Fauna and Flora
CNRD-PEDRR	: Center for Natural Resources and Development-Partnership on Environment and Disaster Risk Reduction
csv	: comma-separated value
GAM	: Generalized Additive Models
GDM	: Generalized Dissimilarity Modelling
GIS	: Geographic Information System
GLM	: Generalized Linear Models
GPS	: Global Positioning System
IUCN	: International Union for Conservation of Nature
KSDA	: Konservasi Sumberdaya Alam (Nature Resources Conservation)
LCP	: Least Cost Path
MaxEnt	: Maximum Entropy
NP	: National Park
ROC	: Receiver Operating Characteristic
RS	: Remote Sensing
SDM	: Species Distribution Modelling
TNGM	: Taman Nasional Gunung Merapi
TNGMb	: Taman Nasional Gunung Merbabu (Gunung Merbabu National Park)
TSS	: True Skill Statistic
UNEP	: United Nations Environment Programme
USA	: United States of America
VIF	: Variance Inflation Factor

1. INTRODUCTION

1.1. Background

1.1.1. Javan Leopard (*Panthera pardus ssp. melas*)

Leopard (*Panthera pardus*) is considered as the most adaptable species amongst the family of Felidae which widespread distributed from South Africa to South-east Asia (Nowell & Jackson, 1996; Uphyrkina et al., 2001). In Indonesia, there is a subspecies of leopard namely Javan Leopard (*Panthera pardus ssp. melas*) which only exists in Java Island. It becomes the remain big cat species in Java after the claiming of Javan Tiger's (*Panthera tigris ssp.sondaica*) extinction in 1980s. Below is the taxonomy of Javan Leopard:

Kingdom	: Animalia
Phylum	: Chordata
Class	: Mammalia
Order	: Carnivora
Family	: Felidae
Genus	: Panthera
Species	: *Panthera pardus ssp. melas*
Species Authority	: G. Cuvier, 1809

Source: IUCN, 2008

Figure 1.1. Javan Leoprads in Batu Secret Zoo, East Java
(source: private property, 28 September 2014)

As a part of Panthera Genus alongside Lion (*Panthera leo*), Tiger (*Panthera tigris*) and Jaguar (*Panthera onca*), leopard becomes the smallest size with 215 cm and 185 cm length (from head to tail) for male and female, respectively. Its weight range from 39 to 52 kilograms with approximately shoulder height is 60 – 65 cm. The pattern of black rosettes is printed on its pelage of light-straw yellow to beautiful orange-yellow. It spreads in all over the leopard's body. In addition, there are also melanistic leopards which appear in black color in response to a high percentage of melanin which cause the fading of all the lighter shades on its pelage. Even on this appearance, the rosettes pattern still visible under the light at a certain angle (Hoogerwerf, 1970). However, rosettes pattern of leopard is similar with jaguar. In jaguar, there is often a small spot within the rosettes which does not exist on leopards' coat (Stein & Hayssen, 2013).

Furthermore, Hoogerwerf (1970) explained that the size of Javan Leopard's preys range from small mammals like mice and bats to medium ungulates such as barking deer. The latter considered as the preferred prey since its abundance in most of protected areas in Java. Several studies also experienced that muntjac deer, wild boar, long-tiled macaque, javan gibbon, lesser mouse deer are categorized as the diet of Javan Leopard (Ario, 2007; Santiapillai & Ramono, 1992). In addition, domestic livestock such as dogs, goats and chickens are likely to be hunt by Javan Leopard especially when the leopard passes near human settlements and agriculture area.

The distribution of Javan Leopard population is detected within the protected areas and forest plantations in Java Island. It resides from the south-west of the island with dense tropical rainforest to the east part of which are dominated by dry deciduous forest and scrub (Santiapillai & Ramono, 1992). In Central Java, Gunawan (2010) revealed that Javan Leopards inhabit several forest plantations (teak). Indeed, several national parks (NP) such as Ujung Kulon NP, Gunung Gede pangrango NP, Gunung Halimun-Salak NP, Gunung Ceremai NP, Gunung Merbabu NP, Gunung Merapi NP, Bromo Tengger Semeru NP, Meru Betiri NP, Baluran NP and Alas Purwo NP are justified as the habitats for Javan Leopard (Ario, 2007; Gunawan, 2010; IUCN, 2008).

According to IUCN (2008), the population status of Javan Leopard is categorized as 'critically endangered'. Its population trend is decreasing with population number less than 250 matures individuals (IUCN, 2008). In addition, CITES (2013) puts this exotic species into category of Appendix I. All species, flora and fauna, which belong to this category is the most threatened of being extinct due to international trade of specimens including skins and other body parts of fauna except for scientific purposes (CITES, 2013).

Beside human activities around the forest, Javan Leopard's population is likely to be threatened by habitat loss, fragmentation habitat, trading activities, poaching (Ario, 2007) and hunting on its prey (Khorozyan, 2001). As Karanth & Nichols (1998) said that prey abundance determine the relative abundance of large felid species and it should be considered as the significant aspect of habitat. Moreover, volcanic hazard of Merapi and wildfire in Merbabu presumably also become a serious threat for the habitat.

1.1.2. Habitat Conservation

As one of the conservation efforts for the declined-population of Javan Leopards, understanding their habitat becomes a critical point. Habitat as a home for wildlife which provides food, cover, water and spatial area (space) plays an important role in survival (Creighton & Baumgartner, 1997; Morrison, et al., 2006).

As it mentioned before that Gunung Merbabu NP which is situated in Central Java and so does Gunung Merapi NP with several areas of it also belong to Yogyakarta Special Region are considered as the habitat for Javan Leopard. These parks also become one of priority landscapes for conserving Javan Leopard with population estimation in 2005 was not more than 10 individuals (Indonesia, 2013). Nevertheless, the understanding about habitat for wildlife conservation efforts should be equipped by the study of habitat connection. Gunung Merapi NP and Gunung Merbabu NP which are located amid the highly populated area have been threatened by fragmentation habitat. The ecosystem of those areas are oppressed by agricultural expansion (Franck Lavigne & Gunnell, 2006). A main road which separates those national parks becomes the other barrier in habitat connection. More in general, habitat fragmentation and land degradation are reported as reasons for species' decline (Rodríguez-Soto, Monroy-Vilchis, & Zarco-González, 2013).

Habitat connectivity between protected areas is supposed to be a means of population continuation. The finite population in fragmented habitat will drive circumstances into inbreeding process over time which severely leading into extinction proneness (Frankham, 1998). According to Lindenmayer & Fischer (2006), fragmentation can be described as small patches of areas which are occupied by remnant population and likely become isolated from one to another. Non-equilibrium population of Javan Leopard in Gunung Merapi NP and Gunung Merbabu NP are in fragile condition without any habitat connectivity (Gunawan, 2010). Likewise in Halimun-Salak NP in West Java, Ario (2007) stated that corridor establishment ascertain gene pool connection between two populations. Hence, corridor as habitat connectivity would guide the process of migration and let the flow of genetic variations for Javan Leopard in eluding population depletion (Owen-Smith & Norman, 2007; Schmiegelow, 2007). For that reasons, the utilization of remote sensing and GIS in identifying possible habitats and predicting its possible corridors would be worthwhile in managing wildlife notably Javan Leopard conservation.

1.2. Problem Statement

In implementing the theory, the understanding about habitat becomes a profound thought. The identifying and mapping habitat for Javan Leopard beforehand become an important step toward the more advanced-analysis. While there are many studies performing the recent situation of Javan Leopard across Java Island, identifying its habitat particularly in Gunung Merapi NP and Gunung Merbabu NP has not been conducting yet. There are several researches related to its distribution and population in Central Java, but neither habitat mapping nor corridor prediction study have been done in those two parks.

The uniqueness of those areas lies on the position of national parks amid the highly populated areas of Central Java and Yogyakarta Special Region. In term of habitat connectivity, those two national parks as the homes for wildlife are severely separated by a main road in which hindering the colonization among the sub-populations. Undeniably, it halts the exchange of immigrants of the same species which becomes the plausible explanation of species extinction (Frankham, 1998). Moreover, as the shrink of Javan Leopard's habitat due to human activities surrounding those parks, isolated populations eventually force to the occurrence of inbreeding.

Considering the fact that in conservation management point of view Gunung Merapi and Gunung Merbabu NPs need to be connected ecologically. The study about predicting possible corridor for Javan Leopard between those areas is worthy to be carried out. It also has not been revealed by researchers yet. Thus, several variables such as landcover, distant to road, settlements, water etc. which might be impeded the movements can be set up in predicting potential corridors. The expected result is several corridor paths which can be modelled to determine the most likely possible corridor in functional aspect for Javan Leopard.

Providing the analysis about the model of habitat and corridor for Javan Leopard have been conducted, then the gap analysis among national parks zoning system, habitat-corridor mapping and regional spatial planning will express the conformity of its functions. The results would be beneficial for Javan Leopard conservation program either for national park's authorities, local government or other institution which might be concern on Javan Leopard.

Figure 1.2. Conceptual design of research

1.3. Research Objectives

The main objective of this research is to predict the possible corridor for Javan Leopard between Gunung Merapi and Gunung Merbabu NPs landscape by using remote sensing and GIS approach. More specific objectives listed as follows:

a. To identify and map the potential habitat of Javan Leopard in Gunung Merapi NP and Gunung Merbabu NP.
b. To predict and map the potential corridor for Javan Leopard between Gunung Merapi NP and Gunung Merbabu NP.
c. To conduct gap analysis among the possible habitats-corridors, national park zoning system and regional spatial planning.

1.4. Research Questions

In order to address the aforementioned specific objectives, below are the lists of research question:

Table 1.1. Research objectives and questions

No	Research Objectives	Research Questions
1.	To identify and map the potential habitat of Javan Leopard in Gunung Merapi NP and Gunung Merbabu NP.	a. Where is the suitable habitat for Javan Leopard in the landscape of Gunung Merapi NP and Gunung Merbabu NP? b. How suitable those habitats for Javan Leopard? c. Which variables is the most influence the habitat for Javan Leopard?
2.	To predict and map the possible corridor for Javan Leopard between Gunung Merapi NP and Gunung Merbabu NP.	a. Where are the possible pathways for Javan Leopard to move from Gunung Merapi NP towards Gunung Merbabu NP and vice versa? b. Where is the most likely predicted-corridor between Gunung Merapi NP and Gunung Merbabu NP? c. What is the characteristic of predicted-corridor? d. What are the potential threats for Javan Leopard's corridor?
3.	To conduct gap analysis among the possible habitats-corridors, NP zoning system and regional spatial planning.	a. To what extend the gap among the possible habitats and national park zoning system, corridors and regional spatial planning? b. What are the authorities of national parks and local government can do related to the corridor issues?

1.5. Research Assumption and Limitation

Since the study about wildlife is regarded as the complicated one, especially for rare species like Javan Leopards, several assumptions which were applied to this research can be described as below:

a. Any information pertaining occurrences of big cats by people in the area of Merapi and Merbabu NPs is considered as Javan Leopard because there is no more big-cat left in the forest of Java Island except Javan Leopard after the claiming of Javan Tigers' extinction. In addition, this study will not reveal the population number of Javan Leopard because it is only focused on distribution model by using Maximum Entropy approach and did not cover the estimation of Javan Leopard's population number.
b. Considering the densely populated area between Merapi and Merbabu and relatively crowded main road during the day, the predicted path is assumed to be used by the leopard during the night as the characteristic of secretive species in avoiding any potential disturbances.
c. The movement of Javan Leopards from Gunung Merapi NP to Gunung Merbabu NP or vice versa is forced by a potential natural disaster occurrence, the need of recolonize to another sub-population and fulfilling their various preys.

Meanwhile, in order to limit the scope of this study, the coverage of the research can be mentioned as follows:

a. The use of remotely sensed imagery on this research has been limited only for Landsat 8. The medium spatial resolution (30 m) of Landsat is able to depict the study area satisfactorily. Its easiness in acquiring the images converts the reason why these images were applied and plausible to be applied also by NP authorities.
b. The focuses of this research are the areas of two national parks as well as the area in between those two parks.
c. The corridor on this research is not only restricted in the form of strip corridor or stepping stones corridor, but also the prediction path (move direction) which probably passed by Javan Leopards.

2. LITERATURE REVIEW

2.1. Species Distribution Modelling

Simplification for the complexity of reality is broadly understood as a model. In order to recognize a specific complex system in the real world, an effort for simplifying visually, schematically and diagrammatic is needed. Model as connectivity between the real world and the concept applies in attempt to explain a phenomenon. The process of developing concept over the real world system is considered as modelling (Marfai, 2011).

In wildlife conservation point of view, there is also modelling activity. The most basically developed-activity is modelling for species distribution. In General, Species Distribution Modelling (SDM) can be described as a prediction of probability for species presence based on environmental factors as the predictor (Elith & Leathwick, 2009; J. Franklin, 2009). It depends on the complex process of quantifying biological data (target species) and environmental data as predictors alongside analytical process (Drew, Wiersma, & Huettmann, 2011). Modelling which organized by the convolution of the biological, ecological and physical process can be tested as information gaps indicator in wildlife management activity (Toxopeus, 1999).

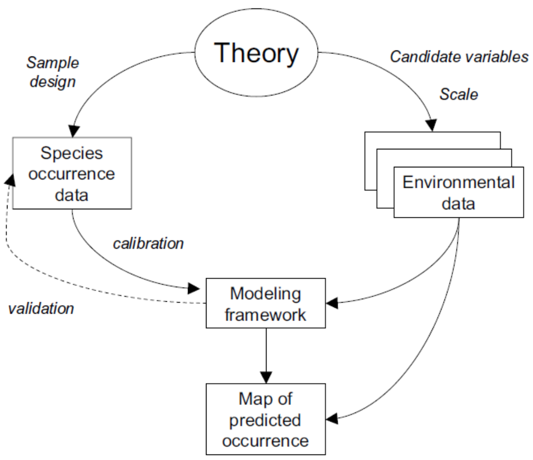


Figure 2.1. Component of SDM (Franklin, 2009)

The diagram above (figure 2.1) describes the component of SDM as the main concept of modelling. The theory concerning target-species becomes fundamental in developing model. Species distributions are controlled by abiotic and biotic factors in space and time and in a difference scale. The record of location for species occurrence and expert knowledge about habitat requirements or preferences will be mapped as a prediction distribution based on the characteristic of species, the scale of the analysis and the data availability. In order to validate the predictions, data and criteria should be applied to anticipate error or uncertainty in the analysis (J. Franklin, 2009).

There are numerous methods of SDM which have their own level of predictive success. Boosted Regression Trees (BRT), Generalized Dissimilarity Modelling (GDM) and Maximum Entropy (MaxEnt) are considered as the best model in term of Area Under receiver operating Characteristic (AUC) and the point-biserial correlation by using independent data set (Austin, 2007).

Maximum Entropy is a machine learning method for species distribution modelling which employs mathematical formulation in a simple and precise approach and possess various aspects (Phillips, Anderson, & Schapire, 2006). It is the most popular application in species distribution and environmental niche modelling since 2006 which has its advantages such as the outstanding predictive accuracy and easy-handling application (Merow, Smith, & Silander, 2013). By using presence-only data, this method will estimate the probability of distribution even though on the situation that there is no complete information related to the target distribution at all scale. This method is relevant to be implemented in the study area since the available data record for leopard is presence-only data.

2.2. Volcanic Hazard

Volcanic eruption becomes one of the most dangerous and complex natural hazards (Bryant, 2005; Kusky, 2008). The events of the volcanic eruption have taken numerous of casualties all over the world. According to Kusky (2008), more than 500 million people worldwide occupy the area nearby active volcanoes.

Cultural and economic reasons have driven the communities to be inherent in some notoriously hazardous location. Productive soils as the result of volcanic ash have lured numerous people to stay there. Moreover, large floodplains which suitable for agricultural purposes in affordable price become the other reason for people who live in high risk of floods and lahar flows. As the consequences, they extremely requisite the knowledge related to risk and how to respond to an emergency situation and minimize the risk when the disaster occurs (Hyndman & Hyndman, 2010; Kusky, 2008).

A volcanic activity generally associated with the activity of tectonic shortening and extension which caused tremendous eruption followed by lava deposit and tephra (Bull, 2007) and has been classified into non-explosive and explosive (Westen, et.al., 2011). Tephra defined as the material which spread out through the air or conveyed as hot moving flow to the land neighboring volcano. It contains new magma together with older broken rock fragments, ash and pyroclasts. The large, smaller and smallest grades of pyroclasts are called volcanic bombs, lapilli and ash, respectively (Kusky, 2008).

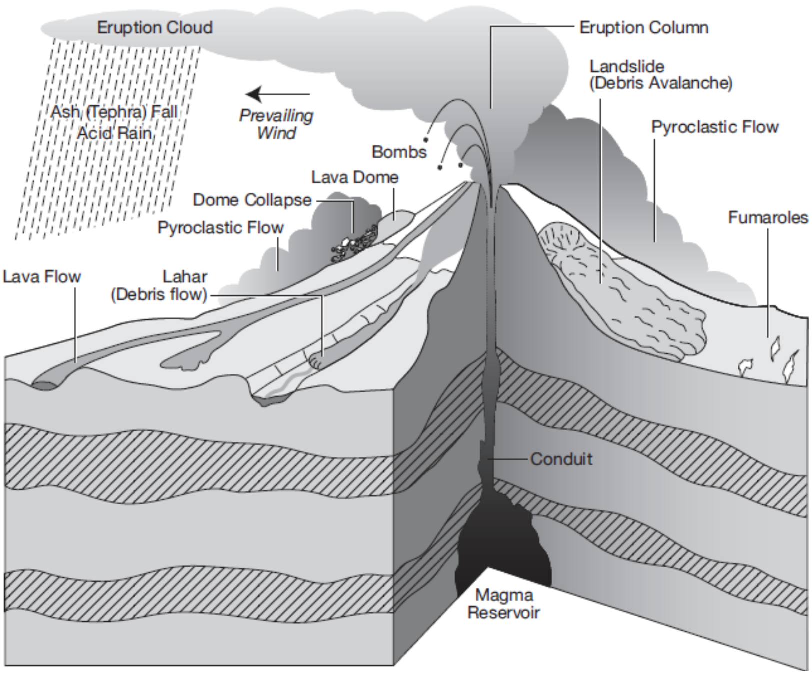


Figure 2.2. Possible hazards of volcanic eruptions
(source: Smith & Petley, 2008)

More specifically, Hyndman & Hyndman (2010) mentioned that the product of volcanic eruption consists of lava; pyroclastic materials such as air-fall ash, pumice, pyroclastic flow deposits; and lahars (volcanic mudflows). Lava is a molten magma that flows out onto Earth's surface while lahar means volcanic ash and other fragments transported by water to downslope. Meanwhile, the definition of pyroclastic material is fragments and pieces of solidified magma blown out of a volcano and deposited by a pyroclastic flow or air-fall ash.

As a dramatic phenomenon on Earth's surface, volcanic eruptions hold directly or secondary effects which have been categorised by Bryant (2005) into six groups of lava flows; ballistics and tephra clouds; pyroclastic flows and base surges; gases and acid rains; lahars; and glacier bursts.

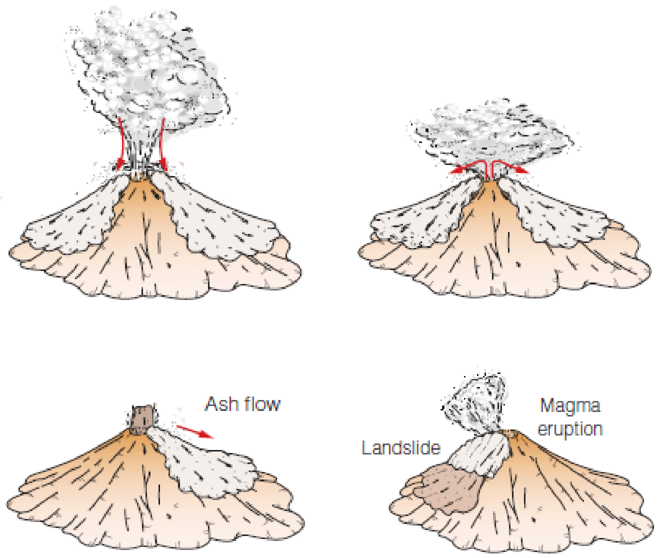


Figure 2.3. Types of eruptions (source: Hyndman & Hyndman, 2010)

The sketches above show the type of pyroclastic flows. Clockwise from the upper left, continuous eruption with continuous or intermittent column collapse; magma rises into vent with resulting collapse of the ash cloud; landslide or bulge releases pressure on magma, initiated eruption; collapse of dome with or without gas explosions.

As the most active volcano in the world, Merapi at least has 23 eruptions of the 63 reported occurrences since the mid-1500s. Approximately 200,000 people live in the prone area of notably pyroclastic flows and heavy tephra fallout and more than 120,000 residents live along 13 rivers which prone to lahar flows (Lavigne, et al., 2000). In contrast to Merapi volcano, a dormant volcano namely Merbabu was reported has its last explosion in 1797 (http://www.volcano.si.edu). Kusky (2008) stated that long-dormant volcanoes are possible to erupt in a huge magnitude and blowout tons of volcanic material to the stratosphere.

2.3. Wildfire Hazard

Biophysical hazards as the result of interaction between geophysical environment and biological organism, as well as humans, comprise several harmful events such as disease epidemic and wildfire (Smith & Petley, 2008). Furthermore, Smith & Petley argued that wildfire emerges caused by natural vegetation as surface material notably in combustible status and augmented by weather condition in spreading the fire. Moreover, it will be severely triggered in water stress circumstances mainly in forest and peat land (Westen et al., 2011).

However, wildfire as a part of natural process of forest evolution plays a critical role in the health of ecosystem (Bryant, 2005; Hyndman & Hyndman, 2010). It assists ecosystem to sparse the forest, decrease understory fuel and provide an opportunity to let another species to grow. It revamps as a hazard if the fire invade human environment including forests in which wildlife exist. In the United States, Busenberg (2004) described that wildfires produce damage within communities and ecosystems.

Figure 2.4. The Fire Triangle (source: Hyndman & Hyndman, 2010)

The figure above illustrates three components contribute to a fire namely fuel, oxygen and heat as it is commonly called as the fire triangle. The fire can only burn with the condition of available elements in fire triangle. Fuel loading like a burnable material such as trees and dry vegetation which the most ignitable fragment of wood contains cellulose, a compound of carbon, hydrogen and oxygen.

Bryant (2005) explained that the potential for fire hazard lies on fire behavior, fuel characteristic, climate and vegetation type. Fire behavior becomes another concern since during the day moisture content is in drop level and wind speed will lead to the severe fire. In Australia bush land, the rate of fire movement escalates exponentially in average fuel content and when the fires reach the treetops the speed estimated 20 km per hour.

The characteristic of fuel material such as compacted litter and uncondensed litter prescribes the process of burn. The former contributes to the slowness of burn and the latter can be burnt rapidly. Leaves and dry grasses which are categorized as lightweight combustible material will produce less heat when it is burnt but ignite easily and burn up rapidly. In contrary, tree trunks as heavy flammable material create more heat but difficult to ignite and burn much longer (Hyndman & Hyndman, 2010).

The influences of climate which regulate the water content in grass and bush litter seemingly determine the process of fire. Obviously, the dry out of fuels in an area is susceptible to wildfire. Lastly, the different type of vegetation is defining the intensity of wildfire spreading. Vegetation which contains high oil on its leaf such as eucalyptus will raise the fire and becomes the most fire prone vegetation (Bryant, 2005).

There were several wildfire occurrences in Gunung Merbabu NP reported by the authority. Starting from 2006, 2007, 2008, 2009 and 2011 wildfires have burnt the area of 463, 10, 12.4, 25 and 50 Ha, respectively. The last event occurred in September and October 2014 recorded burnt approximately 151.98 Ha. Undeniably, those events become a serious threat for Javan Leopard’s habitat.

2.4. Natural Disaster and Ecosystem

According to Oxford Dictionary, disasters express as an unexpected accident or a natural catastrophe which caused great damage and taken death toll. There are two classes of disaster, natural disasters and disasters caused by humans. Natural disasters occur as a result of natural forces like tropical storms, floods, droughts, volcanoes, earthquakes, landslides and tsunamis. Humans also contribute to the occurrence of disaster. Technological failure, building collapse, transportation accident are the evidence of disaster caused by humans. Disasters are still widely regarded as the tremendous event which comes to pass speedily. In fact, there are also slow-strike disaster like climate change and famine (Saltabones, 2006).

Meanwhile, based on UNEP (2009), the definition of ecosystem is a conjunction between biotic component which consist of animals, plants, microorganisms and abiotic components of their environment consist of water, air and mineral soils, and interact each other as a functional unit. Its scope is excessively wide and humans are being in part of an ecosystem.

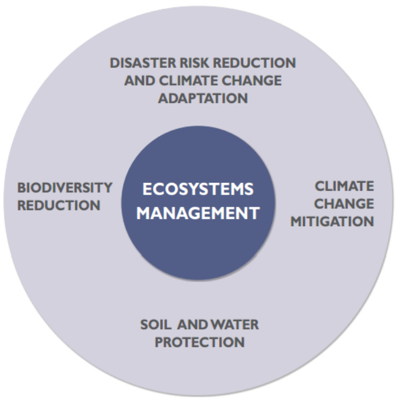


Figure 2.5. The benefits of ecosystem management (source: CNRD-PEDRR, 2013)

Figure 2.5 shows that ecosystem management efforts will bring multiple advantages not only in biodiversity, soil and water protection, but also in climate change mitigation and disaster risk reduction. As a part of elements at risk in disaster occurrence, ecosystems experience an adverse consequence when a disaster materializes. It embraces flora, fauna and biodiversity alongside landscape which will be affected by any natural disaster in a particular location (Westen et al., 2011).

