Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Local Values due to Geothermal Development Progress: an Ecosystem Services Mapping Approach

Jarot Mulyo Semedi[1,2,3], Triarko Nurlambang[2,3], Raldi Hendro Koestoer[2], Freek van Der Meer[1]

[1]Faculty of Geo-Information Science and Earth Observation, University of Twente, Enschede, The Netherlands

[2]Sekolah Ilmu Lingkungan, Universitas Indonesia, Jakarta, Indonesia

[3]Departemen Geografi, Universitas Indonesia, Depok, Indonesia

j.m.semedi@utwente.nl

Keywords: Geothermal Development, Biomass, Wood Provision, Ecosystem Services, Spatial Analysis

ABSTRACT

The Patuha geothermal area located in the agroforestry region of Patuha Mountain at 50 kilometers southwest of Bandung City on West Java, Indonesia. Geothermal development in The Patuha area will have an impact on the environment and the landscape around it. The impact will also affect the services provided by nature. The services provided by nature have their uniqueness in various places, this is due to the availability of services and the habits or culture of the people. Mapping the ecosystem services of the agroforestry region surrounding The Patuha geothermal area can provide an overview of what ecosystem services can be affected by geothermal development. In this paper, we mapped the wood provision ecosystem services by using biomass estimation approach, and field interviews to understand the people behavior in utilizing forest wood and timber. The existence of geothermal infrastructures such as road access and high voltage power line footprint was found to have a contribution in affecting how the people are benefiting the ecosystem services. The results show that the proposed approach can be used to identify the impacts of geothermal development on the ecosystem services in a spatially explicit manner.

1. INTRODUCTION

Geothermal energy is a potential renewable energy to be developed in Indonesia. Currently the installed capacity of geothermal energy in Indonesia is 1,948 MW and is the second largest in the world (Richter 2019). The potential of geothermal energy in Indonesia is concentrated in the fire ring path that extends from the island of Sumatra, Java, Southeast Nusa Tenggara to the island of Sulawesi. In the plan to develop the Indonesian government's renewable energy in 2015 - 2050, energy geothermal has a portion of 7.2 GW to be developed in 2025 and 17.6 GW in 2050. From the potential of geothermal energy in Indonesia, West Java Province has installed geothermal energy capacity of 1,164 MW and is the largest in Indonesia (Ministry of EMR 2016). West Java Province is planned to obtain additional renewable energy from geothermal energy of 1,073 MW.

The development of a region that has the potential for geothermal energy is generally divided into four phases. The first phase is exploration and drilling which is the phase with the highest costs because it has a high level of uncertainty in determining the reserves of energy that can be exploited. The second phase is the phase of infrastructure development which is the shortest phase of geothermal area development, but this phase is also the phase that has the most impact on the surrounding environment due to land clearing and conversion. The third phase is the operational and maintenance phase which is the longest phase of the construction of geothermal areas because exploited energy is renewable if managed properly. For Indonesia, the operational contract of a geothermal power plant is 30 years minimum. The fourth phase is decommissioning which is only done if the energy produced by geothermal wells no longer has economic value so that the power plant infrastructure must be closed and the land rehabilitated. In practice, the phases that are traversed in the construction of geothermal regions in the world generally only reach the third phase because of the nature of renewable geothermal energy.

Every phase of geothermal development has an impact on the surrounding environment. Potential impacts caused by geothermal development phases include: Acoustics / Noise, Ecological Resources, Land Use, Visual Resources, Geological Hazards. A complete list of potential impacts that can occur in each phase of geothermal development can be seen in table 1. The impacts caused by the development are temporary in nature according to the duration of the construction phase, and there are permanent impacts.

