Journal of Applied Agricultural Science and Technology
4 (2): 146-154 (2020)
E-ISSN: 2621-2528
ISSN: 2621-4709

LAND SUITABILITY EVALUATION OF COFFEE IN TOKUNOSHIMA ISLAND, JAPAN

Endar Hidayat[1], Asmak Afriliana[1,2], Gusmini[3], Hiroyuki Harada[*, 1]

[1]Department of Environmental Science, Prefectural University of Hiroshima, Shobara, Japan
[2]Department of Agricultural Product Technology, University of Jember, Jember, Indonesia
[3]Department of Soil Science, Andalas University, Padang, Indonesia

*Corresponding author
Email: ho-harada@pu-hiroshima.ac.jp

Abstract. *Japan is the 3rd largest importer and consumer of coffee in the world. Considering have many demands of coffee, Japan is looking alternatives for improving to growing and the productivity of coffee. The research was aimed to assessment land suitability class for (arabica and robusta) coffee and land suitability evaluation of coffee. 3 soil samplings were collected from the study area. Matching method is used to evaluate the land suitability with parameter: temperature, elevation, rainfall, slope, pH, and nitrogen. The results showed that climate and physical condition of land area very suitable to grow robusta crops, and its level appropriateness is S1 (highly suitable). However, typhoon is problem in every year for growing coffee crops, but it can be handling by planting protecting crops.*
Keywords: *land suitability evaluation; tokunoshima island; coffee*

1. Introduction

Coffee is a major product of consumption on a global scale. In April 2020, Japan`s import of green beans coffee as much as 31,167 tons (All Japan Coffee Association, 2020), and become is the 3rd largest importer and consumer of coffee in the world. Therefore, Japan don`t have production (International Coffee Organization, 2020). Considering have demands of coffee, Japan is looking alternatives for improving to growing and the productivity of coffee by determination the potential of land use.

Land evaluation is alternative way to predicting the potential of land according to the specific types of use (Sonneveld *et al*., 2010; Martin & Saha, 2009). The principle land suitability evaluation is defined the potential and limitation (Pan & Pan, 2012), also process to assess of land performance for crop production (He *et al*., 2011; Mu, 2006; Prakash, 2003).

Coffee crops (arabica and robusta) can grow optimal in the range of temperature between 16-25°C (Djaenuddin *et al.,* 2003). The area of suitable for growing coffee crops in Japan is Tokunoshima Island. In summer, the average temperature of 25–29°C and in winter, the average temperature of 15–18°C (Yamazaki & Okamura, 1989). Therefore, it is necessary to analyze land suitability for coffee crops in Tokunoshima Island as an effort to increasing coffee productivity to become one of the main comodities in Japan. This study aimed for assessment land suitability class for (arabica and robusta) coffee and land suitability evaluation of coffee in Tokunoshima Island, Japan.

Received 26 May 2020; Received in revised form 20 August 2020; Accepted 27 August 2020

https://doi.org/10.32530/jaast.v4i2.169

2. Methods

2.1. Description of The Study Area

These study was conducted in Tokunoshima Island, Japan. The island divided into three administrative towns: Tokunoshima, Isen, and Amagi can be seen in Figure.1. Tokunoshima is located in East China Sea. The island is divided three administrative towns: Tokunoshima, Isen, and Amagi. The area of island is 247.77 km^2 (95.66 sq mi) (Wikipedia, 2020).