Kreimer & Munasinghe (1991) stated that environmental impact infrequently emerge in a natural disaster report or news even tough natural disasters are possible to distress ecosystems. Direct effect of natural disaster (Hurricane Hugo) had performed in Carolina (USA) and Caribbean which destroyed wildlife, important ecosystems and sensitive natural habitats. In case of Gunung Merapi, a high volcanic activity threats its biodiversity which potentially caused an extinction (Marhaento & Faida, 2014). Indeed, therefore alterations of landscape are initiated by natural processes (D. B. Lindenmayer & Fischer, 2006).

2.5. Wildlife and Disaster Management

A massive volcanic eruption was mentioned as one of species' extinction causes upon the Earth (Sodhi, Brook, & Bradshaw, 2009). It is followed by the other driving factors such as a rapid loss of habitat or even an asteroid hit. On this situation, wildlife becomes one consideration to take into account in the process of disaster management.

Disaster management embraces several activities in a disaster management cycle. According to Baas, et al. (2008), it distinguishes into three main phase: pre-disaster, response and post-disaster.

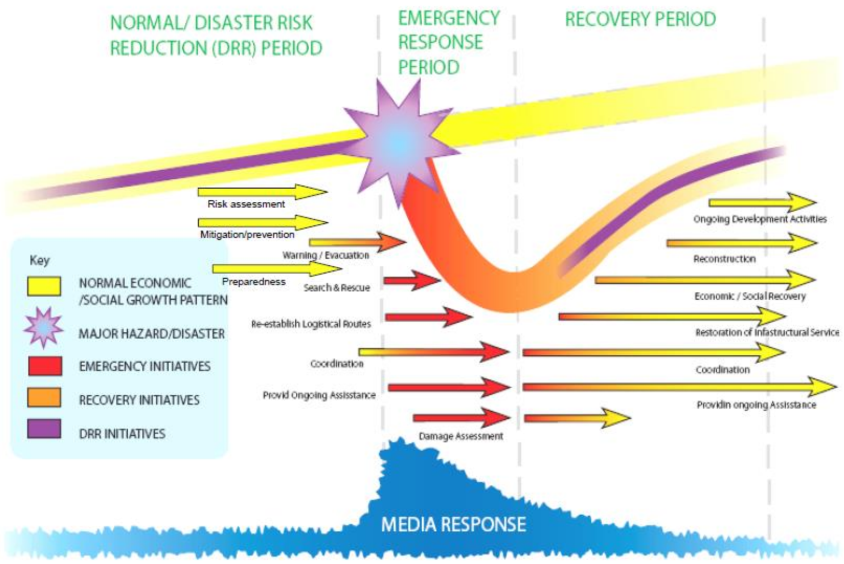


Figure 2.6. Disaster Risk Management Framework (source: Bass, et al., 2008)

The framework for managing disaster risk showed in figure 2.6. Pre-disaster consists of ongoing development activities, risk assessment, prevention, mitigation, preparedness and early warning. A number of activities like evacuation, immediate assistance and assessing damage-loss are classified into response phase. In the meantime, post-disaster fully loaded with ongoing assistance, recovery (infrastructure, services, social, economy), reconstruction, ongoing development activities and risk assessment.

Considering the concept of disaster management, ecosystems as element at risk of disaster occurrence is inevitable to be elaborated. The basic concept of wildlife management based on Clark (2007) lies on providing habitat components contiguity in order to satisfy wildlife's daily and seasonal requirements. Wildlife management in a successful effort was believed able to help restore a system of multiple ecological levels.

Additionally, natural disasters become important aspects in managing habitat. It is considered as a factor which influences in habitat disturbance together with human activities in the forest, over exploitation of forest's product etc. Disaster occurrences have changed wildlife's habitat in which some of them are severely affected landscapes. Evidently, it will cost a lot in rehabilitation activity. Hence, monitoring and mitigating natural disaster for habitat become paramount in wildlife conservation. Even though wildlife have their own instinct in fleeing from disaster, an endeavor of preparing the save paths to wildlife for moving is important (Alikodra, 1993).

2.6. Habitat Connectivity

According to Alikodra (1993), habitat can be described as an area comprises physic and biotic components as unity where wildlife can live naturally. Wildlife occupy particular habitat based on their environmental needs in supporting life. In detail, Clark (2007) mentioned that the component of wildlife habitat consists of cover, food and water which are possible to be managed correspondingly.

Especially for large mammals, habitat size and the availability of wooded corridors for moving between habitats have become limited factor for wildlife.

Generally, as expansion of settlements and agricultural needs, habitats have been degraded and severely fragmented into patches. Forman (1995) in Lindenmayer & Fischer (2006) explained the contribution of humans in shifting process in landscapes spatially. Figure 2.7-A depicts spatial pattern of landscape which divided into five pattern: perforation (mine site in remote area), dissection (road across forest), fragmentation (remnant vegetation in grazing lands), shrinkage (patch size reduction) and attrition (cleared patch in shrinkage). In general, Merapi-Merbabu seems similar to dissection type because of the existence of main road across the landscape. Moreover, figure 2.7-B illustrates the level of modification which caused edge effects from low, low-high and high namely intact; variegated and fragmented; relictual respectively.

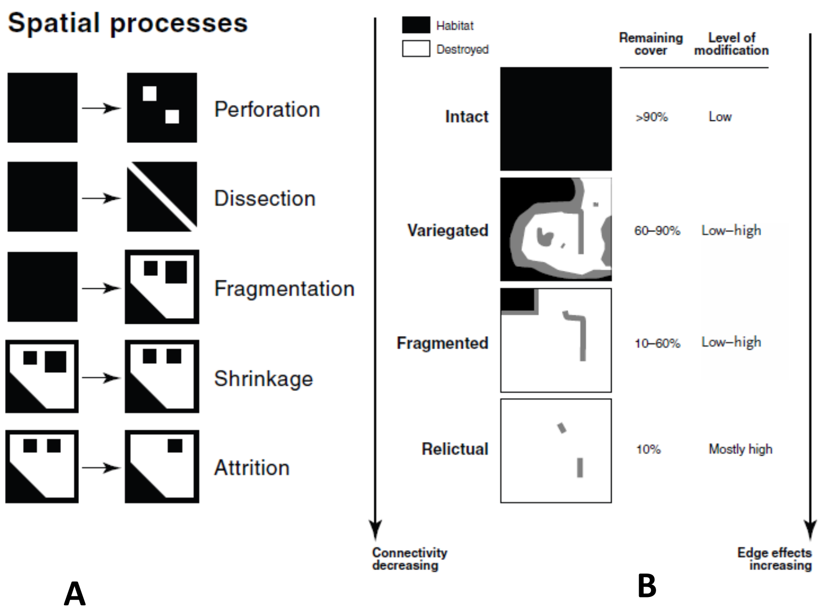


Figure 2.7. Alteration of landscapes spatially
(source: Forman, 1995; McIntyre & Hobbs, 1999 in Lindenmayer & Fischer, 2006)

Considering the phenomena above, habitat connectivity which facilitate particular species to be linked to another suitable patch is vital in promising species' survival (Government, 2012; D. B. Lindenmayer & Fischer, 2006). The movement of species from certain habitat to otherwise isolated patch needs to be equipped by a linier strip as it is commonly called a corridor (Government, 2012; D. B. Lindenmayer & Fischer, 2006). Adopted the method in establishing Jaguars' corridor in Latin America (Macdonald & Loveridge, 2010), the steps were identifying and protecting the population alongside its dispersal pathways in moving to another area, then considering the most secure track with trivial disturbance from any circumstance.

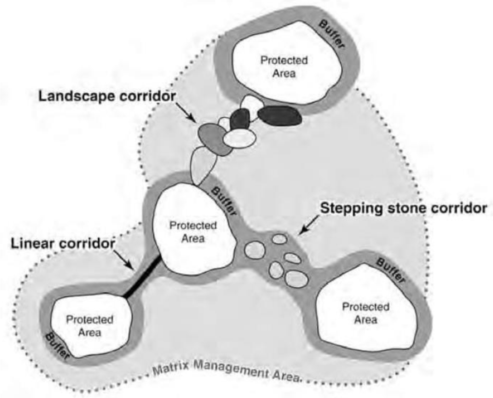


Figure 2.8. Type of corridor (source: Bennet, 2004 in Lindenmayer & Fischer, 2006)

There are three types of corridor as it displayed in figure 2.8. Linear corridor, landscape corridor and stepping stone corridor portrayed as the linkage over a number of protected areas within matrix management area in specific landscape. The reasons of species' movement rely on decreasing the adverse consequences of fragmented habitat which leads to lack of habitat components and extinctions as a terrible situation. The latter is caused by the failure of recolonize among sub-population of species and genetic interchange process (Bond, 2003). Applying those concepts, a fragile ecosystem of Gunung Merapi NP caused by its volcano activity (Djuwantoko, Purnomo, & Laksono, 2005) requires a connectivity study for wildlife to migration purposes.

2.7. Remote Sensing and GIS in Managing Wildlife

Remote sensing (RS) is broadly understood as the science, art and technology in acquiring information about an object, phenomenon and/or scene by device (technology-based) without performing any contact under investigation

(Graham, 1999; Lillesand, Kiefer, & Chipman, 2004; Tempfli et al., 2009). It divided into two main processes consist of data acquisition and data analysis. The first process covers energy sources from the sun to the Earth and retransmitted through the atmosphere as electromagnetic energy. It will be captured by sensing system in pictorial and/or digital type and processed in data analysis phase. Sensing products, combined with reference and experience data about particular area, are then interpreted and analyzed to produce information in the form of maps or files. Finally, the product of remote sensing can be further processed through Geographic Information System (GIS) and used for the decision-making process (Lillesand et al., 2004).

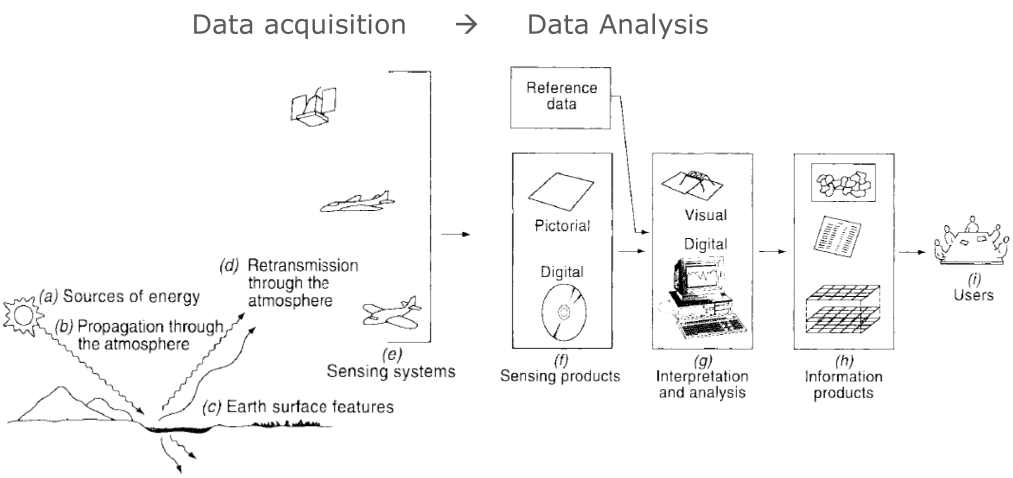


Figure 2.9. Remote sensing process (source: Lillesand et al. 2004)

Meanwhile, GIS is a computer-based system which proficient in collecting spatial data (remotely sensed imageries are being one of them), relating, performing and displaying spatial data and tabular data into a map (Huisman & By, 2009; Tempfli et al., 2009). There are six component parts of GIS which consist of software, data, procedures, hardware, people and network (Longley et al., 2005). GIS software is provided in wide range starting from a simple package to a major industrial-strength. Data which represent an object of interest on Earth’s surface digitally will be processed to some specific purposes. The component of software, hardware, database and network need organizations and procedures to run the system. Over the whole elements aforementioned above, people are considered as the vital component to perform the entire process.

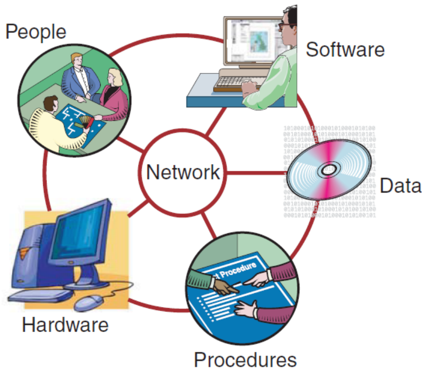


Figure 2.10. Six component parts of GIS (source: Longley et al, 2005)

Recently, the application of RS and GIS has been broadly recognized. Lillesand et al. (2004) and Wing & Bettinger (2008) explained that wildlife management notably habitat enormously needs RS and GIS to provide up to date and accurate information related particular site. By applying RS technology and GIS data processing as a tool, specific feature of wildlife like habitat can be figured out sufficiently as well as its possible threats (Horning et al, 2010; Leeuw et al, 2002; Store & Kangas, 2001). The use of remotely sensed imageries has become prominent as its products which similar to the original form (Rusydi H, Hartono, & Hadi, 2010) and let the scientists to analyze the objects or phenomena without performing any contact to the object of interest.

2.8. Spatial Planning

Spatial planning in general can be described as a planning which involves spatial or geographical component to organized landuse (activities or spatial structure) in attempt to produce enhanced condition that would perform without planning (Hall, 2002). In line with the definition above, Healey et al. (2006) elucidated that spatial planning is arranged to direct the development of physical infrastructures into a proper location. Indeed, it becomes the authority of government in the planning process, implementing strategies, policies and performing time schedule for developing activities.

Principally, spatial planning is designed to a level of region, city and rural settlements which stressed on the appropriateness of a certain project in a particular area (Healey et al., 2006). In accordance with Indonesian Law, Act No. 26/2007 about Spatial Planning, spatial planning divided into three level of national, provincial and local (district/city). The former become the authority of central government while the two latter belong to local governments on the process arrangement. In term of spatial scales and the content of information, spatial plans are classified into two types as general and detail spatial plans. Pattern and structure spatial usage for settlements, transportation and utility are covered in general spatial plans while zonation, density, ratio of open space and built area are included in detail spatial plans (Sutanta, Rajabifard, & Bishop, 2010).

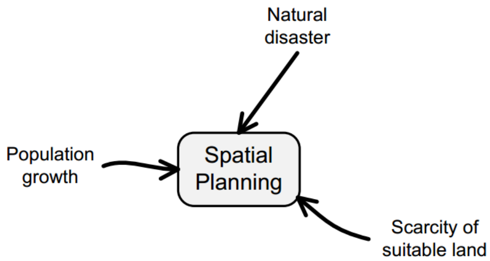


Figure 2.11. Spatial planning and external pressure

Furthermore, Sutanta, Rajabifard, & Bishop (2010) explained three difficulties possibly faced in spatial planning nowadays are the increasing population, shortage of land and potential natural disaster events as it displayed in Figure 2.11. As it can be seen that recently disasters are rampant occur across the globe, spatial planning in disaster risk management plays an important role in reducing the adverse consequences (Greiving & Fleischhauer, 2006; Sutanta, Rajabifard, & Bishop, 2009). It simply becomes one of many aspects determining the successfulness of risk management process but significant in defining the future constellation of land (Greiving & Fleischhauer, 2006).

Boyolali District which is located in between Gunung Merapi and Gunung Merbabu NPs plays an important role in facilitating an ecological connection for wildlife. Its spatial planning should consider conservation aspect in order to support the sustainable development concept.

3. RESEARCH METHODOLOGY

3.1. Study Area

The study area for this research is the landscape of Gunung Merapi, Gunung Merbabu NPs and area in between. Below is the map of research location:

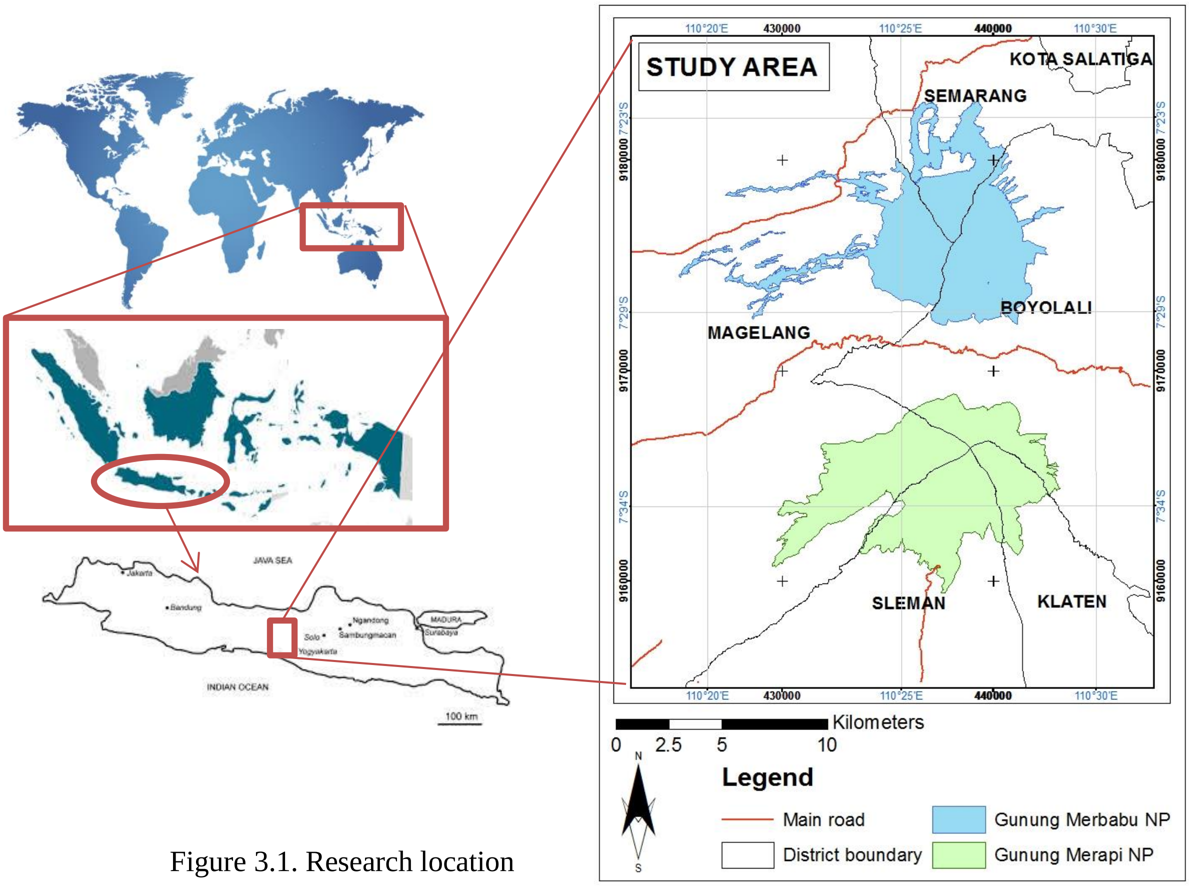


Figure 3.1. Research location

Gunung Merapi National Park was designated as national park on 4 May 2004 based on the Decree of Ministry of Forestry (*Surat Keputusan Menteri Kehutanan No.134/Menhut-II/2004*). It is geographically located between 110°15’00” - 110°37’30” E and 07°22’23” - 07°52’30” S. The area of this park is ca. 6,410 hectares which located in two provinces, namely Central Java and Yogyakarta Special Region which hold roughly 5,126 hectares (80%) and 1284 hectares (20%) of area, respectively. The elevation of this area is 50 - 2,500 meters a.s.l with annual precipitation range from 2,500 - 3,500 millimeters. Its temperature recorded from 20 to 33 centigrade and the humidity has variation starting from 80% to 99% (KSDA, 2004).

The aim of its establishment is to protect the water catchment area for the region surrounding and to conserve the high-value biodiversity. This park is considered as the habitat for more than a thousand of floras whereas 75 of them are included as rare species. Vegetation such as Pines, *Casuarina sp*., *Acacia decurrens, Schima wallicii*, *Euginia polyantha*, *Panicum muticum* are growing well on the landscape. In addition, numerous of fauna like *Macaca fascicularis, Tracyphitecus aurutus, Muntiacus muntjak, Spizaetus bartelsi*, *Panthera pardus ssp. melas* are also occupying Merapi NP. Considering the fact that Merapi is the most active volcano in the world, this park is also expected as the buffer zone in term of disaster occurrence.

Figure 3.2. The area amid Gunung Merapi (right side) and Gunung Merbabu (left side; source: fieldwork, 4 November 2014)

Meanwhile, at the north side of Gunung Merapi NP, there is another park, namely Gunung Merbabu National Park. On the same date with Gunung Merapi NP designation, the Decree of Ministy of Forestry (*Surat Keputusan Menteri Kehutanan No.135/Menhut-II/2004*) asserts that the habitat of flora and fauna in Merbabu landscape should be managed sustainably. Located in 110^{o}26’22” E to 07^{o}27’13” S geographically, this park lies in three districts (Boyolali, Magelang, Semarang) of Central Java. Its size of 5,675 hectares is also reflected as the prominent water catchment area.

Gunung Merbabu NP has two peaks, Syarif Peak and Kenteng Songo Peak with heights 3,119 and 3,142 meters a.s.l, respectively. Its temperature range is 17 to 30 centigrade with precipitation of 2,000 - 3,000 millimeters per year. As a dormant volcano, Merbabu landscape holds plenty of wildlife such as *Acacia decurens, Schima wallicii, Albizia falcataria, Pinus mercusii*, *Egelhardia serrata* for floras and *Tracypithecus aurutus*, *Macaca fascicularis*, *Ichtinaetus malayanensis*, *Panthera pardus ssp. melas* for faunas (CITES, 2013; IUCN, 2008; TNGMb, 2009).

Alongside Gunung Merapi NP, Gunung Merbabu NP has been appointed as the landscape priority to Javan Leopard conservation program 2013 - 2023 by Forestry Ministry. Hence, as mentioned on the problem statement, the objectives of this research are obviously feasible to be carried out on those parks. The landscape of Gunung Merapi and Gunung Merbabu NPs will be observed in figuring out the possible habitat and corridor for conserving the stunning creature of Javan Leopard.

3.2. Methods

In order to develop modelling for Javan Leopard's distribution alongside its habitat connectivity, several activities and processed-data as environmental layers need to be prepared beforehand. Basic needs for habitat as it has been initiated before (food, water, cover, spatial area) become the main consideration in predicting the preference habitat for Javan Leopards. Nonetheless, the impede factors for their moving will determine the possible corridors which connect these two parks. Below are sequences of the method:

3.2.1. Maximum Entropy

As a machine learning method which requires presence-only data in modelling, Maximum Entropy (MaxEnt) has high accuracy in predicting species geographic distribution (Phillips & Dudık, 2008). Basically, according to Phillips et al. (2006) maximum entropy can be applied to solve the problem of unknown distribution in any constraints. The principle of maximum-entropy in species distribution exposes unknown probability of species occurrence over the set of pixel in the study area. An individual element as pixel will be regarded as points and defined a non-negative probability to each point.

Phillips & Dudık (2008) also clarified the process of prediction distribution of species by record 1 if the species is present and 0 for absent in every pixel over the study area. The value will be 0 or 1 for plants and range from 0 to 1 to animals which depicts the probability of species in every pixel. It will not be estimated directly, but the employment of estimation distribution of prediction area will consider pixel as a site rather than a vector of environmental conditions. The aim behind that idea lies on the incapability of determining species' prevalence only by occurrence data (Philips et al., 2006).

3.2.1.1. Presence Points

Presence points of Javan Leopard were collected from primary and secondary data. The former were collected from fieldwork activity and the latter were historical data from national parks authorities. The combination of those kinds of data was applied in the modelling process by using MaxEnt programme.

Fieldwork was conducted in two weeks in both of Gunung Merapi NP and Gunung Merbabu NP. Purposive sampling method was applied in a relatively short period of fieldwork (Brus & de Gruijter, 2003) to record wildlife data in both national parks. The aim of this observation was to find the Javan Leopards in the wild by recording the coordinate points of their sign such as footprints (pug marks), spray, scratch (on the tree and ground), scats, preys' carcass and also preys' presence. The tracks of a tiger, as well as leopard in tropical areas, are difficult to treasure because of relatively thick leaf-fall on the forest floor and soil condition in which frequently washed by rain. Therefore, an approach suggested by Karanth & Nichols (2002) is that scats and the existence of prey can be used as identification for range-mapping purposes.

A Global Positioning System (GPS) device was applied to record the points and a digital camera was used to take pictures during this activity. As a prerequisite data for MaxEnt, presence points of Javan Leopard alongside their prey was converted into csv type file.

3.2.1.2. Prey Distribution

Based on Karanth & Nichols (1998) the distribution of large felids is also determined by the abundance of their prey. More specifically, Stein & Hayssen (2013) discussed that *Panthera pardus*' spatial use depends on the present of competitors, prey size vary and the availability of cover. In India, researchers described that the distribution of leopards' prey gave them a hint to understand their distribution (Ghanekar, 2014).

