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Developing Vulnerability Analysis Method for Climate Change Adaptation on Agropolitan Region in Malang District

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Abstract. Agriculture plays a strategic role in strengthening sustainable development. Based on agropolitan concept, the village becomes the center of economic activities by combining agriculture, agro-industry, agribusiness and tourism that able to create high value-added economy. The impact of climate change on agriculture and water resources may increase the pressure on agropolitan development. The assessment method is required to measure the vulnerability of area-based communities in the agropolitan to climate change impact. An analysis of agropolitan vulnerability was conducted in Malang district based on four aspects and considering the availability and distribution of water as the problem. The indicators used to measure was vulnerability component which consisted of sensitivity and adaptive capacity and exposure component. The studies earned 21 indicators derived from the 115 village-based data. The results of vulnerability assessments showed that most of the villages were categorised at a moderate level. Around 20% of 388 villages were categorized at high to very high level of vulnerability due to low level of agricultural economic. In agropolitan region within the sub-district of Poncokusumo, the vulnerability of the villages varies between very low to very high. The most villages were vulnerable due to lower adaptive capacity, eventhough the level of sensitivity and exposure of all villages were relatively similar. The existence of water resources was the biggest contributor to the high exposure of the villages in Malang district, while the reception of credit facilities and source of family income were among the indicators that lead to high sensitivity component.

Keyword: agriculture, economy, industry, Podes, Poncokusumo, tourism, village, water

1. Introduction

Agriculture is an important sector ensuring the sustainability of human life on earth through its function in the provision of food. Agriculture becomes one of the important pillars of the village to improve livelihood and welfare of the community. By strengthening the agricultural sector, there are opportunities to expand employment, improve social welfare and increase the sustainability to reduce dependency on imported goods [1]. Because the farm is identical to the village, the sustainable agriculture means to

support the existence of the village as a base area of agricultural land, labor availability in enough quantities, and the presence of environmental resources, including water sources as one of the main prerequisites agricultural activities.

Total food requirement of agricultural products continuously increases along with the increase of world population which reached more than 7 billion. Many countries realize how agriculture plays a strategic role in sustainable development, but the data showed a lowering trend in the agricultural sector's contribution to Gross Domestic Product (GDP) globally. There was a significant reduction of agricultural sector's contribution to world GDP from 8.1 percent in 1995 to 3.9 in 2014. As the country with the greatest economic value in Southeast Asia, Indonesia is an agricultural based country which also experienced a lowering trend in GDP contribution coming from the agricultural sector. Although the contribution of the agricultural sector in Indonesia was quite high (around 17.1% of GDP) in 1995, but there trend continuously decreased to became 14% in 2007 and 13.3% in 2014. This trend was in line with the magnitude of agricultural land conversion and decrease the number of workers and family farmers who are the backbone of the agricultural sector.

Friedmann and Douglass [2] has introduced a new concept of Agropolitan as one of the regional development planning concept. It was quite popular in many decades in developing countries such as Indonesia. Agropolitan has been defined as a centers of economic activity based on agriculture, where the agricultural sector will be able to grow and thrive because it is able to serve, encourage, and transporting activities (agribusiness) in center of farming villages and surrounding villages. According to Rustiadi and Hadi [3], agropolitan is a concept of regional development that arises because of the problems of development gaps between city as a center of economic activity and the growth of rural areas as a center of agricultural activities. Agropolitan development is a solution to reduce the flow of urbanization as well as to empower the rural economy. Through the concept of Agropolitan, agriculture can be developed as part of regional planning and development that can make the village as the center of economic activities based on agriculture and agro-industries that have high added values to encourage people in the villages to live in their respective areas. Agropolitan can be developed in rural areas with the population between 50,000 and 150,000 people [2].

Mercado [4] mentions five characteristics of agropolitan area, which includes a) a relatively small geographical scale; b) a high level of self-sufficiency and independence in decision making and planning, based on popular participation and cooperative action at the local level; c) the diversification of employment in rural areas to include agricultural and non-agricultural activities, emphasizing the growth of small-scale rural industrialization; d) the function of urban-rural industries and their relationship to local resources and economic structures; and e) the use and evaluation of local resources and technology. The idea of agropolitan introduced by Friedmann and Douglass [2] will basically empower the village for not only maximizing production and local trade, but also can increase social knowledge to the wider community, thereby increasing the capacity of communities to address difficult and complex problems.

