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THE EFFECT OF MERAPI VOLCANO ERUPTION ON LAND USE CHANGE AND AGRICULTURE

I N F O A R T I K E L

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A B S T R A C T

There are four purposes of this research. To know the effect of Merapi Volcano eruption on land use change and agriculture. Identify the most suitable crops in for affected areas. To advise the Sleman government about more suitable land use, thus increasing the local potential. To help the farmers overcome negative effects of the eruption as soon as possible. This research conducted in Cangkringan District, Sleman Regency, Yogyakarta Province, Indonesia and only focused on three eruptions, 2001, 2006, and 2010. The methodologies to do this research are interviews, questionnaires, observations, collect data from Sleman Regency Government, and study the satellite images from the United States Geological Survey. The researcher interviews seven government officers and uses 300 questionnaires to get the information from the farmers. The researcher observes the study site and distributes the questionnaire at the same time. Data from Sleman Regency government is about the farming product of Cangkringan and maps of Sleman Regency. This research use satellite image from Landsat 7 ETM+ starts from 2000-2011 in path 120 and row 65. The result shows that the eruption in 2001 and 2006 did not give significant effect on land use change and agriculture in Cangkringan. The eruption in 2010 gives huge effect to the land use and agriculture in Cangkringan. Agriculture is the most suitable land use in Cangkringan. In addition, the suitable crops for the areas around Merapi Volcano are corn, peanut, spring onions, and onions that resistant to silica content in the fresh volcanic soil. To improve the local potential and improve the socio-economic level for people in Cangkringan, a combination of agriculture and recreation industry in Cangkringan can be use.

Key words: Merapi Volcano, eruption, Cangkringan, agriculture, land use, socioeconomic

I. INTRODUCTION

Eruption is a common disaster around volcanoes not only in Indonesia but also in around the world. The eruption occurred at least 50 - 60 times a year in the world, for example, an eruption occurs twice a year in Alaska (Keller, 1996). The percentage of active volcanoes about 13% - 17% in the world are located in Indonesia (Wahyunto and Wasito, 2013). Seventy of active volcanoes are very dangerous so the government and the society have to pay attention to it. One of the most active and dangerous volcanoes is Merapi Volcano (Wahyunto and Wasito, 2013). According to Sparks (1981) and Voight et. al. (2000), MerapiVolcano is the most active volcano in the world. The eruption period of Merapi Volcano is between three to six years or nine to twelve years for a major eruption (Wahyunto and Wasito, 2013).

In general, the land around the volcano is fertile because of the volcanic material that mixed with the soil. In Indonesia, especially Merapi Volcano surrounded by nine sub-districts in Yogyakarta and Central Java, which has a high population. The society prefers to stay around the volcano even it is dangerous rather than move to the other place because the soil is fertile and suitable for agriculture (Muharam, 2013). Farmers can grow many kinds of the crop in the land around an active volcano. Nevertheless, different countries have different agricultural land use around the volcano. For example, in Rabaul Mountain Papua New Guinea, most of the farmer plant cocoa and coconut (Neumann, 1996 cited in Lebon 2009). In Mount Santa Maria, Guatemala, coffee is the main commodity (Thornton, 2000 cited in Lebon 2009) as well as in Mount Poas, Costa Rica (Rymer and Haris, 2002 cited in Lebon 2009). In Pinatubo Mountain, the Philippines, sugar cane, and Rice are the main agriculture product (Lebon, 2009). The different condition happens in Japan, Mount Unzen. The farmers were planting tobacco before the eruption. However, it changed to be greenhouse horticulture after the eruption (Nagasaki Prefectural Government, 2007a, cited in Lebon 2009). Volcano eruption often destroyed the settlement, agriculture land, the mountainside, and alongside streams which flowed volcanic material. The damaged area is the areas passed by the lava, pyroclastic and volcanic mudflow. The most significant damage of them usually occurs in the farming area and the settlement. One of the biggest eruptions happened in 2010. According to Wahyunto and Wasito (2013), the destruction because of the eruption in 2010 divided into four criteria:

(1) Burned area and the area which covered by volcanic material because it exceeded by the lava
(2) Burned area and the area covered by volcanic material because it passed by the Pyroclastic
(3) The area which covered by the thick volcanic ash
(4) The area that covered by the volcanic material because of the mudflow. Volcanic mudflow is the second highest threat of an eruption after pyroclastic flow.

