ISSN 0024-9521
IJG Vol. 46, No.2, December 2014 (156 - 166)

INDONESIAN JOURNAL OF GEOGRAPHY

Agricultural Loss Caused by 2007 Sidoharjo's Flood and its Household Impact

Leo Agung Widiarto, Nanette Kingma

Received: 14 05 214 / Accepted: 1 06 2014 / Published online: 31 12 2014

Abstract Flood is an undeniable reality that threaten Sidoharjo Village, as part of Sragen District. It is affected by the presence of Mungkung River, the tributary of Solo River, which crosses in the area. It is certainly going to be one of the factors inhibiting the development and economic growth in the region, given the agricultural sector is one of the backbones of the economy potentially disturbed by the flood. The information about the flood and its impacts specifically related to agriculture are needed to determine the precise policies. The research focuses on 2007-flood mapping, agricultural production loss assessment, and farmer resilience, as expressed in their ability to continue the next cropping after being hitten by the 2007-flood. The flood map was built by integrating the local knowledge and the Digital Terrain Model (DTM). The information about 2007 flood was collected by interviewing the local people. The DTM was built by interpolating the detailed spot height directly measured in the field. As the result of the integration, the depth of the flood immersing the paddy fields reaches approximately 3 meters. Beside the flood depth, the growth stage of rice also determines the paddy vulnerability. It refers to the plant height and the sensitivity to the water immersion. There are three stages i.e. vegetative, generative, and graining phases. The vulnerabilities were constructed based on the synthetic data obtained via Focus Group Discussion (FGD). The production loss of paddy of the research area was counted based on the vulnerability. A grid-based GIS method is used in the loss calculation which produces a value of Rp. 1,137,350,000.00 (about USD 100,000.00). The losses influence the farmer ability to continue the cultivation in the next season, which in this study is defined as farmer resilience. To investigate the resilience level, 32 respondents were proportionally randomized to each flood zone. There are three zones created based on the flood depth. The influencing factors and their weights and scores were determined by the farmer representatives via FGD. Meanwhile, the socioeconomic data were collected by using the questionnaires. The results show that most of the farmers in the area (56.3%) are categorized in moderate resilience level.

Keywords: agricultural loss, digital terain model, floods, Sidoharjo

Abstrak *Banjir merupakan realitas permasalahan fisik yang melanda Desa Sidoharjo yang merupakan bagian dari Kabupaten Sragen. Kejadian banjir dipengaruhi oleh adanya Sungai Mungkung, anak sungai dari Sungai Solo yang melintasi daerah tersebut. Hal ini menjadi salah satu faktor penghambat pembangunan dan pertumbuhan ekonomi di wilayah tersebut, terutama sektor pertanian, mengingat sektor tersebut merupakan salah satu sektor perekonomian utama yang berpotensi terdampak banjir. Informasi tentang banjir dan dampaknya terhadap pertanian secara khusus diperlukan untuk menentukan kebijakan yang tepat. Penelitian ini berfokus pada pemetaan banjir tahun 2007, valuasi kerugian pertanian, dan daya lenting petani, yang disajikan dalam kemampuan mereka untuk melanjutkan aktivitas pertaniannya setelah terkena banjir. Peta banjir dibangun dengan mengintegrasikan pengetahuan lokal dan* Digital Terrain Model *(DTM). Informasi tentang kejadian banjir 2007 dikumpulkan dengan mewawancarai masyarakat lokal. DTM ini dibuat berdasar interpolasi ketinggian tempat secara detail yang diukur langsung di lapangan dengan Sebagai hasil dari integrasi, data menunjukan kedalaman banjir mampu merendam sawah hingga mencapai sekitar 3 meter. Selain kedalaman banjir, tahap pertumbuhan padi juga menentukan kerentanan tanaman. Hal ini mengacu pada tinggi tanaman dan kepekaan akibat terendam air. Tahap pertumbuhan padi terdiri tiga tahap yaitu vegetatif, generatif, dan fase pertumbuhan bulir padi. Kerentanan dibangun berdasarkan data sintetik yang diperoleh melalui Focus Group Discussion (FGD). Hilangnya produksi padi dari daerah penelitian dihitung berdasarkan tingkat kerentanan. Metode GIS berbasis* raster grid *digunakan dalam perhitungan kerugian yang menghasilkan nilai Rp. 1,137,350,000.00 (sekitar 100,000.00 USD). Kerugian mempengaruhi kemampuan petani untuk melanjutkan budidaya di musim setelahnya, dimana dalam penelitian ini didefinisikan sebagai daya lenting petani. Untuk mengetahui tingkat daya lenting, 32 responden diwawancarai secara* proporsional random sampling *untuk setiap zona banjir. Ada tiga zona yang dihasilkan berdasarkan kedalaman banjir. Faktor yang mempengaruhi dan bobot dan skor masing-masing ditentukan oleh perwakilan petani melalui FGD. Sementara itu, data sosial ekonomi dikumpulkan dengan menggunakan kuesioner. Hasil penelitian menunjukkan bahwa sebagian besar petani di daerah tersebut (56,3%) dikategorikan dalam tingkat daya lenting sedang.*

Kata kunci: *kerugian pertanian,* digital terrain model, *banjir, Sidoharjo*

Leo Agung Widiarto
DPU Kabupaten Sragen
email: lillo_esdpo@yahoo.co.id

N. Kingma
International Institute for Geo-Information and Earth Observation, Encshede, the Netherlands

1. Introduction

Sragen Regency which is located in the eastern part of Central Java province, Indonesia, is one of the areas traversed by Solo River, one of the longest rivers in Indonesia. The existence of the river support the agricultural sector in this region, especially in term of soil fertility and water supply. However, the presence of the river and its tributaries has also led to flooding in this area. According to Indonesian Disaster Bureau (BNPB), the natural disaster management agency of Indonesia, there were 15 flood events in the last decade in Sragen.

The flood-based information specifically related to the agricultural sector thus needs to know as anticipatory measures and as a basis in the policy determining in term of sustainability of food. The production loss of paddy, the flood-based impact on the farmer households, the capability of the farmers to continue cropping the rice for the next season which is defined as resilience level, as well as the public perception about the agricultural policies particularly in post-flood recovery efforts are needed to be known trough this research.