The goals of agropolitan development can be achieved if some factors such as social, economic, spatial planning and the environmental are completed. One component of the environment is the management of sustainable water resources. Water is one of the resources that most vulnerable to climate change. Changes in the climatic parameters such as precipitation and air temperature and other parameters directly or indirectly affect the condition of water resources in the region. In the development of agricultural areas, water availability for agricultural land is very important. Water availability can be met either through rainfall or irrigation, but water provision and arrangements are important to ensure the availability of water in agricultural activities.

As a whole model of development, agropolitan composed some key aspects in achieving its goals, i.e., agriculture itself, economic aspects, aspects of the industry (agro-industry) and aspects of tourism (agro-tourism). However, behind the excellent concept of agropolitan model, there are also many challenges.

Water resources became one of the main problems is quite important to note. Because the source of the water is very vulnerable to the impacts of climate change. Based on the results of the survey in 2012, Malang regency is one area that has a high degree of vulnerability to climate change, especially in the sector of water resources and agriculture. However, so far there was no models that has been developed especially in the focus of agropolitan vulnerability in Malang. Therefore, it is very important to develop assessment methods of vulnerability with the focus on Agropolitan region to be used as part of climate change adaptation analysis in Malang[5].

2. Related works

Model of agriculture vulnerability now has evolved. But the development model of vulnerability to climate change with a focus on the agropolitan and some considered aspects of water resources has not been developed. Developing indicators of vulnerability has been proposed by Perdinan *et al.* [6] based on the aspect of supply chain i.e. production, post-harvest and storage, distribution and consumption. Meanwhile, Agustian [7] analyzed the factors that affected the production of maize cultivation in Garut. Agustian [7] concluded that the scale (land area) and seed investment significantly and positively related to corn production. In addition, Boer e*t al* [8] has divided indicators of vulnerability with a focus on aspects such as ecosystem development, poverty, education, health, infrastructure, livelihoods and governance. Meanwhile, the Indonesian government through the Ministry of Agriculture especially Balitklimat has developed indicators of food security which is in accordance with the definition of food security of the FAO [9] and Law No. 7 1996. According Estiningtyas *et al.* [10], there are four components in this focus: 1) the availability of food; 2) the stability of food supply; 3) accessibility / affordability of food, and 4) the quality/food safety.

3. Methodology

The differences in meaning between the components, indicators, sub indicators and data/variables is important to note before developing vulnerability assessment method of agropolitan region. The components are among the largest part of the division. While the indicators are part of the components and the data/variables are a constituent part of the indicators. The development of vulnerability assessment in this research is based on IPCC concept (AR-5) where the climate-related disaster risk (R) is a function of the hazards (H), vulnerability (V) and exposure (E) [11].

The vulnerability and exposure were assessed using data and socio-economic information. Therefore, data selection for each indicator was determined based on the availability of data to the village level. BPS data was a major source of data usage in this study. Among them are BPS Kecamatan Dalam Angka 2015 from each subdistrict in Malang District, Population Census of 2010, Potensi Desa (Podes), Data of 2014 and Agricultural Census 2013, and the baseline set was in 2014.

Understanding variation or range of values for socio-economic data in aimportant, an therefore it is necessary to normalize socio-economic data. Normalization data was done so that any data that was used has a range of zero to one (0-1). Normalization step aimed to equalize the value of the variable to be calculated by other variables that have been normalized as well. In this guide, normalization techniques were caculated based on Mechanical Normalization Median proposed by Perdinan *et al.* [12]. Then the next step was to calculate a combined score between variables normalized into sub-indicators in each component. Combination of the indicators into Components was using the following equation:

$$\text{Component } A\ (KK)_i = w * (\text{K1+K2+K3+K4}) \quad (1)$$

where: *i* represent the village-i and w is weights for each indicator. Selection of the appropriate amount of weight carried the relation between the indicator and sensitivity to agriculture and climate change. The maximum value of the weight is 1.

The use of the same value range for measuring the level of vulnerability on each component is required as a standard value. Each component has a value range by 0-1. Furthermore, the each component was grouped by the value/index. Classification was done by dividing the proportional value of the degree of vulnerability (0-1) into five classes (table 1). Component-level vulnerabilities categorized as "Very High" if the index above 0.8 to 1, and categorized as "Very Low" when vulnerability index below 0.2 to 0. There were five groups, namely VL (Very Low), L (Low), M (moderate), H (High), and VH (Very High). Staining of each category of components was made for mapping purposes vulnerability index agropolitan area in Malang.

Table 1. Criteria of index.