Every volcanic material will give the different impact to the environment. Winarti (2012) cited in Wahyunto and Wasito (2013) explain that eruption materials that can destroy the environment are lava, pyroclastic, ash rain or sands, toxic gas, and the volcanic mudflow. The lava can be damage all infrastructure in its path, but it can be the stone source after the lava is getting cold. The pyroclastic can burn all living creatures are exposed. Volcanic ash can destroys the leaves, house, and contaminates the water source. Mudflow flood can happen when the water volume in the crater is overflow and it is dangerous for the community around the river.

Deposition of volcanic material on the soil surface can change the physical andchemical characteristic of the soil. Accumulation of volcanic material sized dust, sand, and stone can affect the structure and texture of the topsoil. It can give effect to the soil fertility (Wahyunto and Wasito, 2013). The changes of soil chemical characteristic might change the suitability of land. Based on field observation in February 2011, Merapi eruption affected to the changes of physical and chemical condition of the soil (Wahyunto and Wasito, 2013).

In general, the geological history of Merapi Volcano divided into four periods, namely Pre Merapi, Old Merapi, Young Merapi, and New Merapi. The first period was Pre Merapi that began around 700,000 years ago and currently can be seen as Bibi Mountain (2,025 meters above sea level) on the northeast slope of Merapi Volcano. The lava characteristic of Bibi Mountain is basaltic andesite lava. The second period was Old Merapi that leaving Turgo and Plawangan Hill 60,000 - 8,000 years old. Turgo and Plawangan Hill located on the southern slopes of Merapi Volcano. The third period was Young Merapi that active between 8,000 - 2,000 years ago. Young Merapi formed Batu Lawang and Gajah Mungkur Hill and leaving Pasar Bubar Crater. The fourth period called the New Merapi where the peak of Merapi formed in the former Pasar Bubar crater called the New Merapi Volcano (Geological Agency, 2014).

Merapi Volcano is located crosses two transverse and longitudinal faults (Sutikno et. al., 1996). Geographically, Merapi is located in 7º32’30’’S and 110º26’30’’E (Geological Agency, 2014). Administratively, Merapi volcano is located in Special Region of Yogyakarta and Central Java. Merapi is part of four regencies, Sleman Regency in Yogyakarta, Magelang, Klaten, and Boyolali Regency in Central Java (Geological Agency, 2014). The most active volcano located near the junction of tectonic plates because volcanic activity closely related to the activities of tectonic plates (Keller, 1996).

In normal conditions and activities, Merapi volcano provides many benefits to the surrounding community (Soelaeman and Idjudin, 2013). The first benefit is the fertile soil around Merapi. It can produce many kinds of the farming commodity in good quality and quantity. The second benefit is Merapi area has a large number of springs that can fulfill the water needs of surrounding community. Another benefit is the beautiful natural scenery and fresh air that strongly support the development of recreation industry. In addition, Merapi Volcano produces volcanic material 1.2 million cubic meters per year that deposited on its slope. Merapi volcanic material sediment density is between 2.65 grams/milliliter and 2.70 grams/milliliter and the clay content is 0.06% - 1.40%. Thus, Merapi volcanic material has a high quality of building materials. This condition makes the sediment (sand) mining popular throughout the area around Merapi as a source of income (Sudarman and Wahyunto, 2013).

Stratigraphic and geochemical studies of Merapi Volcano (Supriyati D.A., 1999 cited in Geological Agency, 2014) showed that two major eruptions occurred during the Middle Merapi and Recent Merapi Period. Verstappen (1963); Gertisser and Keller (2003) in prehistoric times the average return period of the eruption on a scale 4 VEI (Volcanic Explosivity Index) is 100 - 200 years old, whereas on a scale 5 VEI occur on average once every 1,000 years. A major eruption of Merapi Volcano in the 19th up to 10th century occurred in 1872 and reached the scale 4 VEI and pyroclastic flows reached 20 kilometers from the crater (Kadumor and Yamamoto, 1980). The last occurrences in 2010 led to 11,000 people were homeless and 350,000 people who evacuated at the time of eruption (Wahyunto and Wasito, 2013). In addition, the eruption in 2010 also led to the forest, agriculture land, infrastructure, and settlement destruction with the estimated losses + 7.1 trillion rupiahs (Daniel, 2011 cited in Wahyunto and Wasito, 2013). Merapi eruptions have impacts on agricultural, infrastructure, and social (AARD, 2006; Gertisser and Keller, 2003; Charbonnier and Gertisser, 2008).

