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Integration GIS and multicriteria analysis critical land farming in Welang watershed

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Abstract

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The sustainability of the watershed is affected by the activities and behavior of people around it. Determination of agricultural superior commodities that are based on environmental, economic and social sustainability is a resource based theory in realizing the further stages of agricultural management from the complexity of the interrelations that occur in the watershed. The aim of the study was to analyze the integration Multicriteria Analysis (MCA) Land Suitability and GIS approach to determine the superiority commodity of agricultural critical land in the Welang Watershed. Respondents in this study amounted to 110 people. The results showed that physical, soil and agroclimate properties analysis showed that the suitability of land suitable for upland plots in actual and potential for vegetable crops was potato plant while for food crop was corn. The highest income farming for food crops is corn, meanwhile in vegetable garden plant is known potatoes have been highly income. In social dimension approach community aspiration as important thing when decide critical land farming. AHP analysis can be concluded that erosion and temperature became main priority to agriculture cultivation especially in upland subsystem in watershed. Overall, AHP results have consistent values and accurate for decision making.

Keywords: AHP; Critical Land; GIS; Multi-Criteria Analysis; watershed

Introduction

Watershed is a stretch of territory bounded by topographic barriers that receive and collect rainwater, sediment, and nutrients and drain it through the tributaries and empty them into one spot. One of the essential watershed areas in watershed protection is the upland sub- system. Upper watershed is considered a good condition if the river discharges in the rainy and dry season is small, because most of the water by rainfall is absorbed into the soil so that the surface flow is very small.

Welang watershed is a large river that crosses three administrative regions. The downstream part of the Welang River crosses the Pasuruan Regency, the middle and upstream part crosses the Pasuruan Regency, and the most upstream part crosses Malang Regency in the Lawang District in East Java Province, Indonesia. Astronomically the Welang River watersheed is located between 112º37′30″ – 112º52′30″ East Longitude and 7º37′20″ – 7º52′30″ South Latitude. Welang watershed is part of the hydrological cycle which is precisely in the east in Pasuruan Regency, with the main rivers flowing from its headwaters in the highlands to the south, receiving flow from its tributaries in its central area and empties into the Madura Strait which is the the northern border of Pasuruan Regency. Welang River is the largest catchment area, which is 518 km2, also the longest 36 km and 35 m wide (Pasuruan Regency, 2014).

In recent years the existence of watersheds has become the focus of serious management related to the increasingly widespread degradation of land, due to the frequent occurrence of landslides, erosion and sedimentation, flooding and drought, which in turn causes critical land. Welang watershed is one of the many watersheds in Indonesia experiencing the phenomenon of land degradation to critical land. Maroeto et al. (2017), argues based on existing land use maps that are overlaid with critical determinants, it can be seen that almost in Welang watershed area has a critical status.

Critical land is a land whose soil conditions have some sort of physical, chemical or biological damage that is harmful for the hydrological, orological, agricultural, and residential and socio- economic functions of the surrounding area (Ade, 1996). Other perspectives are given by the Washington County Critical Lands Resource Guide (2008) which suggest that the term 'critical land' is used to describe general landscape conditions; lands with natural constraints that could endanger the lives, safety, and welfare of citizens (such as floods and unstable slopes).

The problem becomes complex when the spatial use pattern based on land evaluation in the watershed is far from being expected. If the effort to improve the economic welfare of the people in the watershed area can be synergized with the improvement of watershed management (Halefom et al., 2018), so that efforts to find land use patterns are appraised closely to reality. In order to discover the appropriate pattern of space utilization, it not only requires technical, economic and agroecological knowledge, but also situational understanding among the watershed communities. Jafari & Narges (2010); Shamsi (2010), agreed that in addition to land knowledge factors, there are other social and economic components that are also important in managing the watershed.

Multicriteria analysis was developed to assist spatial decision-making when a set of alternatives needs to be evaluated based on many conflicting criteria. MCA is an effective tool for decision making (Malczewski, 1999) and aims to select a number of possible options and goals (Joerin et al., 2001). There are different approaches used for the selection of tools to solve the problem of land suitability such as fuzzy method, TOPSIS (Technique For Others Reference by Similarity to Ideal Solution), ELECTRE Tri (Elimitation Et Choix Traduisant la REalité), PROMETHEE II method (Tarnanidis et al., 2017) and AHP (Analythical Hierarchy Process) (Joerin et al., 2001; Reshmidevi et al., 2009; Mendas & Delali, 2012; Kazemi et al., 2016). Referring to the opinions of some researchers (Akinci et al., 2013, Mighty, 2015; Zhang, et al., 2015), they suggest that AHP for agriculture land compatibility is reliable, because in AHP, a priority is composed of various a choice that could be a previous criterion has been decomposed first, so priority setting is based on a process that is structured in logical thinking to draw a conclusion.

