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Rapid Appraisal for Agricultural Land Utilization in the erosion and landslide vulnerable mountainous areas of Kulonprogo Regency, Indonesia

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Abstract

Purpose – The purpose of this paper is to assess the land utilization in the erosion and landslide vulnerable mountainous region using the Rapid Appraisal for Agricultural Land Utilization (RApALU) model.
Design/methodology/approach – A multidimensional RApALU model is used for sustainable agriculture land utilization.
Findings – Ecological dimension was less sustainable, whereas socio-economic, socio-cultural, and eco-technological dimensions were comparatively more sustainable. It was found from the analysis that 9 out of 21 attributes have sensitive effect on the sustainability index and status.
Practical implications – One of the implications of this research is that this model could be used to quickly measure the arrangement of an area that is experiencing environmental problems so that the land use planning process could be done more effectively and efficiently. The parameters used in each variable could be chosen by the researchers themselves according to location. As far as known by the researcher, the methods used have not been well integrated, they are still separated, for example, only physical problems, and social problems have not been measured properly. This model is not perfect yet, and it could be developed further because environmental problems are very complex and could be different from one location to another.
Originality/value – RApALU analysis can be used as preliminary analysis to comprehend general and overall description on the status of the sustainability index of land utilization for agriculture in hilly mountainous regions. The study confirmed that RApALU analysis can help determine the status of the sustainability of land utilization in intricate areas. This technique was able to comprehensively identify important factors affecting sustainability status of various dimensions.

Keywords Sustainability index, Agricultural land utilization, Erosion and landslide, Hilly mountainous areas
Paper type Research paper

1. Introduction

This study is aimed to assess the land utilization in the erosion and landslide vulnerable hilly mountainous areas of Kulonprogo Regency, Yogyakarta province of Indonesia using the Rapid Appraisal for Agricultural Land Utilization (RApALU) model. The hilly mountainous areas in Kulonprogo Regency typically have limited land potency, which are mainly utilized as paddy field, moor land, settlement, courtyard, woods and plantation areas. In Kulonprogo Regency, area under the hilly mountain is spread to 154.41 km^2 (51.19 percent) of the total area, where predominant share is under non-forest cover (75.38 percent). In the study area, area under forest was less than 30 percent of total regency area, which indicate that Kulonprogo regency is under the minimum threshold (Law No. 47 year 1997). It means that the forest area could not function well as the safe environmental buffer, especially in terms of water supply, flood control, erosion, recreational needs and to meet the need of forest products for various purposes (Kepas, 1985; Banowati, 2016).

In the study area, various landforms including denuded hills and mountains, karst topography and intrusion hills have been found. All these landforms are the major obstacles

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in sustainable agricultural land use. The patterns of land utilization vary from place to place depending on slope gradient and its suitability for specific purpose. The upper slopes are mainly utilized by the perennials plants, the middle slopes are used for seasonal crops and plantations, whereas the piedmonts are mainly under the settlements.

In Indonesia, the emphasis is on agricultural development, which has negative impacts on the sustainability of natural resources and the environment. To maintain the sustainability of the agricultural land resources, efforts need to be made for sustainable land utilization. In order to evaluate the sustainable utilization of agricultural land, many studies have been done but still limited to the evaluation of ongoing agricultural activities. (Adiningsih and Karama, 1992; Goodland, 1995; Lefroy *et al.*, 2000; Adnyana, 2001; Sena and Marcos, 2009; Hadmoko *et al.*, 2010). The major strength of land sustainability analysis is the integration of four components including ecological, socio-economic, socio-cultural and technological aspects. In assessment models, the level of sustainability has measured by applying dignity systems, and weighting approaches (FAO, 1976, 2007) have used summation parameters, matching system, land characteristics and the growth requirements for plants. Therefore, this research is aimed to assess the land utilization in the erosion and landslide vulnerable hilly mountainous region of Kulonprogo Regency, Yogyakarta province using the RApALU model.

2. Literature review

2.1 Land resource and land use

Land, water and forests are components of life support systems and their existence and dynamics are interconnected and affect one another. Therefore, damage to a component will disrupt the existence and dynamics of other components. Soil problems such as erosion and landslides will ruin the function of the soil in regulating the water cycle, causing floods in the rainy season and drought in the dry season (Hadmoko *et al.*, 2010). Meanwhile, the land is a site for various human activities and a production place of various life necessities, which directly or indirectly will threaten human life itself. Increasing population, often, leads to increased land requirements for agriculture, settlements, infrastructure, and others. Apparently, land use in Indonesia is more dominated by forests, so the conversion of forests for other uses such as for agriculture becomes inevitable; besides that, there is a conversion of land use from a type of use.