Therefore, as one of the habitat elements which comprise cover, spatial area and water (Morrison et al., 2006), prey as food for carnivore was taken into account in habitat modelling. It was also categorized as resource variable by Austin (2007) as one of the environmental predictors. On this study, prey distribution has been modelled in MaxEnt.

Fieldwork data and historical data (from NPs authorities) of wildlife which are considered as prey for Javan Leopard were converted into csv file. Together with environmental layers (landcover, NDVI, elevation, slope, distance to road/path, distance to settlement, distance to river, rainfall, temperature) which will be explained later, it has been modelled by using MaxEnt programme. The result of prey distribution maps were applied in Javan Leopards' modelling as variable alongside the other environmental layers.

3.2.1.3. Landcover

Landcover as one of the environmental layers was processed from a remotely sensed image of Landsat 8 OLI/TIRS acquired on 14 October 2013 and 2 November 2014. Those dates were chosen because of the relatively clean image from clouds. As the interest of study area, path/row of 120/65 has been selected to cover the landscape of Merapi-Merbabu.

The images of Landsat 8 have been simply equipped by Standard Terrain Correction (Level 1T) which provides systematic radiometric and geometry accuracy in combining ground control points in topographic accuracy (USGS, 2013). Due to the presence of cloud which covered Merbabu's peak on Landsat 14 October 2013, an image of 2 November 2014 that captured clearly notably on the peak, was used to fill the patch on it. The process was continued with supervised classification in ArcGIS 10.1. Maximum likelihood was chosen because of its statistically stable algorithm which calculates the probability based on feature space (Danoedoro, 2012). Landcover classification was analyzed based on National Standardization Agency of Indonesia (SNI; 2010) in level II (resolution of 30 – 100 m; Danoedoro, 2012) landcover classification.

3.2.1.4. NDVI

Normalized Difference Vegetation Index (NDVI) is the most popular vegetation index (Xu & Guo, 2014) which can be applied to figure out the greenness on a patch of land and vegetation canopy biophysical properties (Jiang et al., 2006). Its development is broadly used to depict forest condition as a basic for further management (S. E. Franklin, 2001).

As the principle of sunlight exposes to an object, particular wavelengths are absorbed and other are reflected in a certain degree of intensity. On one hand, plant leaves contains chlorophyll absorb visible light (wavelength 0.4 – 0.7 μm) in the photosynthesis process and, on the other hand, its cell structure reflect near infrared spectrum in 0.7 – 1.1 μm. The more leaves immensely reflect these wavelengths of light and vice versa (Weier & Herring, 2000). This index is defined as:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (1)$$

Where *NIR* is near-infrared wavelength and *RED* is red wavelength. Its calculation result has range value spread from (-1) to (+1) which indicate no green leaves (no vegetation) to high density of leaves, respectively. The low value of NDVI below 0.1 considered as bare land, sand or rock, moderate value range from 0.2 to 0.5 correspond to sparse vegetation such as grassland and shrub or senescing crop and the high value 0.6 – 0.8 indicate dense vegetation as that can be found in tropical rainforests or crops in their uttermost growth phase (USGS, 2015; Weier & Herring, 2000). Normalized Difference Vegetation Index value as environmental layers on this study was derived from Landsat 8 which has been processed in ArcGIS 10.1 software.

3.2.1.5. Elevation and Slope

As it has been conveyed by Hoogerwerf (1970) that Javan Leopards held good adaptation in various elevation, hence it was also involved in habitat modelling. This species was reported occupying several peak in Java Island such as Ijang Highland and Mount Gede-Pangrango.

To produce elevation data, contour map from base map (*Rupa Bumi Indonesia*) in 12.5 m interval was processed in ArcGIS under *Topo to Raster* operation and set in 30 m pixel size as the basic resolution of Landsat 8.

Slope layer was derived from elevation data which has been calculated its degree by using *3D analyst tool* in ArcGIS. The spatial resolution of 30 m has been applied to this layer. Slope as a part of indirect factor gradients together with latitude, longitude, elevation, slope angle and aspect (exposure) would always be involved in distribution modelling as predictors (Austin, 1980 in J. Franklin, 2009). For Javan Leopards, Gunawan et al. (2009) described that steep slope until 90° become preferred location as their shelters. Slope classification by van Zuidam (1985) was applied to this study in determining the score for hindrance factors.

3.2.1.6. Distance to Road/Path, Settlement and Water

Based on research about corridor for tiger in India by Rathore et al. (2012), the existence of roads or paths has been affected the tigers' movement activity. Despite of the leopards' characteristic as the most adaptable big cat species, this creature will always attempt to avoid humans and noises naturally. By using base map, *Euclidean* distance was calculated in ArcGIS.

Similar to road/path distance, Gunawan et al. (2009) described that Javan Leopards tend to keep the distance from settlement approximately more than half a kilometer. As the consequences of settlement proximity to protected areas, human-wildlife conflicts are inevitable (Naughton-Treves, 1997). Evidently, even in Cape Town-South Africa where human-wildlife conflicts are prevalent, a leopard was found killing a sheep within 100 km (Lamarque et al., 2009).

In order to provide distance to settlement as an environmental layer, settlement distribution from image classification was calculated its distance in every pixel by applying Euclidean distance in ArcGIS. *Euclidean* distance was chosen because it calculates the distances for each cell to the closest source based on straight-line distance from the center raster (ESRI, 2012).

In contrary, proximity to water source was important to wildlife. It is commonly used by park officials in India to direct their survey in obtaining leopards' sign since it is considered as the place where numerous of prey presence for drinking (Ghanekar, 2014). In Central Java, Gunawan et al. (2009) also argued that Javan Leopards' habitat identified to have proximity to water. The same method in calculating distance above, distance to water was created by applying *Euclidean* distance in ArcGIS from the base map of river.

3.2.1.7. Rainfall

Annual precipitation is commonly used as environmental layer in predicting species distribution (Phillips et al., 2006). Rainfall as distal variable affects directly to organisms and have a role as a proximal variable in the availability of water for plants (Austin, 2007).

Preparing the data rainfall as a predictor in SDM, rainfall data layer resulted from nine rain gauges in surrounding area of Merapi-Merbabu landscape, in the period of 2009 to 2013, were interpolated in ArcGIS. Spatial pattern of rainfall across the study area was formed in the value of average rainfall, annual, maximum and minimum rainfall. Resample operation was also applied in providing rainfall layers in the basic of 30 x 30 m pixel resolution.

3.2.1.8. Temperature

Temperature as an environmental variable which gives direct psychological effect to wildlife is regularly used to be elaborated in distribution modelling (Austin, 1980 in J, Franklin, 2009). The value of minimum, maximum and annual mean temperature data are also deployed by Philips et al. (2006) as predictor variables in SDM.

The same method as rainfall data was applied to create temperature layer. Annual mean, maximum and minimum temperatures from two weather stations of Borobudur and Pakem, during 2009 to 2013, and equipped with data from www.worldclim.org (BIO1, BIO5,BIO6) were interpolated across the study area.

3.2.1.9. Volcanic Hazard

Pyroclastic flow scenarios by Darmawan (2012) were chosen as habitat threat due to eruption event. The model of pyroclastic hazard performed by Darmawan was built by considering the historical event of Merapi eruption in the last 100 years. It has been set into four eruption indexes from Volcanic Eruption Index (VEI) 1 to 4 which indicate low to high magnitude, respectively.

Table 3.1. Pyroclastic flow model (source: Darmawan, 2012)

VEI	Exposed area (Ha)	Travel distance from peak (Km)
1	125	3.2
2	391.79	7
3	818.5	12
4	3,559	16.5

Considering the most devastated event is VEI 4, therefore the map result of SDM was subtracted by this worst scenario. Below is the pyroclastic hazard for Gunung Merapi NP in all levels of pyroclastic hazard:

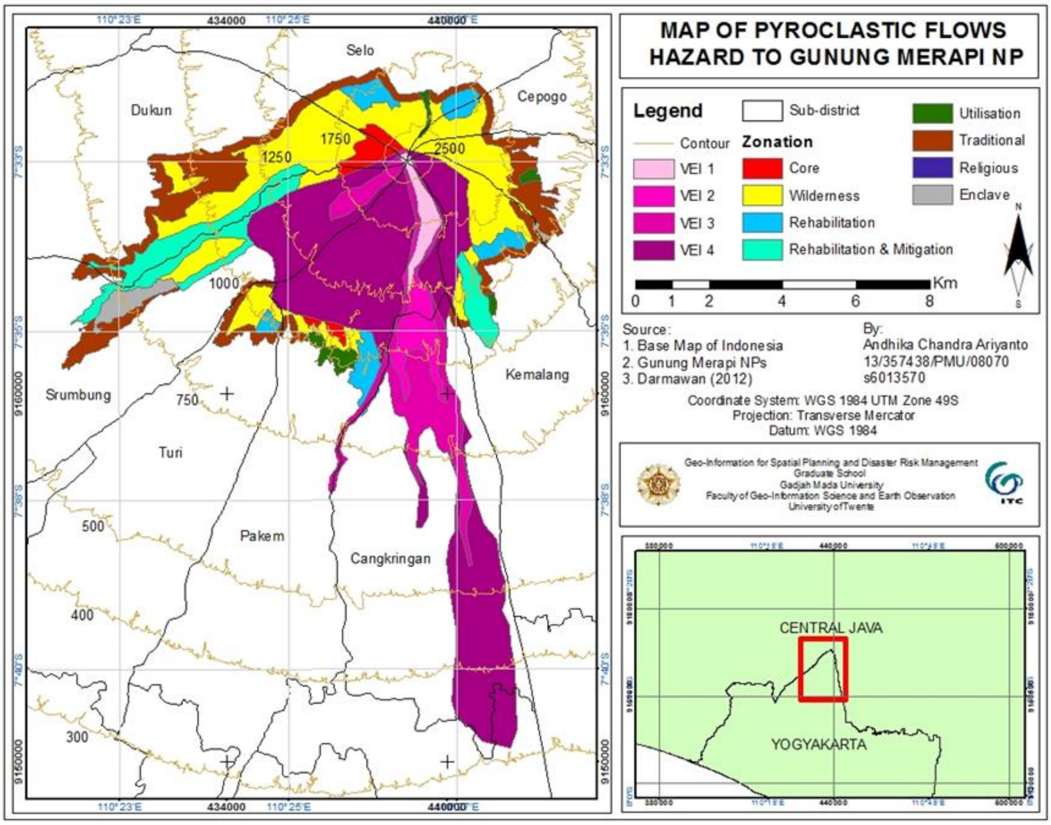


Figure 3.3. Pyroclastic hazard to Gunung Merapi NP (source: data processing)

As can be seen that the worst scenario tends to overwhelm the area of Gunung Merapi NP in a jeopardy situation, the effort of corridors prediction to link Merapi and Merbabu seems indispensable in conserving wildlife notably Javan Leopard.

3.2.1.10. Wildfire Hazard

Similar concept to volcanic hazard, wildfire hazard was applied to subtract the map of distribution for Javan Leopards especially in Merbabu area. In order to obtain the hazard map of wildfire in Merbabu landscape, vulnerability to fire hazard has been generated by considering the component of fire such as radiant heat, fuel and oxygen.

Radiant heat represented by the proximity to path and settlement, slope-aspect, and fuel was obtained from the availability of combustible materials such as dry grass and dry shrub. Distance to path was calculated as what has been done in distance to settlement layer whilst combustible material map was generated from landcover classification result mainly shrub and grass. Lastly, hazard map of wildfire was resulted from the overlay among distance to path map, distance to settlement map, slope-aspect map and combustible material map.

3.2.1.11. Preparing Environmental Layers for MaxEnt

Maximum Entropy programme needs environmental layers in ASCII raster grid format on its execution. Therefore, all processed variables should be converted in ASCII format in the exactly same size cell, bond and coordinate system. First of all, the boundary of the study area was created by considering the extent which covers Merapi-Merbabu landscape. The focus areas are NPs and the landscape in between whilst considering the crowdedness of settlements and agricultural area neighboring the parks. The boundary was used as layer mask (raster based with pixel value is “1”) in *environmental setting* under *Geoprocessing* tool in ArcGIS. Output coordinate was set in WGS_1984_UTM_Zone_49S. For *processing extent* was set the same to layer mask (top extent 9186096.52471, left 422326.113546, right 447481.113546, bottom 9155166.52471). Before executed the process, cell size under *raster analysis* menu was defined as 30 m.

To finalize the process, clipping and resampling were applied to make all the layers matching by using *raster calculator*. All the layers were multiplied by mask layer and the final products resulted in the same cell size and number

(Columns 839, rows 1031), cell alignment, projection system and extent as the mask. The origin value of each layer do not change since the multiplying factor (mask layer) has the value of “1”. The last step in preparing the layers was converting all files into ASCII format and saving into an environmental layers folder.

3.2.1.12. Running the MaxEnt Model

MaxEnt programme requires samples and environmental layers in its process. For Javan Leopard distribution modelling, a csv file of Javan Leopard was put as a sample and environmental layers folder which contains all variables in ASCII format was employed in MaxEnt’s environmental layers menu. After that, the data type of each variable has been changed either categorical or continuous.

The box of *create response curves*, *make pictures of predictions* and *do jackknife to measure variable importance* have been ticked in MaxEnt menu (Annex 3). In order to determine *random test percentage*, basic setting of MaxEnt has been set into 25 (number of predictors >10; Huberty, 1994 in Franklin, 2009) in 10 replicates. On *replicated run type* menu, bootstrap was chosen as Guisan & Zimmerman (2000) suggested in relatively few observation data (Annex 4). Finally, *equal training sensitivity and specificity* was chosen as threshold rule in advanced setting (Annex 5) while *write background predictions* was ticked to obtain pseudo-background data for AUC and TSS calculation purposes (Annex 6).

Those steps were also applied to prey distribution modelling before Javan Leopard distribution modelling process. Considering the data set availability, there were only four preys (Javan Langur, Muntjac, Wild Boar, Macaque) which have been modelled. Those result maps were combined and included as predictor variables in Javan Leopard distribution modelling.

3.2.1.13. Model Evaluation

According to J. Franklin (2009), model evaluation in SDM is needed in order to quantify the accuracy of prediction which describe the level of model performance or validity. A model can be regarded as valid if it encounters particular performance requirements. Starting from conceptual formulation, statistical formulation, model calibration and will be finished in model evaluation, modelling holds a certain degree of validity.

As the model calibration stage which examines the estimation of variables, multicollinearity test was applied to inspect the linear function among continuous variables. Multicollinearity described as the condition where two or more explanatory variables have linear function (Voss, 2004). It will arise a problem in descriptive ecological data set which leads to the failure identification of relevant variables because of the increasing in regression variance (Dormann et al., 2013).

Therefore, correlation or multicollinearity test was conducted prior modelling process over the whole predicted continuous variables as it suggested by J. Franklin (2009). To conduct this step, R-Studio software was applied to seek the high value of variance inflation factor (VIF; Belsley, 1991; Hair et al., 1995 in Dormann et al., 2013). Firstly, all continuous variables were put in multicollinearity test, and then excluded the variables which had VIF value more than 10 (as a rule of thumb). The next step was repeating the calculation until each variable had VIF less than 10. Finally, the selected continuous variables were used in model development.

Meanwhile, model validity can be assessed by calculating AUC (Fourcade et al., 2014). The area under receiver operating curve (ROC) is the probability of a presence site which chosen randomly will be ordered from a randomly chosen absence site (Philips & Dudik, 2008). High performance models are indicated by high value of AUC, where 0.5 - 0.7 considered as low, 0.7 - 0.9 as useful application and more than 0.9 indicate high accuracy in measuring model discrimination between presence and absence (Swet, 1988 in Manel et al., 2001). In addition, the measurement of sensitivity and specificity are necessary. The former describes the proportion of actual presence that predicted accurately and the latter refers to an actual absence in accurate prediction. On this case, TSS was applied as what Allouche, Tsoar, & Kadmon (2006) suggested.

3.2.1.14. Optimum Habitat

In order to obtain the optimum habitat for Javan Leopard, the result of SDM in both of NPs were analyzed by overlaying those maps in ArcGIS software with volcanic hazard map of Merapi and wildfire hazard map of Merbabu. Eventually, the predicted distribution map for Javan Leopards was prepared to be analyzed in attempt to figure out the possible corridors which link the two NPs.

3.2.2. Least Cost Path

After Javan Leopards' distribution model has been identified, connectivity for those areas was analyzed by using Least Cost Path (LCP) under ArcGIS operation. The most optimum distance which connects the two NPs was calculated least-cost value from a source location to certain destination in raster-based operation. Considering the endorse factors for Javan Leopards' moving, the impede factors also employed for this calculation. The cost distance from each pixel in origin location to destination calculated to determine the most effective path which indicated by the low-cost movement (Poor et al., 2012; Rathore et al., 2012). The models of corridor were developed in three scenarios called equal-weighted of variables and two of priority-weight variables.

3.2.2.1. Hindrance Factors

A set of impede factors applied to this analysis consist of the presence of main road and distance to settlement, augmented by specific circumstances in habitat, landcover, NDVI, distance to water source, distribution of prey and slope. It derived from the element of habitat as it has been mentioned before. Each of impede factor was scored to obtain the degree of an acceptable condition with trivial disturbances for Javan Leopards' movement. The elusive, secretive, nocturnal and solitary species like leopard presumably corresponds to those concepts. The variables were chosen based on literatures and several experiences related to big cats' habitat factors and ecological requirements (Larue & Nielsen, 2008).

3.2.2.2. Scoring variables

The aforementioned variables considering the halt factors for Javan Leopards' movement were scored as below:

Table 3.2. Variable score

Variable	Description [Score]
Habitat	Habitat Model [1], Non-habitat Model [5]
Landcover	Dense Forest [1], forest [1], Shrubs-grass [2], Bare land [4], Cultivation land [4], Settlement [5]
NDVI	< 0.2 [5], 0.2 - 03 [3], 0.3 - 0.5 [2], > 0.5 [1]
Prey base	Presence [1], Absence [5]
Distance to Water	< 50 meter [1], 50 - 100 [2], 100 - 250 [3], 250 - 500 [4], 500 - 1000 [5], > 1000 [6]
Main road	With bridge-under crossing [1], no bridge [7]
Distance to Settlement	< 50 meter [6], 50 - 100 [5], 100 - 250 [4], 250 - 500 [3], 500 - 1000 [2], > 1000 [1]
Slope	< 2% [1], 2 - 7% [2], 7 - 15% [3], 15 - 30% [4], 30 - 70% [5], 70 - 140% [7], > 140% [7]

All continuous variables have been converted into categorical variable for scoring purposes. The score range was intentionally determined starting from one [1] which indicates the low cost for movement to seven [7] which denotes the highest cost for Javan Leopard to travel from the source to the destination point. In addition, adopting the method of Rathore et al. (2012), equation to depict the calculation of weight and score variable displayed as:

$$CM = W_H{*}H + W_L{*}L + W_N{*}N + W_P{*}P + W_{WT}{*}W + W_{MR}{*}MR + W_S{*}S + W_{SL}\ SL \qquad (2)$$

In order to develop scenarios based on certain condition, below is the table of weighting assignment for variables:

Table 3.3. Weights to corridor scenarios

Variables	Weight score		
	Scenario 1	Scenario 2	Scenario 3
Habitat model	5	4	1
Landcover	5	5	1
NDVI	5	5	1
Distance to water	5	2	1
Prey availability	5	2	1
Main road	5	1	5
Distance to settlement	5	1	1
Slope	5	1	5

The weight score range from one (1) as the unimportant variables, to five (5) which indicate the most important variable in the leopards' dispersal. Scenario 1 assigned an equal priority for entire variables resulted in the first composite cost of movement as below:

$$CM = 5*H+5*L+5*N+5*P+5*WT+5*MR+5*S+5*SL \qquad (3)$$

The second composite movement put the first-priority weight variable of 4 for habitat, 5 for each landcover and NDVI which illustrate the most important variable for the leopards' movement. Distance to water and the presence of prey were given 2 for each, the main road, distance to settlement and slope had given 1 weight as the following the formula:

$$CM = 4*H+5*L+5*N+2*P+2*WT+1*MR+1*S+1*SL \qquad (4)$$

The last scenario assigned the main road and slope as the high priority, equal to five folds, compare to the rest variables. The composite of movement described as:

$$CM = 1*H+1*L+1*N+1*P+1*WT+5*MR+1*S+5*SL \qquad (5)$$

Where,

CM = Composite Movement	N = NDVI	MR = Main Road
H = Habitat model	P = Prey base	S = distance to Settlement
L = Landcover	WT = distance to Water	SL = Slope
W = Weight		

3.2.3. Gap Analysis

Gap analysis has divided into two phases to figure out the conformity of national park zoning system in accommodating the distribution of Javan Leopard. The second was to reveal the movement paths of Javan Leopard over the landuse between Gunung Merapi and Gunung Merbabu NPs which prearranged by spatial plan of Boyolali District.

3.2.3.1. Habitat Prediction vs National Park Zoning Systems

The results of species distribution maps of Javan Leopard both in Gunung Merapi and Gunung Merbabu NPs and zoning system of those parks were processed by overlay operation with ArcGIS software. The focus of this analysis lies on to what extent the gap between distribution maps and zoning system of NP.

3.2.3.2. Predicted Corridor vs Spatial Planning

The same operation with the previous overlay between distribution maps and zoning system was applied to the predicted corridor maps versus the map of Boyolali District's spatial plan. On this case, the emphasis analysis was to type of landuse and landcover category which passed by the predicted corridors. The last analysis was the recommendation for Boyolali government regarding the spatial plan which directed toward the ecological perspective notably for Javan Leopards' conservation.

3.3. Raw Data

Below is the list of data materials used in this research:

Table 3.4. List of raw data

Data	Description	Source
Map		
Base Map	Road, river, contour	The Ministry of Forestry
Spatial Plan of Boyolali District	Landuse	Local government of Boyolali
Zoning system Map of Gunung Merapi NP	National park zoning system	The authority of Gunung Merapi NP
Zoning system Map of Gunung Merbabu NP	National park zoning system	The authority of Gunung Merbabu NP
Pyroclastic Hazard Map	Scenario VEI 1 to 4	Darmawan (2012)
Observation point		
Javan Leopard's data	Presence points	Fieldwork, The authority of Gunung Merappi-Merbabu NP
Prey's data	Presence points	Fieldwork, The authority of Gunung Merappi-Merbabu NP
Environmental variables		
Landsat ETM+ image path/raw 120/65	Landcover, NDVI	http://earthexplorer.usgs.gov/
Rainfall data	Annual, monthly, minimum, maximum	Meteorological, Climatological and Geophysical Agency
Temperature data	Annual mean, monthly mean, minimum, maximum	Meteorological, Climatological and Geophysical Agency http://www.worldclim.org/current

3.4. Tools and Software

Tools which have been used to conduct fieldwork are GPS Garmin and digital camera. In processing and analyzing the data, software which have been employed on this research were, ArcGIS 10.2, R-Studio, Maximum Entropy Species Distribution Modeling 3.3.2 and Microsoft Excel.

3.5. Methodological Flowchart

The resume of methodological sequence can be seen in figure 3.4.