Sidoharjo village is one of granaries in Sragen Regency. Most of the area in the village is designated as agricultural land. Irrigation system and the existence of farmer groups show that agriculture is the leading sector in this village. The area is traversed by Mungkung River, a tributary of Solo River, as the source of the flood in this area (Figure 1 to Figure 3). The 2007 flood was the biggest flood in the area in recent decades, so even though it was quite a long time ago, the incident still lingering in the memories of the residents and the farmers.

2. The Methods

This research aims to construct the 2007 flood event map by integrating local knowledge and DTM, to do the agricultural loss assessment, and to analyze resilience level of the farmers. It consists of three main activities, namely data collection; data processing; and data analyzing.

The collected materials include both primary and secondary data. The secondary data consists of Topographic map, Quickbird image, data of parcel ownership of paddy field, as well as data on the 2007-flood-based production loss of paddy published by government. Each secondary data has their respective functions in building the research framework. Quickbird image function for updating and refinement of landuse map extracted from Topographic map. Paddy fields have been identified in Topographic map is fitted with parcel boundaries obtained from the Quickbird. It was what would be filled with the attributes of field owner based on proprietary data obtained from the local government, to build a map of paddy field ownership. Meanwhile, data of the 2007-flood-based production loss of paddy published by government became the material to be compared with the production loss calculated in this study.

There are two kinds of primary data collected in this study, namely detailed spot height to build the DTM (Digital Terrain Model) and information about socioeconomic condition of the farmers, paddy cultivation, and flood impact, to assess the resilience. The detailed spot height is directly measured using RTK-GPS (Real Time Kinematic – Global Positioning System) method. The measurement results are interpolated to build the DTM which is then integrated

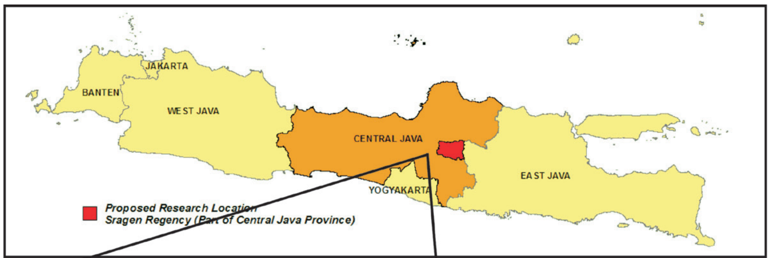

Figure 1. Location of Sragen Regency in Java Island. (source : RBI map)

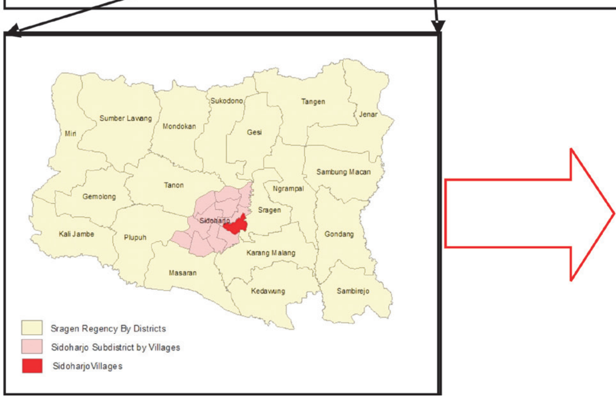

Figure 2. Location of Sidoharjo Village in Sragen Regency (source : RBI map)

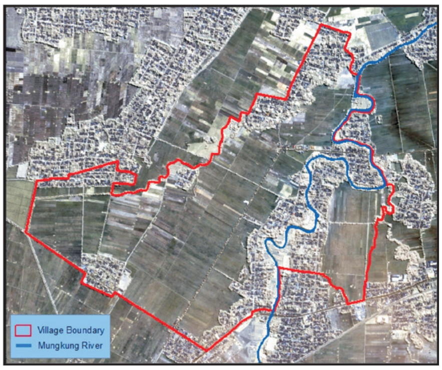

Figure 3. Figure of Sidoharjo Village (source : Quickbird Image)