Basically, landslides are natural phenomena to achieve regional stability. Like floods, land movement is actually a natural disaster occurrence of which can be predicted, because it is associated with large rainfall. And again, it is naturally evident that the area has a geological structure more prone to landslides than other regions. Rocks that are easily disintegrating, rock fracture patterns, rock layers, weathered soil thickness, steep slopes, high water content and earthquake vibrations are geological characteristics that affect the landslide process, humans can act as a trigger for the landslide process, for example intentionally adding loads, adding levels water, additional slope angles. Because the water content factor is quite dominant, landslides often occur in the rainy season. North Temanggung, Wangon, Wonosobo, Sukabumi, Sumedang, Padalarang and Bogor are potential areas in Java. Areas of potential landslides are generally areas on the edge of steep mountains.

Land use is a form of human intervention on land resources in order to meet their needs, both material and spiritual (Arsyad, 2006). This human intervention is very real, especially in manipulating conditions or ecological processes that take place in an area. In land use, humans play a role in regulating ecosystems, namely by eliminating components that are considered useless or by developing components that are expected to support land use (Mather, 1986). Land use for agriculture in a place has a varied pattern. Variation in land use patterns for agriculture is influenced by many factors, including the condition of the land, water availability, physical condition of the environment and factors of the community (farmers), as well as capital and institutional resources (Brady and Kosasih, 1991; Barlowe, 1986; Sys *et al.*, 1991).

2.2 Multidimensional scaling

The multidimensional scaling (MDS) approach used in this research is to see the existence of land use management in hilly mountainous areas in terms of ecological, socio-cultural, socioe-conomic and technological dimensions that can then be used as a guideline to evaluate the sustainability status of land use in hilly mountainous areas. MDS analysis is used to present similarities/inequalities between individual pairs and characters/variables (Fauzi and Anna, 2005). According to Van Sickle (1997), MDS can effectively present the method of ordination (Arifin, 2008). MDS is an ordination method based on the distance between objects/points in two dimensions or three dimensions. Alder *et al.* (2000) stated that the ordination technique is by configuring the distance between points in the *t*-dimension that refers to the Euclidean distance between points (Fauzi and Anna, 2005). In other words, two points or the same object are mapped in a point that is close together. Conversely, objects or points that are not the same are described as distant points. Pythagoras' proposition is used to calculate Euclidean distances between two points. In the two-dimensional space Euclidean distances are formulated as follows:

$$d_{1,2} = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2 + \cdots}, \tag{1}$$

where as for the *n*-dimensional, Euclidean distances are formulated as follows:

$$d = \sqrt{(|x_1 - x_2|^2 + |y_1 - y_2|^2 + |z_1 - z_2|^2 + \cdots)}, \tag{2}$$

where $X_1 =$ first object at i observation and $Y_2 =$ second object in the i observation.

In evaluating the condition of land resources, each category consisting of several attributes is assessed (score). Scores are generally ranked between 1 and 5. The score results are entered into a matrix table with *I* rows representing land use management and *J* columns representing attribute scores. The data in the matrix are interval data that show good and bad scorings. The configuration or ordination of an object or point in MDS is then approximated by regressing the Euclidean distance (d_{ij}) from point i to point j with the origin (δ_{ij}) as in the following equation:

$$d_{ij} = \alpha + \beta\delta_{ij} + \varepsilon. \tag{3}$$

To regress the equation above, the ALSCAL algorithm is used with the consideration that this technique is widely available in almost every statistical software (SPSS and SAS) (Fauzi and Anna, 2005). The ALSCAL technique optimizes the distance squared (d_{ij}) to quadratic data (origin $= O_{ijk}$), which in three dimensions (i, j, k) is written in the *S*-Stress formula as follows:

$$S = \sqrt{\frac{1}{m}\sum_{k=l}^{n}\left[\frac{\sum_i \sum_j \left(d_{ijk}^2 - o_{ijk}^2\right)^2}{\sum_i \sum_j o_{ijk}^4}\right]}, \tag{4}$$

squared distance of which is the weighted or written as Euclidean distance:

$$d_{ijk}^2 = \sum_{o=l}^{r} w_{kn}\left(x_{in} - x_{jn}\right)^2. \tag{5}$$

Source: Alder *et al.*, 2000 in Fauzi and Anna (2005).

A low stress value indicates a good fit, whereas a high stress value indicates the opposite. A good model shows a stress value that is smaller than 0.25 ($S < 0.25$).