Components Value	Staining Exposures; Sensitivity and Vulnerability	Staining Adaptive Capacity
0.0 – 0.2	Very Low (VL)	Very Low (VL)
0.2 – 0.4	Low (L)	Low (L)
0.4 – 0.6	Mediun (M)	Mediun (M)
0.6 – 0.8	High (H)	High (H)
0.8 – 1.0	Very High (VH)	Very High (VH)

4. Result and Discussion

4.1 Determination of Component Agropolitan

Regional vulnerability assessment method of Agropolitan was prepared with basic consideration that agropolitan as a single model of development that consisted of several main aspects in achieving its goal of agricultural aspects, economic aspects, aspects of the industry (agro-industry) and aspects of tourism (agro-tourism). Each aspects was composed of supporters of each component. Agropolitan is a model of development that relies on centralized infrastructure development similar cities in rural areas which aims to boost agricultural production, support the growth of agro-processing small and medium scale, and to encourage the diversity of economic activities in rural areas [13]. Referring to the notion of agropolitan and water resource issues that occur in Malang agropolitan, it is important to consider in the development of the vulnerability assessment of agropolitan region should consider the availability and distribution of water resources as one of the main problems of climate change impacts.

4.1.1. Aspects of Agriculture. Agriculture becomes the main focus in the development of the concept Master Plan Agropolitan, so that all constituent components of Agropolitan consider this aspect. In the preparation of the agricultural component, the various indicators that support agricultural water resources as affected by climate change impacts should also be considered. Various indicators constituent aspects of agriculture including the density of agricultural workers, the existence of the affected buildings, agricultural pollution, the existence of the affected farm, and decreased quality of land (the exposure component) also need to be included. Non-productive age population, agricultural workers, labor agriculture industry and sources of income (the sensitivity component) and access to the agricultural also important component for adaptation capacity.

4.1.2. Aspects of Economy. Economic aspects and agriculture in Malang was very closely related. The district's main economy was highly dependent on agriculture. The agricultural was a primary sector in the economy of Malang. Therefore, most of the economic indicators was very closely linked to the concept of agropolitan. This indicator was developed by the density of the component exposure of agricultural workers, the productive age population, agricultural workers, level of poverty, and income sources and public acceptance of credit facilities for component sensitivity. In the adaptive capacity component,

constituent indicators consisted of economic levels were compiled based on the availability of venture capital agriculture, agricultural markets, supporting agricultural enterprises, cooperatives and local revenue (Pendapatan Asli Daerah or PAD). The adaptive capacity was also composed by indicator of regional tourism.

4.1.3. Aspects of Industry. Malang had prospective industries, but they were not able to develop progressively. This can be seen from the difference between production and their potential. Not all areas suitable and conducive to be used as an industrial area. Many factors still needed to develop the industrial sector, such as: the availability of qualified human resources, natural resources, and considerable investment. However, referring to the availability of data, the drafters of this indicator consisted of industrial pollution, agricultural and industrial workforce proportion of micro and small industries.

4.1.4. Aspects of Tourism. Tourism in Malang Regency is determined by a variety of indicators that strongly influence including tourist location, traders inside and outside of the tourist attractions, facilities of tourist attractions, cleanliness sights, human resources (managers, traders, visitors), the availability of water resources, and ticket prices to enter tourist sites. However, referring to the availability of data, the indicator is organized by the indicators of the presence of tourist attractions and the ability of excursions.

4.2 *Selected Indicators for Vulnerability Assessment Method of Agropolitan*

Considering four aspects which were mentioned above and water resources as the main issue then drafted vulnerability concepts matrix constituent agropolitan was established with reference to the third component, namely the IPCC vulnerability exposure, susceptibility consisting of sensitivity and adaptive capacity. Table arrangement with a rationale for the data on each indicator is shown in Appendix 1 and Appendix 2. The selection of these indicators also referred to the availability of data at the village level throughout Malang. After selection of indicators, selection of data at the village level was carried out as a material forming indicator. This selection puts 115 village-level data and information to be used to compile the 51 variables derived. From the 51 variables, these derivatives were combined to form 36 sub-indicators used to compile the 21 indicators in all components of the degree of vulnerability (table 2).

Table 2. Total use of data and information constituent indicators.

Komponen	Indicator	Sub Indicator	Variabel	Data
Exposure	8	12	15	115 Data and information
Sensitivity	7	10	13	
Adaptive capacity	6	14	23	
Total	21	36	51	

4.3 *Analysis of Vulnerability of Malang District and Sub-District Poncokusumo*

The map of exposure, sensitivity, adaptive capacity and vulnerability of the entire village in Malang based on Podes Data 2014 is presented in figure 1. From the total number of 388 villages in the district of Malang, for exposure map, there were 341 villages or 88% in the category of "medium" while 41 villages or 11% were in category of "low". Specifically for agropolitan region in District Poncokusumo, village Ngadas was the only village from 17 villages with "low" level of exposure whereas the remaining of 16 villages were in the category of "medium".