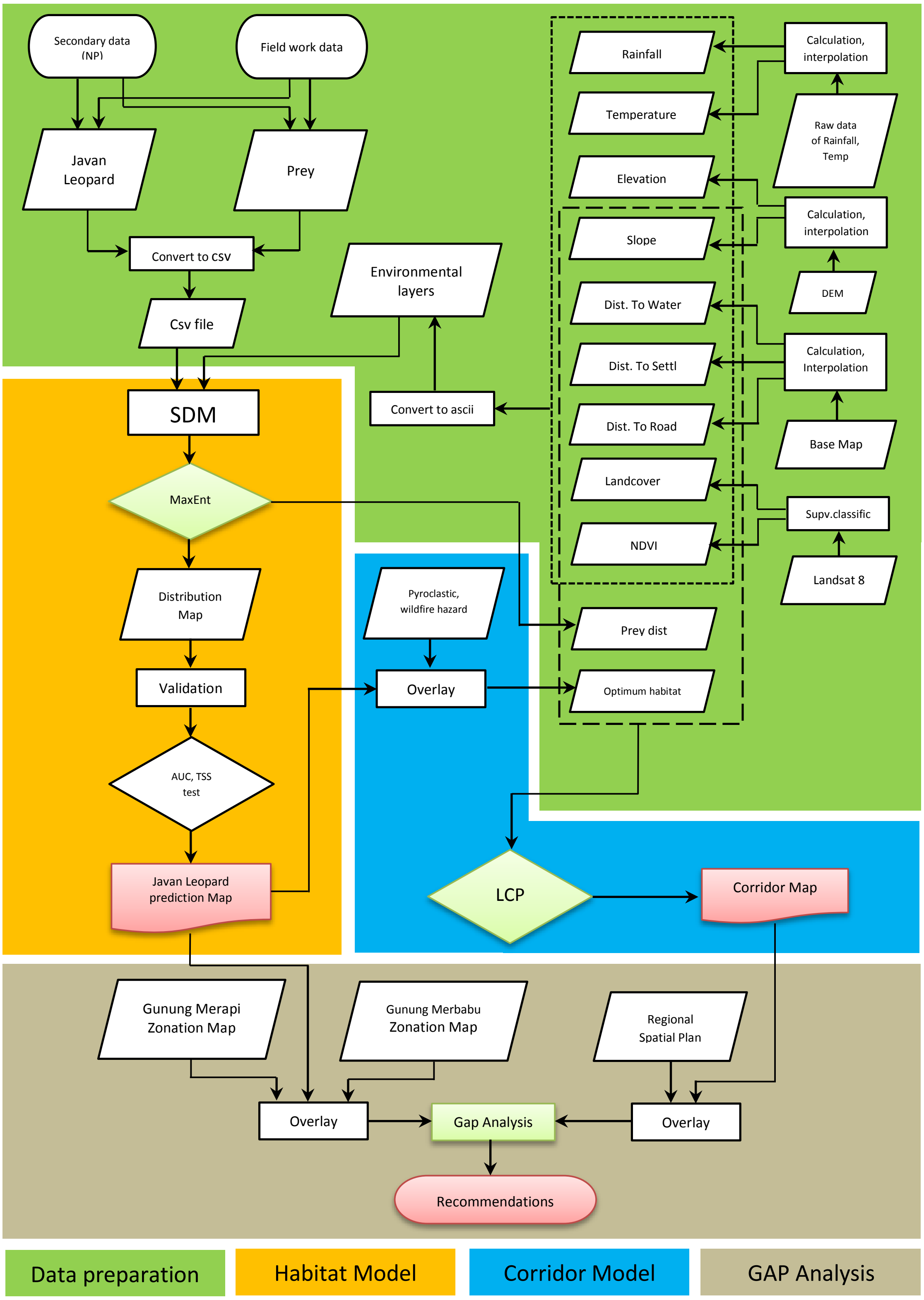


Figure 3.4. Flowchart for the sequences of research

4. RESULTS

Maximum entropy in predicting the distribution of Javan Leopard, and LCP in portraying the direction of their movement from Gunung Merapi NP to Gunung Merbabu NP (or the other way around), need data preparation which have been analyzed according to the methodological sequences, and can be seen as follows:

4.1. Presence Points of Javan Leopards and Prey

Presence points data which have been collected from fieldwork activity and data from NP authorities are displayed as below:

Tabel 4.1. Presence point data

Presence	Foot Prints	Scratch	Scats	Dens	Sight seeing	Prey's Carcas	Total
Javan Leopard	4	2	3	1	4	2	16
Other wildlife	17	5	13	3	13	0	51

There are 16 points of Javan Leopards' presence in both of Gunung Merapi and Gunung Merbabu NPs. Five of observation point were recorded in 2009 by Edy Dwi Atmaja on his undergraduate research of Biology Faculty - Gadjah Mada University, located in the southern flank of Merapi. Five points were recorded by Gunung Merapi NP authority during their survey in 2012 as well as a point from BPPTK's employee.

In Merbabu area, there were two points reported by mount climbers and photographer. Meanwhile, there were only three points which have been collected from fieldwork activity which consist of one location for Javan Leopard's scat in Merbabu, report from local people who went through the forest and the local people whom his cattle were killed by Javan Leopard in Merapi.

The difference between Javan Leopards' scat and other wild cats is portrayed as below:

A (x,y: 440474, 9173461) B (440664, 9174372)

Figure 4.1. Wild cats' scat in Merbabu (source: fieldwork 5 November 2014)

Scat in picture A is supposed to be Javan Leopard's while picture B belongs to other wild cats'. Diameter approach was applied in determining the scats. The characteristic of Javan Leopard's scat diameter is more than 2.2 cm (Swanepoel, 2010) while Raharyono & Paripurno (2001) argued it is range from 2 – 3 cm. By definition, the scats which have a diameter less than 2 cm are assumed as wild cats'.

The other approaches to distinguish are the present of a leaf piece at the tip of scats and pieces of bones as well as furs of Javan Leopard's prey (Raharyono & Paripurno, 2001). The scat found in Merbabu meets the criteria as Javan Leopard'. Its diameter is approximately 2 cm with pieces of bone inside alongside furs. Admittedly, the wild cat's scats also contain furs, but the length is relatively short which indicates that wild cats eat prey which has short fur such as mice.

The other wildlife points which have been collected from fieldwork activity and NP authorities are 51 points which consist of Asian palm civet (*Paradoxurus hermaphrodites*), Green junglefowl (*Gallus varius*), Javan Langur (*Trachypithecus auratus*), Javan mangoose (*Herpestes javanicus*), Javan surili (*Presbytis comate*), Long-tailed macaques (*Macaca fascicularis*), Muntjac (*Muntiacus muntjak*), Porcupine (*Hystrix javanica*), Squirel (*Sundasciurus sp*.), Wild boar (*Sus scrofa*) and wild cat (*Prionailurus bengalensis javanica*). In order to model the distribution of Javan Leopards' prey, wild cat were excluded since it is not preferred food for leopards.

4.2. Landcover Classification and NDVI

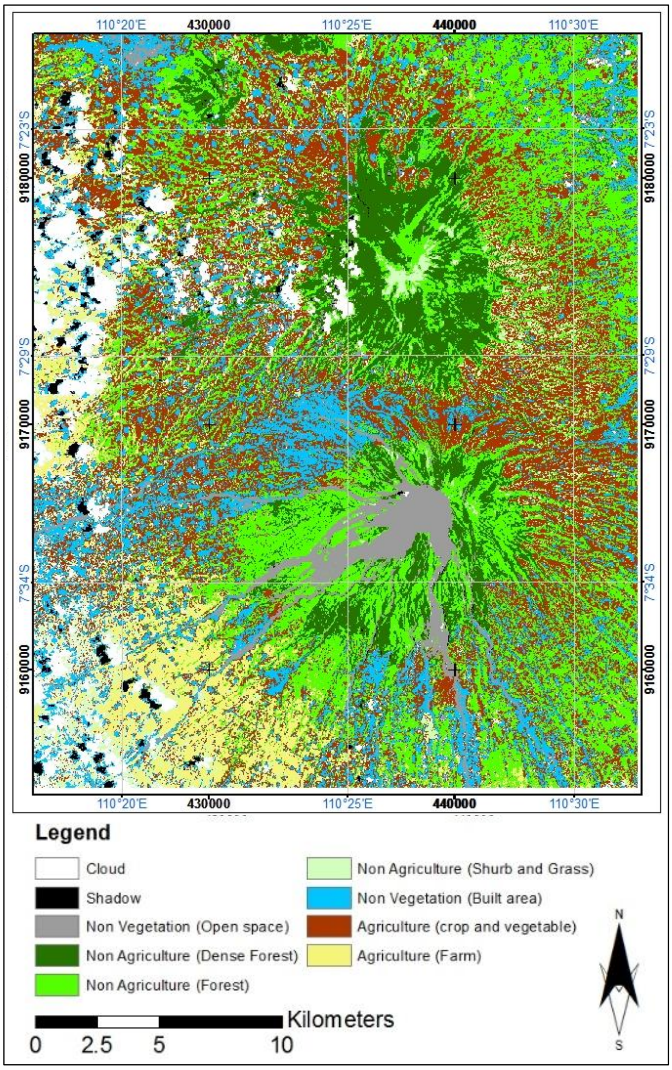


Figure 4.2. Supervised Classification

Landsat imagery acquisition on 14 October 2013 was filled by an image on 2 November 2014 to investigate the area covered by clouds notably on the Peak of Merbabu Mountain. These images were processed by supervised classification which applied maximum likelihood method. False color of 532 composite bands was used in the identification of landcover. There were 3 classes of level II classification (SNI, 2010) excluded cloud and shadow: non-vegetation (open area, built area), non-agriculture (dense forest, forest, shrub-grass), and agriculture, which identified visually to create training area by considering tone, texture, association, shape, size, shadows, site, and pattern as stated by Reddy (2008).

Based on the result, the landscape of the study area was dominated by agriculture area of 287,385 pixels which equal to 25,865 hectares. The detailed size of landcover can be seen in table below:

Tabel 4.2. Landcover size

Landcover		No. Pixel	Area (Ha)	%
Non-vegetation	Bare Land	36,404	3,276	5%
	Built Area	118,772	10,689	15%
Non-agriculture	Dense Forest	87,412	7,867	11%
	Forest	212,074	19,087	27%
	Shrub and Grass	53,129	4,782	7%
Agriculture	Crop and Vegetable	236,805	21,312	30%
	Farm	50,580	4,552	6%
Total		**795,176**	**71,566**	**100%**

As it can be observed from the table above that non-vegetation area occupy 20% portion of study area, while non-agriculture areas have taken the portion of 11%, 27% and 7% for dense forest, forest, and shrub-grass, respectively.

In order to assess its accuracy, confusion matrix was applied by deploying 30 stratified random points on each class (expecting accuracy 0.90; van Genderen et al., 1978 in Richards & Jia, 2006) except for open area, shrub-grass and farm with 10 samples each, because of the variability within their class (Lillesand, Kiefer, & Chipman, 2004). Due to the past date of the image (14 October 2013), the ground truth samples were deployed in Google Earth as its high-resolution image and various recorded date. Below is the confusion matrix for assessing classification:

Tabel 4.3. Confussion matrix (data processing)

Classification	Open area	Dense Forest	Forest	Shrub and Grass	Built Area	Crop and Vegetable	Farm	Total	Accuracy
Open area	**10**	2	0	2	4	0	0	18	55.56%
Dense Forest	0	**27**	2	0	0	0	0	29	93.10%
Forest	0	1	**26**	1	0	0	1	29	89.66%
Shrub and Grass	0	0	2	**7**	0	1	2	12	58.33%
Built Area	0	0	0	0	**25**	1	0	26	96.15%
Crop and Vegetable	0	0	0	0	1	**28**	0	29	96.55%
Farm	0	0	0	0	0	0	**7**	7	100.00%
Total	10	30	30	10	30	30	10	**150**	
Ground Truth	100.00%	90.00%	86.67%	70.00%	83.33%	93.33%	70.00%		

Kappa coefficient	88.42%
Average accuracy	84.19%
Average ground truth	84.76%
Overall accuracy	86.67%

The result of accuracy assessment showed that the kappa coefficient was 88.42% while the average accuracy, average ground truth (producer) and overall accuracy (user) noted as 84.19%, 84.76% and 86.67% respectively with no significant differences among them. It means that approximately 84.76% of ground truth pixels were accommodated in classification. However, only 84.19% of whole pixels were represented correctly even though the classifier covered more portion with 84.76% of ground truth samples. In other words, overall there were four samples as omission whilst 16 samples as commission on this classification.

Kappa coefficient describes the percentage of correct values of an error matrix between *true* agreement and *change* agreement (Lillesand, Kiefer, & Chipman, 2004). The kappa value of 0.8842 illustrate that the observed classification is 88.42% better compared to the classification resulting from change.

Meanwhile, the range of NDVI in the whole study area is -0.26 to 0.85 which indicates the greenness of a patch of land. As it can be seen in figure 4.3, the two NPs have the high value of NDVI (indicated by bright color). It means that those areas comprise dense forests as have been specified by Weier & Herring (2000) that 0.6 – 0.8 of NDVI values are categorized as tropical rain forest. Yet, outside NPs,

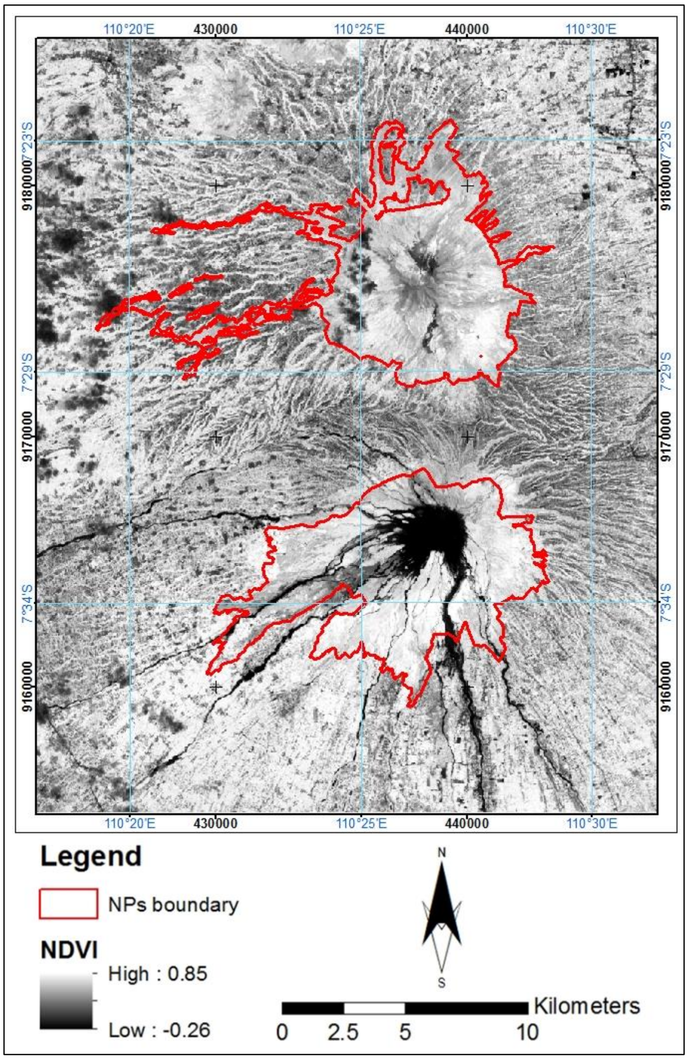


Figure 4.3. NDVI value

there are also high NDVI value which indicate that those areas are covered by vegetation (farm/crops) in a peak growth phase.

4.2. Elevation and Slope

Figure 4.4 below show the result of elevation and slope percentage by ArcGIS software (for map visualization purposes, the data have been converted into categorical type). The variation of elevation in the study area starts from 274 up to 3,100 meters a.s.l. The area of Merbabu is dominated by high elevation while it is relatively few in Merapi landscape.

Slope classification based on van Zuidam (1985) was applied to distinguish the steepness of study area. It divided into seven classes from flat to steep which nodded as 2%, 7%, 13%, 20%, 55%, 140% and >140%. As it can be seen in figure 4.4-B that the area of Merbabu is surrounded by extremely steep area, more than

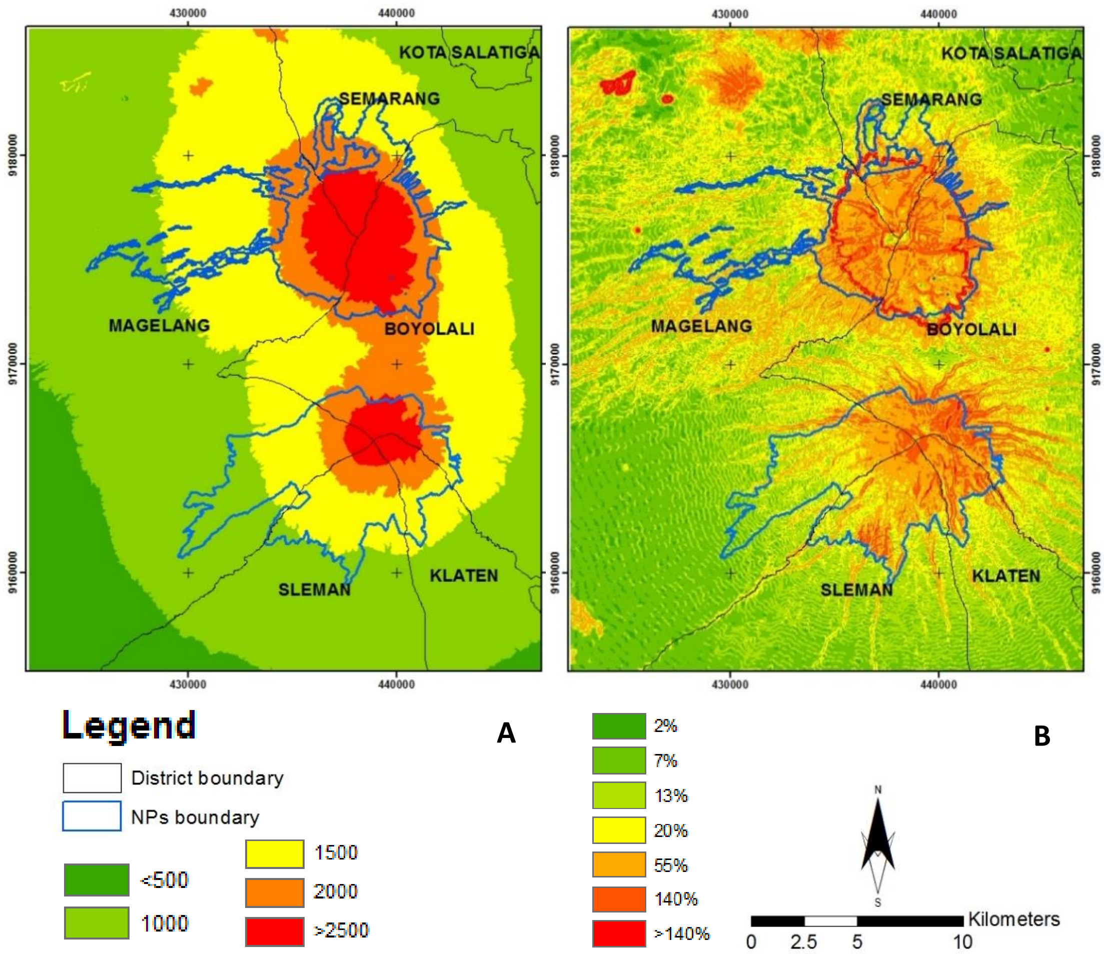


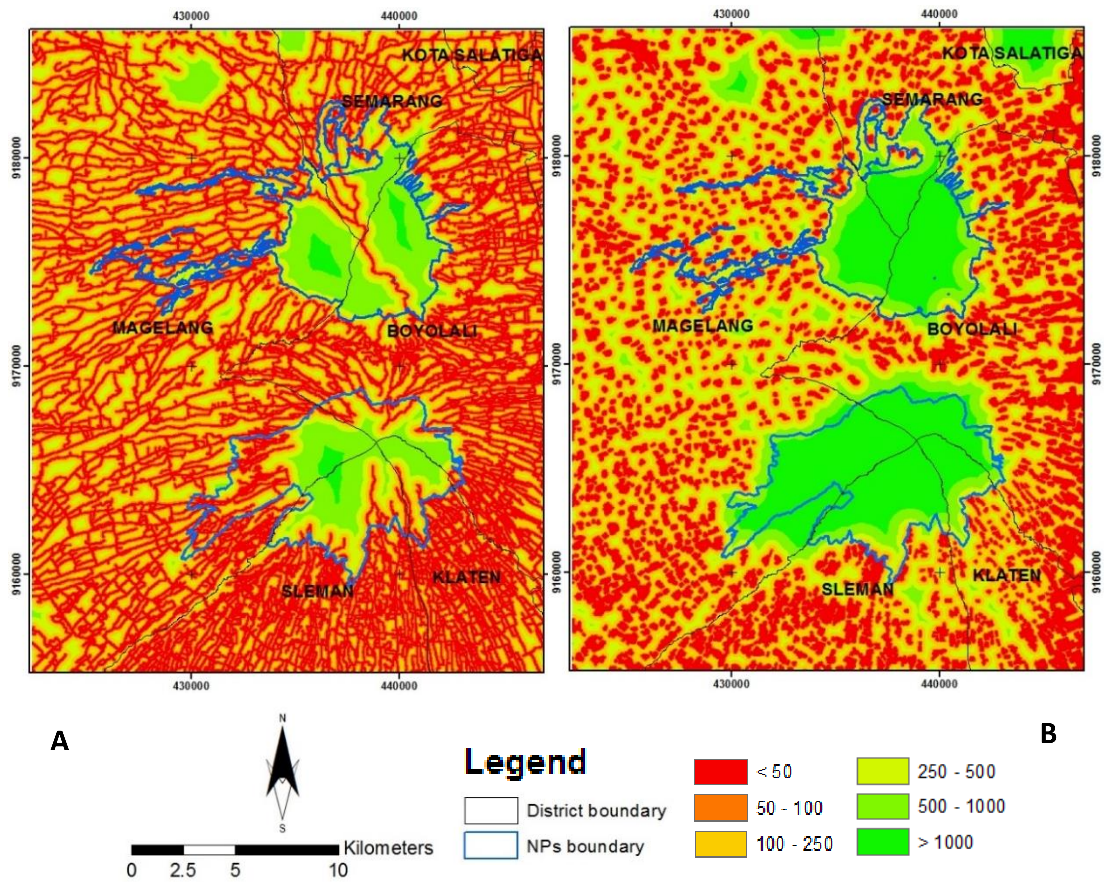
Figure 4.4. Elevation and slope

140% slope. In contrary, the steep area of Merapi can only be found on the summit of the volcano, its northern part up to the northeast. The southeast area of it categorized as relatively medium steep.

4.3. Distance to Road/Path, Settlements and Water

Based on the presence data of Javan Leopard in both Gunung Merapi and Merbabu area, their proximity to road/path, settlements and water were calculated by applying Euclidean distance in ArcGIS software. There was a point where the scat has been found on the path in Merbabu area and a point reported by people in Merapi which located nearby stream.

There was also a point of Javan Leopard's occurrence which located amid settlement area. It was reported by local people of Merapi whom his cattle have been preyed by the leopard. It was considered as the closest point to settlement. In order to provide a robust group in proximity to those criteria, for map displaying



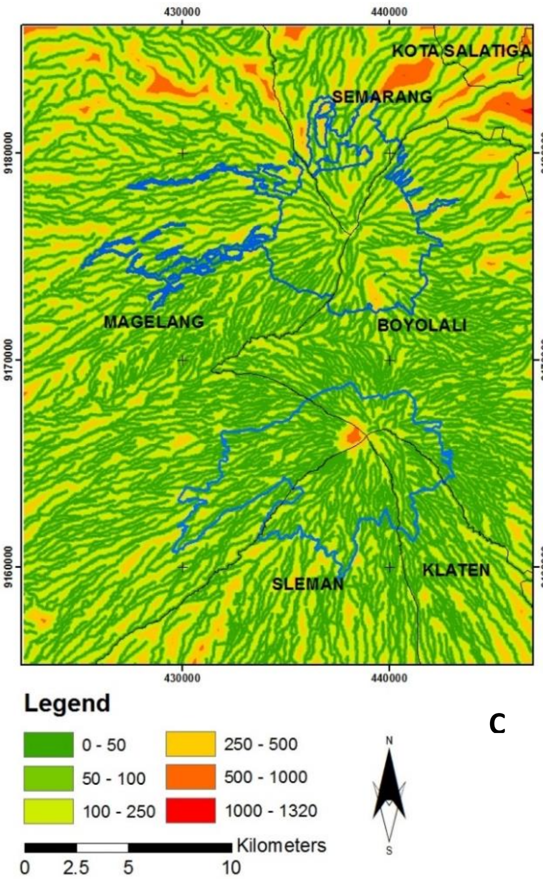


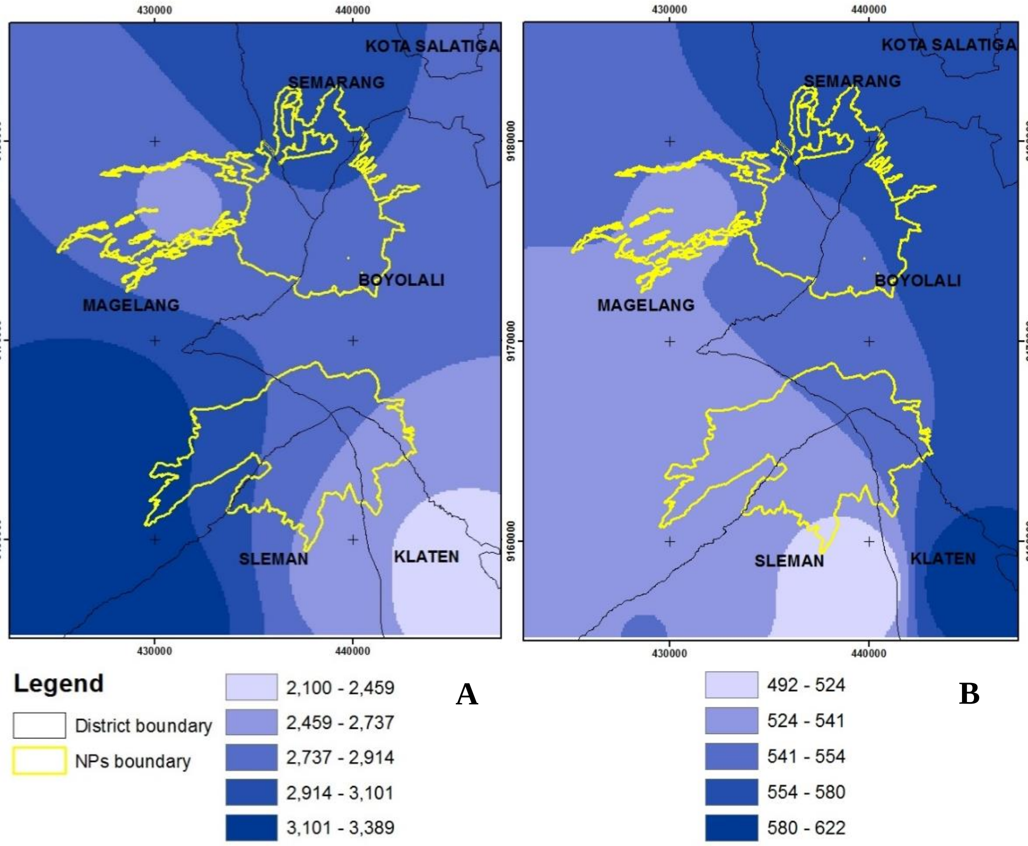
Figure 4.5. Proximity to path (A), settlements (B), river (C)

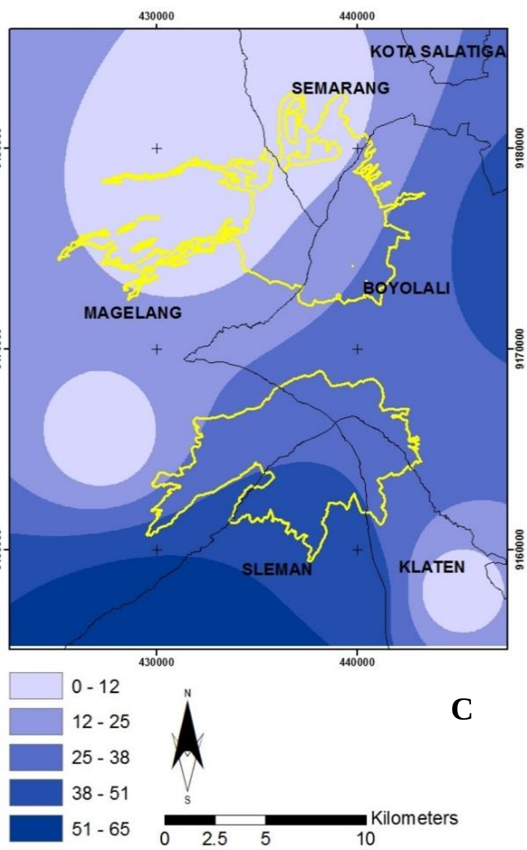
purposes only, the distances were classified into six groups (<50 m, 50 – 100 m, 100 – 250 m, 250 – 500 m, 500 – 1000 m, >1000 m).