Multidimensional scaling analysis is a multivariate method that can handle non-metric data. This method is also known as one of the methods of ordination in reduced space (dimensions) (ordination in reduced space). Ordination itself is a process in the form of plotting point objects (positions) along the axes arranged according to a particular relationship (ordered relationship) or in a graph system consisting of two or more axes (Arifin, 2008). Through the method of ordination, multidimensional diversity (dispersion) can be projected in a field that is simpler and easier to understand. The ordination method also allows the researcher to obtain a lot of quantitative information from the resulting projected value. The multidimensional approach has been widely used for ecological analysis, as conducted by Alder *et al.* (2000) to evaluate the condition of capture fisheries with various types of variable based on distance. This approach has also been developed for environmental analysis where one of the methods used is the MDS method (Arifin, 2008).

The results of MDS-based research have been carried out including Green *et al.* (1989), Huang *et al.* (2005), Pitcher and Preikshot (2001), Fauzi and Anna (2005), Nababan *et al.* (2017), Arifin (2008), Bohari *et al.* (2008). However, research that examines issues of agricultural land and/or more specifically in the perspective of MDS-based geography has not been found.

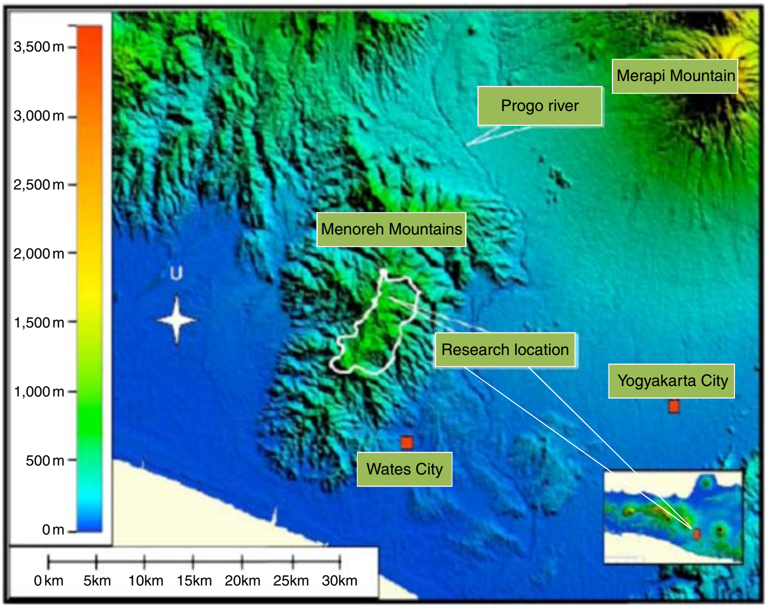
In this study, the researchers used a Rapfish (Rapid Appraisal for Fisheries)-based MDS that was developed/modified so that it was expected to be applied to the land sector. The model is called RApALU. The RApALU model was developed from the Rapfish model which is usually used to assess the status of capture fisheries sustainability (Fauzi and Anna, 2005). The Rapfish technique is the latest technique developed by the University of British Columbia Canada, which is an analysis to evaluate the sustainability of fisheries in a multi-disciplinary manner (Kavanagh, 2001).

In this study, the model was developed from the aspect of the substance of the variables and the framework of the presentation. The substance of the variable in this study is different from the variable in the Rapfish model. Variables in the Rapfish model relate to issues of marine fishery resources, fishing techniques, fishing gear, fish marketing and others. The applied focus is on research into the sustainability of marine fishery resources. The RApALU model is based on land resource variables that are grouped into four dimensions, namely, the ecological dimension, the socio-economic dimension, the socio-economic dimension and the technological dimension. In the RApALU model, the evaluation results are presented in addition to descriptive qualitative and quantitative, supplemented by tables and graphs/diagrams and are presented in a geospatial information format based on a geographic information system. The applied focus is the holistic, integrated and adaptive and adaptive implementation of the status of land resources.

3. Materials and methods

The study area, hilly mountainous part of Kulonprogo Regency, is located at a distance of about 25 km to the west of provincial capital city of Jogjakarta, Indonesia (Figure 1). The study site is part of protected area and recently a rapid but gradual change to farmland has been recorded. This was the major factor behind the selection of hilly mountainous part of Kulonprogo Regency and to contribute for regional sustainable land use planning. In addition, the study area serves as an ecological buffer zone between city waste water and surroundings.