Integration between GIS and MCA aims to generate an efficient spatial decision-making system to produce land suitability maps (Reshmidevi et al., 2009; Elsheikh et al., 2013; Alkinci et al., 2013). Further (Mighty, 2015), the key advantage of incorporating MCA techniques into GIS-based procedures so that it reflects the weighting factor (their preference for evaluation criteria and or alternatives) to GIS-based decision-making procedures, and receive feedback on the implications for evaluation and policy recommendation (Mendas & Delali, 2012). The aim of the study was to analyze the integration Multicriteria Analysis (MCA) Land Suitability and GIS approach to determine the superiority commodity of agricultural critical land in the Welang Watershed (Figure 1).

Materials and Methods

Physics and Chemistry Soil

The method used in soil sampling is based on the stratified sampling method (StS). Soil sampling using the StS method is more precisely done in the survey area in a moving sequence as well as in the highlands (Mason, 1992). The distribution of stratum samples in this study used three (3) approaches to the general state of the research areathat include : 1. Land use, divided into vegetable plantations; rainfed paddy fields; and moor; 2. The height of land, ie> 700 meters above sea level (MASL); 3. Critical land, divided into rather critical lands, or critical potential land. Critical land means lands with natural constraints that could endanger the lives, safety, and welfare of citizens (Washington County Critical Lands Resource Guide, 2008). In order to support the research needed materials from soil physical including soil parent material, soil texture, density, porosity and also soil temperature.

Soil chemistry shows ion activity which cannot be seen directly but can be tested using chemicals. Soil chemical properties can also be used as recommendations in fertilization for plant nutrients. Soil sample taken from the field are then taken to the laboratory. The undisturbed soil sample is directly saturated in water in the tray to keep the soil in a field and keep the water in the tray dry. When the air is dry, pounded with a pestle, and sieved with a 2 mm sieve, it qualifies for the physical properties of the ground and passes 0.5 mm sieve for soil chemistry followed by soil sampling at every minipit using a ring sample for testing purposes in the soil physics laboratory. Prior to sampling, the soil surface is cleaned first from grasses, rocks, gravel, and the remaining plants or fresh organic matter / litter. In the soil sampling, chemical tests were conducted to test the content of soil pH (H_2O), Cation Exchangable Capacity (CEC), Base Saturation (BS), exchangeable bases (K, Ca, Na, Mg) Al saturation, N-total and P_2O_5 and soil organic C content.

Spatial Analysis

The maps were digitized into GIS layers by on-screen digitizing tools in Arcgis 9.3. The attribute data is structured to provide information about the existing spatial appearance so as to generate a database consisting of spatial data and attributes. The data digitization process produces a layer containing specific information (Halefom et al., 2018). The overlay data is then analyzed by weighting and scoring based on terms and criteria aimed at identifying the leading commodities of agriculture of critical land (Figure 2). The level of suitability of a land is based on the classification system with the category that is declining. First the order indicates a suitable land (S) or Not Suitable (N) for the development of a particular agricultural commodity. Both classes show the degree of land suitability of each order, S1 (Highly Suitable), S2 (Moderate Suitable), S3 (Marginal Suitable), N1 (Not Suitable) and N2 (Not Permanent) (Figure 2).

Net Farm Income

Agriculture and Agri-Food Canada (2000) stated that farm receipts are measures to obtain agricultural cash receipts (production multiplied by prices) from agricultural production. Soekartawi (1995) explained that farm income is obtained by multiplying the amount of crop (kg) with the selling price per kilo for one period (e.g one planting period or one year). TR = P.Q where: TR = Total Revenue; P = Price, and Q = Product Quantity. In addition, the R / C ratio is used to assess the feasibility of farming. R / C Ratio (Return Cost