Using remote sensing/satellite imagery method, the damage caused by the eruption of Merapi Volcano can be distinguished (Wahyunto and Wasito, 2013):

1) Areas burned and covered by volcanic material as lava flow area.
2) Areas burned and covered by volcanic material since elapsed pyroclastic flow.
3) Areas covered by thick volcanic ash material.
4) Areas covered by volcanic material because of the lahar or secondary mudflow. Based on the sequence or chronological occurrence of damage caused by Merapi

Volcano eruption can be distinguished (Wahyunto and Wasito, 2013):

1) Direct damage, occurred at the stage of eruption caused by the pyroclastic flow, including lava flow and volcanic ash.
2) Indirect damages, occurred after the eruption because of lahar flow (volcanic material pile fading due to water flow).

Generally, land use around volcanoes in Indonesia is forest, agriculture area, settlement, bare land, bush, and other land use (Bashori et.al., 2013). Like the other volcanoes surrounding the area, Sleman Regency has seven kinds of land use such as residential, wetland farming, dryland farming, forest, bare land, bush, and some other land use (Statistics of Sleman Regency, 2014). The vegetable is one of the main product in the area surrounding Merapi Volcano that very susceptible to the natural hazard and climate change (Muharam, 2013 and BPTP Central Java, 2011). Volcanic soils have very good properties for all types of crops (Verheye, 2009).

Agriculture is a common land use in a volcanic area such as in Dieng Plateau that surrounded by Sindoro Volcano and Sumbing Volcano (Fandik, 2011). In Dieng, some environmental problems occurred due to agricultural activities. The agriculture intensification and extension often destroy the forest (Fandik, 2011). The decreasing of forest area because of the other land use is a serious problem worldwide (Achard et. al., 2006). However, the forest is still the largest area around active volcanoes because the terrain morphology does not influence the forest formation (Bashori et. al. 2013).

The volcanic ash from Merapi Volcano did not give negative effects on the affected wetland. The composition ofminerals in the volcanic material can easily mold and release the nutrients that useful for crops. The soil condition could have been better if fertilized with organic material and volcanic ash. Areas that covered by the volcanic material from Merapi tend to be more fertile. Organic fertilizer application on the affected area can increase the rate of ash weathering. So, the land can use for the agricultural purpose as soon as possible (Suriadikarta et. al., 2013).

The eruption occurred in Merapi Volcano and damaged the surrounding ecosystem (Wahyunto and Wasito, 2013). Merapi eruption in 4 - 5 November 2010 was the largest eruption since 1872 and killed 386 people (Wahyunto and Wasito, 2013). Because Merapi eruption occurred more than 80 times and killed thousands of people, the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI) in 1994 set Merapi as one of the most dangerous volcanoes in the world (Putra et.al., 2011). According to Winarti (2011), some of the eruption materials from Merapi Volcano are:

1) Lava is liquid silica, incandescent, concentrated, hot, and destructive of all infrastructure in its path.
2) Pyroclastic caused by the debris of plinian when the eruption occurs.
3) Dropping pyroclastic (ash/volcanic sand) occurs at the same time with the eruption.
4) Poisonous volcanic gasses, normally gasses emitted include CO, CO2, HCN, H2S, and SO2 that can lead to death if the concentration is more than the threshold.
5) Lahar occurs when the volume of water in the form of hot mud in the crater is overload.

II. METHODS

This research conducted in Special Region of Yogyakarta, Indonesia, particularly in Cangkringan District in Sleman Regency. Cangkringan District located in Latitude S 7.66406' and Longitude E 110.46143'. Total wide of this research area is 4,800.60 hectares that divided into five sub-districts with 73 villages. The five sub-districts are: 1) Argomulyo consists of 22 villages; 2) Glagaharjo consists of ten villages; 3) Kepuharjo consists of eight villages; 4) Umbulharjo consists of nine villages; 5) Wukirsari consists of 24 villages (Central bureau of statistics, 2014). Cangkringan Sub-district is located in the southern part of Merapi Volcano. Cangkringan passed by two big rivers, Gendol and Opak River (Central bureau of statistics, 2014). The river is the path of lava flows and volcanic material in case of eruption, therefore, all part of Cangkringan Sub-district involve into the disaster area of Merapi eruption.