Figure 4.5-A illustrates the proximity of path in the whole study area. As can be seen that Gunung Merbabu NP’s area has been intersected by several jungle tracks for tourism purposes. It also appears in Gunung Merapi NP whereas penetrated by several tracks mostly on the southwest and south area. The distance to settlement shows the relatively similar pattern. Apparently that there was no settlement area within NPs’ boundary as its restriction for human living. The crowded area between the two NPs showed on figure 4.5-B. It also can be seen that most of NPs’ area do not experience the lack of water due to its proximity to the water source. Within Gunung Merbabu NP boundary, the farthest location to the river was recorded as not more than a half kilometer while in Merapi area there were numerous of water sources.

4.4. Rainfall

Spatial distributions of rainfall were interpolated which resulted annual rainfall, average rainfall, maximum rainfall and minimum rainfall distribution across the study area. The annual rainfall reached the highest record of 3,389 mm on the southwest of Merapi and the lowest was 2,100 mm experienced by southeast area of Merapi.





Maximum rainfall up to 580 mm was occurred on the northern part of Merbabu whilst southwest part of Merapi was poured by 524 to 541 mm. As it showed in figure 4.6-C that most of Merbabu area, stretching from north to west side, were experienced the lowest minimum rainfall range from zero to 12 mm.

Figure 4.6. Rainfall distribution, annual (A), maximum (B), minimum (C)

4.5. Temperature

Figure 4.7 below depict the distribution of maximum temperature (left) and minimum temperature (right). Temperature data from two stations were combined with bioclim data notably BIO1, BIO5 and BIO6 which represent temperature mean, temperature maximum and temperature minimum, respectively.

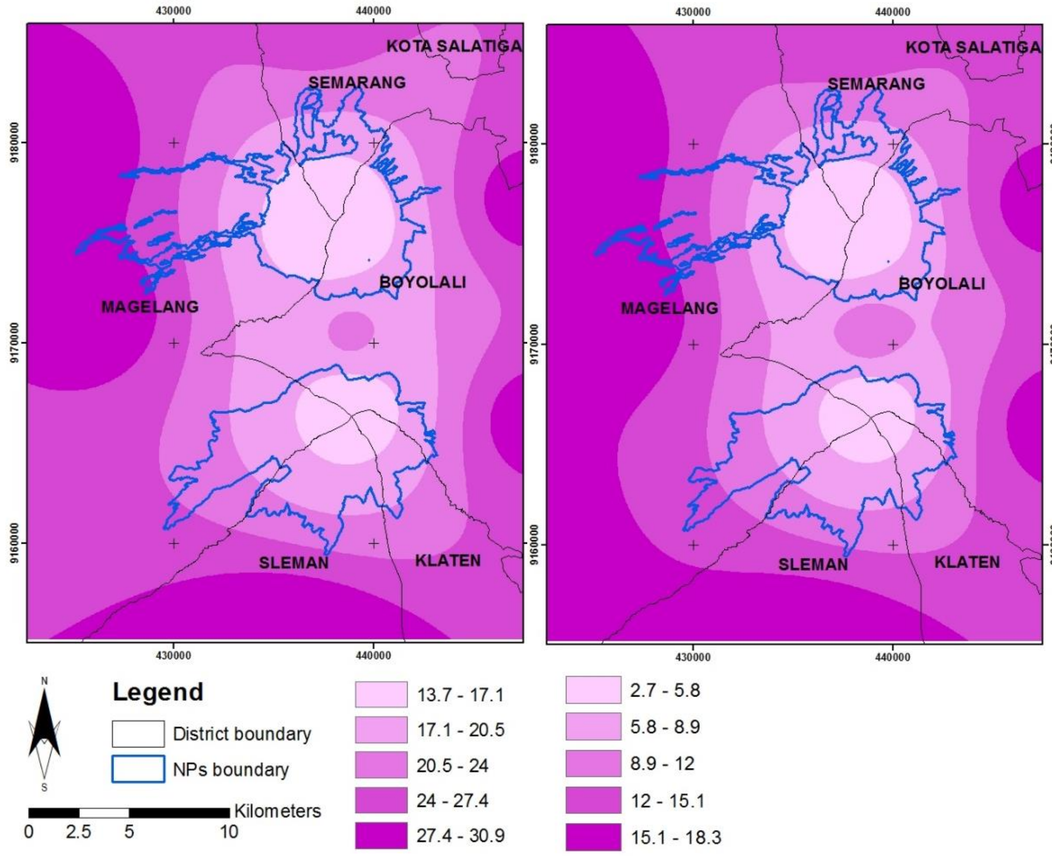


Figure 4.7. Temperature interpolation

It can be observed that there is no significant differences among those patterns. The maximum temperature ranges from 13.7 to 30.9 centigrade and the minimum spreads from 2.7 to 18.3°C. Obviously, the pattern showed that the peak of both mountains experienced the lowest value in maximum and minimum temperature.

4.6. Wildfire Hazard Map

In order to map the potential location of wildfire event within Gunung Merbabu NP, several variables which contribute in triggering wildfire occurrence were used on this hazard map. As the fire triangle element (fuel, radiation heat, oxygen), the availability of shrub-grass represents fuel, distance to settlement and road/path as potential ignition element, slope and aspect as the spreading agent.

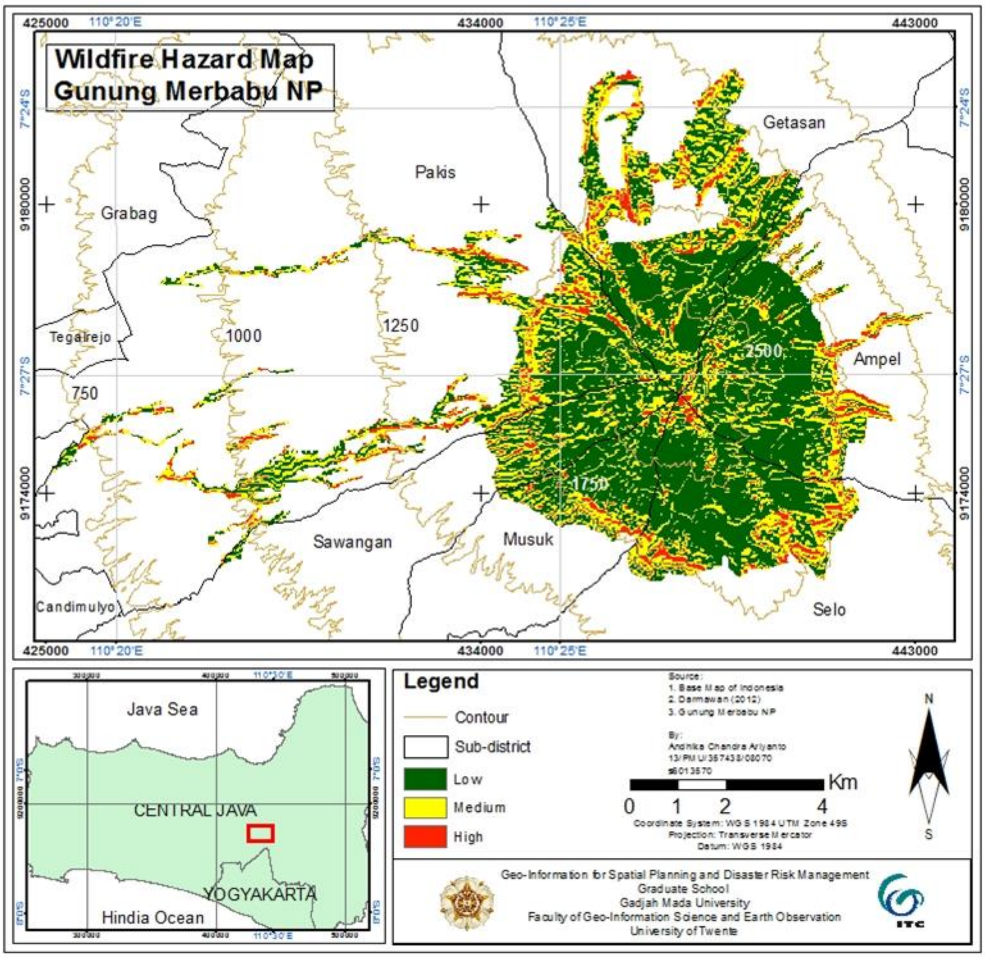


Figure 4.8. Wildfire hazard map in Gunung Merbabu NP

The map above depicts the level of wildfire hazard which had been represented by red color for high, yellow for medium and green as a low level of hazard. It can be seen that high level of hazard located in the center of NP's area and almost the entire edges of NP boundary due to its proximity to settlements and paths. Local people who collect the grasses for their cattle and several visitors who hike up the mountain through the paths are the main cause of fire ignition coming from their incompletely extinguished cigarettes/fires.

Table 4.1. Wildfire hazard calculation

Hazard	No of pixel	Size (Ha)
Low	37,298	3,357
Medium	21,380	1,924
High	6,024	542
Total	**64,702**	**5,823**

The high level of wildfire hazard occupied roughly one-tenth portion of Gunung Merbabu NP area which scattered all over its region. Most of Merbabu's area were in low hazard of 3,357 ha and the medium level took part as 1,924 ha.

4.7. Multicollinearity Test

There were 13 continuous environmental variables which have been tested its collinearity. As it has been initiated before, that as the rule of thumb of VIF value more than 10 should be omitted in modelling, there were only seven variables left. R-Studio software was applied in multicollinearity test resulted the value of VIF as table below:

Table 4.2. Multicollinearity test

Variable	VIF
Slope	1.971
Distance to settlement	5.551
Distance to river	3.292
Distance to road/path	1.704
Annual rainfall	1.402
Maximum rainfall	2.896
NDVI	1.948

Considering the importance of several omitted variables such as elevation, minimum rainfall and minimum temperature, therefore those variables were still used in the modelling process. To sum up, continuous variables applied to the model consist of elevation, slope, distance to settlements, distance to river, distance to road/path, rainfall (annual, maximum, minimum), NDVI and temperature (maximum, minimum). The summary of whole variables described as table 4.3.

Table 4.3. Variable summary

Habitat Componen	No	Variable	Code	Range	Unit	Data type
Food	1	Prey distribution	prey	presence, absence		Categorical
Cover	2	Landcover	landcover1	seven classes		Categorical
	3	NDVI	ndvi	-0.26 - 0.85		Continuous
Water	4	Distance to river	river	0 - 1,317	meter	Continuous
Spatial area (space)	5	Distance to settlement	settlm	0 - 3,878	meter	Continuous
	6	Distance to road/path	path1	0 - 2,068	meter	Continuous
	7	Elevation	dem	274 - 3,100	meter a.s.l	Continuous
	8	Slope	slope	0 - 497	%	Continuous
Micro climate condition	9	Annual rainfall	rf_ann	2,100 - 3,389	milimeter	Continuous
	10	Maximum rainfall	rf_max	492 - 622	milimeter	Continuous
	11	Minimum rainfall	rf_min	0 - 65	milimeter	Continuous
	12	Maximum temperature	t_max	13.7 - 30.9	°C	Continuous
	13	Minimum temperature	t_min	2.7 - 18.3	°C	Continuous

4.8. Species Distribution Modelling

In attempt to predict the distribution of Javan Leopards in the two NPs by using presence-only data, MaxEnt was applied by employing aforementioned environmental variables and prey distribution. Habitat component consist of food, cover, spatial area (space) and water become the main consideration in determining environmental variables to predict the leopards' distribution. On this model, prey distribution as the representation of food, landcover and NDVI denoted as cover have been embroiled together with the distance to water as the representation of the water component. Nonetheless, the component of spatial area was demonstrated by elevation, slope, settlement and road/path proximity. As it has been displayed in table 4.3 above, rainfall and temperature which have direct effects on species are likely to be included in this model as micro climate condition.

4.8.1. Prey Distribution

Based on the available data on prey presence record, there were only four species of prey (Javan Langur, Muntjac, Wild Boar, Macaque) which have been modelled as the predictors variable for Javan Leopard's distribution. Below is the distribution of prey by MaxEnt programme:

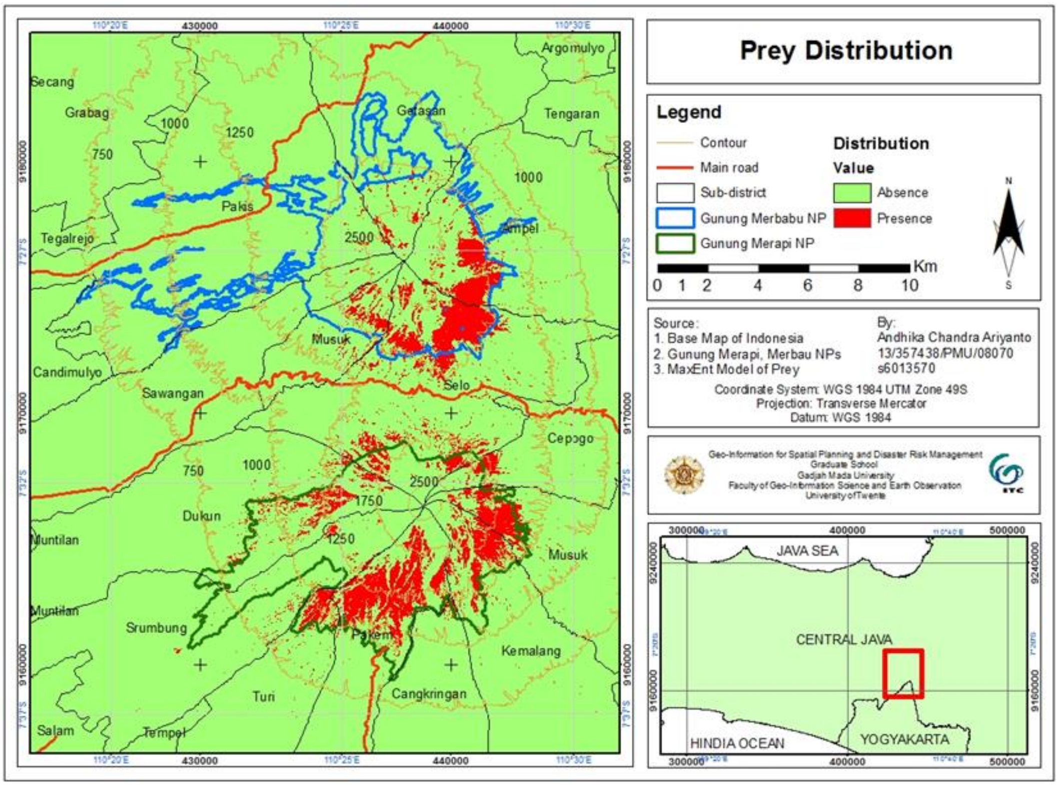


Figure 4.9. Prey distribution

It can be seen that the combined distribution of langur, muntjac, wild boar and macaque concentrated in the east, southeast up to southern part of Merbabu. In Merapi, the prey of Javan Leopard engaged almost all over the NP area while the southwest area of it was considered as absence. Based on the pixel number, the presence of prey within Gunung Merbabu and Gunung Merapi NPs' boundary occupied 1,093 ha and 1,768 ha, respectively.

4.8.2. Javan Leopard Distribution

Presence-only data of Javan Leopard were deployed alongside environmental variables (have been tested its collinearity) in MaxEnt programme. Regarding several important variables having VIF value more than 10, the final environmental variables as predictor of leopard's distribution consist of: elevation, slope, landcover, NDVI, distance (to road/path, settlement, river), prey distribution, rainfall (annual, maximum, minimum) and temperature (maximum, minimum).

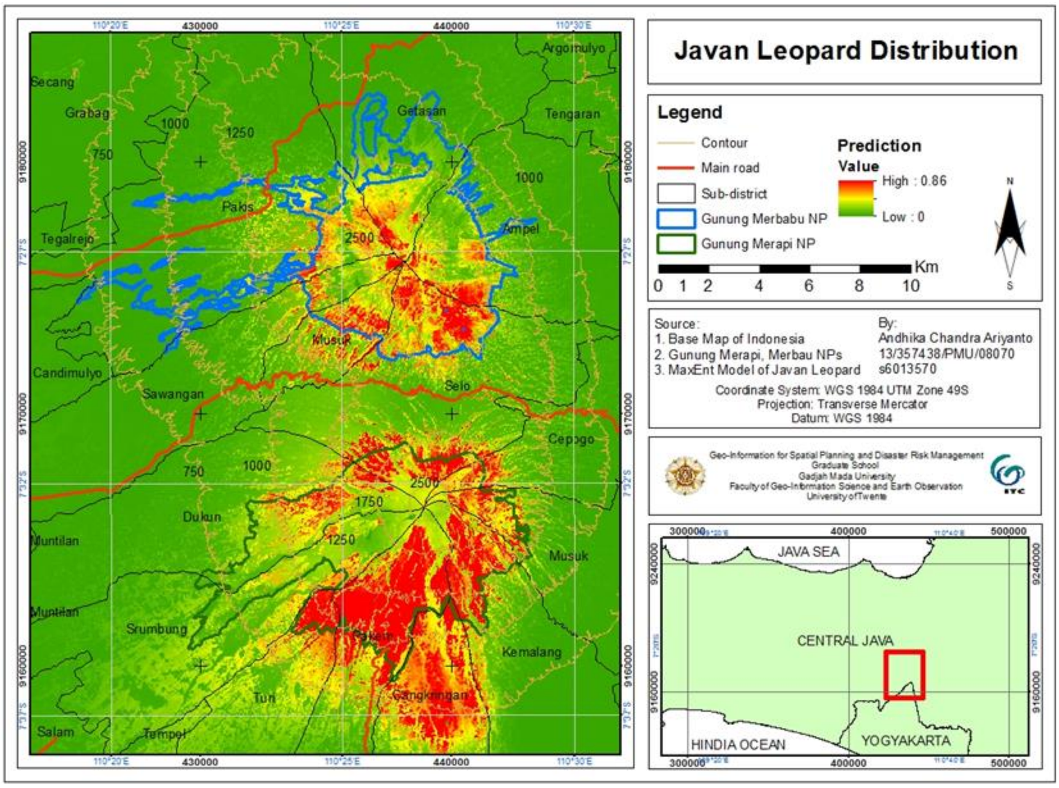


Figure 4.10. Distribution model for Javan Leopard

The result of MaxEnt in predicting the probability of Javan Leopard's occurrence showed on figure 4.10. The green color indicates that those locations have the low probability and the warmer color designates as the high probability of Javan Leopard occurrence.

4.8.3. Model Evaluation

The model of Javan Leopard's distribution (figure 4.10) performed the average training AUC of 0.982. The most contributed variables in developing that model were landcover, prey and minimum temperature distribution which took 33.4.2%, 16.9% and 13.8% contribution, respectively. In contrary, elevation, distance to river and maximum temperature were the less variables contributed to this model. The detail of variable contributions displayed below:

Table 4.4. Variable contributions

Variable	Land cover	Prey	Max rainfall	Min temp	Min rainfall	NDVI	Dist to road/ path	Slope	Dist to settlement	Elevation	Annual rainfall	Dist to river	Max temp
Contribution (%)	33.4	16.9	13.8	12.2	10.7	3.3	2.1	2.1	1.9	1.4	1.3	1	0.1

Maximum rainfall, minimum temperature and minimum became the top three variables which contributed in the model beside landcover and prey as categorical variable. Their response curve display in figure below:

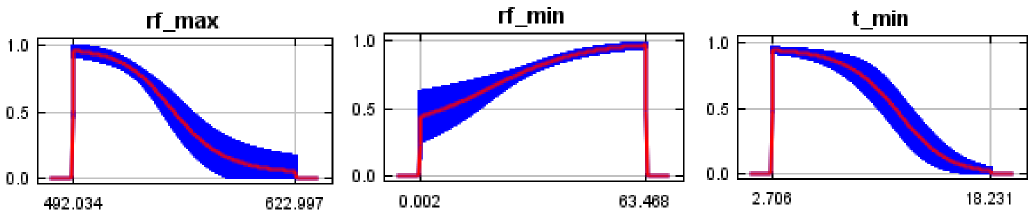


Figure 4.11. Response curves of variables

Maximum rainfall (rf_max) and minimum temperature (t_min) have the same pattern of curve which the probability of presence leopard can be found. As the high value of maximum rainfall and minimum temperature, the probability of leopard’s presence will be less. The opposite pattern performed in minimum rainfall.

The Jackknife of training gain of each variable in the model can be observed in figure 4.12. Omitting distance to path (path1), annual rainfall (rf_ann), distance to river (river) and slope as variables in the model will not affect the training gain. As the opposite, neglecting landcover will disturb the training gain.

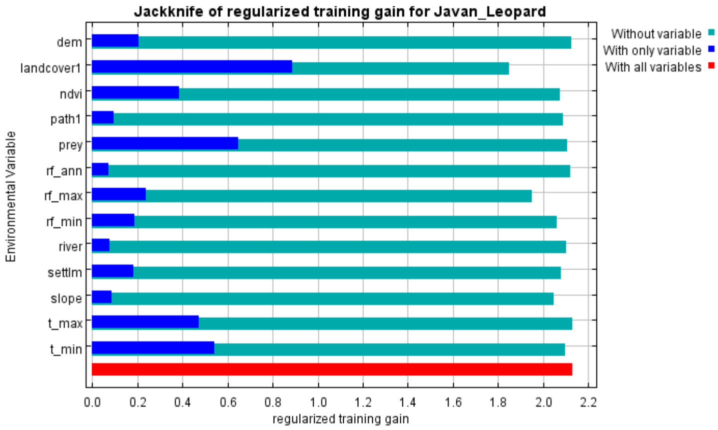


Figure 4.12. Jackknife of regularized training gain

On this model, landcover as the environmental variable held the most important information in which would cause decreasing the gain if it had been omitted. Its information is not exist in the other variables. The other jackknifes resulted by MaxEnt are test gain and AUC as figures below:

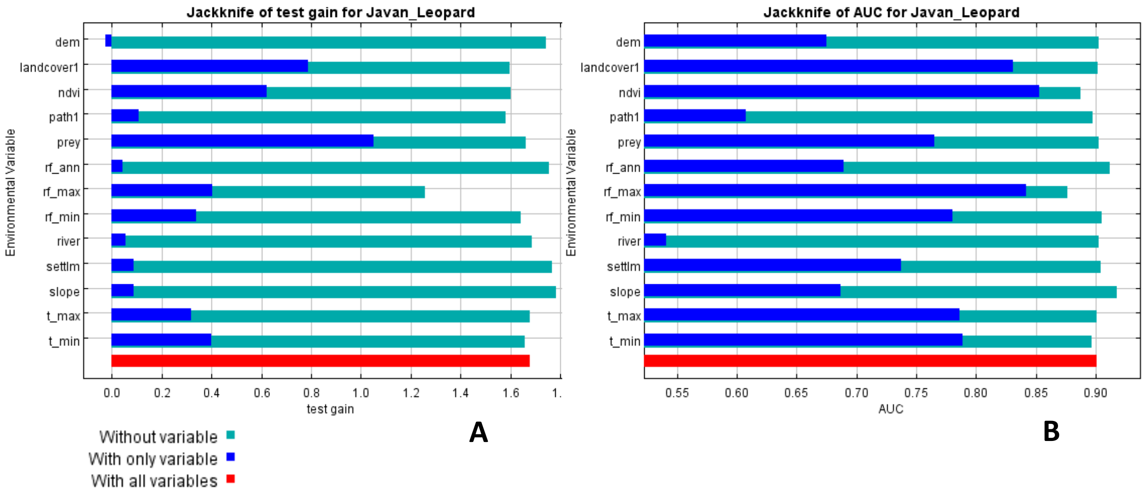


Figure 4.13. Jackknife of test gain (A) and jackknife of AUC (B)

Jackknife of AUC (figure 4.13-B) illustrates the effective single variable for predicting the distribution. On this case, NDVI, maximum rainfall (rf_max) and landcover were the most effective single variables. On the other hand, removing slope and annual rainfall (rf_ann) in modelling will keep the overall value of AUC remain high (indicated by light-blue bars surpass the red bar). In addition, figure

4.13-A shows that elevation (dem) was not the best choice for predictor since its negative value on test gain (the negative value of blue bar).