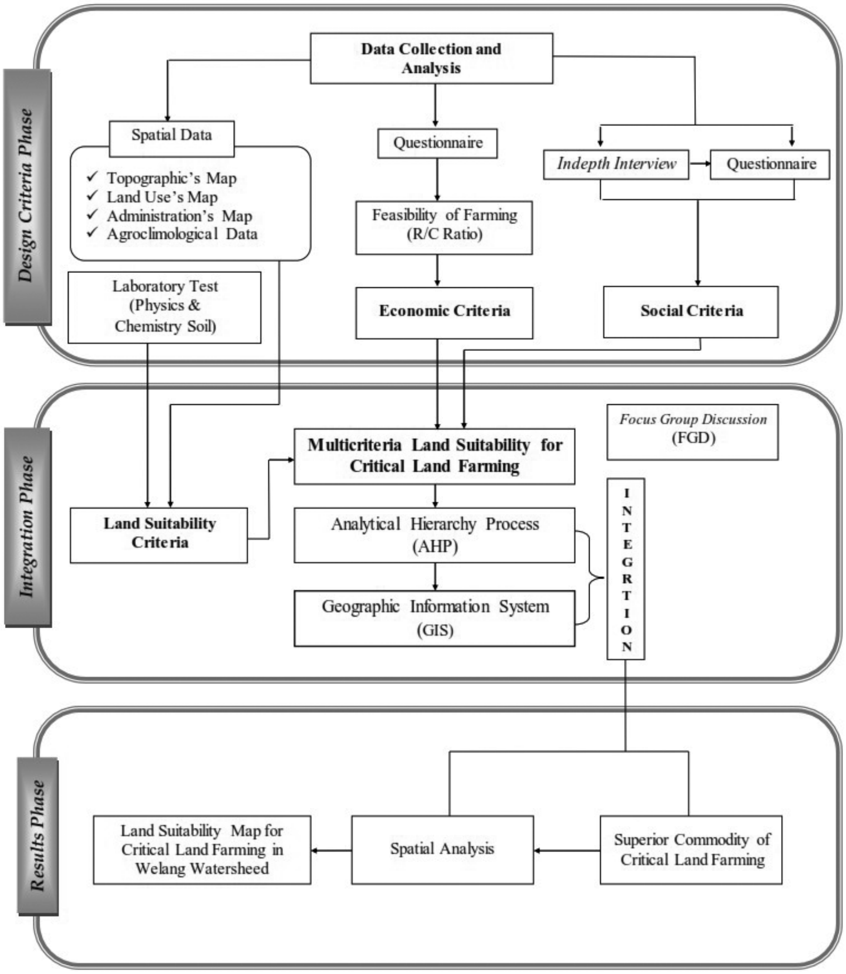

Fig. 1. Research framework

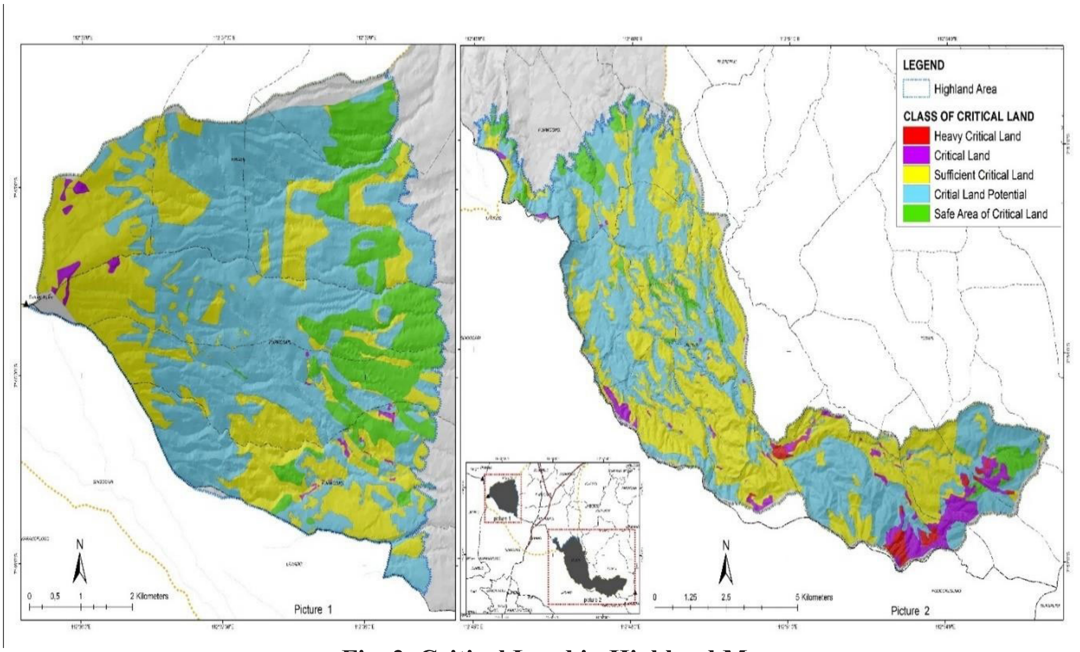

Fig. 2. Critical Land in Highland Maps

Ratio) is the ratio between acceptance and cost, which can be mathematically expressed as R / C = PQ. Q / (TFC + TVC), where: R = acceptance; C = cost; PQ = output price; Q = output; TFC = fixed cost; TVC = variable cost (variable cost). Criteria R / C ratio, namely: R / C ratio> 1, then the business is efficient and profitable; R / C ratio = 1, then the farm is BEP; R / C ratio <1, then inefficient or losses.

Farming analysis is used by considering economic valuation in evaluating the feasibility of agricultural superior commodities through calculation of farm income, so that agricultural cultivation is economically in accordance with its designation. Proportionate Stratified Random Sampling method was used to determine farmers for collecting the answer of the questionnaire so it is known as 80 respondents.

Farming Social-Economic Factors

In this research, farming socio-economic factors it means factors from society that affect economic decision making from agricultural cultivation is carried out based on score preferences (Kepel et al., 2000; Riswan & Lutfi, 2010; Ramli, 2015), so that sampling was determined as much as 25 respondents. All respondents will be asked about leading agricultural commodities from different points of view a) Suitability with community aspirations, b) Employment, c) Local Knowledge Farming and d) Local and export market potential. Furthermore, it will be analyzed by descriptive frequency approach from likert scale approach (Joshi, et. al., 2015). The criteria and the weight of the score assessment are set to 5 = "Strongly Agree", 4 = "Agree", 3 = "Neutral", 2 = "Disagree" and 1 = "Strongly Disagree". The social analysis approach is applied because land use human- oriented. Land use that is based on personal interests without considering the compatibility of the land, if it is not accompanied by efforts to conserve land resources will result in another decline in productivity.