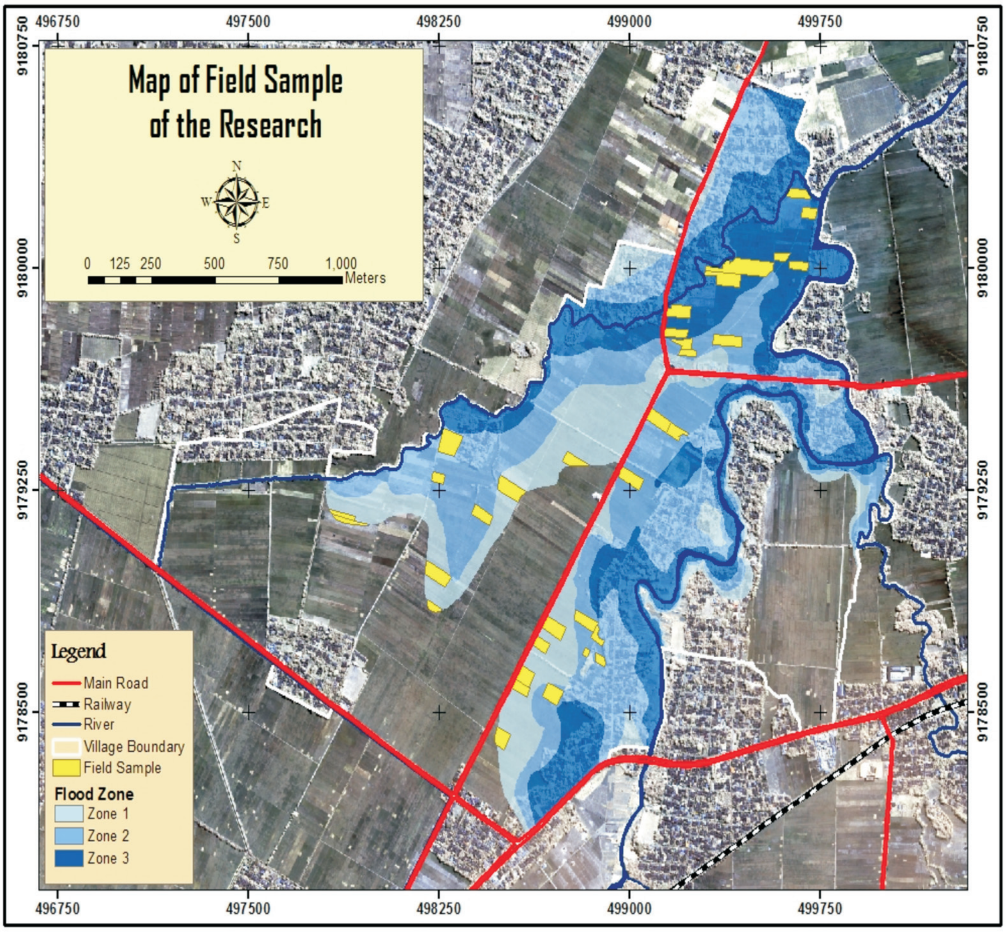

Figure 4. The Spatial Distribution of the Field Sample by the Food Zone

with the hazard-related information provided by the local people. The information can be obtained by using participatory approach method [Achmadi, 2012]. In this research, the method was done by interviewing people to get information about 2007 flood traces in several locations.

The other primary data are collected using questionnaire and FGD (Focus Group Discussion). Questionnaire is a data collection technique by giving written questions to be answered by respondents [Sugiyono, 2009]. FGD is a discussion by a group of people on a specific topic. The group is not just a collection of people talking to each other but rather to focus on particular people appropriate to goals to be achieved [Riyanto, 2011]. In this study, the questionnaire is divided into five groups of questions i.e. socioeconomic condition, paddy cropping, flood impact, recovery process, and flood-based strategy. It is given to the farmers having the flood-affected field. However, only 10% of them are included as the sample [Sevilla, 2009]. They are randomized proportionally by considering the area ratio of flood zones, i.e. less than 50 cm, 50 – 150 cm, and more than 150 cm, (Figure 4). This zoning considers the damage in paddy as the result of pre-survey measure, in which the rice start to be damaged at the flood depth of 50 cm and become very severe at the flood depth of 150 cm and above. Meanwhile, the FGD is used to obtain information about synthetic damage data of several flood scenarios and score and weighting value of resilience-influencing factors.

In this stage, the detailed spot height as the result of satellite-based measurements are interpolated using four methods i.e. kriging, spline, natural neighbour, and inverse distance weighted (IDW). The using of four interpolation methods aimed to determine the most appropriate method in this research area. The results of four methods are validated twice using 10% and 20% of validating points which are chosen randomly from the measured spot height.

Also, the 2007 flood event map, consisting of flood extend and flood depth, is constructed in this stage. First, the elevations of flood traces as the result of participatory GIS process are interpolated to construct the raster of flood level in the research area. Then, the raster of flood level and DTM were processed using raster calculator in ArcGIS software. The flood extent and flood depth would be the result of the process.

Some other data processing such as resilience level calculation, vulnerability curve construction, and production loss calculation are also conducted in this phase. The individual resilience value of each sample was computed by using the weighting value and score obtained from FGD. Damage level of several scenarios which is also obtained from FGD was processed and converted into vulnerability curves. Using the curve, the production loss of paddy in the research area is calculated in each grid cell (pixel).

The data are analyzed in terms of the production loss of paddy and the resilience level. The loss data obtained from the relevant authority, Agriculture Agency of Sragen Regency, was validated using the value of production loss calculated in this study. The calculated value was also previously validated using loss data obtained from the questionnaire. In term of resilience level, the obtained value was analyzed by looking for relationship trend with the factors that build it. Also, in this section the relationship propensity between the flood zone and resilience level as well as the influencing factors were also sought.

Topographic data is a very important material in flood modeling, and DTM is the inner part which is widely used in the topographic analysis [Masood and Takeuchi, 2011; Neelz and Pender, 2007]. There are 930 sampled points resulted from satellite-based measurement which is interpolated to create the DTM in this study. The most suitable method used in this area was determined by comparing the methods in term of the validation result. They were validated statistically by computing RMSE values.

Figure 5 shows the results of interpolation methods used in this study. Visually, they show differences of each used method. However, the natural neighbour and spline give results visually close to each other. Similar results are also seen in the second validation process in which 20% of the measured points are randomly selected to be validating points, see Figure 6. However, the most appropriate outcome is determined not visually but statistically by looking at the overall correspondence between the source and result which is expressed in RMSE values of the representing points.

According to Table 1, the most suitable method to be used in DTM construction of the research area is natural neighbour. It refers to the RMSE value in which

Table 1. RMSE values of interpolation results

Validating Point	RMSE of Several Interpolation Methods			
	Spline	Kriging	IDW	Natural Neighbour
10%	0.516	0.792	0.615	0.262
20%	0.919	1.267	1.068	0.903