In assessing an impact caused by geothermal development, an approach is needed that can link the existing resources in regions that have geothermal potential with the beneficiaries. Ecosystem services are the benefits humans derive from the ecosystem (Millenium Ecosystem Assessment 2005) it is classified by The Common International Classification of Ecosystem Services (CICES) into three categories (Haines-Young and Potschin 2010; Notte et al. 2017; United States Environmental Protection Agency 2015): provisioning, regulation and maintenance, and cultural. With the existence of Indonesia's geothermal resources within the forest area, the forest ecosystem will be vulnerable to the impact of geothermal energy development. However, it is unclear how the geothermal development phase (i.e. drilling, construction, operation and eventual decommissioning) and their related activities and infrastructure, will impact the forest environment, and the ecosystem services for human well-being.

Table 1. Potential environmental impact of geothermal development phase activity (Semedi et al. 2018)

Potential Impact	Geothermal Development Phase			
	Resource Exploration and Drilling	Construction	Operations and Maintenance	Decommissioning and Site Reclamation
Acoustics/Noise	Yes	Yes	Yes	Yes
Air Quality	Yes	Yes	Yes	Yes
Cultural Resources	Yes	Yes	Yes	No
Ecological Resources	Yes	Yes	Yes	No
Environmental Justice	No	Yes	Yes	Yes
Hazardous Materials and Waste Management	Yes	Yes	Yes	Yes
Health and Safety	Yes	Yes	Yes	Yes
Land Use	Yes	Yes	Yes	Yes
Paleontological Resources	Yes	Yes	Yes	Yes
Socioeconomics	Yes	Yes	Yes	Yes
Soils and Geologic Resources	Yes	Yes	No	Yes
Transportation	No	Yes	No	Yes
Visual Resources	No	Yes	Yes	No
Water Resources (Surface Water and Groundwater)	Yes	Yes	Yes	Yes
Geological Hazards	Yes	Yes	Yes	No

In this study, we examine how information on ecosystem services can provide an overview of the use of natural resources by the community and its relation to the phase of geothermal area development.

2. METHODOLOGY

This study was carried out in Patuha Mountain area around 50 km southwest of Bandung City, West Java Province, Indonesia (7°3'1.33" - 7°15'38.52" South, 107°31'22.38" - 107°15'2.85" East) has an area of 39,572 km², and a total population of 227,704 people, of which 71% of the household are farmers. The Patuha Mountain area or what is referred to as the Ciwidey Agropolitan Area has land cover dominated by plantations estate, forest cover, and agricultural land. Coverage of plantation estate is 14,455 Ha (36.53% of the total area), followed by 14,360 Ha (36.29%) of forest land cover, agricultural lands and pastures cover 8,854 Ha (22.40%), and settlement areas cover 1.891 Ha (4,78%). (see fig 1.)