Table 4.5. Accuracy assessment

Accuracy	Value
AUC MaxEnt	0.982
AUC calculated	0.962
Sensitivity	0.938
Specificity	0.895
TSS	0.848

In term of model accuracy, table 4.5 displays the accuracy assessment for the model of Javan Leopards' distribution. The presence-only data were split into two parts as 75% and 25% for training data and test data, respectively, conducted in 10 replications. On this case, bootstrap was chosen as a population of accuracy indicator (Guisan & Zimmermann, 2000). As can be seen that there is no significant difference between AUC produced by MaxEnt and the one that has been calculated by R-Studio software. The high value of Sensitivity and Specificity informed the capacity of the model to predict the presence from a particular location as it supposes to be a presence, and so does absence. The figure below portrayed the Javan Leopards' points over the predicted area.

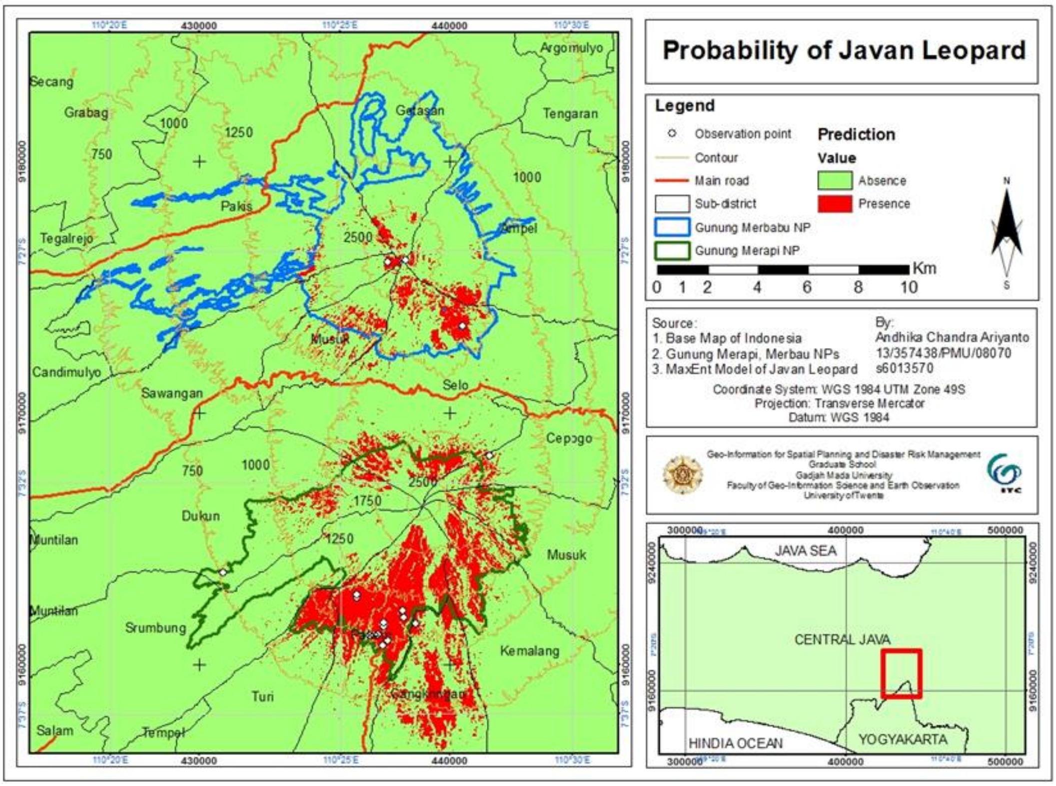


Figure 4.14. The probability of Javan Leopards' presence

As it has been stated by Fourcade et al. (2014) and Allouche et al. (2006) that TSS value can be used as variability in correction performance, the result showed that the value of TSS is 0.848.

4.9. Optimum Habitat

Considering the hazard of natural or biophysical, the distribution map of Javan Leopard (categorial presence and absence by applying a threshold = 0.2895) have been overlaid and subtracted by wildfire hazard and pyroclastic flows hazard map respectively. As a result, there is a map that depicts the prediction of Javan Leopards' occupancy in Merbabu area with respect to any possible disturbance caused by wildfire. Within Gunung Merbabu NP, the total area of 699 ha for Javan Leopards' distribution, 31 ha of it considered as the high level of wildfire hazard, 187 ha as medium and 481 ha as low level (table 4.6). Its spatial distribution can be seen in figure below:

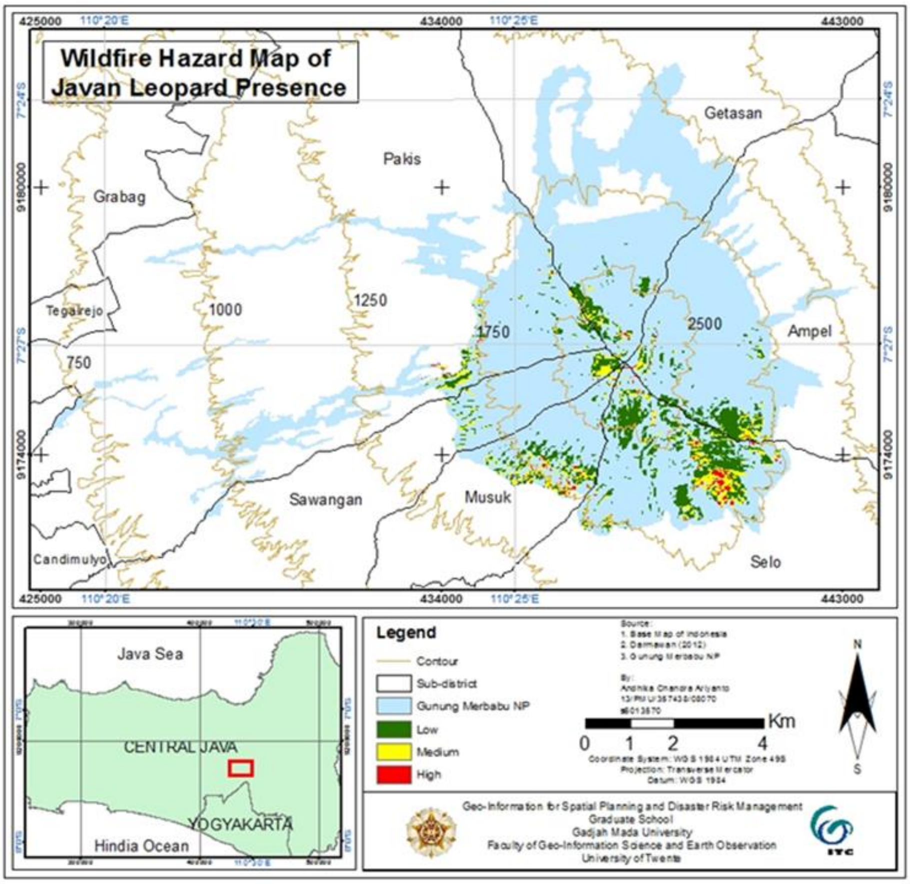


Figure 4.15. Wildfire hazard of Javan Leopards' distribution in Gunung Merbabu NP

In Merapi area, the threat of pyroclastic flows toward the presence of Javan Leopard displayed as below:

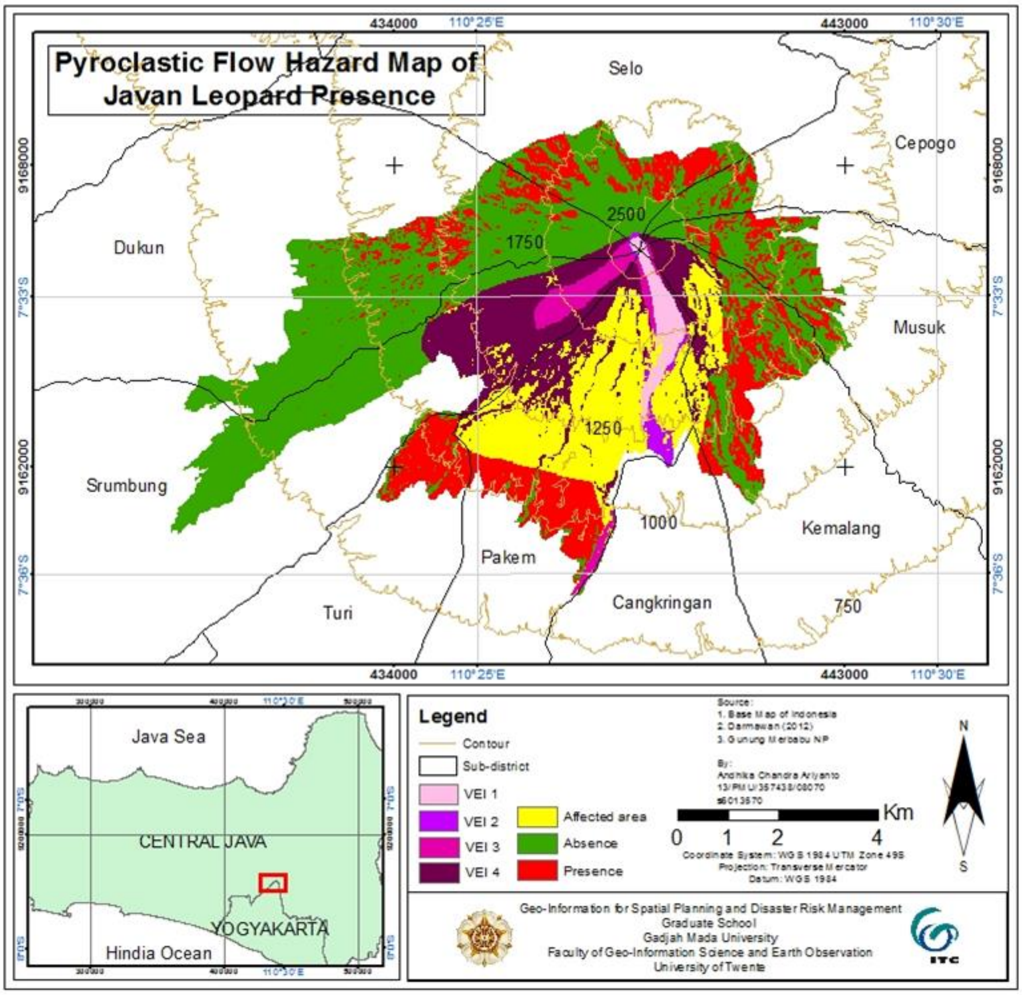


Figure 4.16. Pyroclastic flow hazard of Javan Leopards' distribution in Gunung Merapi NP

Applying the scenarios of pyroclastic flows developed by Darmawan (2012), the areas of Javan Leopards' presence inside the park's boundary were devastated by VEI 4 almost 45% of entire distribution in Gunung Merapi NP. Meanwhile, VEI 1 to 3 were considered as minor destruction which caused less than 2.5% each of damage within NP boundary. The detail number of the whole hazards can be observed in the table below:

Table 4.6. Affected presence distribution by pyroclastic flows and wildfire hazard

Presence	Presence (Ha)	Hazard (pyroclastic /wildfire)	Size (Ha)	% damage of total presence
Gunung Merapi NP	2,226	VEI 1	9	0.4%
		VEI 2	36	1.6%
		VEI 3	53	2.4%
		VEI 4	981	44.1%
		Sub-total	***1080***	***48.5%***
Gunung Merbabu NP	699	Low	481	68.8%
		Medium	187	26.7%
		High	31	4.5%
		Sub-total	***699***	***100%***
Sub-total	**2,925**			

4.10. Least Cost Path

The result of three scenarios of LCP is displayed in figure 4.17. The origin point was chosen from the presence distribution of Javan Leopard in Merapi and so did the destination point in Merbabu's area (a location where the Javan Leopard's scat was found).

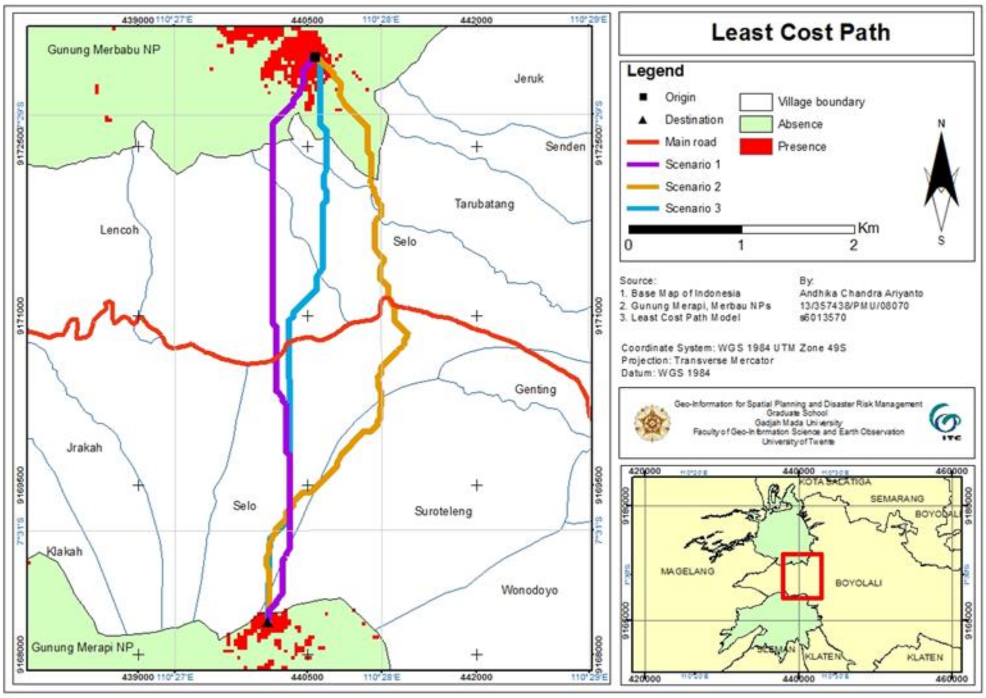


Figure 4.17. Least Cost Path as the prediction of corridor

The first scenario showed that the movement of leopard was relatively straight toward the destination and turn into northeast direction right after entering Gunung Merbabu NP's boundary. The second scenario illustrated the looped path in the right direction toward the end point. The last scenario directed the movement of leopard straight to the north side reaching the main road and continued with the right-bent direction before it went straight to the destination.

The profile of the paths of movement for Javan Leopards was displayed in figure 4.18. There are significant different pattern among the profiles. Scenario-1 resulted in 5.3 km route which started with downslope track until 750 m away and continued with relatively plain track until 3.4 km. It went go up steadily and met the steep slope in 4.75 km before arrived at the end point.

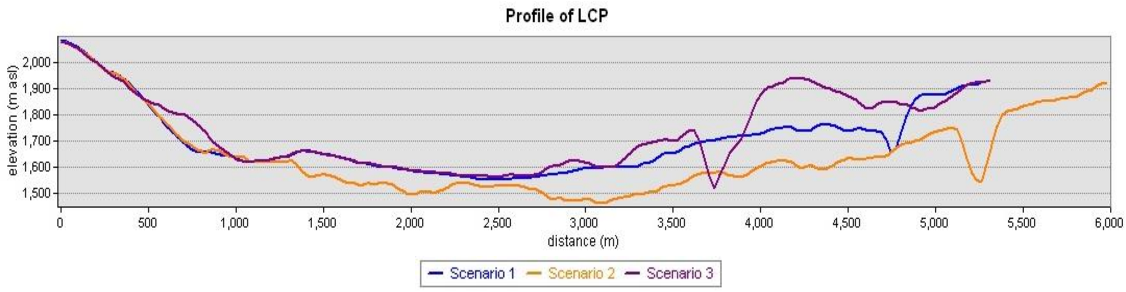


Figure 4.18. Elevation profile of Least Cost Path

The different profile performed by scenario-2 which downing the slope until three-forth kilometer and went to wavy surface until kilometer 3. It went up steadily until the steep downslope found in kilometer 5.1. The rest track recorded as a slightly up before reaching the end which 6 km away from the origin point.

The last path in which 5.3 km length showed the major difference in 3.5 km. The curvy tracks exist at that location and it continued with extremely ascend up to 1,900 m above sea level before arrive at the destination point.

4.11. Species Distribution Modelling vs National Parks Zoning System

The result of MaxEnt can be determined its binary categorical presence and absence by applying a threshold on equal training sensitivity and specificity of 0.2895. Its distribution over NP's zoning system displayed as below:

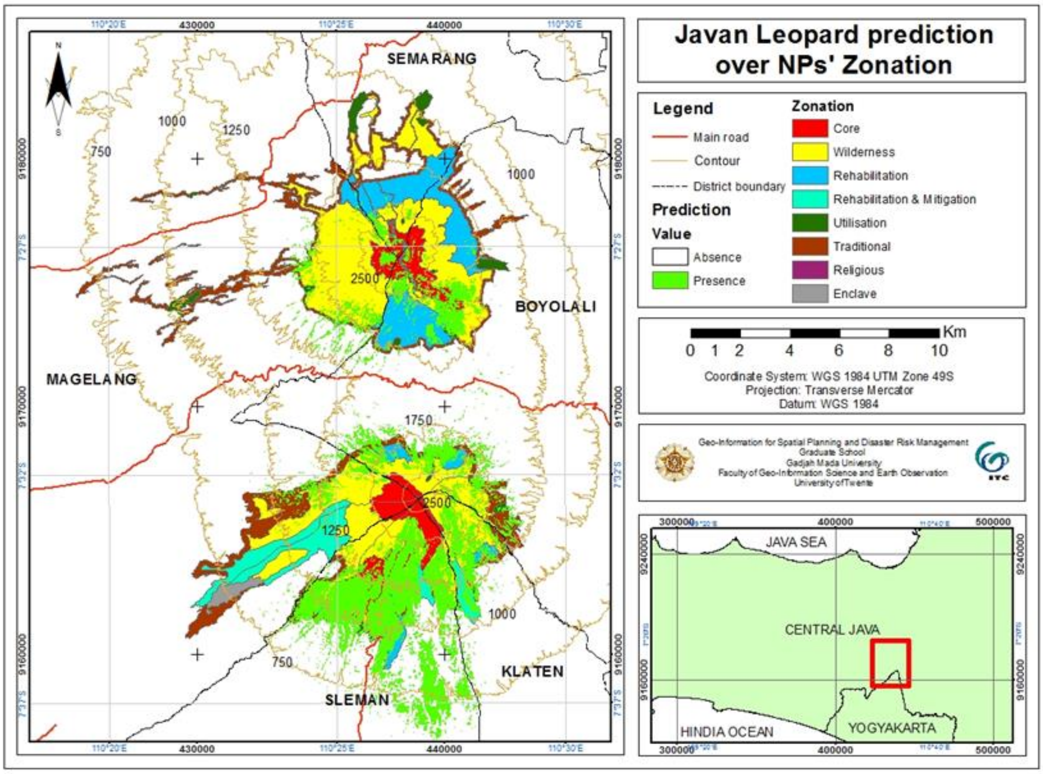


Figure 4.19. Javan Leopards's distribution over the national parks' zone

As it can be seen, Javan Leopards were predicted presence in the core zone of Gunung Merbabu NP and southeast area of it which are noted as utilization and rehabilitation zone. On the other part, leopards were predicted exist in all zone types of Gunung Merapi NP, notably southern part of it. The calculation of its occupancy was displayed in table below:

Table 4.7. Percentage of presence distribution over zonation system as per NP

National Park	Zone	No of pixel	Presence area (Ha)	Portion area (%)
Gunung Merapi	Core	4,088	368	17
	Wilderness	11,803	1,062	48
	Utilisation	939	85	4
	Rehabilitation	2,614	235	11
	Rehabilitation & Mitigation	1,288	116	5
	Traditional	3,995	360	16
	Enclave	11	1	0
Sub-total		**24,738**	**2,226**	**100**
Gunung Merbabu	Core	1,494	134	19
	Wilderness	1,464	132	19
	Utilisation	332	30	4
	Rehabilitation	4,040	364	52
	Traditional	436	39	6
Sub-total		**7,766**	**699**	**100**
Total		**32,504**	**2,925**	

Based on the zonation system of Gunung Merapi NP, the presence of Javan leopard laid dominantly, almost 50% or equal to 1,062 ha in the wilderness zone. Less than one-fifth of it predicted in the core zone of Merapi and followed by traditional and rehabilitation zone which took the portion of 16% and 11%, respectively. In the meantime, the core and wilderness zone of Gunung Merbabu NP has been occupied by the leopard as 19% for each and total of 69 ha in the zone of utilization and traditional. The biggest portion of presence leopard was predicated in rehabilitation zone which has taken a part as 52%.

4.12. Least Cost Path vs Regional Spatial Plan

Least Cost Paths as the prediction of Javan Leopards movement from Gunung Merapi toward Gunung Merbabu NP were inevitably crossed the areas which belong to the local government, especially Boyolali District. Spatial pattern planning within Boyolali Spatial Plan which have been intersected by the three scenarios of LCP displayed as below:

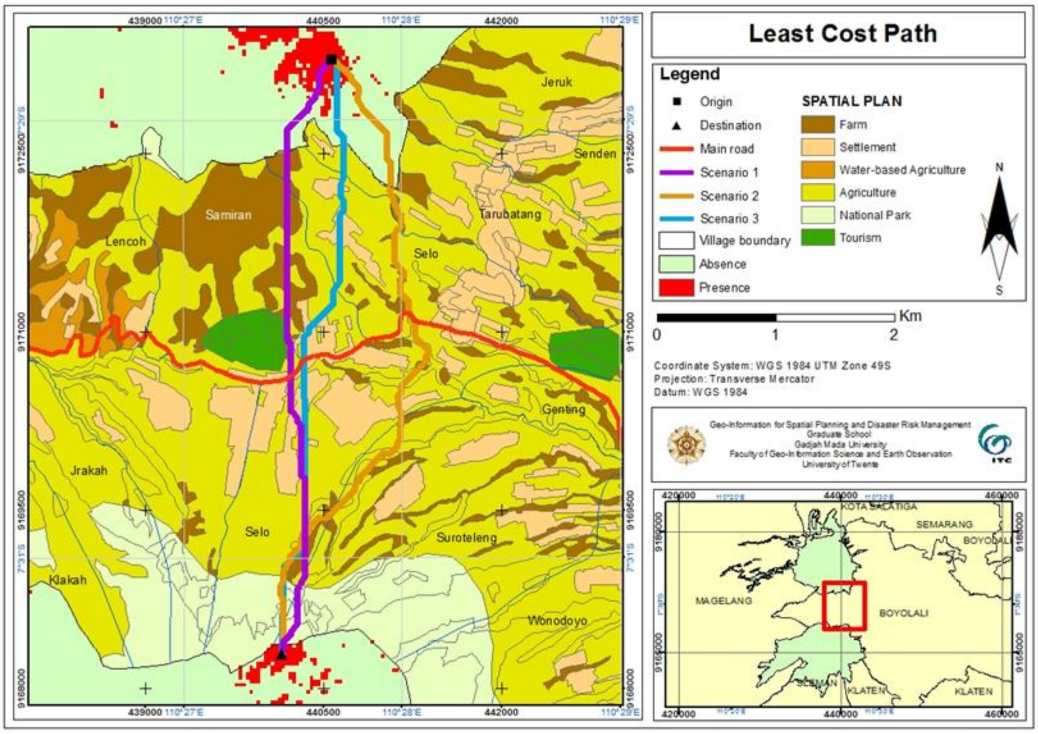


Figure 4.20. Least Cost Path over the Spatial Plan of Boyolali District

It can be observed that LCP's scenarios intersected landuse arranged by Boyolali's government. Forest, settlement, agriculture, farm, and area for tourism were passed by predicted leopard's movement. For detail sequences of each path scenario displayed in figure 4.21.

Starting from the origin point within Gunung Merapi NP's area, the predicted path of the first scenario will pass dry farm and farm before reaching settlements and a main road. The next will be tourism area, continued to agriculture and farm alternately before reaching the end point. The second scenario engaged only once in passing the settlement area along the track. As the consequences, it will pass along path upon agriculture (dry farm) and farm area. Finally, the distinct scenario have performed by the last scenario which predicted to intersect several settlement areas before and after cross the main road. To reach the destination, agriculture and settlement landuse will be passed alternately.