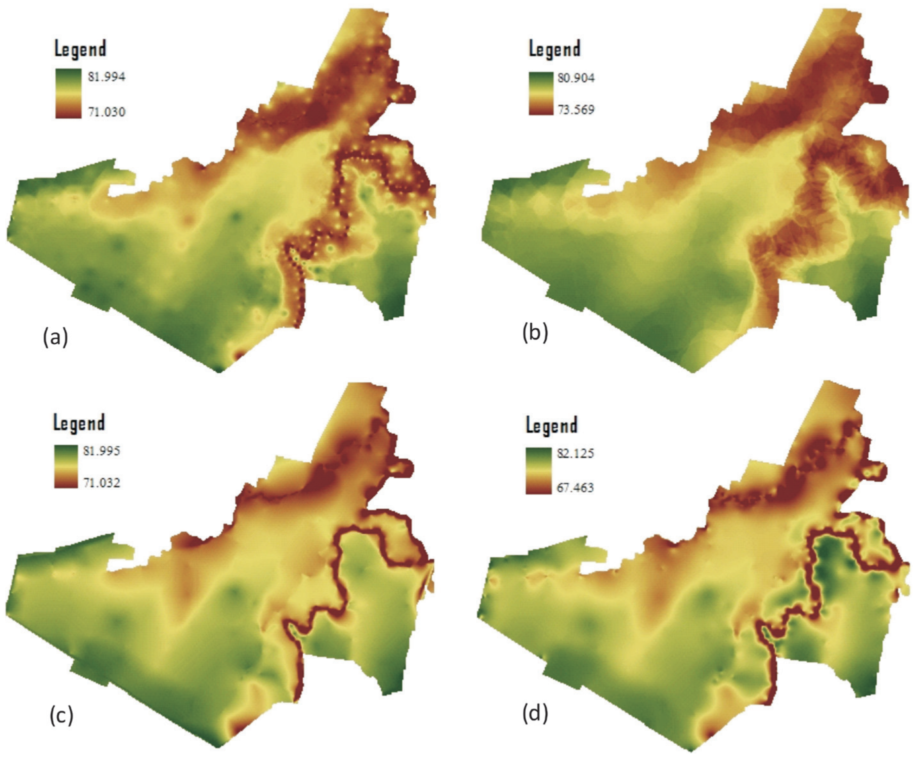

Figure 5. DTM as the Results of (a).IDW Method, (b).Kriging Method, (c).Natural Neighbour Method, (d).Spline Method, (minus 10% Validating Points)

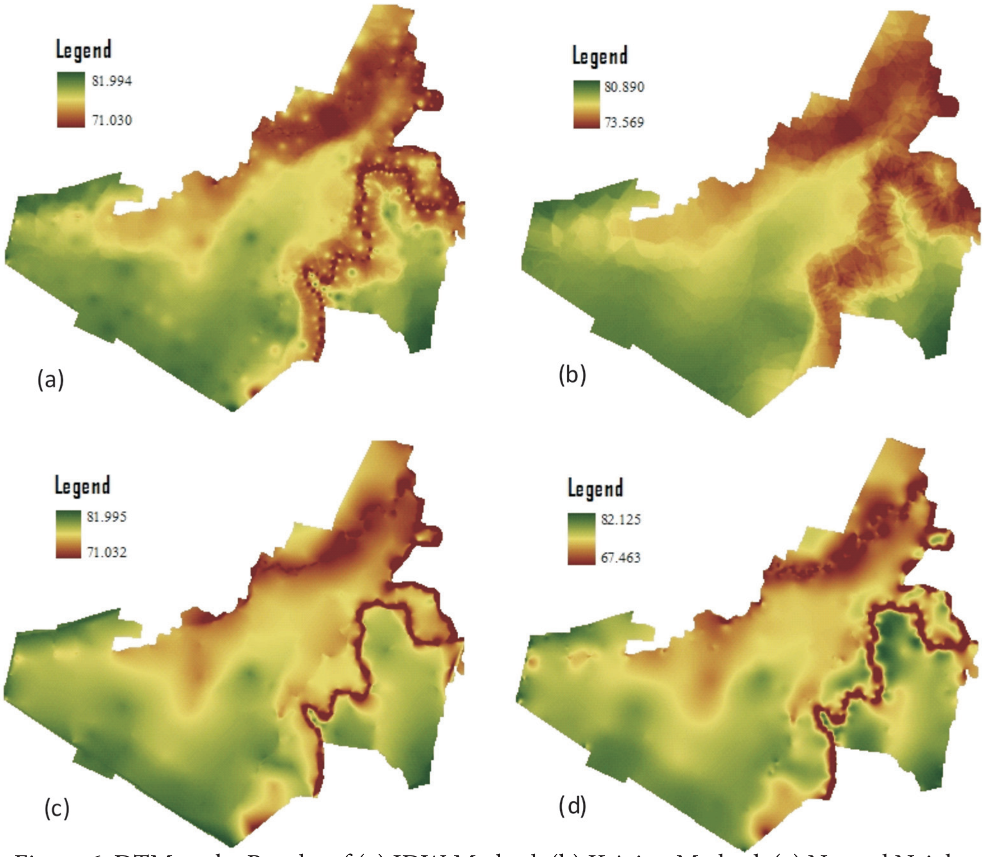

Figure 6. DTM as the Results of (a).IDW Method, (b).Kriging Method, (c).Natural Neighbour Method, (d).Spline Method, (minus 20% validating points)