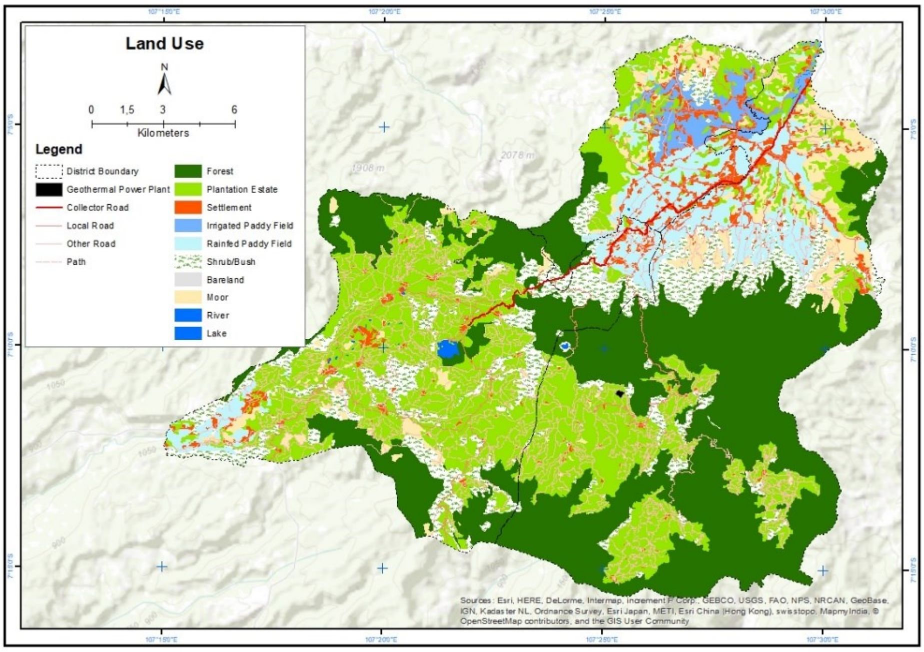

Figure 1. Land Use of The Patuha Mountain area

The Patuha Mountain area is found in three sub-districts, namely Ciwidey District, Rancabali District, and Pasirjambu District of Bandung Regency, West Java. Based on Digital Elevation Model (DEM) data, the Patuha Mountain Area has an elevation of 835-2,430 m above sea level (masl) with varying slope levels. Based on Junghunh's classification which divides the climate according to the altitude of the place and the distribution of cultivated plants, the Patuha Mountain Area is divided into two elevation classes, below 1,500 masl and above 1,500 masl. This height difference affects many biophysical factors, one of which is changes in temperature due to elevation that affect the distribution of plant species.

2.1 Ecosystem Services Selection

We decided to evaluate a single cultural ES (wood provision) instead of a bundle, to delve deeper and achieve a better understanding of the factors that might influence social valuation. To guide the exercise of mapping social values, we used natural capital as a proxy in explaining the stock of natural objects and relationships between these objects that are capable of producing a sustainable flow of biophysical resources that sustain both life and the human economy (Benra Ochoa et al. 2016). There are several factors that cause people to utilize wood from forest, namely economic factors, educational factors, natural factors, access, limited forest officials, and weak legal sanctions (Subarna 2016). In practice, management or utilization of forest resources by the community is positive and negative. The socio-economic characteristics of the people, such as the number of family members, age, education level, income level, length of stay, land ownership and number of plots of land that are controlled indirectly can affect forest cover.

2.2. Data Acquisition and GIS Analysis

To identify the stock of wood provision in the Patuha Mountain we used biomass estimation approach. Biomass as a mass or dry weight of vegetation can be calculated by several approaches. The calculated biomass can be either stem, root, or overall vegetation biomass. Anaya et al (2009) state that remote sensing is the best approach in estimating biomass at the regional level, especially when field data is difficult to obtain. The approach in estimating biomass through remote sensing is done by determining the level of vegetation density. The denser the vegetation at a location, the greater the biomass value (Frananda, Hartono, and Jatmiko 2015). In this case, the level of vegetation density can be measured through the vegetation index algorithm that is applied to the digital number of Landsat 8 satellite images.

Allometric data in the form of tree species, diameter at breast high (DBH), and individual tree height were collected from measurements in the field. Allometric data then processed to obtain field biomass values. In this study, the approach used in estimating biomass values is as follows (Krisnawati, Adinugroho, and Imannudin 2012) .

$$AGB = V \times WD \times BEF \quad (1)$$

Where AGB, V, WD, BEF are Aboveground biomass (kg), Volume (m^3), Wood density (kg/m^3), and Biomass expansion factor (BEF = 1.49), respectively

Tree volume is calculated through geometric equations using diameter at breast height and tree height (Krisnawati, Adinugroho, and Imannudin 2012). Wood density of each type of vegetation is obtained from worldagroforestry.org.

$$V = 0.25\, \pi\, (DBH/100)^2 \times H \times F \quad (2)$$

Where V, π, DBH, H, F are Volume (m^3), 3.14, Diameter at breast height (cm), Height (m), and F value is 0.6, respectively