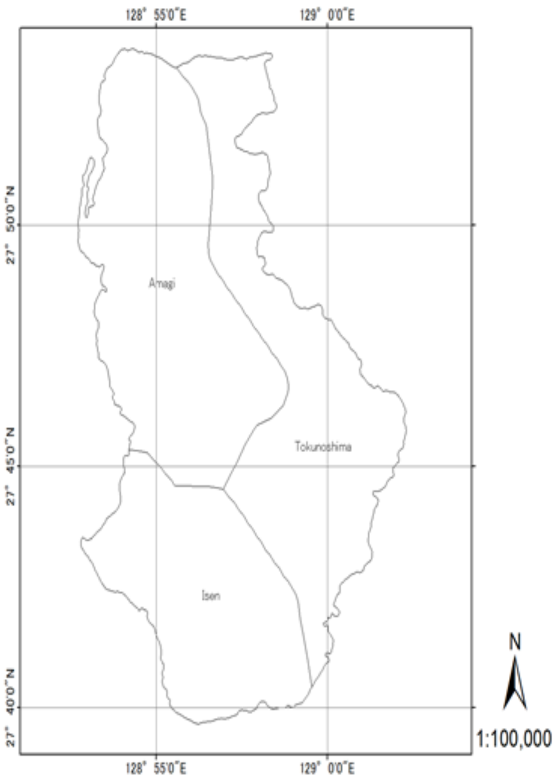

Figure 1. Administrative map

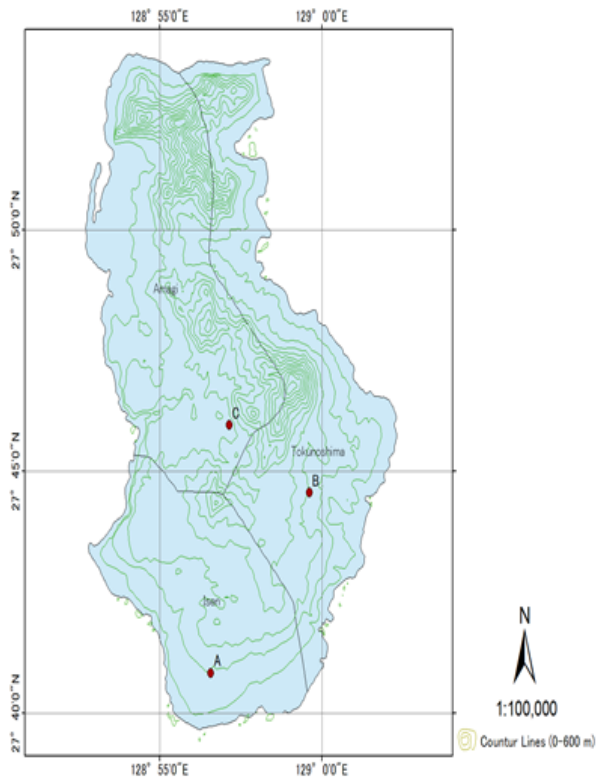

Figure 2. Soil sample map

2.2. Data and Soil Samples

Total samples taken 3 soil samplings were collected from the study area by purposive area sampling as shown in Figure 2. The soil samples were air dried and grounded to pass throught a 2-mm sieve and some were further crushed to pass through a 0.5-mm sieve before laboratory testing. The digital elevation model (DEM) dataset with a 30 m x 30 m resolution were obtained from the SRTM (Shuttle Radar Topography Mission) and then were processing for the topography map can be seen in Figure 3 and elevation map can be seen in Figure 4 by used ArcGIS 10.41.

2.3. Chemical Analysis

The chemical analysis included: the pH was measured used IAQUA twin-pH-22B using a suspension of 1:5 (w/v) (Rice, 1996; Houba *et al.*, 1995). Total nitrogen were determined in dry sample by Macro Corder-MT 6. To obtain a homogenous, the samples were air-dried for one week. Afterward, the sample was ground by using a coffee mill to pass through a sieve (Dadi *et al.*, 2012).