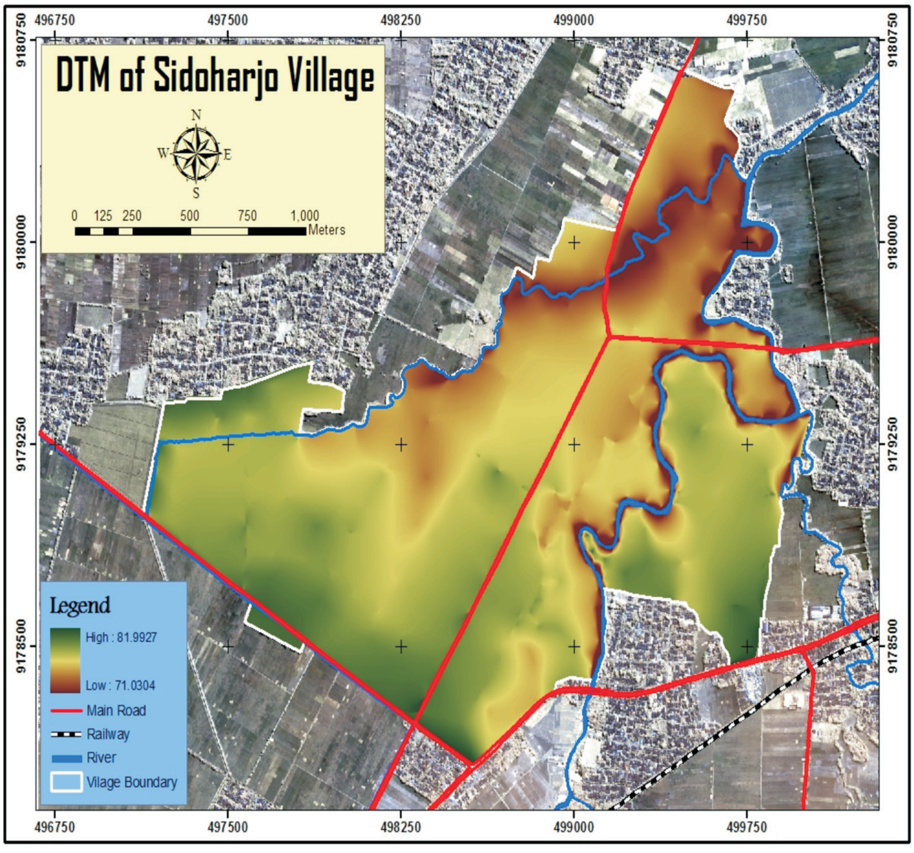

Figure 7. DTM of Research Area Based on Measured Points

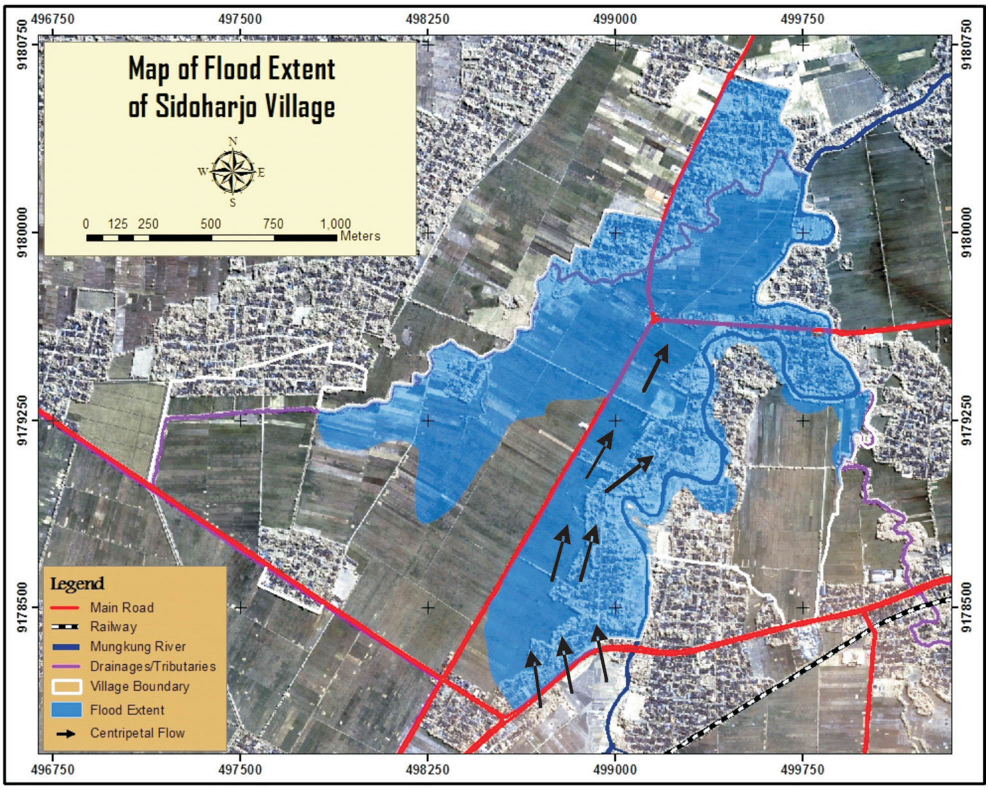

Figure 8. Map of 2007 Flood Extent of the Study Area

the natural neighbour results the lowest one both of the 10% and 20 % validating points. Henceforth, all measured points were interpolated using the natural neighbour method to build a DTM of the research area based on the measured points.

There are six characteristics determining the danger level of the flood, namely water depth, inundation duration, water velocity, sediment load, rate of rise, and frequency of occurrence [Marfai, 2003]. However, according to the result of pre-survey interview conducted to some farmers, the only influencing characteristic in the area is flood depth. Thus, only flood extent and flood depth were resulted from the integration of DTM and local knowledge. Beside gives the traces of 2007 flood, the local knowledge also provides information about the flood sources i.e. the rise of Mungkung River as the main source, the accumulation of rain collected and stuck in local channels and sunken areas, as well as the water runoff that does not follow the turned direction of the river. For the last mentioned, it can be explained that the water discharge getting larger in the river bend. There is centripetal force causing the water flow pushed to the outer bend [Warnana, 2008]. The flow caused by the centripetal force then become the main stream of the flood, as shown in Figure 7.

In the north and upper east parts (Figure 8 and Figure 9), the flood was interrupted by border of research area which is signed with the white line in the map, while in the middle; it was cut off by the road as the natural levees, shown by the red line in the map. The flood depth varies up to about 3 meters in the paddy field and settlement area, and up to more than 7 meters in the area around the river.

3. Result and Discussion

This study is restricted to the assessment of production loss of paddy. The value of loss is calculated using a vulnerability approach. The vulnerability can be described in some manner such as vulnerability indices, vulnerability curve, fragility curve, and vulnerability table [van-Westen and Kingma, 2012]. This study displays it in the curves relatively by associating the damage percentage of paddy and the hazard magnitudes. The damage data was obtained from synthetic survey through FGD considering flood depth and growth stage of paddy. Flood depth is related to the several scenarios of magnitude to construct the curve, the growth stage of paddy are related to the plant height during the exposure. Related to the cropping stages, there are three main phases to be considered i.e. vegetative, generative, and graining phases [Hanum, 2008].

Table 2 shows the result of synthetic survey to get the damage data on paddy of several flood depth scenarios through FGD. As a note, the results are associated with the research area that has brief flow duration, so it can be ignored. Next, those information are used to build the paddy vulnerability curve of each cropping stage.