Expert Judgment Sample for AHP

The AHP model uses human perception which is considered expert as its main input. The criteria of excellence here refers to people who understand the problems posed correctly, feel the effects of a problem, or have an interest in the problem (Saaty, 1980; Saaty, 2008). Sampling techniques for as many as 5 people based on purposive sampling with expert judgment provisions include: 1. Farmers representative; 2. Agricultural Extension; 3. Expert staff of Department of Agriculture and 4. Academics, researchers/lecturers representative, and the supporting tool using Software Expert Choices.

Results and Discussion

Land Suitability

The moor land had dominated are a corn with a class of S3wa land suitability, nr (Marginal Suitable) with problems on water availability at ideal rainfall ranging from 500 to

Table 1. Laboratory Results of Land Suitability of Crops

Land Condition	Crops												
	Moor Plants						Rainfed Lowland Plants						
	Corn		Cassava		Chili		Ketela Pohon	Corn		Paddy		Cassava	
	Actual	Potential	Actual	Potential	Actual	Potential		Actual	Potential	Actual	Potential	Actual	Potential
TgTK	S3wa,nr	S3wa	S3wa	S3wa	S3wa,nr	S3wa	STHTK	Nlp	Nlp	Nrc,lp	Nrc,lp	Nlp	Nlp
TgPK	S3wa,nr,eh	S3wa	S3wa,eh	S3wa	S3wa,eh	S3wa	STHPK	S3wa,eh,lp	S3wa,lp	S3rc,eh,lp	S3rc,lp	S3wa,eh,lp	S3wa,lp
TgAK	Nlp	Nlp	Nlp	Nlp	Nlp	Nlp	STHAK	S3wa,lp	S3wa,lp	S3rc,eh,lp	S3rc,lp	S3wa,lp	S3wa,lp
TgK	S3wa,oa,rc,lp	S3wa, rc,lp	S3wa,oa	S3wa	S3wa,oa.rc,lp	S3wa,rc,lp							

Source : Data Analyzed
TgTK: Moor Not Critical, STHTK : Rainfed Lowland Not Critical, tc: Temperature, eh: Erosion, TgPK: Moor Potential Critical, STHPK: Rainfed Lowland Potential Critical, wa: Water Availability, lp: Land Cultivation, TgAK: Moor Sufficient Critical, STHAK: Rainfed Lowland Sufficient Critical, rc: Root Media,TgK: Moor Critical, nr: Nutrient retention

1200 mm, but the research location is over 3500 mm / y and nutrient retention at base saturation of less than 35% of the corresponding land require alkaline saturation of more than 50% in uncritically unfixed land (Table 1). While for critical matters, there is a class of suitability of S3wa, oa, rc, lp (Marginal Suitable) with factor on water availability and oxygen or drainage availability, rooting media and land preparation but potentially if land improvement is obtained S3wa class, rc, lp for land Critically has a value of Nlp (Not Suitable) on land preparation. Based on very little field conditions in the highland areas that grow chili.

Maize is also dominant in rain fed lowland crop and the last of cassava plants and from the assessment of land suitability class for rainfed lowland crop is obtained as a result of Nlp (not suitable) with limiting factor on land preparation at surface rock and rock outcrop. Potentially fixed on land preparation Paddy and cassava for upland plots of land for rainfed lowland is very few.

The most dominant vegetable garden plant is the potato plant and the second is the next cabbage carrots with the suitability class actually show that the more critical land the more constraints for non-critical vegetable garden for the potato plant has the S3tc class (according to the marginal) with the constraints on the temperature, which is suitable at temperatures of 16°C to 18°C whereas overall on the plateau of the study the average temperature of 22°C for vegetable gardens is very critical to have Neh class (Not Suitable) with constraints on the dangers of erosion and flood, if the land is improved it will reduce the constraints Which is in the field, potentially for non-critical vegetable garden remains S3 tc (Marginal Suitable) with only constraint at temperature while vegetable garden is critical to S3tc (Marginal Suitable) with constraints on temperature and erosion hazard (Table 2; Figure 2).