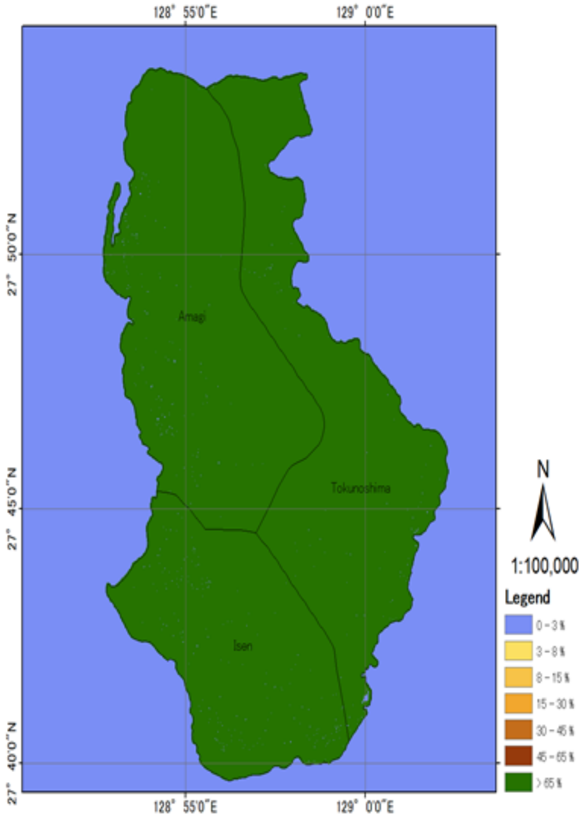

Figure 3. Topography map

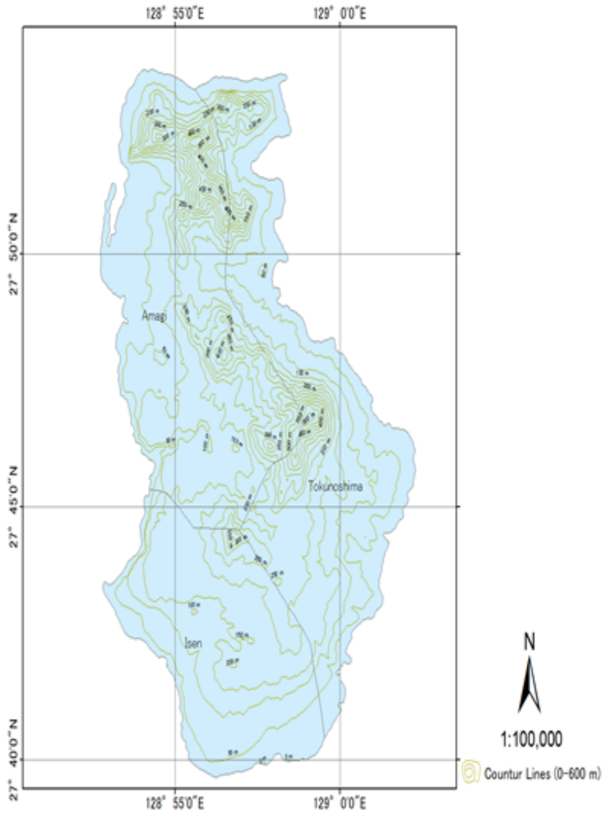

Figure 4. Elevation map

Table 1. Land characteristic of arabica and robusta coffee

Land Characteristic	S1	S2	S3	NS
Temperature (^{0}C)				
Arabica Coffee	16-22	15-16	14-15	<14, >22
Robusta Coffee	22-25	-	19-22	<19, >25
Elevation (m asl)				
Arabica Coffee	1000 – 1500	1500 – 1700	1700 – 2000	>2000, <1000
Robusta Coffee	200 - 700	0 - 200	700 - 1200	>1200
Rain fall (mm)				
Arabica Coffee	1200-1800	1000-1200	2000-3000	<1000, >3000
Robusta Coffee	2000-3000	1750-2000	1500-1750	<1500, >3000
Slope (%)	<8	8-16	16-30	>30
pH				
Arabica Coffee	5.6-6.6	6.6-7.3	<5.5, >7.4	
Robusta Coffee	5.3-6.0	6.0-6.5	>6.5	
		5.0-5.3	<5.0	
Nitrogen (%)	>0.21	0.1-0.2	<0.1	

S1: highly suitable, S2: moderately suitable, S3: marginally suitable, NS: not suitable

2.4. Assesment and Interpretation Data

The evaluation procedure was based on Djaenuddin *et al*., (2003) as shown in Table 1. This implies that land will be classified into one of the suitability classes highly suitable (S1), moderately suitable (S2), marginally suitable (S3), or not suitable (NS). A matching process is where the values of each land characteristic observation are compared with the requirement in each land utilization type can be seen in Table 1. If the value within the range accepted by the land utilization type, then land characteristic observation is classified within the relevant suitability class.