At vegetative stage, the plants are safe until the 50 cm high of inundation, and begin to be affected thereafter. The damage is getting bigger until they are totally damaged at the 200 cm of inundation or larger (Figure 10). At this condition, the flood normally reaches a maximum duration occurred in the area i.e. one day inundation. Meanwhile, paddy will reach a

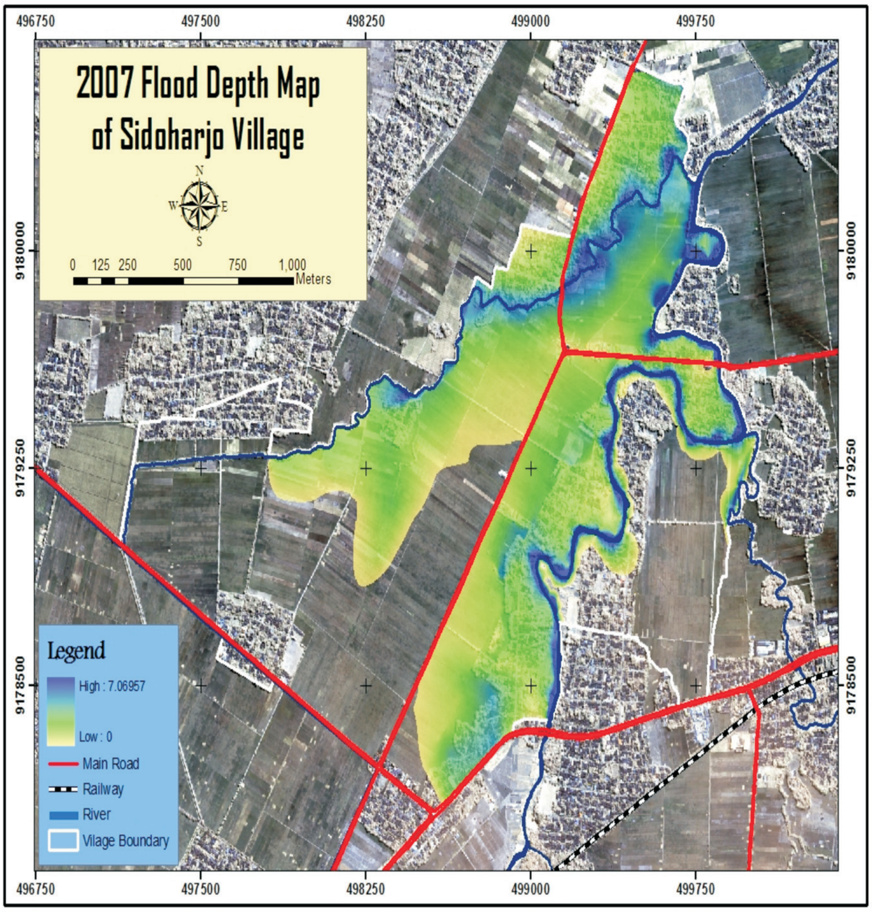

Figure 9. Map of 2007 Flood Depth of the Study Area

Table 2. Synthetic Damage Data of Paddy in Sidoharjo Village

Cropping	Age of Paddy (days)	Plant Height (cm)	Damage Percentage When Exposed by Flood up to			
			50 cm	100 cm	150 cm	200 cm
Vegetative	60	75	0	30	60	100
Generative	80	120	30	80	100	100
Graining	115	105	40	60	80	80

Table 3. Comparison Between Loss Calculation used by the Government and Used in the Research

Comparators	The Government	The Research
Method	Based on statistical data	Grid-based GIS method
Area Assessing	Converting the flooded parcels into a unit area based on farmer reports	Using "Calculate Geometry" tool on GIS based on the flood extent map
Base of Calculation	Loss index refers to the value of cultivation cost	Loss of production (harvest)
Calculation Unit	Global, by generating the flood depth in all area (70-110 cm)	Pixel, according to the flood depth (pixel value) of each grid cell