Cangkringan District located at an altitude 300 – 1,400 meters above sea level. The nearest distance from Merapi crater is 3.16 kilometers located in Glagaharjo Sub-district and the farthest distance is 16.80 kilometers located in Argomulyo Sub-district. All parts of Cangkringan area are included into four hazard levels of the dangerous area in case of eruption since 2010 (National Disaster Management Authority, 2010). Level III is the area, which is very close to the dangerous area that directly affected by pyroclastic, lava, rock avalanches, and heavy ash rain. In Cangkringan, the area that included into hazard level III is 2,364.53 hectares (49.25%). The next lower level is hazard level II. Hazard level II area divided into two parts: (1) the area which affected by mass flow (pyroclastic, lava, and lahar), and (2) the area affected by volcanic materials rain. The area that included into hazard level II is 1,438.88 hectares (29.97%). Level I is the area that has high potential to be affected by lahars, sometimes pyroclastic and lava flow. The area which included into hazard level I is 3.84 hectares (0.08%). Lahar is a mass flow that contains a lot of water and volcanic material as the result of Merapi Volcano activity (National Disaster Management Authority, 2010). Hazard level 0 is the area that gets the indirect effect of Merapi eruption. The area that included into hazard level 0 is 993.35 hectares (20.69%). Picture 3.2 shows the classification of the disaster area in Cangkringan. Besides the hazard level classification, hazard area also distinguished by the distance from the crater. After eruption 2010, the dangerous area becomes wider that is 20 kilometers from the crater.

The direction distributions of volcanic materials from Merapi always change every eruption. In 1872 – 1930, the volcanic materials spread and destroy the northwest area. In 1954 – 2001, the volcanic materials spread to the southwest area except in 1994 the eruption material destroyed the south area. In 2006 and 2010, the eruption materials spread and destroyed the southeast area (National Disaster Management Authority- BNPB, 2010).

To get the data, the researchers did some interview, give questionnaires, observation, and collect data from Sleman Regency Government.

Interview

To get the information about disaster management, socioeconomic and agriculture condition in government's view the researcher did some interviews. The people who interviewed are Agricultural Department officer, National Disaster Management Authority officer, Wukirsari Sub-district government, Umbulharjo Sub-district government, Glagaharjo Sub-district government, Kepuharjo Sub district government, and Argomulyo Sub-district government.

Questionnaires

To get the information about disaster management, socioeconomic and agriculture condition in societies' view, the researcher gave the questionnaire to the farmers. The sample for the questionnaire is 300 farmers who live in Cangkringan. The researchers directly distribute the questionnaires to the respondents.

Observation

To see the current condition of the study area, particularly in land use and agriculture condition the researcher observes the study site. The researcher observes the study site and distributes the questionnaires at the same time.

1) Collect data from Sleman Regency Government

Data from Sleman Regency Government is about the farming product of Cangkringan District and some maps of Sleman Regency. Data collected from Sleman Regency were the farming product of Cangkringan as the result of Sleman Central Bureau ofStatistics census. The other data from Sleman Regency government are some maps of Cangkringan District and annual report of Sleman Regency government. The maps given by the government are maps about land use, disaster classification, and land use planning.

III. RESULTS

A. Eruption effects on land use change

The eruption in 2001 did not give any effects for the land use in Cangkringan because no volcanic material goes through Cangkringan. The lava dome characteristics that formed in 2001, remains the same with the previous eruption and still heading toward the southwest area. Besides that, before 2006 there was a lava dome, called "Geger Boyo" by local people, in the ridge of Merapi that protects the southeast area from volcanic materials flow when the eruption occurred (Wilson et.al., 2007). Based on the interview result with Sleman National Disaster Management Authority officer, the eruption in 2001 did not give any land use effects in Cangkringan area. The result of satellite imagery analysis shows that there was no severe damage of the eruption because no volcanic materials deposition in Cangkringan area. The questionnaires result also indicates the same information. Some respondents (23%) who stay more than 20 years experienced the eruptions two times, in 2006 and 2010. They said that they do not have any effects of eruption in 2001.