3. Results and Discussion

3.1. Topography

Topography is frequently used as criteria to assess land capability and suitability for agriculture (Van Orshoven *et al.*, 2008). Topography have greatly impact to the speed and volume of water run-off. As shown in Figure 3, that Tokunoshima Island have relief are flat <8% and very steep mountainous >65%. According to Djaenuddin *et al.* (2003), that the area included S1 (highly suitable) and included NS (not suitable) as shown in Table 1. Relief as such has little or no direct influence on the yield of crops. However, the deep of relief more difficult it becomes to manage land and growing coffee crops. Santoso and Nursandi (2004) reported that for decreasing level slope can conduct with two kind crops or more by random between the main of crop and protecting crops. This model can apply to the land at level slope 15-40%. While in under 8% can be made terrace bench and rorak (Ministry of Agriculture Republic Indonesia, 2014). Protecting crops have function for decreasing water erosion (Battany & Grismer, 2000). Wati *et al*., (2014) reported that the highest level slope will impact to grow and productivity of coffee crops.

3.2.Elevation

Elevation of Tokunoshima Island are shown in Fig. 4, which between range from 0 to 600 m above sea level. This is indicate that Tokunoshima Island is suitable for growing robusta coffee than arabica coffee is included S1 (highly suitable) and S2 (moderately suitable) as shown in Table 1 (Djaenuddin *et al*., 2003).

3.3.Temperature

Temperature is the main factors for growing coffee crops. Tokunoshima Island have average annual temperature is 21.3^{0}C (Climate-data, 2020). Djaenuddin *et al*. (2003) reported that Tokunoshima Island is suitable for growing arabica and robusta coffee crops. If arabica coffee crops grow more than the temperature of 25^{0}C, the photosynthesis rate will decrease and defective on leaves is marked by chlorosis (Willson, 1985). Robusta coffee crops can grow optimal in both of high and low humidity along the short of dry season, while arabica coffee crops requires low humidity (Coste & Cambrony, 1992).

3.4. Soil Reaction (pH)

The pH is very important to detected. The pH value of soil is directly impact to nutrient availability of plant growth, for instance coffee tree. In acid soils, many elements such as Fe, Zn, Mn, and Cu become easily soluble while N, P, K become less available and it will become toxic to the plant. Generally, nutrients are absorbed by the roots at pH 6-7 and easily soluble in water.

If the values above or below these ranges may result. As shown in Table 2, the criteria of pH value in the research area are netral which in the range 6.85 to 7.15. According to Djaenuddin *et al.* (2003), that all research area included S2 (moderately suitable) for arabica coffee and S3 (marginally suitable) for robusta coffee.

Table 2. The pH of value in the research area

Area	pH	Land Suitability	Criteria*
A	6.85	S2 (Robusta coffee) S3 (Arabica coffee)	Netral
B	7.15	S2 (Robusta coffee) S3 (Arabica coffee)	Netral
C	7.08	S2 (Robusta coffee) S3 (Arabica coffee)	Netral

**Hardjowigeno (2003), S2: moderately suitable, S3: marginally suitable*

3.5. Total Nitrogen

Nitrogen is macro nutrient that is important to plant growth. As shown in Table 3, total nitrogen in the research area are low and moderate which in the range 0.1% to 0.36%.

Table 3. Total nitrogen properties in the research area

Area	Total Nitrogen (%)	Land Suitability	Criteria*
A	0.36	S1 (Arabica and robusta coffee)	Moderate
B	0.1	S2 (Arabica and robusta coffee)	Low
C	0.22	S1 (Arabica and robusta coffee)	Moderate

**Hardjowigeno (2003), S1: highly suitable, S2: moderatelly suitable*

According to (Ministry of Agriculture Republic Indonesia, 2014), that area A included S1 (highly suitable), area B included S2 (moderately suitable), and area C included S1 (highly suitable) for arabica and robusta coffee as shown in Table 3. One of the efforts to increasing the value of nitrogen is growing protecting crops. Protecting crops have function produces organic waste (Ramadhani, 2011; Soedradjad & Usmadi, 2011) and provide food and energy source for soil microorganisms and fauna that improve to soil physical, chemical and biological properties and plant (Parkin *et al*., 2006).