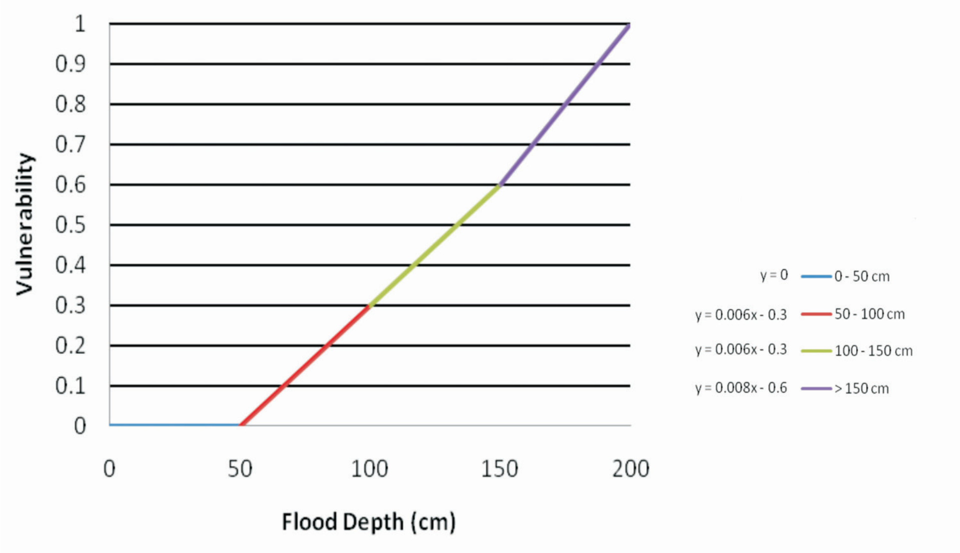

Figure 10. Vulnerability Curve of Paddy at Vegetative Stage

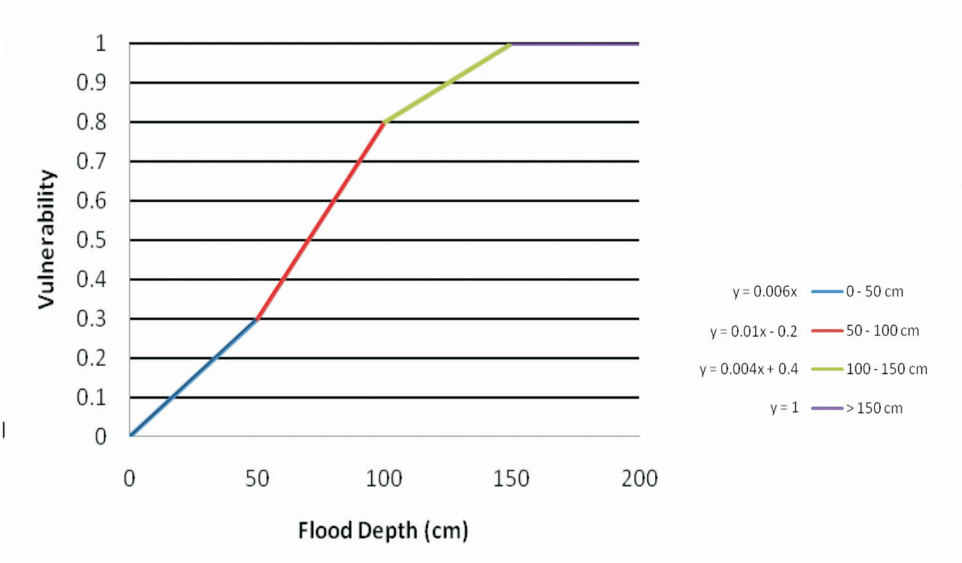

Figure 11. Vulnerability Curve of Paddy at Generative Stage

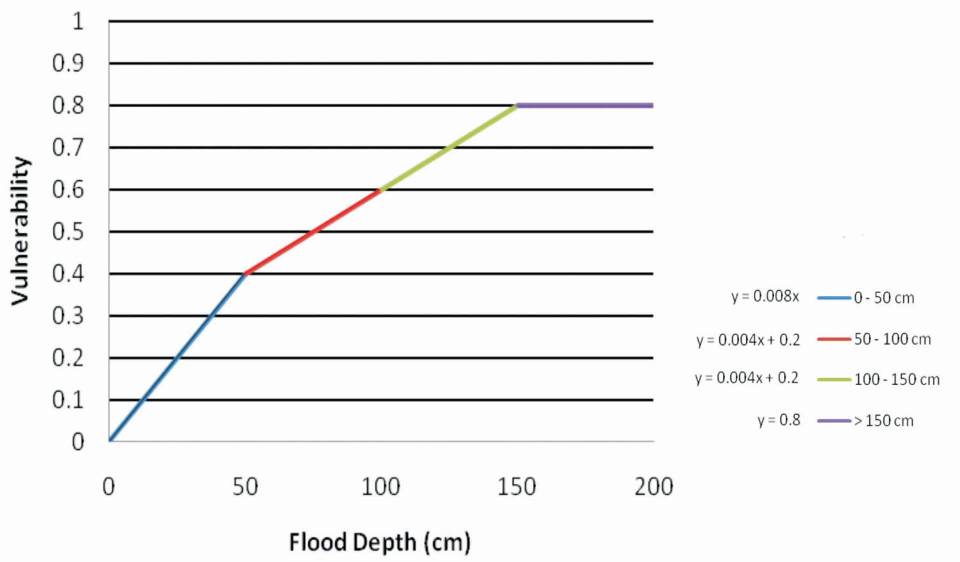

Figure 12. Vulnerability Curve of Paddy at Graining Stage

maximum height at generative phase, but the plants are very sensitive to water. They do not need a lot of water in this stage. Water immersion will affect the process of pollination. The damage at this stage is not associated with damage to crops, but the failure of the pollination process (Figure 11). Further, at the graining stage, the immersion impacts to the harvest both in quality and quantity. In quality, the produced grain will be changed in the flavor and color; while in quantity, tonnage of the harvest will be reduced along with the disruption of process that occurs at this stage (Figure 12).

The basic concept of loss calculation in this study uses the risk approach, where risk is formulated as follows [van-Westen, 2012a].

Risk = Hazard * Vulnerability* Amount of element-at-risk

Since the risk is defined as the expected losses resulting from interactions between hazards and vulnerable conditions [van-Westen, 2012b], and hazard itself is defined as a potentially damaging event that may cause the loss of life, property damage, social and economic disruption or environmental degradation [Alkema et al., 2012], so if the hazard is changed into a real hazardous event then the risk is turned into loss. Thus the risk equation above can be derived into an equation of production loss of paddy based on 2007 flood as calculated in this study as follow.

Loss = 2007 Flood Event * Vulnerability * Amount of element-at-risk * Value

The characteristic of 2007 flood considered is only flood depth as previously described. The vulnerability used is it at graining stage due to the flood occurred at the graining phase, while the value is the selling price of paddy at the time.

The loss was calculated in each grid cell, while the total loss is the accumulation of them. In this research, the information about the selling price of rice was obtained through FGD. It was agreed at amount of Rp. 21,000,000.00 (about USD 1,500.00) per hectare. The total production loss of paddy in the area is Rp. 1,137,350,000.00 (about USD 100,000.00).

The local government publishes the production loss of paddy globally of each sub-district; so that it can not be directly compared with the loss value resulted in this study. Nevertheless, there are some principles that can be compared between them, as presented in Table 3.

The use of grid-based GIS method does provide a more objective method because each site has different levels of damage. Also, the result can be displayed spatially. The GIS, especially supported by the presence of the DTM, provides more accurate information of flooded area based on the flood extent as well as information about flood depth distribution. This information can be integrated with the vulnerability curves to give the information of damage level of paddy in every location. As a note, the government assumes that the level of damage across the area is considered equal. Every paddy field affected by the flood is deemed to have the same loss value regardless to the differences of the damage rate based on the diversity of the flood depth. Also, the flood-affected area is assessed by converting the parcel number reported by the farmers into hectares, ignoring how many parts are flooded and how deep the immersion is.

The amount of production cost took account in index determining should be not simply the total cost in a single season, but the total cost incurred during the flood. In other words, the loss is accounted as the lost investment. Such an approach is more appropriate in case of the flood occurred in generative phase and the farmers have to replant to be able to harvest in the same season, as if they spend a higher production cost to produce the same volume of that season. In the case of the flood occurred in graining stage, the loss of flooded ready-to-harvest paddy is accounted as a reduction of income, which are valued as the farm gate prices [*FAO*, 2011].

The resilience in this research is focused on the farmer ability to continue the paddy cultivation after a flood event, as the impact of the 2007 flood event toward the farmer households. The five major forms of capital; Social, Economic, Physical, Human, and Natural, can be used as a framework to assess community disaster resilience [Mayunga, 2007]. However, only two forms of capital are studied i.e. human and economic capitals.

In the beginning, there are three aspects of this section investigated through questionnaire, i.e. age, education level, and farming experience. The age is considered related to the mobility to respond the flood effect, while the level of education and farming experience assumed to be related to the knowledge of farmers for replanting efforts. In fact, only the third aspect is took into account as the influential factor of the resilience in this study. The others, age and education, are considered having no effect in replanting capability of the farmers.