The eruption in 2006 occurred bigger than the eruption in 2001 and overthrew the lava dome on the ridge of Merapi, Geger Boyo (Wilson et.al., 2007). Consequently, this eruption changes the direction of the volcanic materials spread from the southwest towards the southeast. According to the result of an interview with Sleman National Disaster Management Authority officer, the distribution of volcanic material change in direction was because after the eruption in 2001 Merapi Volcano summit reshaping the lava dome and the crater has openings towards the southeast. Besides that, the collapsed of Geger Boyo lava dome in June 2006 resulted in the change of the volcanic materials flow direction. The direction and distribution of volcanic materials from Merapi Volcano more influenced by the directions of the crater opening that formed during the lava dome formation. The result of satellite image analysis shows that there was a volcanic material deposition in Gendol Upstream and in the forest area in Cangkringan. As a result, some of the land use in Cangkringan got the effects of the eruption in 2006 such as forest, plantation, some dryland farming, and shrubs. Because of the eruption, 1.35% of land in Cangkringan becomes bare land. The increasing width of bare land occurred especially in the higher elevation area and around Gendol upstream because Gendol River was the main line of the volcanic material during the eruption in 2006. Based on thequestionnaires result, more people realize that there was an eruption in 2006. However, the people in Cangkringan, especially the people who lives in the lower elevation area such as Argomulyo and Wukirsari, do not change their land use because of the eruption effects. It shows that the eruption in 2006 did not give any significant effect on the land use in Cangkringan.

The eruption in 2010 that occurred in November was the greatest eruptions compared to the eruption in 2001 and 2006. Newhall et.al., (2000) and Voight et.al., (2000), has predicted the existence of a large eruption of Merapi with little signs retrieve the explosive eruption of Merapi record to 10,000 years. According to Sutikno et.al., (2007), since 1872 until 2006 there was no major eruption occurred at Merapi Volcano. Nevertheless, in 2010 a huge eruption occurred, reached scale 4 VEI (Volcanic Explosivity Index) and it was the largest eruption since 1872 (Wahyunto and Wasito, 2013).

Based on the interview result with the head of the disaster mitigation agency in National Disaster Management Authority (BNPB) Sleman, the eruption in 2010 was a continuation of the eruption in 2006. The result of BNPB observations by measuring the lava dome volume in 2006 and compared to the peak of Merapi Volcano after the eruption shows that not the entire lava dome formed in 2006 collapsed after Merapi activity back to normal. However, when Merapi Volcano

activity increased in 2010, the lava dome continues to form with increasingly large volumes in former lava dome in 2006. Then, when the eruption occurred in November 2010, the entire lava dome that formed since 2006 collapsed.

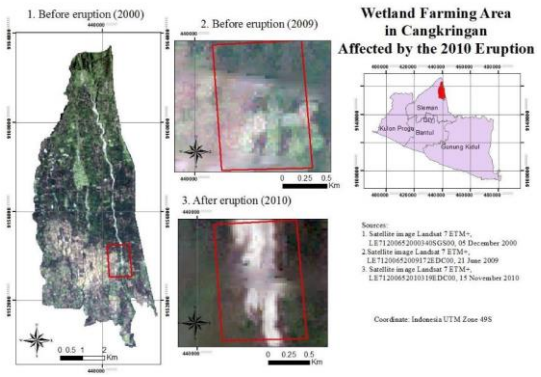
Because of the great eruption in 2010, the affected areas become wider in almost all part of Cangkringan District. Lava flows further in Gendol River. The result of satellite imagery observation and

some resources from the government show that the direction and distribution of volcanic material in 2010 at the direction and distribution of the eruption in 2006, which was towards to the southeast area. It affected by the eruption in 2006 that paved the way of volcanic material to the southeast because there was no Geger Boyo that deflects the volcanic material flow.

The eruption in 2010 has leveled the landscape and land use in the slope of Merapi into an expanse of volcanic material. Because the volcanic material covered dryland farming, forests, and the area close to Merapi summit, those areas changed into bare land and unproductive. The areas that changed becomes bare land also occurred along Gendol River because of the volcanic material overflow. The questionnaire result shows that more than 25% of the respondents' farming land damaged by lahars and totally burned. As seen in figure 1., the range of volcanic material reached more than 10 kilometers radius from Merapi summit that was previously a secure area of the danger of Merapi eruption.

B. Eruption effects on agriculture

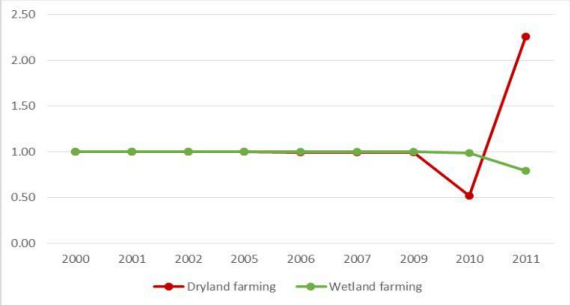
The volcanic material from the eruption influences soil condition and properties in the area around an active volcano. Tan (2013) said that lahars and volcanic material could improve soil fertility so that people around Merapi Volcano do not want to move.