To be able to find out how the patterns of behavior of the community in wood utilization, interviews were conducted with qualitative methods with non-probability sampling techniques and a mapping exercise (figure 2). The snowball sampling technique was chosen in this study as one type of non-probability sampling. Snowball sampling is a sampling technique that is carried out by taking a number of cases through a relationship between one person and another, who then seeks further relationships through the same source. The informants chosen in this study were Perhutani assistants as gate keepers, heads of the village forest community institutions (LMDH) as informants 1 and the community as informants. Information needed from Perhutani assistants is information related to programs or policies related to forest management and cases of timber theft cases in forest areas. The reason for choosing LMDH as informant 2 was because LMDH was an organization of community groups responsible for forest areas at the village level. The information needed from LMDH is information related to who is using the forest and how the forest is in the village. The selection of the community becomes a resource to find out information about how the distance and time needed to do forest encroachment. In addition, information on how the community moves towards the location of forest encroachment in the form of a travel route will also be generated from in-depth interviews with resource persons.

Spatial representation of natural capital and recreational activities relied on a printed map of the research area showing current land uses and covers. The base map also displayed rivers, main road networks, urban areas, names of particular places, and landscape attributes such as lakes, rivers, and volcanoes. For each interview, each informant draws based on their knowledge about the locations where they collected wood or timer from the forest.

Figure 2. Mapping exercise with respondent by plotting wood collecting locations

3. RESULT AND DISCUSSION

The relationship between biomass from field measurement and NDVI is explained through the regression equation. Based on regression analysis and correlation tests were conducted between the value of the biomass results of field measurements and NDVI value, the value of the coefficient of determination (R^2) is 0.8393 or 83, 93% with value of correlation (R) is 0.916 (Figure 3).The resulting regression equation is as follows.

$$Y = 253{,}89\ X - 124{,}58 \quad (3)$$

where Y and X are Biomass value (ton/ha) and NDVI value, respectively

The value of R^2 shows that the value of the contribution of the independent variable to the dependent variable. It is known that the NDVI value contributes 83,93 % to the biomass value, while 16.07% is influenced by other factors. The correlation coefficient of 0.916 which approaches a positive value of 1 indicates that the level of closeness between two variables is at a very close level, with the direction of the relationship being directly proportional. This regression equation will be used to estimate biomass values based on NDVI values in the study area

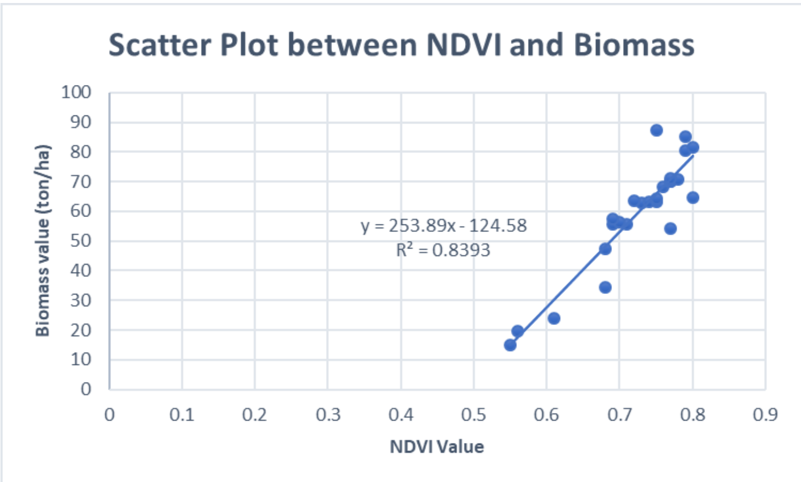

Figure 3. Regression analysis between NDVI and Biomass field measurement

Based on calculations through the regression equation, the total estimated biomass value in forest land cover in the study area is 10.360.730.09 tons / ha with distribution as shown in figure 4. Biomass distribution in the study area consists of pixels with a size of 30m x 30m , according to the pixel size of the spatial resolution of Landsat images. In figure 4, biomass values can be seen through three classifications based on the classification of natural breaks (jenks). This biomass classification presents biomass values per pixel. The biomass classification consists of low class (value less than 40 tons / ha), medium class (40-65 tons / ha), and high class (more than 65 tons / ha).