This study investigates all factors related to the economic strength of each farmer household, either reinforcing or debilitating. The reinforcing factors cover household income and resources used in next cropping. There are two elements studied in relation with income i.e. the sources and farmer status. In term of the sources, the households having only one source of revenue have lower level of resilience than those who have more sources [Freudenburg, 1992]. The farmer status is actually included in human capital in case of it affects the willingness of the farmers to continue the cultivation. In this study, the status is seen from the economic perspective, in which farmers who hire fields have yields less than those who own the fields. There is a value to be paid as a rental fee. Another factor which strengthens the resilience is the finance resource of the next cropping. This is the most influencing factor to the resilience according to the FGD result. They said that the farmer capability on continuing the cropping depends on the used finance resource.

Meanwhile, the debilitating factors include number of dependent and the losses. The number of dependent directly affects the amount of domestic spending that will ultimately affect their ability to cultivate in the following season. For example, in the same condition in which they lost 50% of their crops, farmers having fewer dependents may still be able to use the outcome as the cost of the next planting, while those having more dependents only cover the costs of daily life. Next, the loss of flooded ready-to-harvest paddy suffered by the farmer impacts on their earning since it is accounted as a reduction of income [FAO, 2011]. Disruption in revenue will affect the balance of household economy. Further, the farmers also said that their losses apart of agricultural production also influence the level of resilience. In particular they mention the breakdown to their houses. The cost that should be utilized as the capital for the next cropping must be used to repair the breakage.

The resilience level is determined based on the resilience value of each respondent. It is calculated using weighting value and score of each influencing factor. All of them; the weighting value, the score, and the influencing factors, were decided by the farmer representatives through FGD, as displayed in the following table.

According to the weighting values of the influencing factors, the resilience value of the farmers in Sidoharjo village can be calculated using this following formula.

$$RES=(0.2)FE+(0.08)DN+(0.4)FR+(0.128)IS+(0.032)FS+(0.128)LP+(0.032)OL$$

in which,

RES : Resilience Value	IS : Income Source
FE : Farming Experience	FS : Farmer Status
DN : Dependent Number	LP : Lost Production
FR : Financing Resource	OL : Other Losses

The results show that the resilience values of the farmers in Sidoharjo village vary between 0.21 and 0.92. The average value is 0.52. In order to more obviously see the relationship between the resilience values and the flood zone, those values are classified into three classes, namely low, moderate, and high; as displayed in the following figure.

According to the figure, most of the respondents are categorized in moderate resilience level. Further, there seems to be an effect of the flood zone toward the resilience level. From zone 1 to zone 3, which means the inundation is getting deeper, there is number increase of low-level and number decrease of moderate-level. Nevertheless, the socioeconomic condition of the farmer also has an influence on those levels. It is seen from the slight rise of high-level number from zone 1 to zone 2 which has a deeper immersion.

The condition is possible to be worse since the farmers predict that the future losses are getting bigger related to the road elevating. The road crossing through the middle of the rice fields, shown as black line in figure 18, is raised about 80 cm. Participants are asked to predict the losses if the flood with a 2007-flood-like magnitude happened again after the road raising. All the participants said that the losses will be much greater. The farmers state that the flood depth will increase around 80 cm as the level of road rising. They also believe that the length of inundation will also increase. Both the depth and duration will significantly affect the damage level of paddy. There should be a regular monitoring and normalization of the Mungkung River to guarantee that the river is able to accommodate the water discharge.

4. Conclusion

The RTK-GPS method gives benefit in spot height measurement, which is then interpolated to create DTM, in term of the speed and accuracy. Refer to the DTM construction, the most appropriate interpolation method in this area is natural neigbour. Further, the presence of the DTM is very significant to give real and detailed flood information, including flood extent and flood depth, which is integrated with the local knowledge. According to the local people, there are three flood sources in this region i.e. rising of water level of the Mungkung River, accumulation of the run off which is restrained by the rising water, and "water jump" due to the influence of centripetal force on the river bends. The depth of the immersion on the paddy fields reaches around 3 meters. Beside provide the flood information, the local people also provide synthetic damage data to build paddy vulnerability and socioeconomic data to assess the resilience.

The paddy vulnerability is influenced by the flood depth and the growth stage of paddy. There are three growth stages i.e. vegetative, generative, and graining phases. Next, the integration of the vulnerability and the 2007 flood depth results production loss of paddy as a consequence of the flood. A grid-based GIS method is used in the loss calculation. It is a more objective method, compare to the method used by the government, because each site has different levels of damage. Also, the result can be displayed spatially. Further, the government uses a loss index based on the production cost in a single growing season to calculate the loss, while this study uses the lost harvest. Both are equally able to be used, but in different cases. If the flood hit the paddy at the vegetative phase and the farmers must replant to obtain the results of the season, the loss is calculated based on the cost of production which is considered as lost investment. On the other hand, when the flood hit the ready-to-harvest paddy, the loss is calculated as lost production.

The losses have an impact on farmer households, including the ability to continue the cultivation in the next season, which in this study is defined as resilience. To determine the level of resilience, 32 respondents were proportionally randomized to each flood zone. The influencing factors of the resilience and its weights and scores were determined by farmer representatives via FGD. As a result, most of the farmers in the village (56.3%) are categorized in moderate level. There seems to be an effect of the flood zone toward the resilience level. Yet, the socioeconomic condition of the farmer also has influences on the level.

This study only focused on the agricultural sector, in particular on rice production. There are many things associated with the losses to be investigated, both in agriculture and other fields. In addition, the mud effect on the damage level of paddy could be a concern for the future research, especially for areas having a longer duration of inundation due to the deposition process. Farmer perception about the risk associated with road rising also investigated in this study. However, a hydrodynamic model is necessary to know exactly the effect of the elevating. Furthermore, the normalization of Mungkung River periodically be a strategy to reduce losses in this area. Thus, a study of the rate of sedimentation in the river will likely give a clear picture of the normalization period.

Acknowledgement

Thank to Dr. M Pramono Hadi for valuable comments and his support during the research and thanks to review for the constructive comments.

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