Picture 1. Wetland farming area affected by the eruption in 2010

Argomulyo and Wukirsari mostly use their land for wetland farming area because the altitude lessBased on the interview results to the Sleman Regency agricultural officer, generally, there is six land use in Cangkringan, namely dryland farming, forest, plantation, settlement, shrubs, and wetland farming. Dryland farming is an agricultural system in Cangkringan practiced by farmers in the area with an altitude of more than 400 meters above sea level, such as farmers in Glagaharjo, Kepuharjo, and Umbulharjo. Farmers who live in than 400 meters above sea level

and have the continuous water supplyThe results of satellite imagery analysis show that Merapi eruption in 2010 can cause severe damage in both direct and indirect affected areas. In 2010, dryland farming area decreased significantly while wetland farming is still relatively the same as the previous years. This may be due to the dryland farming areas that located on the plateau, closer to the crater, and volcanic material flow path in Gendol River got the higher impact of eruption directly. As a result, some dryland farming changed the function or become bare land. In contrast, in 2011, the dryland farming area increased sharply while wetland farming area decreased (picture 2.). This condition might be because many lands transformed into dryland farming, such as bare land and wetland farming area. The direct and indirect effect of eruption in 2010 reduced the wetland farming area. The direct eruption effect to wetland farming area was the volcanic materials directly burn that area which located nearby Gendol River. In addition, the eruption also could have an impact indirectly on wetland farming area. Indirect eruption effects are the volcanic materials destroy the dam and spring along the river that passed by the eruption material. As a result, wetland-farming areas have no water supply for irrigation so that after the eruption some wetland farming areas turned into dryland farming Picture 2 shows that the eruption in 2010 gave significant effects to the land use especially in agriculture. This condition Based on the land-use analysis result of the map from Sleman Regency government and satellite imagery, there were no significant changes in land use in Cangkringan particularly land use for agriculture. To find out if the eruption in 2010 affects the productivity of agriculture in each commodity, the researcher compared the trend of production changes with the changes of the agricultural area both dryland and wetland farming..



Picture 2. Changes in agricultural area

Out of the eight types of crops grown in wetland farming area, there are five plants that the productivity decreased continuously since 2010, namely rice, spinach, melon, may relate to the decreasing of agricultural productivity. watermelon, and swamp cabbage. Two commodities production decreased in 2010 and increased in 2011 are corn and peanuts. Those two commodities are crops that suitable for volcanic soil. Peanut is one of the crops that resistant to Silica content in the soil (Soelaeman and Idjudin, 2013) while corn is one of the common crops grown around the volcano and produce a high yield in a fertile volcanic soil (Verheye, 2009). The cucumber was the only commodity that not cultivated by farmers in Cangkringan since 2010. These was consistent with the downward trend in the wetland farming area that occurred in 2011, which led to the decreasing of wetland farming production, or even

The results of the questionnaires addressed to 300 respondents indicated that as many as 45.67% of respondents planting more than four kinds of plants, 5.33% of them planting only one crop, and the rest of the farmers plant. This means that farmers in Cangkringan prefer to use intercropping system than monocrop. Therefore, in one planting season, the farmer can grow several types of crop, so the production can be higher and varied. However, due to the eruption, that affects both directly and indirectly to wetland farming, it can decrease the production of eight commodities grown in wetland farming area.

Different trends occurred in cucumber production. Cucumber production decreased in 2010 and there was no production in 2011 likely to be due to the high demand for staple food after the eruption. As a result, farmers prefer to plant paddy and corn than a cucumber.

Farmers in lowland area that mostly has wetland-farming area, Wukirsari and Argomulyo Sub-district, grow crops. However, farmers in the highland area who has dryland farming, Umbulharjo, Kepuharjo, and Glagaharjo, grow crops and the other plants. Furthermore, farmers in the higher elevation change their crops rarely and farmer in the lower elevation often change their crops. disappear. In addition, because of the eruption in 2010 that destroys the agricultural area can reduce the production of affected area.