Net Farm Income

Farming is basically an applied knowledge about farmers or farmers in determining, organizing and coordinating the use of production factors effectively and efficiently to provide maximum income. According to Agriculture and Agri-Food Canada (2000); Soekartawi (1995), the cost of farming is differentiated into fixed costs are relatively fixed costs, and continue to be issued even if the production is large or small. This study has identified fixed cost expenditure by farmers for taxes, farm equipment, and irrigation fees. In addition, variable cost is also incurred: the cost of which is greatly influenced by the production obtained, such as the cost of input (labor, fertilizers, pesticides, and seeds). The large and small production costs result in low and high income earned and ultimately determine wheth-

Table 2. Laboratory Results of Land Suitability of Vegetable Garden Plant

Land Condition	Vegetable Garden Plant					
	Potatoes		Cabbages		Carrots	
	Actual	Potential	Actual	Potential	Actual	Potential
KSTK	S3tc	S3tc	S3wa,nr	S3wa	S3tc	S3tc
KSPK	S3tc,eh	S3tc	S3wa,nr,eh	S3wa	S3tc,eh	S3tc
KSAK	Neh	S3tc, eh	Neh	S3wa,eh	Neh	S3tc, eh
KSK	Neh	S3tc, eh	Neh	S3wa,eh	Neh	S3tc, eh
KSSK	Neh	S3tc, eh	Neh	S3wa,eh	Neh	S3tc, eh

Source : Data Analyzed

KSTK: Veg. Garden Not Critical, tc: Temperature, eh: Erosion, KSPK: Veg. Garden Potential Critical, wa: Water Availability,lp: Land Cultivation, KSAK: Veg. Garden Sufficient Critical, rc: Root Media, KSK: Veg. Garden Critical, nr: Nutrient retention, KSSK: Veg. Garden Heavy Critical

er or not proper farming is practiced. As for the highland farmers passed by the Welang watershed scattered in various areas of Tosari District as many as 10 people, Purwosari District as many as 22 people, Tutur District as many as 25 people and Prigen District as many as 23 people so that a total of 80 farmers respondents. The results of farm analysis in highland are shown in Table 3.

Table 3 shows that the largest mean value of revenue for food crops is corn which is 318.69 USD/kg followed by second largest is paddy commodity with revenue earning of 288.72 USD/kg. Interesting to observe is the cassava commodity that produces the highest production of 198.71 USD but on the other hand has the lowest acceptance value of 287.89 USD/kg. This is due to the large cost incurred during cultivation of Cassava especially on the allocation of labor costs. The use of labor is a factor that must be met for sustainability of cassava farming activities. Generally labor involvement starts from the time of planting to harvest. Most of the labor used comes from within the family, resulting in limited cassava maintenance. They only do the maintenance of the activities of pruning, they are have not spare time only and finally decide use of labor outside the family, so implicate large ofcost production.

Otherwise with Vegetable Crops, hieghest income yeilds is the potato commodity with a value of 1980.68 USD/kg, followed by cabbage and carrots with each receiving value of 839.63 USD/kg and 134.07 USD/kg. Potato farming became the foundation of farmer's livelihood in upland areas passed by Welang watershed especially Tutur District and Tosari District, Pasuruan Regency, because the income of farmers mostly come from potato farming. The sustainability of potato farming is determined from the economic aspect, considering the relatively stable price, high business potential, the business segment can be selected according to the capital, the guaranteed and reliable market, and the long shelf life compared to other vegetable products.

In general the value of R/C ratio above 1, it means that both cultivation of food crops and vegetable crops is technically feasible to continue to be done. However, the note is that cassava where the crop is present when the harvest arrives can affect the structure of the soil will change so that the aggregate stability of the soil smaller and eventually lead to land erosion. Therefore, although cassava cultivation is economically feasible but not physically recommended land related to land conservation measures. This review of economic analysis provides an illustration of the leading commodities of agriculture of critical land in Welang Watershed for the determination of corn and potato commodities.

Table 3. Comparison production, total cost, revenue and R/C ratio between crops and vegetables

Means of Value Crops				
Commodities	Production, kg	Total Cost, USD	Revenuem USD/kg	R/C ratio
Corn	1.379	139.01	318.69	2.29
Paddy	1.123	136.18	288.72	2.12
Cassava	3.020	198.71	287.89	1.44
Means of Value Vegetables				
Potatoes	4.534	801.11	1980.68	2.48
Cabbage	9.168	384.6	839.63	2.18
Carrot	1.119	67.77	134.07	1.97

Social-Economic Sustainability

The concept of superior commodities from farm reflection can be seen from two sides, namely the supply side and the demand side. In the supply side, superior commodities are the most superior commodities in their growth in environmental conditions, technology, and socio-economic conditions of farmers in a region (Laura et al., 2017). This understanding is closer to the understanding of locational advantages, whereas when viewed from a strong demand side both for the domestic and international markets. Thus leading commodities are dynamic from the supply side due to changes in demand because there is always a shift in consumer demand (Laura et al., 2017). Bachrein (2003) agreed that the determination of superior commodities is a must with a sustainable and efficient consideration in terms of technology, socio-economy and has comparative and competitive advantages.

Highland farming communities on the Welang Watershed, generally live in clusters on the hills approaching farmland. They live from farming in the fields, with rainfed irrigation. At first they planted corn as a staple food, but now it has changed. In the rainy season they grow vegetables such as potatoes, cabbage, onions, and carrots as a trading crop. At the end of the rainy season they planted corn as a staple food. The agricultural products are mainly corn, potato, cabbage, carrot and others. Most of them lived far away from their fields, so they had to make simple huts in their fields for shelter in the afternoon. They work very diligently and in the morning until the evening in the fields.