3.6.Typhoon

Tokunoshima Island is located in South of Japan that have typhoon season on July to October (Okinawa Meteorological Observatory, 1998) with average rainfall 320 mm/12.6 inch in June and 2418 mm/95.2 inch per year (Climate-data, 2020). Matiello *et al*. (2002), reported that typhoon have impact on the development of the flower and cherry of the coffee crops even there are some plant it was lifted up from the ground. Based on interview with coffee farmers that typhoon a passed through Tokunoshima Island when the coffee crops began to harvest and impact to productivity. Alternative way to control typhoon is by planting protecting crops. The importance of protecting crops in controlling water erosion and produce organic waste as source nutrient to soil and plant (Zuazo & Pleguezuelo, 2008) also prevention from wind (Battany & Grismer, 2000). Protecting crops has two types i.e permanent and temporary. For protecting crops by permanent can used by silver oak *(Grevillea robust)*. Advantages of this crops is exposed to strong winds (Orwa *et al.*, 2009; Winston 2005; Harwood, 1989). For protecting crops by temporary can used i.e *Flemingia Congesta* included *Leguminosa*. Advantages of this crops is rapid grows, leaves are soft and easily destroyed on ground surface.

3.7. Land Suitability

Land and climate have role in the grow, production, quality and flavor of coffee crops. On a wide scale, land is difficult to modification for avoid death risks on coffee crops. Land information for coffee crops should be a main guideline in carrying out the development of coffee crops in central coffee plantation. Ritung *et al.* (2007) reported that land evaluation is a process assessment for a particular purpose by using approaching, where the results of land evaluation will provide information land use. The methods were used by comparison (matching) (Djaenuddin *et al.*, 2003). The matching method is comparing land suitability class based on the lowest value as a limiting factor in the evaluation of land suitability.

3.7.1. Land of current suitability

The current of suitability were determined by considering without any improvement to the factors limiting. Limiting factors in land evaluation divided into two factors i.e permanent and non-permanent factors. Permanent limiting factors need high technology while nonpermanent limiting factors without high technology for suitable on land characteristic.

As shown in Table 4, that current suitability for robusta have limiting factors i.e slope included NS (not suitable), pH included S3 (marginally suitable) and total nitrogen included S2 (moderately suitable). While as shown in Table 5, that current suitability for robusta have limiting factors i.e elevation included NS (not suitable), slope included NS (not suitable), pH included S2 (moderately suitable), and total nitrogen included S2 (moderately suitable).

Table 4. Currently suitability for robusta coffee

Land Characteristic	A	B	C
Temperature (^{0}C)	S1	S1	S1
Elevation (m asl)	S1	S1	S1
Slope (%)	NS	NS	NS
pH	S3	S3	S3
Nitrogen (%)	S1	S2	S1

S1: highly suitable, S2: moderately suitable, S3: marginally suitable, NS: not suitable

3.7.2. Land of potential suitability

The potential of suitability were determined by considering input and management measures given to each of land unit. Based on Table 4 and Table 5, the criteria of pH are S3, S2 for robusta and arabica coffee, respectively. According to Djaenuddin *et al.,* (2003), the highly suitable (S1) for arabica coffee in the range 5.6 – 6.6, and 5.3-6.0 for robusta coffee. For decreasing the soil pH are giving aluminium sulfate and sulphur to the land area of coffee plantation (McCauley *et al.,* 2017).

Table 5. Currently suitability for arabica coffee

Land Characteristic	A	B	C
Temperature (^{0}C)	S1	S1	S1
Elevation (m asl)	NS	NS	NS
Slope (%)	NS	NS	NS
pH	S2	S2	S2
Nitrogen (%)	S1	S2	S1

S1: highly suitable, S2: moderately suitable, S3: marginally suitable, NS: not suitable

Table 6. Potential suitability for robusta coffee

Land Characteristic	A	B	C
Temperature (^{0}C)	S1	S1	S1
Elevation (m asl)	S1	S1	S1
Slope (%)	S1	S1	S1
pH	S1	S1	S1
Nitrogen (%)	S1	S1	S1

S1: highly suitable

Table 7. Potential suitability for arabica coffee

Land Characteristic	A	B	C
Temperature (^{0}C)	S1	S1	S1
Elevation (m asl)	NS	NS	NS
Slope (%)	S1	S1	S1
pH	S1	S1	S1
Nitrogen (%)	S1	S1	S1