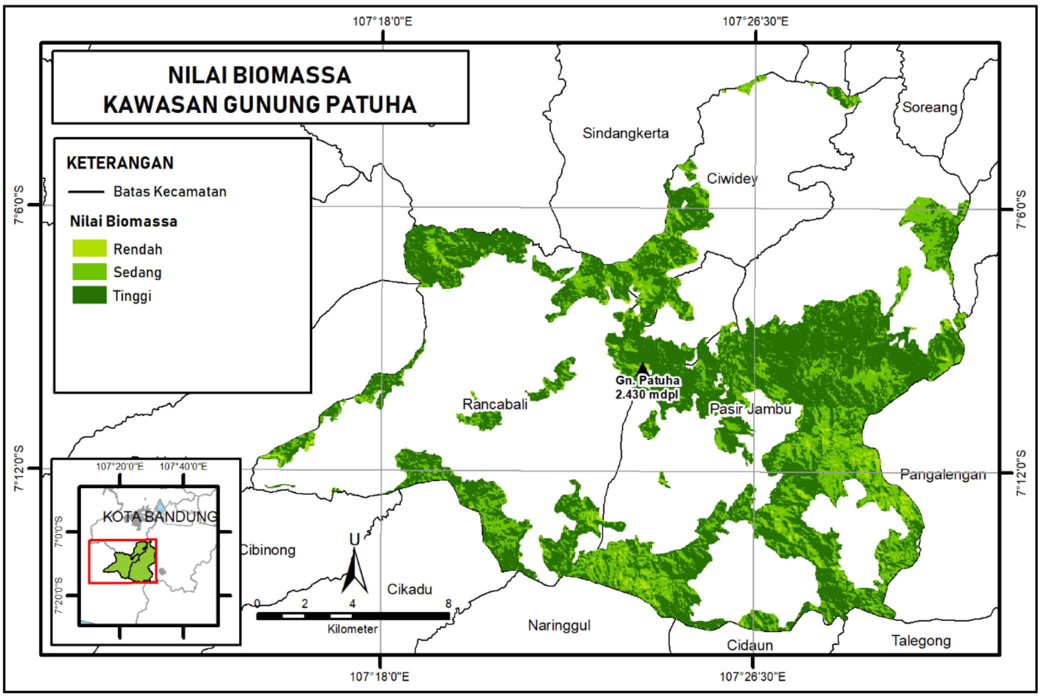

Figure 4. Forest cover biomass distribution of Patuha Mountain

The location of timber extraction in the Patuha Mountain Area is in a protected forest area managed by Perum Perhutani. The locations of timber extraction and entry points are spread almost in all protected forest areas. The types of forest that can be accessed are secondary forest and plants. Primary forest is relatively safer from encroachment because there is no access and the terrain is quite difficult to pass. The number of points taken by forest woods carried out by the community amounted to 20 points obtained from observations and interviews with informants. These encroachment points were obtained through plotting through direct observation of the location of the encroachment and the results of plotting by informants by showing on the map the location of the forest that had been encroached and extracted.

Community decision making in choosing locations and routes to utilize timber is influenced by accessibility factors. The existence of roads and road conditions greatly influences their decisions in determining the location and path chosen. In addition to the accessibility of the factors used to use timber, it also influences decision-making behavior in determining the path and location. The purpose of the community around the forest in utilizing forest wood is divided into 2, namely domestic and commercial use. The spatial behavior pattern of the community in utilizing wood can be seen from the usual route through and the reason for choosing the location for taking wood.

Domestic or private use of timber is mostly carried out by communities around the Patuha Mountain Forest. The use of timber by the community is in the form of the use of wood for personal use and not for sale. The use of timber by the community is in the form of utilization as fuel wood and building materials. Timber wood is obtained from forest areas that can be cultivated by the community. Wood that is usually taken by the community to be used as building material is eucalyptus, rasamala, or puspa. Meanwhile, wood for fuel is usually obtained from twigs or fallen trees.