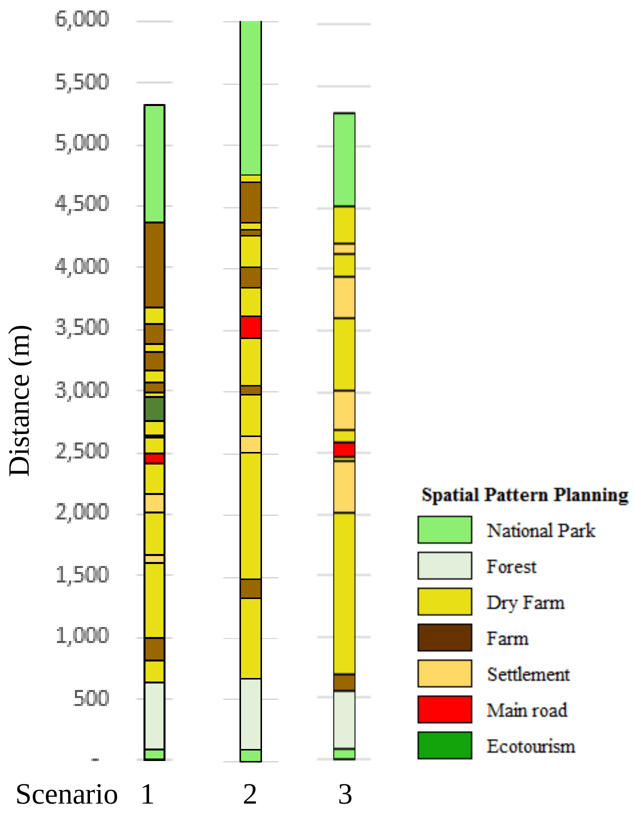


Figure 4.21. Sequences of predicted paths over Boyolali's landuse planning

5. DISCUSSION

5.1. Habitat Prediction for Javan Leopard

Following the steps in species distribution model by Franklin (2009), conceptual and statistical formulation which continued by calibration and evaluation model have been applied to Javan Leopards' distribution model. The main concept of this modelling is to figure out the spatial distribution of leopard in Merapi-Merbabu landscape by considering the ecological theory pertaining Javan Leopards which have been represented by a set of environmental variables.

A statistical formulation as the second step in modelling has been directed the model development into MaxEnt programme due to a limited data record for Javan Leopard in both NPs. Several relevant environmental variables were kept deliberately even though indicated having multicollinearity. Elevation, minimum rainfall and minimum temperature were involved since their importance in explaining geographic characteristic. Based on the model, it has been proven by jackknife of AUC which showed that landcover, NDVI and maximum rainfall were relatively effective as a single variable to predict the distribution (figure 4.13-B). However, elevation was regarded as the one and only variable that resulted negative test gain. By definition, it was not considered as limited factor for leopard.

In order to evaluate the model, applying equal sensitivity and specificity threshold (0.2895) in determining presence-absence probability to the map result showed the suitability of Javan Leopards' distribution. Figure 4.14 portrayed the observation points were located exactly in the presence prediction areas. Its validity has been performed by accuracy assessment in table 4.5. The result of MaxEnt showed that the model of Javan Leopards' distribution has performed the AUC value of 0.982. It is considered as an excellent model because of the value more than 0.9 (Hanley & McNeil, 1982 in Drew et al., 2011). The TSS value (0.848) also considered as adequate (>0.75; Franklin, 2009) in discriminating binary output as presence-absence.

The model of leopard's distribution on the study area assigned the total area of 2,925 ha within NPs' whereas roughly 76% (2,226 ha) of it located in Gunung Merapi NP. The rest predicted area is located in Gunung Merbabu NP which occupied 699 ha. The preference habitat distributions for the leopard extend from dense forest to shrub-grass and the elevation variation starting from 602 meters a.s.l to the highest upland of 3,051 meters a.s.l.

Table 5.1. Preference distribution for Javan Leopard

Variable	Range	Unit
Prey distribution	presence, absence	
Landcover	seven classes	
NDVI	0.014 - 0.841	
Distance to river	0 - 522	meter
Distance to settlement	0 - 3,556	meter
Distance to road/path	0 - 1,762	meter
Elevation	602 - 3,051	meter a.s.l
Slope	0.02 - 382	%
Annual rainfall	2,498 - 3,109	milimeter
Maximum rainfall	492 - 558	milimeter
Minimum rainfall	2 - 39	milimeter
Maximum temperature	13.7 - 28.2	°C
Minimum temperature	2.7 - 16.1	°C

Looking back on variable contributions (table 4.4), except for landcover and prey as categorical variables, maximum rainfall, minimum temperature and minimum rainfall were the top three contributed on this model. These variables can be regarded as the limit factor for the leopards' distribution.

Since MaxEnt model produces the prediction of species' spatial distribution as current and potential conditions (Young, Carter, & Evangelista, 2011), areas outside NPs which have been predicted as presence can be regarded as the potential area for the leopards. Four villages in the southern areas of Gunung Merapi NP namely Kepuharjo, Glagaharjo, Umbulharjo and Hargobinangun were predicted as leopard's distribution as approximately 312 ha, 148 ha, 139 ha and 110 ha, respectively.

Those location, therefore, can be regarded also as the prone area for human-leopard conflict whenever the leopard come into that villages for any particular purposes. It can be seen in table 5.1 that the minimum distance to the settlement was zero (0 meter), indicated that the leopards also presence within settlement areas (special case when the leopards come to the village to hunt the cattle).

Figure 5.1. Villages predicted as presence

(Clockwise from the upper left: cattle-cage which have been preyed by leopard-Umbulharjo, Pagerjurang-Kepuharjo, Srunen-Glagaharjo, Gading-Glagaharjo; source: fieldwork)

5.2. Possible Corridors

Least cost path generates possible corridor in three scenarios in which an origin point and a destination point were determined according to Javan Leopard's presence prediction. The origin point was chosen from the presence prediction inside Gunung Merapi NP's boundary, nearby the leopard's occurrence point in Gunung Bibi (the northeast part of Merapi). In the meantime, the destination point was the location where the leopard's scat was found during the fieldwork. By that condition, the prediction path was expected as the most reasonable corridor.

There are two important concepts in LCP namely weight and cost variable. Those values are needed to calculate the composite cost of movement. The first scenario divided the composite cost movement into equal portion (equation 3). This scenario has been set in zero condition which mean there was no priority among variables. The second scenario (equation 4) allocated landcover, NDVI and habitat model as the top priority due to their high variable contribution in the distribution model. Although prey availability also categorized as it, there was only a few area distribution in the area between NPs. Water as the location where the prey frequently present appointed as low as prey availability in weighting assignment.

As the opposite of the second scenario, the last scenario has emphasized on the main road and slope as a priority for leopards' movement and relegated the rest variables (equation 5). The reason for that scenario is to figure out the path in a situation of sparse vegetation as cover along the route.

Based on the results of scenario-1, as the consequence of equal variables, two segments of extremely crowded settlement areas have to be passed before reaching a main road. By definition, the weakness of the path emerged from this location. Human intensity becomes the potential threat in creating a secure track for leopards' dispersal.

Became the longest route amongst the path models, the second scenario was promising the relatively more secure path since the track predicted to pass the settlement area only once. As long as 6 km of this route only passed two kinds of landuse plan specifically agriculture and farm area. The more weighted priority for landcover and NDVI for the composite movement have been responded by LCP adequately even though the path has to pass through the settlement area. As the result of remote sensing imagery (Landsat 8), those variables were encouraging in supporting the corridor model.

Additionally, along the second track, there will be underpass track beneath the bridge before reaching the end point. The characteristic of this passage engaged the secure area by taking the path under the good cover (figure 5.2). Visually, the track was supposed to be following vegetation strip without facing the settlement area before reaching the main road, but it would end up with a long track. Thus, that matter also becomes the drawback of this corridor model.

On the last scenario, the existence of bridged under crossings along the main road have been set in lower cost of movement compare to the road without a bridge.

The more weighted priority have been placed on the main road and slope variables created the 5.1 km route towards the destination point. Became the shortest track compared to the others, this path responded the scenario to get by an underpass. However, conducting ground check for this passage, there was no opportunity for the leopard to follow this path since four times skipping the settlement areas and the narrow underpass were considered as the price to be paid on this scheme.

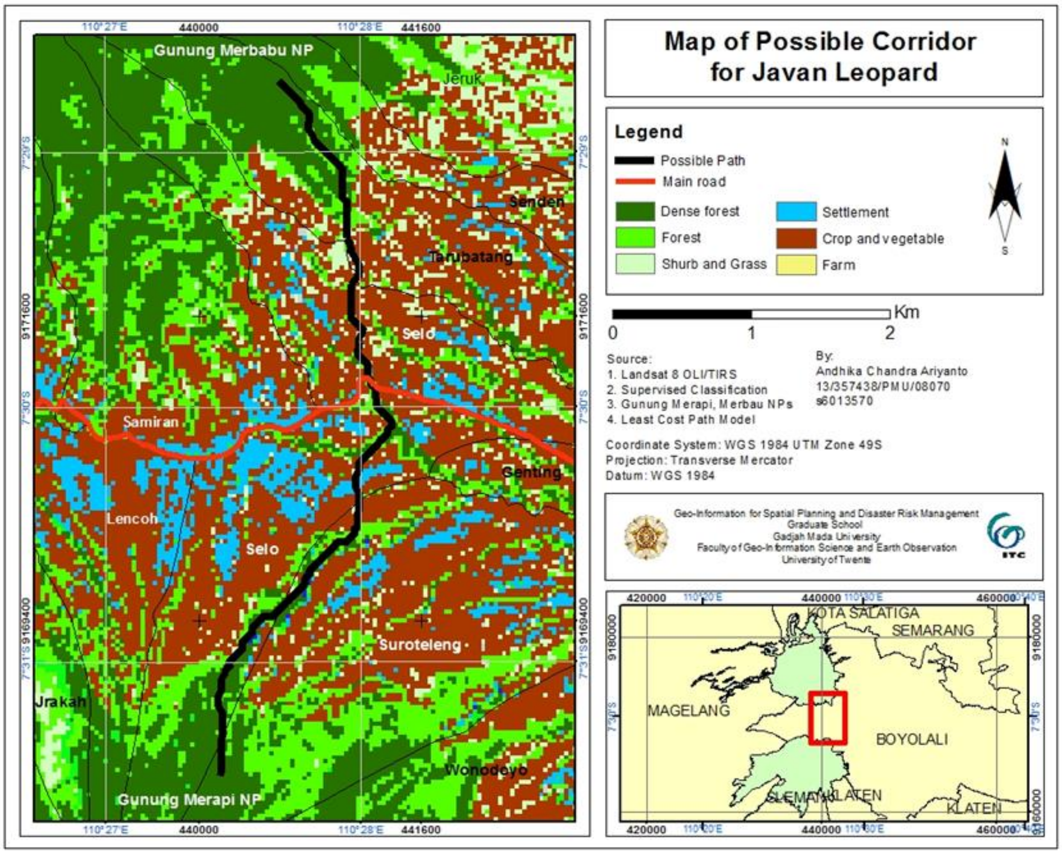


Figure 5.2. Path over the landcover

Finally, the decision in assigning several important variables determines the possible corridor which is very beneficial for conservation effort in term of providing habitat connection. It helps the process of corridor planning for the authority of NPs in collaboration with the local governments of Boyolali District. Despite the lack of field validation in those models, the prediction paths for Javan Leopard are sensible to be implemented in order to facilitate not only the leopards but also the other wildlife to disperse.

5.3. Gap Analysis

The result of MaxEnt showed that the prediction of Javan Leopards' distribution was not only within the NPs concession, but also several areas outside which are recognized as a highly populated area with a high intensity of human activity. Moreover, the results of prediction path connecting Merapi and Merbabu landscape were laid upon the fertile landscape as the local government (Boyolali District) has prioritized it as agriculture field on its spatial planning.

5.3.1. Conformity of National Park Zoning System

In accordance with Ministry of Forestry (2006), national park as one of protected areas is managed by zoning system in order to optimize the management of protecting area with respect to ecology, social, economy and local tradition. Comprising core zone, wilderness zone, utilization zone, traditional zone, rehabilitation zone, cultural zone and special zone, national park designated to conserve the nature.

In wildlife point of view, notably Javan Leopard, its predicted distribution in Merapi-Merbabu landscape has been accommodated by protected area adequately. Approximately two-third of leopards' presence occupied within NPs' area and the rest distribution (1,308 ha; for detail see table 5.3) spread around it especially in the southern part of Gunung Merapi NP.

Table 5.2. Leopards's presence as per zone type in Merapi and Merbabu NPs

National Park	Zone	NP area (Ha)	Leopards' presence area (Ha)	Portion area (%)
Gunung Merapi	Core	847	368	43.4
	Wilderness	2,753	1,062	38.6
	Utilisation	122	85	69.1
	Rehabilitation	400	235	58.8
	Rehabilitation & Mitigation	843	116	13.7
	Traditional	1,182	360	30.4
	Enclave	119	1	0.8
Sub-total		**6,267**	**2,226**	**35.5**
Gunung Merbabu	Core	460	134	29.2
	Wilderness	1,297	132	10.2
	Utilisation	283	30	10.6
	Rehabilitation	2,603	364	14.0
	Traditional	1,176	39	3.3
Sub-total		**5,818**	**699**	**12.0**
Total		**12,085**	**2,925**	**24.2**

Within the NPs' boundary, the total of leopards' presence occupied almost a quarter area (24.2%) of Gunung Merapi and Gunung Merbabu NPs. Apparently, it can be seen that the leopards prefer to wilderness zone of Merapi and rehabilitation zone inside Merbabu area. A fortunate situation that enclave and traditional zone where human activities frequently occur were not predicted extensively to be occupied by the leopards. Though the southern part of Merapi namely Kepuharjo, Glagaharjo, Umbulharjo and Hargobinangun hold the higher probability of being trespassed by this species. The first three belong to Cangkringan Sub-district and the last was under Pakem Sub-district administration. An evidence have proved that the conflict between human (their cattle) and leopards was inevitable in a particular situation which forced the leopard to come by settlement/agriculture area.

Table 5.3. Javan Leopard Presence outside NPs boundary as per sub-district

Boyolali	**Ha**	**Magelang**	**Ha**	**Sleman**	**Ha**	**Klaten**	**Ha**
Ampel	2	Dukun	31	Cangkringan	599	Kemalang	49
Cepogo	46	Pakis	17	Pakem	185		
Musuk	102	Sawangan	5	Turi	63		
Selo	192	Srumbung	17				
	342		**70**		**847**		**49**
						Total	**1,308**

Admittedly, there is nothing can do related to that circumstances. National parks authorities can only conduct numerous of conservation endeavor in many aspects. Social and ecological aspects can be taken into account in the leopard conservation strategy. Human activities need to be limited to the forest, notably several zones which are considered as the leopard's presence in order to create a secure area for the leopard. Indeed, because of human disturbances are able to reduce the use of habitat by wildlife, preventing any potential ecological destructions would be beneficial for wildlife management.

Nonetheless, providing the spatial distribution of leopard has been known, then it can be used as the basic knowledge for the next level of conservation activity for the leopard. Population number monitoring of Javan Leopard will be the next sequences that the NP authorities can do. Conserving the Javan Leopards in their home called forest by organizing the zones becomes a paramount responsibility of NPs management authority.

5.3.2. Regional Spatial Plan Review

Considering the fact that Boyolali District is located between Gunung Merapi and Gunung Merbabu NPs, this district becomes *the matrix* for the landscape. The matrix refers to an area different from patches (Destefano, 2009). On this case, Merapi and Merbabu are considered as the large patches of wildlife's habitat. In order to support both of national parks' conservation activities, spatial planning of Boyolali becomes the main consideration for conservation. Unfortunately, it is not included as a part of spatial pattern planning.

Based on the result of LCP as the prediction for Javan Leopards' passages from Merapi toward Merbabu, it can be taken into account in creating some possible corridors for wildlife dispersal. The second scenario, as the most logic path which can be developed as a strip corridor to facilitate wildlife's dispersal notably Javan Leopard. As the rule of thumb for corridor's width which approximately 1,000 feet (Bond, 2003) or equal to 304.8 m, the predicted routes of LCP were buffered to meet that criteria. As the consequences, there will be large of areas to be intersected by the proposed route.

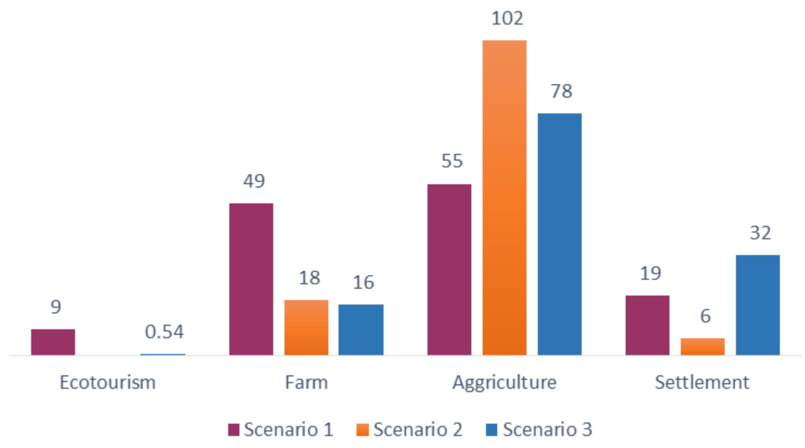


Figure 5.3. Landuse intersected by buffered-LCPs (in Hectare)

Applying the second scenario seemingly as the least risk in area conversion, particularly for settlements. Merely six hectares of it are included in the proposed corridor while it will be more than five folds of settlement areas intersected on the third scenario. In the agriculture field, more than 100 ha are counted in the buffered path. It equals to twice of agriculture area on the first scenario.

Certainly, it is problematic to convert six hectares of the settlement area, 18 ha of farm area and 102 ha of agriculture to generate strip corridor on that location. The primary commodity of vegetable such as carrot, cabbage, chili, celery, tomato, etc. are combined with *Toona sureni*, *Coffea arabica*, *Paracientes falcataria*, etc. becomes the main livelihoods for the community.

Therefore, it will be fraught with difficulties to accommodate the corridor on spatial pattern plan. Several wildlife connection techniques such as green bridge or eco-duct are impossible to be applied on this area. Hilly landscape with steep slope become the reasons of it.

However, there are several opportunities for modifying the landuse in the way that the previous landuse sounds more like vegetated-area. Vegetation restoration as Bond (2003) has suggested can be applied as an alternative solution for facilitating the wildlife's movement, particularly in cultivated areas. Keeping the settlement areas inside the corridor, human activities are plausible to be reduced especially from dusk to dawn period which are considered as the most active time for leopards. In addition, the support from local community correspondingly becomes the key role in an ecological connection. Eventually, as the most important thing for the conservation effort is coordination among stakeholders, local government as one of it plays a critical role in accommodating ecological connection for Gunung Merapi and Gunung Merbabu NPs.

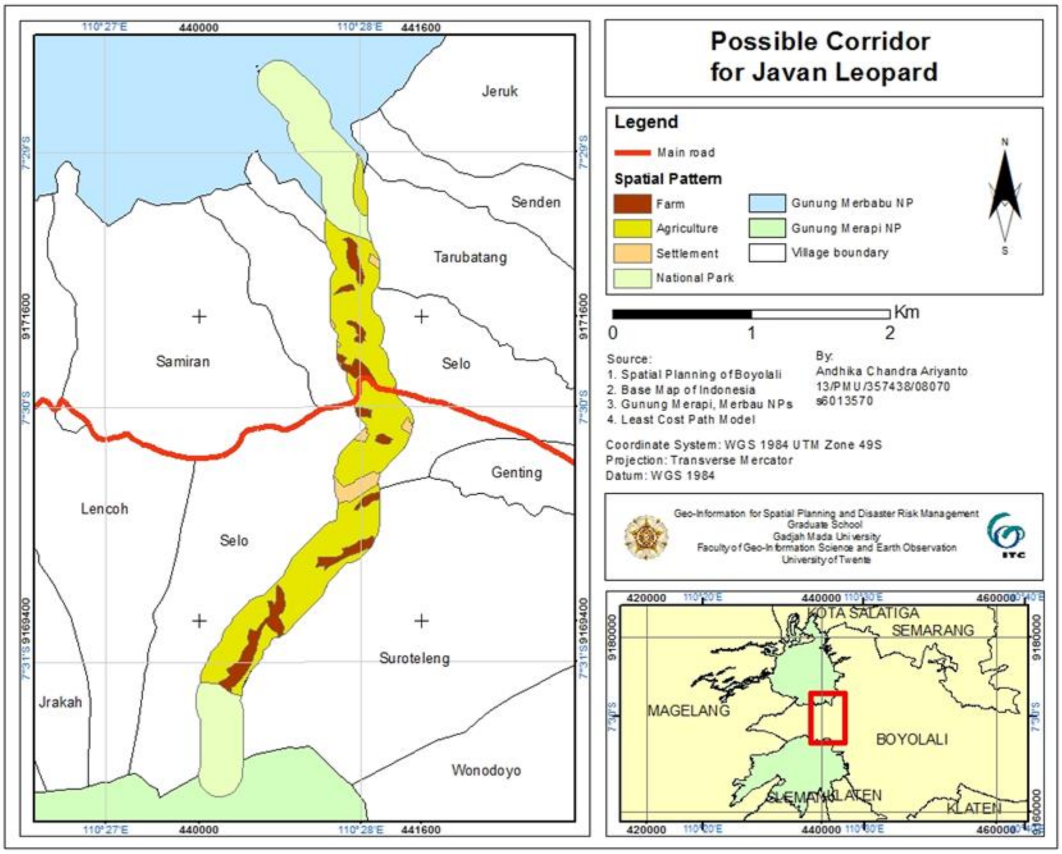


Figure 5.4. Proposed corridor for Javan Leopard over Boyolali's landuse

5.4. Disaster Risk Management for Javan Leopard Conservation

Following the pyroclastic hazard of Merapi eruption from Darmawan (2012) particularly VEI 4 as the worst scenario, leopards' distribution will be severely affected by that event. Wildfire in Merbabu also turns into a serious problem to wildlife habitat. Those two kinds of hazard become the basic reason for considering dispersal mechanism for wildlife. As their instinct in escaping from any natural disturbances, preparing the save path for their movement is important as it was suggested by Alikodra (1993).

Discussing about preparing the save path for the leopard dispersal purposes, a prerequisite activity of understanding their habitat is regarded as the basic effort. The application of MaxEnt in modelling the distribution of Javan Leopards has been able to portray the characteristic of their habitat. It has an advantage in figuring out the spatial distribution in particular landscapes. Providing the distribution already known, then the probability of those areas to be connected can be analyzed by developing corridor model. Least cost path as one of methods in corridor modelling promised the most reliable track with respect to several hindrance variables for wildlife movements.

Furthermore, the concept of distribution recognizing as well as its connectivity is applicable to disaster risk management. Risk assessment and mitigation as the part of a pre-disaster activity in ecosystem point of view are conceivable to be implemented in disaster risk management. The different situation with human as an element at risk in a natural disaster, wildlife's movements are impossible to be directed to a certain path or evacuation route. Therefore, the only measure that sensibly to be conducted is facilitating their movement by creating the corridor in the way that it will be more or less similar to their habitat. By doing so, the leopards and the other wildlife can disperse naturally in a secure situation as their need to survive. On this case, the second scenario becomes the most possible corridor for facilitating Javan Leopard's dispersal.

Starting from pyroclastic flows and wildfire hazard consideration, the needs of Javan Leopards dispersal, more definitely their movement between Gunung Merapi and Gunung Merbabu NPs area (or vice versa) can be included in pre-disaster phase in disaster risk management in term of ecosystem. As remain exotic big cat species on those NPs, Javan Leopard population which has been threatened by several things is still facing the other serious threat of natural disasters. By developing a corridor for connecting the two NPs, not only the matter of natural hazard for Javan Leopards can be minimized, but also the issues pertaining isolated population are possible to be addressed.

To sum up, the hybrid method of SDM and LCP is applicable to be implemented in wildlife conservation with respect to disaster risk management. The combination of those relatively handy methods serves the basic proficiency for national parks authorities and the other institutions which might be concerned not only with Javan Leopard but also wildlife conservation program in general.

6. CONCLUSIONS AND RECOMMENDATIONS

As the main objective of this research, possible corridor for Javan Leopard which connect Gunung Merapi and Gunung Merbabu NPs has been figured out by using least cost path tool in ArcGIS and MaxEnt programme as a method for predicting leopard's distribution. Landcover and NDVI as the results of remotely sensed imagery (Landsat 8) have been supporting the modelling of Javan Leopards' distribution adequately as the most effective single variables in this model. Maximum entropy programme and LCP have developed the model of the leopard's distribution and its possible path with the specific results as follows:

6.1. Conclusions

1. Suitable habitat for Javan Leopard has been identified and mapped as 2,226 ha within Gunung Merapi NP which occupied 35.5% of the total area. Wilderness zone became the most occupied area by the leopard with the size of 1,062 ha. In Gunung Merbabu NP, 699 ha of its area, equivalent to only 12% of total area, were predicted as suitable habitat for leopard. On this park, 364 ha of rehabilitation zone was the most preferred habitat for the leopards. The species prefers to habitat type of shrub until dense forest.
2. The result of MaxEnt the model of Javan Leopards' distribution has performed the AUC value of 0.982. It is considered as an excellent model because of the value more than 0.9 (Hanley & McNeil, 1982 in Drew et al., 2011; Swet, 1988 in Manel et al., 2001). The TSS value (0.848) also considered as adequate (>0.75; Franklin, 2009) in discriminating binary output as presence-absence. Consequently, this presence distribution prediction was suitable for Javan Leopard.
3. On this model, variables which were represented by environmental layers have showed its contribution percentage. Among the 13 variables which have been deliberately chosen, the most important variables of

this model consist of landcover, prey distribution, maximum rainfall, minimum rainfall, minimum temperature and NDVI.