S1: highly suitable, NS: not suitable

The nitrogen in soil might be used by plants as source minerals for plant growth. The lack of nitrogen in plant is usually pale green or yellowish and leaves often become necrotic. The criteria of nitrogen in the study area are from S1 (highly suitable) to S2 (moderately suitable). Alternatives for increasing total nitrogen in soil are giving nitrogen source such as fertilizers. While for improving criteria of slope that planting protecting crops. Protecting crops have function for preventing from wind such as typhoon. run off and erosion. As shown in Table 6, that potential suitability for robusta coffee included S1 (highly suitable). While potential suitability for arabica coffee have heavy limiting factors i.e elevation included NS (not suitable) as shown in Table 7. Based on the results that Tokunoshima Island is suitable for growing robusta coffee crops than arabica coffee crops. But have heavy limiting factor is typhoon which is not included in land characteristic of arabica and robusta coffee.

4. Conclusions

Tokunoshima Island suitable for growing robusta coffee crops than arabica coffee crops. However, the area have limiting factor such as elevation, slope, pH value, nitrogen value, and typhoon. For increasing nitrogen value that might giving source nitrogen such as fertilizers, and planting protecting crops for preventing from wind such as typhoon, run off, and erosion. Also as source nutrient for soil that leaves fall to the ground.

Acknowledgement

I would like to thanks to Japanese Government for support financial during master degree program at Prefectural University of Hiroshima, Japan.

References

All Japan Coffee Association. (2020, July 15). Monthly Trade Statistics (IMPORT). Retrieved from : http://coffee.ajca.or.jp/english/monthlydata.

McCauley, A., Jones, C., & Olson-Rutz, K. (2017). *Soil pH and organic matter. Nutrient management module No. 8*. Bozeman: Montana State University.

Battany, M., & Grismer, M. E. (2000). Rainfall Runoff and Erosion In Napa Valley Vineyards: Effects Of Slope, Cover And Surface Roughness. Hydrol. Process. 14, 1289–1304.

Climate-Data. (2020, August 20). Tokunoshima Climate. Retrieved from: https://en.climate-data.org/asia/japan/kagoshima-prefecture/tokunoshima-50765/#temperature-graph.

Coste, R., & Cambrony, H. (1992). Coffee: The Plant and The Product. London, England: Macmillan Press Ltd.

Dadi, D., Sulaiman., H., & Leta, S. (2012). Evaluation of Composting and The Quality of Compost from The Source Separated Municipal Solid Waste. *Journal of Applied Science Environmental Management.* 16, 5–10.

Djaenuddin, D., Marwan, H., Subagjo, H., & Hidayat, A. (2003). Technical Guidance of Land Evaluation for Agricultural Comodities. Soil Research Institute. Bogor, Indonesia: Agricultural Research and Development Agency.

Hardjowigeno, S. (2003). *Soil Science. Ilmu Tanah* [ID]. Jakarta, Indonesia: Akademika Pressindo.

Harwood, C. E. (1989). *Grevillea robusta: an annotated bibliography*. Nairobi, Kenya: International Council for Research in Agroforestry (ICRAF); 123 pp.; 224 ref.

He, Y., Yao, Y., Chen, Y., & Ongaro, L. (2011). Regional Land Suitability Assessment for Tree Crops Using Remote Sensing and GIS. Computer Distributed Control and Intelligent Environmental Monitoring (CDCIEM) IEEE, Changsha, pp. 354–363.

Houba, V. J. G., Novozamsky, I., & Van der Lee, J. J. (1995). Influence of storage of plant samples on their chemical composition. *Science of the total environment*, 176(1-3), 73-79.

International Coffee Organization. (2020, July 15). Imports of Coffee by Selected Importing Countries. Retrieved From: http://www.ico.org/prices/m4-imports.pdf

Martin, D., & Saha, S. K. (2009). Land Evaluation by Integrating Remote Sensing and GIS for Cropping System Analysis in a Watershed. Current Science 96, 1.

Matiello, J. B., Santinato, R., Garcia, A. W. R., Almeida, S. R, & Fernandes, D. R. (2002). Cultura do café no Brasil : novo manual de recomendações. Rio de Janeiro, Brasil: MAPA.