From the informant's statement 2 it can be seen that the LMDH still tolerates the people who take wood with the aim of fulfilling their daily needs. They feel that the community has the right to benefit from wood from the forest because the community feels that they have guarded and cared for the forest, but on the other hand taking forest products in the form of wood is an illegal activity as stated in Article 26 of Law No. 41 of 1999 concerning Forestry.

Commercial use of timber is actually an illegal act if done in a protected forest area. But in reality in the Mount Patuha area there are still people who use wood in protected areas. One of them is informant 5 who is a coffee entrepreneur and also has processed wood products. In addition to having capital, informant 5 also has a high social position, namely as Chairperson of LMDH and Chair of RW in Cibodas Village.

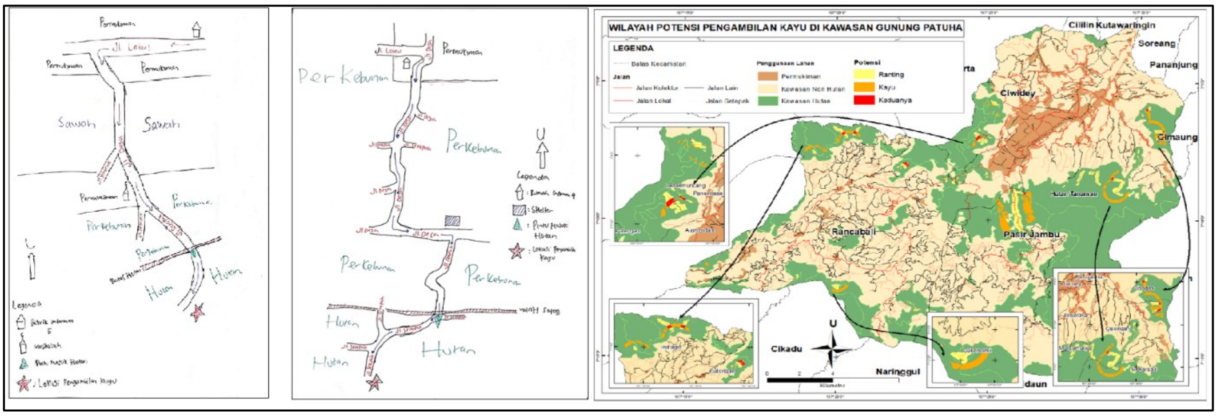

Figure 5. Result of informant mental map drwing and the GIS result of the potential location of wood and timber collection

The wood used by informants 5 is eucalyptus for building materials and cinnamon for the use of wood skin as food and stems as building materials. Informant 5 stated that the use of wood he did was because he felt that he was planting with personal capital and when he took the results he also did replanting. Commercial use of wood in the Patuha Mountain area is usually carried out secretly and tends to be clandestine from the government. The amount of wood taken for the intensity of cinnamon production is 10 trees once harvested every week. But the fact is that once transporting the crops, informants can use as much as 1 truck or 10-20 trees if seen from the specifications of the truck and the type of tree taken.

Geothermal development activities related to improving the quality of roads in forest areas indicate a connection with timber extraction activities in forest areas. This is also in accordance with the opinions of Laurance et al (2009) and Barber et al. (2014) that the construction of roads or linear clearing in forest areas can have an impact on the quality of forests and ecosystem services in them. Within the research area it was also found that unofficial access to forest access was found on road access which was also part of geothermal infrastructure.

4. CONCLUSION

Based on the results of the study it can be concluded that the forest area on Mount Patuha has a high biomass potential in the form of forest wood. The utilization of forest wood on Patuha Mountain is very limited because the status of the forest is a protected area. Community behavior in utilizing wood also determines the amount of timber ecosystem services. Such behavior is driven by the economic background of the people who still rely on forest wood for domestic and commercial purposes. Geothermal development activities in the form of improving the quality of roads that intersect with forest areas can affect the provision of timber ecosystem services in the region.