The concept of a highland peasant man refers to "Tengger Philosophy" which has a simple, diligent and peaceful life habit. In addition, life is also very simple and frugal. The advantages of selling the saved fields for home improvement and the need for other household needs. The life of the people of Tengger is very close to the customs that have been passed down by their ancestors from generation to generation. All problems can be solved easily over the role of the people who influence the community with the system of deliberation.

Highland farming communities, in subsequent research asked a statement or argument related to the determination of superior commodities corn farming and potatoes from the economic aspects that have been done previously. This statement signifies the sustainability of farming as well as understanding the importance of land conservation in line with the suitability of local cultures and traditions without regard to economic considerations because most of the peoples are farming livelihoods. The result of social dimension analysis is in Table 4.

Based on Table 4 with a sample of 30 respondents obtained aggregate results of the factor of rate of labor employment into the main consideration in the cultivation in the highlands that is equal to 112 and the average value of 3.73. The second consideration of respondents' answers is the presence of local and export market potentials of 102 out of the total answers (or average 3.40). So it becomes a conclusion that the farmer in Welang watershed is pleased to cultivate the superior commodity of corn and potato, in social dimension considering the number of local labor that is used, it becomes important when most of agriculture in Indonesia experiencing deregeneration of farmers means that many have left the agricultural sector, or shifting to more profitable industrial and trading sectors. While the consideration of local and export market potential means that farmers believe that any cultivated crops currently sell well in local and regional markets and are possible for export market scale.

Multicriteria of Agricultural Commodities by AHP Technique

Watershed Management is an effort to manage the interrelationships between natural resources, especially vegetation, soil and water with human resources in the watershed and all its activities to obtain economic benefits and environmental services for the interests of the development and sustainability of watershed ecosystems. The critical level of the Welang Watershed is indicated by the decrease of permanent vegetation cover and the extent of critical land so as to decrease watershed capability and store water that affects the increasing frequency of floods, erosion and the spread of landslides during the rainy season and dry season drought. In addition, it also relates to the socio-economic level of farmers communities in the upper watersheds of Welang watersheds, because the level of awareness and economic ability of low farming communities will prioritize the primary

Table 4. Analysis of Social Dimension – Descriptive Statistic

	N	Min	Max	Sum	Mean	Std. Devia-tion
Suitability_Comm._ Aspiration	30	2	5	98	3.27	0.691
Employment	30	3	4	112	3.73	0.450
Uniqueness	30	2	4	97	3.23	0.568
Potential_Loc.&Exp._Market	30	2	4	102	3.40	0.621
Valid N (listwise)	30					

needs of food is not a concern for the environment so often encroachment of forests in the upper watershed and practices Agriculture with a high slope of land in the hills will continue to increase the criticality of the watershed.

This research uses analytical hierarchy process (AHP) method, by determining criteria that are important to support decision making in choosing the most important priority in agriculture of critical land from land suitability criteria, economic criteria and social criteria in Welang watershed based on questionnaire results in the form of comparison matrix In pairs. From the results of questionnaires that have been filled and processed can determine the percentage (weight) of the criteria used. The next calculation uses the index consistency formula to determine the validation of the data used.

Table 5 and Figure 3 show the erosion is the highest priority selection of experts weighs 0.533. Secondly priority is the acceptance of farming with a weight value of 0.516. While on the other hand suitability factors aspirations of society as a representation of the social dimension into the third priority with weight value 0.476. Erosion is seen as a major concern for most of the corn crop as seed highland region does not have a deep root. In addition, the preparation of land for corn requires intensive processing so that the soil becomes tend to be unstable and has a steep slope so that the land is likely to occur surface erosion or groove.

On the whole, the value of Consistency Ratio (CR) AHP analysis of critical land for crops (maize) is less than 0.10% (Figure 3), it means that the model presented is a consistent model in the test and is accurate for decision making. Nevertheless, the direction of the experts' jugdment shows that

Table 5. Priority rank of critical land farming for crops

Rank	Factor	Value
1	Erosion	0.553
2	Revenue	0.516
3	Community_Aspiration	0.476
4	Production	0.283
5	LocalFarming_Knowlegde	0.254
6	Water_Availability	0.196
7	Employment	0.177
8	Root_Media	0.151
9	Feasibility	0.141
10	Temperature	0.100
11	Local&Eksport_Market	0.093
12	Cost	0.060

they agree to consider the physical or land criterion in the land suitability approach determining the highland farming critical land passed by the Welang Watershed either erosion, temperature, root media neither water availability.