Ministry of Agriculture Republic Indonesia. (2014). Pedoman Teknis Budidaya Kopi yang Baik. Good Agriculture Practices/GAP on Coffee [ID]. Number: 49/Permentan/OT.140/4/2014.

Mu, Y. (2006). Developing a Suitability Index for Residential Land Use: A Case Study in Dianchi Drainage Area. University of Waterloo, Canada.

Okinawa Meteorological Observatory. (1998). Commentaries on the Meteorology of Okinawa (Climate of the Ryukyu Chain). Naha, Japan: Japan Weather Association Okinawa Branch. (in Japanese).

Orwa. C., Mutua. A., Kindt. R., Jamnadass. R., & Simons, A. (2009). Agroforestry Database: a tree reference and selection guide version 4.0. World Agroforestry Centre. Retrieved from : http://www.worldagroforestry.org/af/treedb/.

Pan, G., & Pan, J. (2012). Research in Crop Land Suitability Analysis Based on GIS. Computer and Computing Technologies in Agriculture 365, 314–325.
Parkin, T. B., Kaspar, T. C., & Singer, J. W. (2006). Cover crop effects on the fate of N following soil application of swine manure. Plant Soil 289, 141–152.
Prakash, T. N. (2003). Land Suitability Analysis for Agricultural Crops: A Fuzzy Multicriteria Decision Making Approach, Science in Geoinformatics. ITC, Netherlands, pp. 6–13.
Ramadhani, A. (2011). *Study of Soil Nitrogen Status of Farmer Coffee Plantation with Different Plant Shade in Sidomulyo-Silo, Jember*. (Master's thesis). Retrieved from http://repository.unej.ac.id/handle/123456789/6468
Rice, H. (1996). Monitoring Compost pH, C/N ratio. Cornell Waste Management Institute Dept. of Crop and Soil Sciences Cornell University. Retrieved from http://cwmi.css.cornelledu.
Ritung, S. W., Wahyunto, Fahmuddin, A., & Hidayat, H. (2007). Guidelines for Land Suitability Evaluation of Land Use Map in West Aceh. Soil Research Institute and World Agroforestry Centre. Bogor.
Santoso, U., & Nursandi, F. (2004). Plant Tissue Culture. (Kultur Jaringan Tanaman). Malang, Indonesia: University Muhammadiyah Malang..
Soedradjad, R., & Usmadi. (2011). Role of Shade Plant in Supplying Macro Nutrients to Coffee Plantation. *Agritop : Journal of Agriculture Science*. Pages: 166-170.
Sonneveld, M. P. W., Hack-ten Broeke, M. J. D., Van Diepen, C. A., & Boogaard, H. L. (2010). Thirty years of systematic land evaluation in the Netherlands. *Geoderma*, 156(3-4), 84-92.
Van Orshoven, J., Terres, J. M., & Eliasson, A. (2008). *Common Bio-physical Criteria to Define Natural Constraints for Agriculture in Europe*. EUR. 23412 EN. Luxembourg: Office for the Official Publications of the European Communities.
Wati, Y., Rusli, M., Alibasyah, & Manfarizah. (2014). The Effect of Slopes and Organic Fertilizers on Runoff, Erosion and Yield of Potatoes in Atu Lintang Sub-district Aceh Tengah Regency. *Jurnal Manajemen Sumberdaya Lahan*, 3(6), 496-505.
Wikipedia. (2020, August 20). Tokunoshima. Retrieved from https://en.wikipedia.org/wiki/Tokunoshima.
Willson, K. C. (1985). *Climate and soil. In Coffee* (pp. 97-107). Springer, Boston, MA.
Winston, E., Op de Laak, J., Marsh, T., Aung, O., & Chapman, K. (2005). Arabica Coffee Manual for Myanmar. Food and Agriculture Organization of the United Nations. FAO Regional Office for Asia and the Pacific, Bangkok. IABN: 974-7946-72-6.
Yamazaki, T., & Okamura, Y. (1989). Subducting Seamounts and Deformation of Overriding Forearc Wedges Around Japan. *Tectonophysics*, 160, 207-229.
Zuazo, V. H. D., & Pleguezuelo, C. R. R. (2009). Soil-erosion and Runoff Prevention by Plant Covers: a review. *In Sustainable agriculture* (pp. 785-811). Springer, Dordrecht.