Consequently, commodities in dryland farming more varied than that in wetland farming. In Cangkringan, there are 17 kinds of crops planted in dryland farming areas. There is five commodity grouping based on the trend of production changes after eruption 2010:

(1) The declining trend occurred in cocoa, zalacca, sweet potato, cassava, mustard green, string beans, pepper, tomatoes, and coffee.
(2) The increasing trend occurred in potato production.
(3) The decreased trend in 2010 and then increased in 2011 occurred in green beans and spring onions.
(4) Stable trend occurred in the production of pepper, cotton, and eggplant.
(5) There was no tobacco and tea production after the eruption in 2010.

Out of the fifth trend of these changes, the most likely affected by the eruption in 2010 was decreasing trend, decreased and then increased and the loss of some commodities. The decline in cocoa, zalacca, sweet potato, cassava, mustard green, string beans, chili, tomato, and coffee production is the most likely influenced by the eruption in 2010. Because of the eruption, dryland farming area that mostly located in highland got more severe damage. Thus, the production of those nine commodities decreased significantly. Moreover, since the eruption in 2010 has a wider range of volcanic materialdistribution, the dryland farming area that located far from Merapi volcano also got severe damage. Besides planting sites and plants damaged by the eruption, the changes of soil chemical elements, due to deposition of volcanic material, can lead to the decreasing of land productivity. This is corresponding with the statement from Wahyunto and Wasito (2013) which states that the pile of volcanic material can affect the physical and chemical characteristics of the soil. If the volcanic material is thicker, then the land will be difficult though and reused for agriculture.

Trend decreases then increase occurred in two commodities namely green beans and spring onion. It may because the harvesting area got the heavy ash rain during the eruption. Vegetables are commodities that severely damaged because the crop characteristics that very susceptible to climate change disturbance and natural disaster (Muharam, 2013; BPTP Central

Java, 2011). Consequently, the farmer failed to harvest their crops. However, the farmer can normalize the land immediately, so in the next year, the area can use to grow crops and increase the green beans and spring onion production. In addition, spring onion is one of the commodities that resistant to high Silica content in the soil (Soelaeman and Idjudin, 2013).

The change in agricultural productivity that may cause by the eruption was the absence of tobacco and tea production in 2010. This is probably because these plants usually planted in the highlands and got the direct effect from the eruption. Areas directly affected eruption severely damaged, so it took longer to normalize the agricultural land. Furthermore, based on the interview with some farmers, the farmers in Cangkringan prefer to grow some kind of crops for food purpose rather than grow the plant for industries.

The eruption likely not too much effects to the changes of potatoes, pepper, cotton, and eggplant. This is apparent from the trend of changes in land use due to the eruption much different from the trend of productivity change to those four commodities.

The questionnaire analysis results show that the soil around Merapi is always fertile in both before and after the eruption, even they do not use chemical fertilizer. The farmers also have their farming habit to tillage their farming land. One of the farmer's farming habit is the planting and harvesting time that may relate to the production in each year. In Cangkringan, the rainfall and the rainy days are about the same because Cangkringan area is not very large. The average minimum rainfall in Cangkringan is 3.07 millimeters/year and the average maximum rainfall is 106.77 millimeters/year (Statistics of Sleman Regency, 2013). The eruption time also influences to the yearly production of every commodity. Besides that, the farming land location influence to the farmers' habit in changing their crops. It also strongly affected by the water supply to their farming area. The economic reason also becomes the main consideration of the farmer to change their crops. Therefore, the farmers' choice in planting system has a stronger effect on the change of crop productivity in the year that there is no huge eruption.

C. Eruption effects on socioeconomic

Damage from the eruption in 2010 was quite significant to the lives of farmers. It indicated from many farmers

who switched professions from vegetable farmers into sand miners to fulfill their needs (Muharam, 2013). Based on the results of questionnaires and interviews to every sub-district government, residents in Cangkringan majority are farmers with and average income about 2 million rupiahs. A total of 96.67% of respondents have been lived in Cangkringan more than 20 years and experienced the eruption more than once. This condition affects to the reaction of the citizens when the eruption occurred.