4. Among the three scenarios of the possible pathway, there was only one corridor (the second scenario) detected as the most likely passage for Javan Leopards. It can be regarded as an ecological link which connects Gunung Merapi and Gunung Merbabu NPs.
5. The characteristic of the possible corridor can be described as relatively secure track, avoiding settlement area and having enough cover along the route. Landcover type and NDVI value became the essential variable in constructing the path direction.
6. The potential threat in term of landuse which might be faced by the proposed corridor were mainly the settlement areas and also the cultivated areas since the areas between Merapi and Merbabu are considered as the fertile soil. Population growth and agriculture expansion become the most serious threat to conservation and sustainable development in general.
7. The total area which predicted presence for Javan Leopard, 70% of it has been accommodated by the existence of NPs while the rest of it (equal to 1,308 ha) was predicted outside NPs area. The prediction outside NPs can be regarded as the potential distribution as well as the prone area for conflict between the leopard and humans (their cattle). Unluckily, spatial planning of Boyolali District did not put any considerations related to wildlife corridor on its spatial pattern plan. The possible corridor (1,000 feet width) intersected the landuse of settlement, agriculture and farm areas in 6 ha, 18 ha and 102 ha, respectively.
8. Related to Javan Leopard's conservation program, the authority of Gunung Merapi and Gunung Merbabu NPs can emphasize the optimization of zonation system as their main responsibility. Delimit human access to particular zones which are restricted to any disturbances and intensify the survey of wildlife can be the noticeable

action to conserve Javan Leopard. Meanwhile, local government, particularly Boyolali District, can take the issue of connecting ecology into account on its spatial planning. Vegetation restoration along the possible corridor and information dissemination related to the important path connecting Merapi and Merbabu are the possible efforts to be carried out by Boyolali District as *the matrix* for the landscape.

6.2. Recommendations

1. In order to make sure the prediction of Javan Leopards' presence in Merapi and Merbabu area, deploying several camera traps within the areas denoted as presence would be beneficial for the next level of wildlife management. By using camera traps, either Javan Leopards or the other wildlife can be recorded as the main attention in managing the parks.
2. Conducting presence-absence survey of Javan Leopards in both of NPs will give another option of species distribution modelling such as GLM, GAM, BRT etc. Grid-based surveys can be applied to the relatively small conservation areas such as Gunung Merapi and Gunung Merbabu NPs.
3. As the prominence of landcover and NDVI on this model, applying high resolution of remotely sensed imagery to obtain more detail landcover will produce more precise result in predicting Javan Leopards' distribution and also the possible corridor to connect the two parks.

REFERENCES

Alikodra, H. S. (1993). *Wildlife Management (in Indonesian)*. (I. Soerianegara, Ed.) (2nd ed.). Bogor, Indonesia: Bogor Agriculture Institute.

Allouche, O., Tsoar, A., & Kadmon, R. (2006). Assessing the accuracy of species distribution models: prevalence, kappa and the true skill statistic (TSS). *Journal of Applied Ecology*, *43*, 1223–1232. doi:10.1111/j.1365-2664.2006.01214.x

Ario, A. (2007). *Javan Leopard (Panthera pardus melas) Among Human Activities: Preliminary Assessment on the Carrying Capacity of Mount Salak Forest Area, Mount Halimun-Salak National Park*. Bogor, Indonesia.

Austin, M. (2007). Species Distribution Models and Ecological Theory: A Critical Assessment and some Possible New Approaches. *Ecological Modelling*, *200*(1-2), 1–19. doi:10.1016/j.ecolmodel.2006.07.005

Baas, S., Ramasamy, S., DePryck, J. D., & Battista, F. (2008). *Disaster Risk Management Systems Analysis: A Guide Book*. Rome: Food and Agriculture Organisation of the United Nations.

Bond, M. (2003). Principles of Wildlife Corridor Design. *Biological Diversity*, (October).

Brus, D. J., & de Gruijter, J. J. (2003). A method to combine non-probability sample data with probability sample data in estimating spatial means of environmental variables. *Environmental Monitoring and Assessment*, *83*(3), 303–17. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12718515

Bryant, E. (2005). *Natural Hazards* (2nd ed.). New York: Cambridge University Press.

Bull, W. B. (2007). *Tectonic Geomorphology of Mountains: A New Approach to Paleoseismology*. (W. B. Bull, Ed.). Oxford, UK: Blackwell Publishing Ltd. doi:10.1002/9780470692318

Busenberg, G. J. (2004). Adaptive Policy Design for the Management of Wildfire Hazards. *American Behavioral Scientist*, *48*(3), 314–326. doi:10.1177/0002764204268988

CITES. (2013). Appendices I, II and III. Retrieved from http://cites.org/sites/default/files/eng/app/2013/E-Appendices-2013-06-12.pdf

Clark, K. E. (2007). Attracting and Managing for Wildlife * (2nd ed., pp. 437–450). New Jersey: Springer.

CNRD-PEDRR. (2013). *Disasters, Environment & Risk Reduction - Eco-DRR Master's Module, Instructor's Manual*. Cologne and Geneva: Center for Natural Resources and Development, Partnership on Environment and Disaster Risk Reduction.

Creighton, J. H., & Baumgartner, D. M. (1997). *Wildlife Ecology and Forest Habitat*. Washington State University.

Danoedoro, P. (2012). *Pengantar Penginderaan Jauh Digital*. Yogyakarta: C.V ANDI.

Darmawan, H. (2012). *Modelling Pyroclastic by using TITAN2D for Predicting Pyroclastic Hazard of Merapi Volcano after 2010 eruption (in Indonesian, English abstract)*. Gadjah Mada University.

Destefano, S. (2009). Wildlife Corridors and Developed Landscapes. In *The Planner's Guide to Natural Resource* (pp. 85–102). Springer Science+Busines Media, LCC. doi:10.1007/978-0-387-98167-3

Djuwantoko, Purnomo, D. W., & Laksono, F. Y. (2005). Taman Nasional Gunung Merapi: Peluang dan Tantangan Realisasi Taman Nasional di Pulau Jawa Bagian Tengah. In *Seminar Nasional: Menuju Taman Nasional Gunung Lawu*.

Dormann, C. F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., … Lautenbach, S. (2013). Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. *Ecography*, *36*(1), 27–46. doi:10.1111/j.1600-0587.2012.07348.x

Drew, C. A., Wiersma, Y. F., & Huettmann, F. (2011). *Predictive Species and Habitat Modeling in Landscape Ecology: Concepts ans Applications*. New York, United States of America: Springer.

Elith, J., & Leathwick, J. R. (2009). Species Distribution Models: Ecological Explanation and Prediction Across Space and Time. *Annual Review of Ecology, Evolution, and Systematics*, *40*(1), 677–697. doi:10.1146/annurev.ecolsys.110308.120159

ESRI. (2012). Understanding Euclidean distance analysis.

Fourcade, Y., Engler, J. O., Rodder, D., & Secondi, J. (2014). Mapping Species Distributions with MAXENT Using a Geographically Biased Sample of Presence Data : A Performance Assessment of Methods for Correcting Sampling Bias. *PLoS ONE*, *9*(5), 1–13. doi:10.1371/journal.pone.0097122

Frankham, R. (1998). Inbreeding and Extinction: Island Populations. *Conservation Biology*, *12*(3), 665–675. doi:10.1111/j.1523-1739.1998.96456.x

Franklin, J. (2009). *Mapping Species Distributions: Spatial Inference and Prediction*. New York, United States of America: Cambridge University Press.

Franklin, S. E. (2001). *Remote Sensing for Sustainable Forest Management*. London New York Washington, D.C: Lewis Publishers.

Ghanekar, N. M. (2014, November 28). Camera Traps at SGNP to Learn more about Leopards. *Hindustan Times*. Mumbai. Retrieved from http://www.hindustantimes.com/india-news/mumbai/leopards-know-how-to-share-spaces-with-humans-study/article1-1289784.aspx

Government, A. (2012). *National Wildlife Corridors Plan : A framework for landscape-scale conservation*.

Graham, S. (1999). Remote Sensing: Introduction and History.

Greiving, S., & Fleischhauer, M. (2006). Spatial Planning Response towards Natural and by Technological Hazards. *Geological Survey of Finland*, *42*, 109–123.

Guisan, A., & Zimmermann, N. E. (2000). Predictive habitat distribution models in ecology. *Ecological Modelling*, *135*, 147–186.

Gunawan, H. (2010). *Habitat dan Penyebaran Macan Tutul Jawa (Panthera pardus melas Cuvier, 1809) di Lansekap Terfragmentasi*. Bogor Agriculture Institute.

Gunawan, H., Prasetyo, L. B., Mardiastuti, A., & Kartono, A. P. (2009). Habitat of Javan Leopard (Panthera pardus melas Cuvier 1809) In the Fragmented Production Forest Landscape). *Penelitian Hutan Dan Konservasi Alam*, *VI No.2*, 95–114.

Hall, P. (2002). *Urban and Regional Planning*. *Arhiv za higijenu rada i toksikologiju* (4th ed., Vol. 25). New York: Taylor & Francis. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/12280040

Healey, P., Khakee, A., Motte, A., & Needham, B. (Eds.). (2006). *Making Strategic Spatial Plans: Inovation in Europe*. London: Taylor & Francis.

Hoogerwerf, A. (1970). *Udjung Kulon, The Land of the Last Javan Rhinoceros*. Leiden, The Netherlands: E.J.Brill.

Horning, N., Robinson, J. A., Sterling, E. J., Turner, W., & Spector, S. (2010). *Remote Sensing for Ecology and Conservation - A Handbook of Techniques*. New York: Oxford University Press Inc.

Huisman, O., & By, R. A. De. (2009). *Principles of Geographic Information Systems An introductory textbook Editors*. Enschede, The Netherlands: The International Institute for Geo-Information Science and Earth Observation (ITC).

Hyndman, D., & Hyndman, D. (2010). *Natural Hazards and Disasters* (3rd ed.). Canada: Brooks/Cole Cengage Learning.

Indonesia, M. of F. Strategy and Action Plan of Javan Leopard (Panthera pardus melas) conservation 2013-2023 (2013). Indonesia.

IUCN. (2008). Panthera pardus ssp. melas. Retrieved from http://www.iucnredlist.org/details/full/15962/0

Jiang, Z., Huete, A. R., Chen, J., Chen, Y., Li, J., Yan, G., & Zhang, X. (2006). Analysis of NDVI and scaled difference vegetation index retrievals of vegetation fraction. *Remote Sensing of Environment*, *101*(3), 366–378. doi:10.1016/j.rse.2006.01.003

Karanth, K. U., & Nichols, J. D. (1998). Estimation of Tiger Densities in India Using Photographic Captures and Recaptures. *Ecology*, *79*(8), 2852–2862.

Karanth, K. U., & Nichols, J. D. (Eds.). (2002). *Monitoring Tigers and their Prey: A Manual for Researchers, Managers and Conservationists in Tropical Asia*. Karnataka, India: Centre of wildlife Studies.

Khorozyan, I. G. (2001). Human attitudes to the leopards in Khosrov Reserve, Armenia. *Cat News*, 14–17.

KSDA. (2004). *Management Plan of Gunung Merapi National Park (2005-2024).*

Kusky, T. (2008). *Volcanoes Eruption and Other Volcanic Hazards*. New York: Facts on files, Inc.

Lamarque, F., Anderson, J., Fergusson, R., Lagrange, M., Osei-Owusu, Y., & Bakker, L. (2009). *Human-wildlife conflict in Africa: Causes, consequences and management strategies*. Rome.

Larue, M. A., & Nielsen, C. K. (2008). Modelling potential dispersal corridors for cougars in midwestern North America using least-cost path methods. *Ecological Modelling*, *212*, 372–381. doi:10.1016/j.ecolmodel.2007.10.036

Lavigne, F., & Gunnell, Y. (2006). Land cover change and abrupt environmental impacts on Javan volcanoes, Indonesia: a long-term perspective on recent events. *Regional Environmental Change*, *6*(1-2), 86–100. doi:10.1007/s10113-005-0009-2

Lavigne, F., Thouret, J. ., Voight, B., Suwa, H., & Sumaryono, a. (2000). Lahars at Merapi volcano, Central Java: an overview. *Journal of Volcanology and Geothermal Research*, *100*(1-4), 423–456. doi:10.1016/S0377-0273(00)00150-5

Leeuw, J. De, Ottichilo, W. K., Toxopeus, A. G., & Prins, H. H. T. (2002). Application of remote sensing and geographic information systems in wildlife mapping and modelling. In *Environmental modelling with GIS and remote sensing* (pp. 121–145). Taylor & Francis.

Lillesand, T. M., Kiefer, R. W., & Chipman, J. W. (2004). *Remote Sensing and Image Interpretation* (5th ed.). New Jersey: John Wiley & Sons, Inc.

Lindenmayer, D. B., & Fischer, J. (2006). *Habitat Fragmentation and landscape Change: An Ecological and Conservation Synthesis*. Washington, Covelo, London: Island Press.

Longley, P. A., Goodchild, M. F., Maguire, D. J., & Rhind, D. W. (2005). *Geographic Information Systems and Science* (2nd ed.). John Wiley & Sons Ltd,.

Macdonald, D. W., & Loveridge, A. J. (2010). *Biology and Conservation of Wild Felids*. New York: Oxford University Press Inc.

Manel, S., Williams, H. C., & Ormerod, S. J. (2001). Evaluating presence-absence models in ecology: the need to account for prevalence. *Journal of Applied Ecology*, *38*(5), 921–931. doi:10.1046/j.1365-2664.2001.00647.x

Marfai, M. A. (2011). *Pengantar Pemodelan Geografi*. Yogyakarta: Geography Faculty Publisher, Gadjah Mada University.

Marhaento, H., & Faida, L. R. . (2014). Risk Analysis of Biodiversity Extinction in Mount Merapi National Park (has not published yet; in Indonesian). *Jurnal Kebencanaan Indonesia*, 1–16.

Merow, C., Smith, M. J., & Silander, J. A. (2013). A practical guide to MaxEnt for modeling species' distributions: what it does, and why inputs and settings matter. *Ecography*, *36*(10), 1058–1069. doi:10.1111/j.1600-0587.2013.07872.x

Morrison, M. L., Marcot, B. G., & Mannan, R. W. (2006). *Wildlife-Habitat Relationships: Concepts and Applications* (Third Edit). Washington, D.C: Island Press.

Naughton-Treves, L. (1997). FARMING THE FOREST EDGE: VULNERABLE PLACES AND PEOPLE AROUND KIBALE NATIONAL PARK , UGANDA. *American Geographical Society*, *87*(January), 27–46.

Nowell, K., & Jackson, P. (1996). Wild Cats: Status Survey and Conservation Action Plan. Gland, Switzerland: IUCN/SSC Cat Specialist Group.

Owen-Smith, & Norman, R. (2007). *Introduction to Modelling in Wildlife and Resource Conservation*. 350 Main Street, Malden, MA 02148-5020, USA: Blackwell Publishing.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*(3-4), 231–259. doi:10.1016/j.ecolmodel.2005.03.026

Phillips, S. J., & Dudık, M. (2008). Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography*, *31*(December 2007), 161–175. doi:10.1111/j.2007.0906-7590.05203.x

Poor, E. E., Loucks, C., Jakes, A., & Urban, D. L. (2012). Comparing Habitat Suitability and Connectivity Modeling Methods for Conserving Pronghorn Migrations. *PloS One*, *7*(11), e49390. doi:10.1371/journal.pone.0049390

Raharyono, D., & Paripurno, E. T. (2001). *Berkawan Harimau Bersama Alam*. Jakarta: Gibbon Foundation and PILI.

Rathore, C. S., Dubey, Y., Shrivastava, A., Pathak, P., & Patil, V. (2012). Opportunities of habitat connectivity for tiger (Panthera tigris) between Kanha and Pench national parks in Madhya Pradesh, India. *PLoS ONE*, *7*(7), e39996. doi:10.1371/journal.pone.0039996

Reddy, M. A. (2008). *Remote Sensing and Geographical Information Systems*. *Components* (3rd ed., p. 472). Hyderabad, India: BS Publications. doi:10.1017/S0376892900039278

Richards, J. A., & Jia, X. (2006). *Remote Sensing Digital Image Analysis* (4th ed.). Berlin, Heidelberg: Springer Berlin Heidelberg. doi:10.1007/978-3-662-03978-6

Rodríguez-Soto, C., Monroy-Vilchis, O., & Zarco-González, M. M. (2013). Corridors for jaguar (Panthera onca) in Mexico: Conservation strategies. *Journal for Nature Conservation*, *21*(6), 438–443. doi:10.1016/j.jnc.2013.07.002

Rusydi H, M., Hartono, & Hadi, M. P. (2010). Application Integration Methods on Landsat ETM+ to Determine Earthquake Potentials in Palu Graben. *Indonesian Journal of Geography*, *42*(1), 91–104.

Saltabones, O. A. (2006). *Disaster definitions* (Vol. 2006, pp. 24–43).

Santiapillai, C., & Ramono, W. S. (1992). Status of the Leopard Indonesia (Pantherapardus) in Java. *Tigerpaper*, *11*, 1–5.

Schmiegelow, F. K. A. (2007). Section 6 Connectivity, Corridors, Stepping Stones Corridors, Connectivity and Biological Conservation. In D. Lindenmayer & R. Hobbs (Eds.), *Managing and Designing Landscapes for Conservation (moving from perspectives to principles)* (pp. 252–262). Blackwell Publishing Ltd.

Smith, K., & Petley, D. N. (2008). *Environmental Hazards: Assessing risk and reducing disaster* (5th ed.). New York: Taylor & Francis.

Sodhi, N. S., Brook, B. W., & Bradshaw, C. J. A. (2009). Causes and Consequences of Species Extinctions. In *Species Extinctions* (pp. 514–520). New Jersey: Princeton University Press.

Stein, A. B., & Hayssen, V. (2013). Panthera pardus (Carnivora: Felidae). *Mammalian Species*, *45*(900), 30–48. doi:10.1644/900.1

Store, R., & Kangas, J. (2001). Integrating spatial multi-criteria evaluation and expert knowledge for GIS-based habitat suitability modelling. *Landscape and Urban Planning*, *55*, 79–93.

Sutanta, H., Rajabifard, A., & Bishop, I. D. (2009). An Integrated Approach for Disaster Risk Reduction Using Spatial Planning and SDI. *Surveying and Spatial Science*, 341–351.

Sutanta, H., Rajabifard, A., & Bishop, I. D. (2010). Integrating Spatial Planning and Disaster Risk Reduction at the Local Level in the Context of Spatially Enabled Government. In *Realising Spatially Enabled Societies*.

Swanepoel, L. (2010). *Seventh Progress Report : Scat analysis* (pp. 1–5). Pretoria.

Tempfli, K., Kerle, N., Huurneman, G. C., Janssen, L. L. F., Bakker, W. H., Feringa, W., … Woldai, T. (2009). *Principles of Remote Sensing*. Enschede, The Netherlands: The International Institute for Geo-Information Science and Earth Observation (ITC).

TNGMb. (2009). *Midterm Management Plan of Gunung Merbabu National Park (2009-2014)*.

Toxopeus, A. G. (1999). *ISM: An Interactive Spatial and Temporal Modelling System as a Tool in Ecosystem Management* (2nd ed.). Enschede, The Netherlands: International Institute for Aerospace Survey and Earth Sciences, ITC.

UNEP. (2009). *ECOSYSTEM MANAGEMENT PROGRAMME A new approach to SUSTAINABILITY*. Nairobi: United Nations Environment Programme.

Uphyrkina, O., Johnson, W. E., Quigley, H., Miquelle, D., Marker, L., Bush, M., & O'Brien, S. J. (2001). Phylogenetics, genome diversity and origin of modern leopard, Panthera pardus. *Molecular Ecology*, *10*(11), 2617–33. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/11883877

USGS. (2013). Landsat 8. Retrieved from http://landsat.usgs.gov/Landsat_Processing_Details.php

USGS. (2015). NDVI, the Foundation for Remote Sensing Phenology. Retrieved April 13, 2015, from http://phenology.cr.usgs.gov/ndvi_foundation.php

Van Zuidam, R. A. (1985). *Aerial Photo –interpretation in Terrain Analysis and Geomorphologic Mapping*. The Hague: Smith Publishers.

Voss, D. S. (2004). Multicollinearity. *Encyclopedia of Social Measurement*.

Weier, J., & Herring, D. (2000a). Measuring Vegetation (NDVI & EVI).

Westen, C. J. Van, Alkema, D., Damen, M. C. J., Kerle, N., & Kingma, N. C. (2011). *Multi-hazard risk assessment*. University of Twente (ITC).

Wing, M. G., & Bettinger, P. (2008). *Geographic Information Systems: Applications in Natural Resource Management* (2nd ed.). New York: Oxford University Press.

Xu, D., & Guo, X. (2014). Compare NDVI Extracted from Landsat 8 Imagery with that from Landsat 7 Imagery. *American Journal of Remote Sensing*, *2*(2), 10–14. doi:10.11648/j.ajrs.20140202.11

Young, N., Carter, L., & Evangelista, P. (2011). A MaxEnt Model v.3.3.3e Tutorial (ArcGIS v10). Colorado State University.

ANNEXES

Annex 1. Javan Leopard observation data

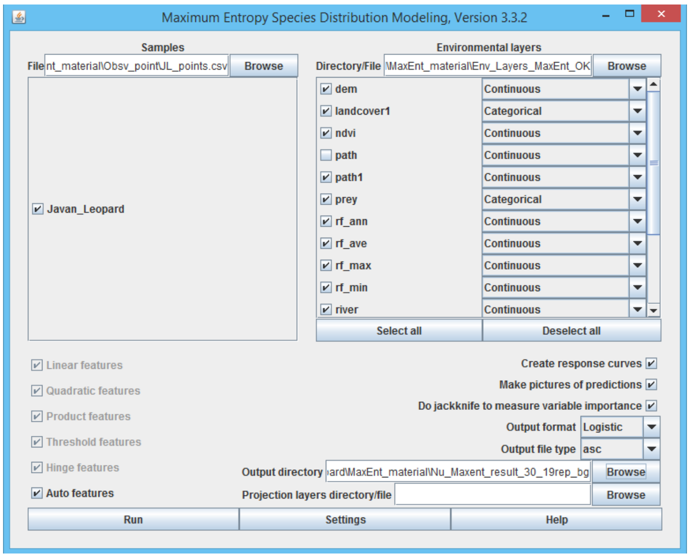
Javan Leopard	Findings						Remarks
	Foot Prints	Scratch	Scats	Dens	Sight seeing	Prey's Carcas	
1	√						
2	√						
3	√						
4			√				
5			√				
6					√		BPPTK's employee (reported as tigers)
7	√						
8		√					on Tree
9		√					on Tree
10						√	Assumption
11				√			
12					√		Information from climber/photographer
13					√		Information from climbers (2cubs and 1adult-tiger)
14			√*				
15					√*		Information from local people (3cubs)
16						√*	livestock (chicken, goat)

√* = Fieldwork data

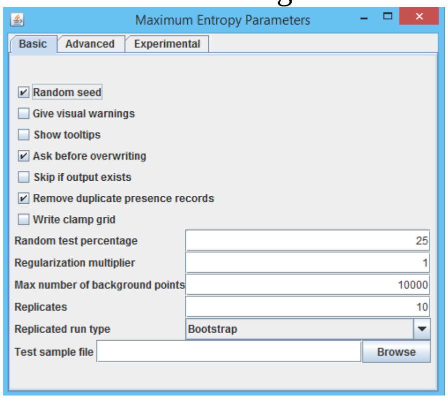
Annex 2. List of wildlife in Gunung Merapi and Gunung Merbabu NPs

Common names	Scientific names
Muntjac	*Muntiacus muntjak*
Long-tailed macaques	*Maccaca fascicularis*
Wild boar	*Sus scrofa*
Wild cat	*Prionailurus bengalensis javanica*
Porcupine	*Hystrix javanica*
Javan mangoose	*Herpestes javanicus*
Javan surili	*Presbytis fredericae*
Javan langur	*Trachypithecus auratus*
Squirel	*Sundasciurus sp.*
Asian palm civet	*Paradoxurus hermaphroditus*
Green junglefowl	*Gallus varius*

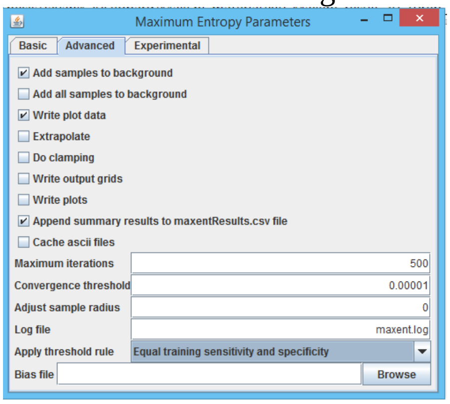
Annex 3. Maximum Entropy Species Distribution Modeling, Version 3.3.2



Annex 4. Basic setting of MaxEnt



Annex 5. Advance setting of MaxEnt



Annex 6. Experimental setting of MaxEnt