Table 6 represents the priority level selected from the experts in determining farming critical land for vegetable garden plant, and as a prime commodity is potatoes. Temperature are the highest priority in high potato cultivation with a weight value of 0.463, followed by acceptance of 0.454 (Figure 4). The less significant difference in weights indicates that the temperature factor of the land criteria and the acceptance of farming from the representation of economic criteria are equally important. Potato plants are related to the temperature at which the plants will be suitable to grow at certain altitudes with a specific temperature of 16°C – 18°C

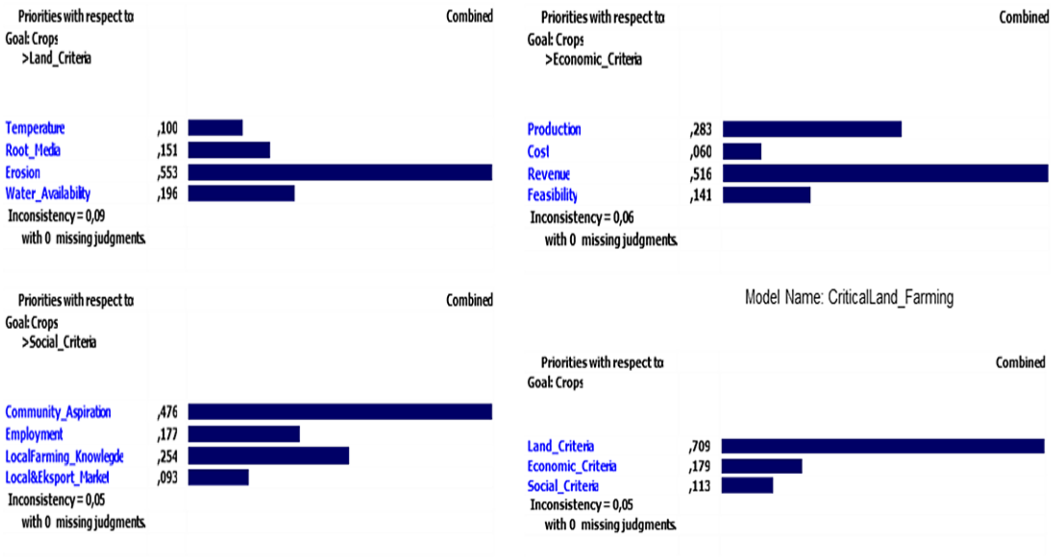

Fig. 3. Multicriteria analysis of critical land farming for crops

Table 6. Priority rank of critical land farming for vegetables garden plant

Rank	Factor	Value
1	Temperature	0.463
2	Revenue	0.454
3	Local&Eksport_Market	0.389
4	Erosion	0.342
5	Employment	0.303
6	Cost	0.282
7	LocalFarming_Knowlegde	0.178
8	Production	0.164
9	Community_Aspiration	0.130
10	Root_Media	0.109
11	Feasibility	0.100
12	Water_Availability	0.086

so that if forced to be planted above the recommended temperature the plants will die and vice versa if below the recommended temperature the tuber formation is reduced so as to decrease Production due to decreased plant metabolism activities. Otherwise, erosion in the order of four factors is important in determining highland farmland critical land in Welang watersheds due to the highland agro-climatic conditions characterized by crumbly and fertile soils but mostly located in areas with slopes that are quite steep and have the possibility of erosion if Land management is less concerned with land conservation.

When the multicriteria analysis phase is completed, the next step of the result will be input in the next GIS process so that the Map of critical land farming in highland Welang Watershed. The AHP method has been used in two different ways within the scope of GIS work. First, it can be used to lower the weights associated with the map layer attribute. Then, the weights can be combined with layers of attribute maps in a manner similar to the weighted additive combination method. Secondly, the AHP principle can be used to aggregate priorities for all levels of the hierarchical structure including levels representing alternatives (Mighty, 2015). In this case, a relatively small number of alternatives could be evaluated when taking on multi-attribute decision-making aspects of the MCA. The integration of the AHP approach and the geographic information system (GIS) resulted in an efficient spatial decision-making system to produce land suitability maps (Mendas & Delali, 2012; Alkinci et al., 2015; Zhang et al., 2015; Sohrab & Halil, 2016) (Figure 5).

Conclusion

The land suitability classification system for food crops, especially maize, is obtained by two different subclass of land suitability, ie S3wa, nr (Marginal Suitable) for moor and Nlp (not suitable) rainfed lowland crops where limiting factor on uncritical land becomes Obstacles in all study sites were water availability (wa), nutrient retention (nr) and land preparation. The classification system of land suitability for the dominant vegetable plants of potato crops on uncritical land of S3tc (Marginal Suitable) with limiting factor at temperature (tc) for very critical land was obtained by Neh suitability class with limiting factor on erosion hazard (eh) .