Huge impacts of Merapi Volcano eruption in 2010 felt by the socioeconomic aspect of the society. Because the eruption in 2010 killed 386 people, many people lost their relatives. Lost relatives and experience the large eruption make citizens in almost all districts Cangkringan traumatized. Even so, they remain reluctant to leave the area of Cangkringan District. Victims who died in Cangkringan District mostly come from around Gendol River who have never directly affected before. People refused to evacuate because they thought their home far away from the volcano, and there was never any lava and pyroclastic flow up to their village. As a result, when the large eruption in 2010 occurred, the eruption materials trapped the people, so the governments face some difficulties to evacuate them. To cope with the trauma and reduce the loss of relatives, the government provides mental coaching and entertainment during their evacuation. Therefore, when returning to their homes or to the relocation sites, the people were ready to socialize and live as usual.

The eruption in 2010 also destroyed hundreds of homes and livestock. At the time of the eruption occurred the people could not evacuate all the livestock, so many cattle died. To overcome this problem, the government then relocates the residents whose homes damaged by the eruption to a more secure by providing a home freely. Besides the residents whose homes damaged, some people cannot inhabit several villages that are included into the dangerous area. Consequently, all citizens must move to a new place that more secure from the threat of eruption.

In addition to lost relatives, homes, and livestock, many residents also suffered losses due to the destruction of their farmland for buried by volcanic material from very thick to thin. Therefore, the people temporary cannot cultivate. Based on the questionnaires result, some villagers said that if the thin ash covered their farming area, the farmer could use their farming land again normally after approximately 3-5 months. A resident who has farming land that buried under the thick volcanic material, they then switched professions become sand and stones miners. Stone and sand from Merapi Volcano have good quality for building materials so that people sell them to supply their income while normalizing their farmland. Because of the very large eruptions in Merapi Volcano, manytourists and scientists are interested in seeing the conditions around Merapi and Cangkringan after the eruption. This sparked the creativity of citizens to develop recreation businesses around Cangkringan.

IV. CONCLUSION

This study focused to three eruptions in 2001, 2006, and 2010. The largest eruption occurred in 2010 and gave the most severe impact on both the society and nature. The eruption in 2001 did not give any significant effect to Cangkringan District. However, starts from the eruption in 2006, the eruption gave significant effect to Cangkringan District and the government moves the dangerous area from the southwest to southeast. The eruption in 2006 gave effects to the land use in the higher elevation especially forest that located nearby the upstream of Gendol River. Agriculture systems in Cangkringan District got the indirect effect of the eruption in 2006, such as low levels of water supply due to the forest and water resources damage. After the eruption in 2006, 64.97 hectares of some land use becomes bare land area.

The eruption in 2010, which was the biggest eruption since 1872, gave much significant effect to the land use and agriculture in Cangkringan District. Material volcanic from Merapi Volcano during the eruption in 2010 affects a wider area. The lava flows further along Gendol River and reaches more than 10 Km radius from the crater.

The eruption in 2010 damaged some area that never got the severe effect of eruption before. After the eruption in 2010, 1608.87 hectares or 33.51% of all land use in Cangkringan becomes bare land area. Volcanic materials that released from Merapi volcano gave both direct and indirect effect on agriculture in Cangkringan. The direct effects are the lava and pyroclastic flow that directly burn and buried the crops and the ash that directly covered and buried the crops. The indirect effects of the eruptions are the loss of water resources because the volcanic

materials destroy the forest and natural springs along the river, especially Gendol River.

After the eruption, the farmer community and the government has to identify the soil characteristics. There are two alternatives to rehabilitate the farming land after the eruption. Firstly, the farmer should modify the rooting zone of the crops by tillage the soil continuously to avoid soil hardening. Secondly, the farmers have to change the sensitive crops to the resistant crops that can survive in the mix of soil and volcanic material. In Merapi Volcano area, the most suitable crops for affected areas after the eruptions are corn, peanut, spring onions, and onions that resistant to high Silica content in the fresh volcanic soil.

Agriculture is still the most suitable land use in Cangkringan. The volcanic soil that rich in nutrient can help the plants to grow and produce yield optimally. Besides the agriculture, mining area can be a suitable land use after the eruption occurred to accelerate the farming land normalization because of the volcanic material damaged. A good scenery in Merapi area can support the recreation industry in Cangkringan District especially for adventure and agro-tourism.

Creating the new jobs opportunities can help the farmers to overcome the effects of eruptions in financial problem. Giving some education to the farmer about agriculture systems and the eruptions effects can encourage the farmer to create some innovation to solve their problem during and after the eruption. The government should assist the farmer to optimize the potential of Cangkringan area and give the information about Merapi Volcano activity as soon as possible to reduce the loss.

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