ACKNOWLEDGEMENT

This work is part of the Ph.D. research joint supervision between the University of Twente – The Netherlands and Universitas Indonesia - Indonesia which is funded by LPDP (Indonesia Endowment Fund for Education), Ministry of Finance, Republic Indonesia and GEOCAP Program under Work Package 2.08 to develop a number of cases showing the environmental impact of geothermal exploration and exploitation in a multi-temporal and spatial context.

REFERENCES

Anaya, Jesús A., Emilio Chuvieco, and Alicia Palacios-Orueta. 2009. "Aboveground Biomass Assessment in Colombia: A Remote Sensing Approach." *Forest Ecology and Management* 257(4): 1237–46. https://www.sciencedirect.com/science/article/pii/S0378112708008426 (July 30, 2019).

Barber, Christopher P., Mark A. Cochrane, Carlos M. Souza, and William F. Laurance. 2014. "Roads, Deforestation, and the Mitigating Effect of Protected Areas in the Amazon." *Biological Conservation* 177: 203–9. http://dx.doi.org/10.1016/j.biocon.2014.07.004.

Benra Ochoa, Felipe et al. 2016. "Mapping Social Values of Ecosystem Services: What Is behind the Map?" *Ecology and Society* 21(3).

Frananda, Hendry, Hartono Hartono, and Retnadi Heru Jatmiko. 2015. "Komparasi Indeks Vegetasi Untuk Estimasi Stok Karbon Hutan Mangrove Kawasan Segoro Anak Pada Kawasan Taman Nasional Alas Purwo Banyuwangi, Jawa Timur." *MAJALAH ILMIAH GLOBE* 17(2): 113–23. http://jurnal.big.go.id/index.php/GL/article/view/222 (July 30, 2019).

Haines-Young, Roy, and Marion Potschin. 2010. "The Links between Biodiversity, Ecosystem Services and Human Well-Being." *Ecosystem Ecology: a new synthesis*: 110–39.

Krisnawati, Haruni, Wahyu Catur Adinugroho, and Rinaldi Imannudin. 2012. *Monograf; Model-Model Allometrik Untuk Pendugaan Biomassa Pohon Pada Berbagai Tipe Ekosistem Hutan Di Indonesia*. Bogor: Ministry of Frestry.

Laurance, William F., Miriam Goosem, and Susan G.W. Laurance. 2009. "Impacts of Roads and Linear Clearings on Tropical Forests." *Trends in Ecology & Evolution* 24(12): 659–69. https://www.sciencedirect.com/science/article/pii/S0169534709002067?via%3Dihub (August 3, 2018).

Millenium Ecosystem Assessment. 2005. 5 Ecosystems *Ecosystems and Human Well-Being*. Washington, DC.

Ministry of EMR. 2016. *Statistik EBTKE 2016 [Renewable Energy Statistics 2016]*. Ministry of Energy and Mineral Resources, Republic of Indonesia.

Notte, Alessandra La et al. 2017. "Ecosystem Services Classification: A Systems Ecology Perspective of the Cascade Framework." *Ecological Indicators* 74: 392–402.

Richter, Alexander. 2019. "Global Geothermal Capacity Reaches 14,900 MW - New Top 10 Ranking of Geothermal Countries | Think GeoEnergy - Geothermal Energy News." *ThinkGeoEnergy*. http://www.thinkgeoenergy.com/global-geothermal-capacity-reaches-14900-mw-new-top10-ranking/ (July 30, 2019).

Semedi, J.M. et al. 2018. "Developing a Framework for Assessing the Impact of Geothermal Development Phases on Ecosystem Services." In *IOP Conference Series: Earth and Environmental Science*,.

Subarna, Trisna. 2016. "Faktor Yang Mempengaruhi Masyarakat Menggarap Lahan Di Hutan Lindung: Studi Kasus Di Kabupaten Garut Jawa Barat." *Jurnal Penelitian Sosial dan Ekonomi Kehutanan* 8(4): 265–75.

United States Environmental Protection Agency. 2015. *National Ecosystem Services Classification System (NESCS): Framework Design and Policy Application*. Washington, DC.