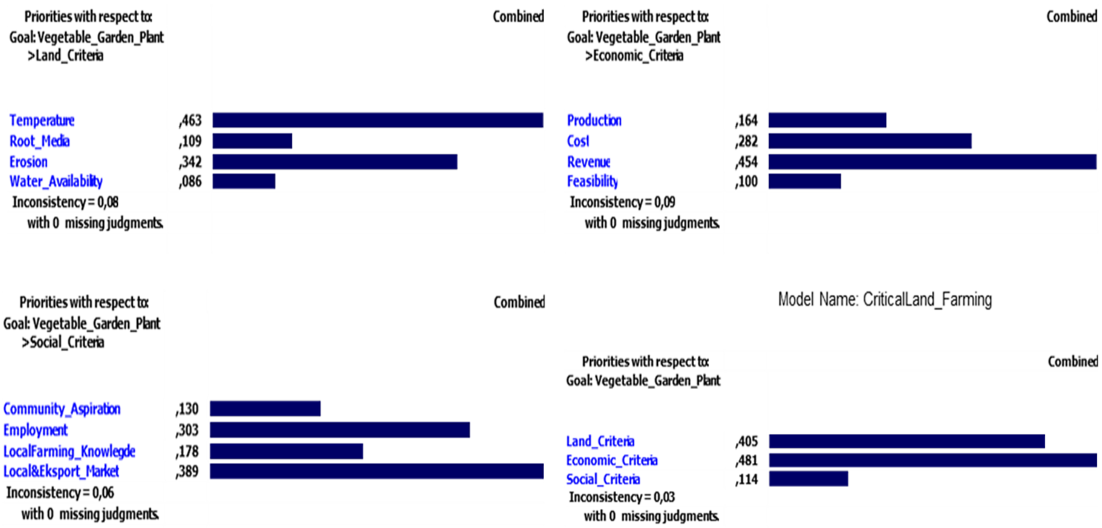

Fig. 4. Multicriteria analysis of critical land farming for vegetable garden plant

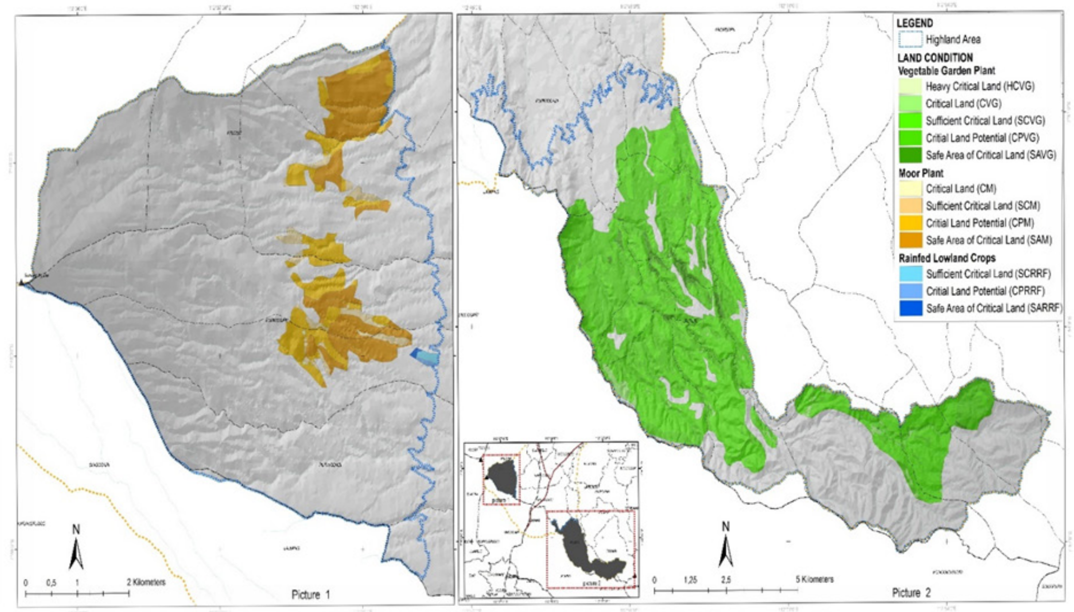

Fig. 5. Land suitability for critical land farming maps

The highest income farming for food crops is corn, followed by second order is Paddy. Cassava that also includes food crops occupies the lowest position during the calculation of farm receipts but able to produce a much higher harvest than the other two commodities. However, the allocation of labor costs incurred for cultivation of relatively high cassava is less effective. In addition, cassava is not recommended because when the harvest arrives will lead to decreased soil aggregate stability and lead to erosion. In contrast, for the type of vegetable crops known potatoes have the highest farming acceptance value followed by the next sequence is cabbage and carrots. In general the value of R/C ratio> 1, meaning that all types of cultivated plants called feasible to do.

Social dimension implies a picture that peasant societies in relation to the cultivation of agricultural superior commodities have a preference for consideration of labor absorption and the potential of local and export markets. In contrast to other areas in the highlands through which the Welang Watershed does not experience agricultural regeneration constraints and most farmers believe their specific product locations are able to penetrate local, regional markets and even opportunities for export.

AHP analysis can be concluded that in determining agriculture of critical land for corn crops the main priority of expert jugdment answers is erosion, revenue and community aspirations. Nevertheless, experts agree that physical or land factors are a major consideration. Unlike the case in determining the agriculture of critical land for potatoes, where the highest priority is temperature while revenue is also an important consideration as well as the local market potential and export. The overall AHP results have consistent values that are either interpreted for use in decision making.

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Data Availability: The data used consist laboratory test to support the findings of this study are included within the article.

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