Most villages including Pujon considered to have high exposure caused by several factors. The first was the poor condition of water sources. This indicator was determined by the existence of water source for bathing/washing and drinking/cooking. Some villages were only using one source of water for various

purposes (rivers, irrigation canals, lake/reservoirs/dam). The existence of natural resources in a region will be exposed to the increasing threat of climate change. If a community activity depends only on one/less water source then the area will be categorized as highly exposed. Meanwhile, the presence of natural attractions also greatly contributed to determine the area dealing with high exposure. Nature tourism was heavily affected by the impact of climate change, therefore, the more places that have natural attractions, the more potentially to be exposed. Ngijo village, Kalisongo, Bendosari and Pandesari have potentially affected by nature of climate change.

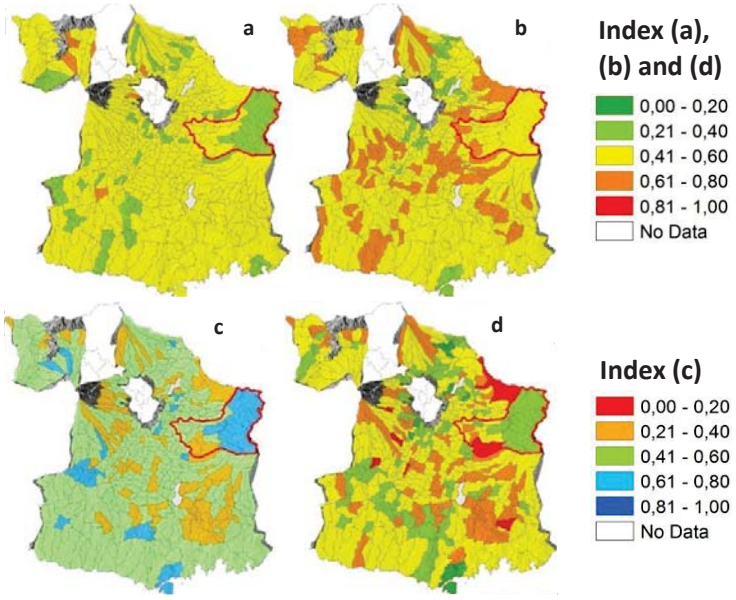

Figure 1. Map of Exposure (a), Sensitivity (b), Adaptive Capacity (c) and Vulnerability (d) of Malang District to climate change.

For sensitivity component, the distribution was more varied throughout the villages (figure 1). However, the majority of the villages are still located on the criterion of "medium" which comprised of 269 villages, or 69% of the villages. In contrast to the exposure, sensitivity component tended to have more vulnerable, because there were 84 villages (22%) categorized as "high" in this criteria. In Sub Poncokusumo, from 17 villages there were three villages that were included in the category of "high" while the rest were classified as "medium". The villages with high category were spread more in the central and southwestern districts and only a small portion was in the north. The villages with the category of "high" had an index interval of 0.60 - 0.80. The name of villages with the value of index that more than 0.65 were Tulungrejo, Wonorejo, Corner, Karangrejo, Maguan, Plandi, Plaosan, Jeru, Sukolilo and Pait. While in Sub-District Poncokusumo there were three villages in the category "High" including Dawuhan, Pajaran and Ngebruk. The factors contributing to the high sensitivity were the main indicators of public acceptance to credit facility and the family income. While the other factors were the dependence of the water source followed by family agricultural workers.

The majority of villagers were still rely their livelihood on staple crop agriculture such as rice. For example, in the Sub-District of Pajaran, The Pajaran village had 6429 inhabitants, and approximately 4.8% (310) of the people worked in agriculture (crop cultivation, fishery, and livestock), while 13.6% (875) people worked as farm labors. More and more resident's livelihood was depend on agriculture, the region will be more sensitive, especially if their agricultural products was in the form of staple crops

(rice). This because agriculture is one of the most vulnerable sectors affected by climate change mainly related to rainfall conditions which have high implication to the presence of water for agriculture.
Analysis of the adaptive capacity of Malang shows that the capacity of most of the villages in the district classified as "medium" (figure 1). This data suggested that the adaptability of the villages to the climate change in the space of Agropolitan was good enough. Based on the recapitulation, the majority of the village which consisted of 291 villages (75%) belong to the criterion of "medium" and 77 villages (20%) included in the criteria of "low". Only 20 villages (5%), which had capacity of adaptation of "high". While in District Poncokusumo, the majority of villages varied from the level of adaptation of "low" to "high", and the majority tended to have the level of "medium".

Villages with low capacity needs to get more attention. Some of these areas were Ringinsari, Sumbersuko, Kepatihan, Sukorejo, Petungsewu, Ngadirejo, Taji, Argosari and Ampeldento. While the village with low capacity in District Poncokusumo were Dawuhan, Sumberejo and Ngadireso. The majority of the villages graded as low capacity mainly caused by some factors including lack of access to agricultural (0175), the economic level (0175) and the industrial level (0.175), followed by lack of disaster preparedness (0100). The values showed the weighting applied when calculations. The analysis also showed that the respective Index dominant indicator worth very low (<0.333). This indicated the ability of the village to adapt, such as inadequate infrastructure which was very low.

Based on calculations, the majority of villages were included in the category of "medium", but its spread fairly distributed throughout the area categorized as "low" and "high". From 388 villages surveyed, around 222 villages (57%) were included in the criteria of "medium" while 81 villages (21%) were counted as "low" and 68 villages (18%) were categorized as "high". Similarly, the Sub-District Poncokusumo, the majority of villages were likely categorized at the level of vulnerability of "low" and "medium". Only two villages were drop into category of "high" and "very high" (figure 1). Although only a view villages that fell into this category but these villages need serious attention. Villages that enter into the category of "very high" were the village Kepatihan, Sukorejo, Dawuhan, Sumberejo, Kranggan, Petungsewu, Ngadirejo, Taji and Argosari. As mentioned before the high vulnerability was caused by low adaptive capacity and/or high sensitivity. For example, with the interval of 0-1 for each component of vulnerability, Dawuhan village in Sub-District Poncokusumo had a sensitivity of 0.60 while the index of adaptive capacity was only 0.30.

In summary, the distribution criteria for each component shows that more than 50% of the villages entered in the category of "medium" based on the calculation of each component. Only a few villages were included in the category of "low" or "high". That is, for the majority of the exposure and sensitivity village is quite vulnerable to the effects of climate change, even though 80% of villagers have enough adaptability above (figure 2).

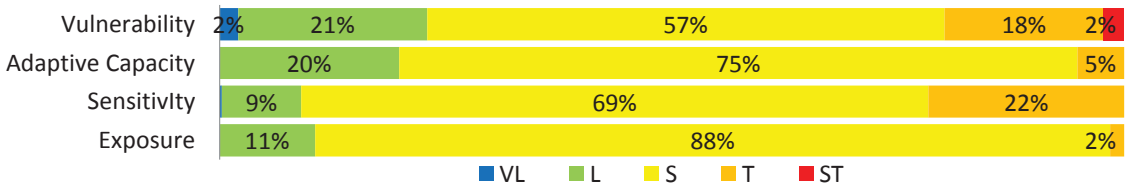

Figure 2. Percentage of villages based on criterya. Note: VL, very low; L. low; S. medium, T, high; ST, very high.

5. Conclusions

Vulnerability assessment method of the impact of climate change on the agropolitan region can reflect the level of vulnerability and exposure as components to a risk assessment. The results of vulnerability

assessments to all villages in the district showed that most of the villages were categorized at the moderate level, but there were 20% of 388 villages that has high to very high vulnerability. One of the causes was the average of economic level for villages in Malang was still low. In the case of agropolitan region in the sub-district of Poncokusumo, the vulnerability of the village varied between very low to very high. Assessment of the factors that contribute to high vulnerability showed that most villages were vulnerable due to the low adaptive capacity, even though the level of sensitivity was not much different and the level of exposure of all villages were relatively similar. Based on the average of the villages in the district of Malang, access to basic facilities contributed the most excellent indicators of adaptive capacity, while the low level of economic contributed to low adaptive capacity. The existence of water resources was the biggest contributor to the high exposure of the villages in the district of Malang. The acceptance of credit facilities and sources of family income indicators led to high sensitivity component at the district level. In the area that was developed specifically as agropolitan region which is in sub-district Poncokusumo, the vulnerability was relatively higher than the average village in the district. One of the villages, which is Sumberejo have very high levels of vulnerability caused by low levels of adaptive capacity. Compared with other villages in the same district, the sensitivity and exposure levels were not too different and have a similar pattern for all indicators.

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