The methodology adopted for this study is multidimensional RApALU model for sustainable utilization of agricultural land (Juhadi *et al.*, 2011). RApALU is a modified form of Rapfish method, which was used to appraise the sustainability of fisheries (Kavanagh, 2001). The Rapfish method was chosen because it is a statistical technique that could used to quickly and accurately describe the status of resource sustainability by transforming multidimensional attributes into simpler dimensions (Nurmalina, 2008; Rohimat, 2015). In addition, the analysis considers the existence of inputs, processes and



Source: Modified after Juhadi (2013)

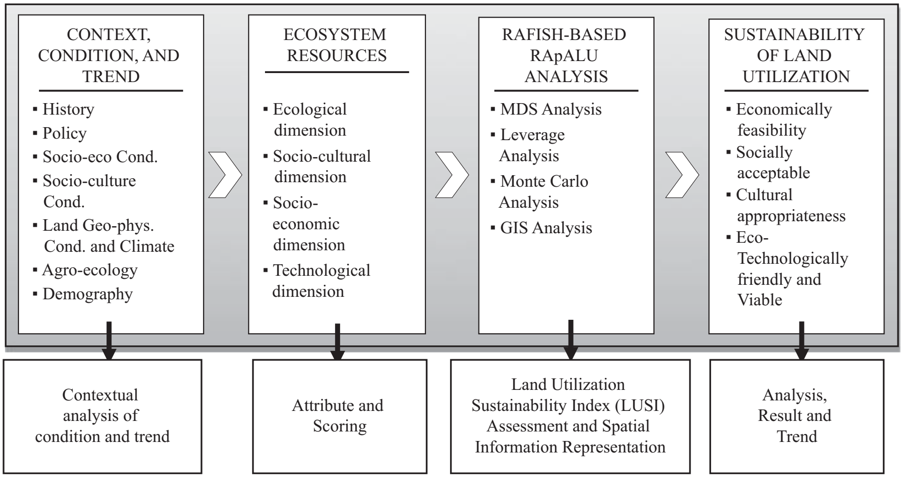
Figure 1. Location of the study area

outputs. Therefore, each dimension analyzed consists of attributes that represent the conditions of the input, the running of the process and something that is produced (output). All of them describe the condition of sustainable development of resources (land) in each analyzed dimension. The next reference is the concept of sustainable development which simply has a definition of development that could meet the needs of the present generation without reducing the ability of future generations to meet their needs (Juhadi, 2013). The ongoing development of activities carried out by humans in the end can realize or improve the standard of living of human beings themselves (human wellbeing) and, at the same time, maintain the long-term function of the environment and the existence of natural resources in it.

In RApALU model, the ordinance technique has been used, where variables are placed in a measurable attribute order using the MDS approach. All four dimensions of sustainability, i.e. ecology, socio-economic, socio-cultural and technological, were assessed. In each dimension, there is a list of indicators for assessing its sustainability.

The analysis was done in five stages (Figure 2): first, the determination of integrated and sustainable attributes in the study site which comprises of four dimensions, namely, ecological dimension, socio-economic dimension, socio-cultural dimension and technological dimension/farmer's preference; second, valuation of each attribute in an ordinal scale based on sustainability criteria for each dimension; third, indexing and sustainability status of land utilization for agriculture.

The concept of sustainable land resources is based on the sustainable development triangle framework presented by Munasinghe from the World Bank, which is oriented toward three dimensions of sustainability that are mutually supportive and related, namely, economic, social and ecological dimensions (Rohimat, 2015). Each attribute of each dimension is scored based on scientific judgment from the score maker. The score was ranged from 1 to 5, with 1 being the worst and 5 the best. The score of each attribute was analyzed in a multidimensional way to determine the status of sustainability of land



Source: Modified after Kavanagh (2001), Fauzi (2005), Juhadi (2013), Juhadi, Tjahyono and Arifudin (2014)

Figure 2.
Process of the RApALU Model

utilization for agriculture. The results were further assessed relative to two references of good and the bad points. Each score was the sustainability index value for each dimension and the same was labeled as Bad, Less Satisfactory, Satisfactory and Excellent (Table I); fourth, Leverage analysis was carried out to determine the sensitivity of attributes that influence the sustainability; and fifth, Monte Carlo trend simulation was applied to predict the errors at 95% confidence level.

Furthermore, the status and level of sustainability were visualized using the RApALU model with horizontal and vertical axes. Using rotation process, the status of sustainability was visualized at horizontal axis with the sustainability index, where the scored 0 percent is "bad" and 100 percent is "good". If the resultant value in the sustainability index is $\geqslant$ 50 percent, the system is said to be "sustainable". Conversely, if the index value is $<$ 50 percent, then the system is "not sustainable."

In this study, the sensitive attribute and its contribution to the sustainability index in the utilization of land for agriculture is applied to explore the change of ordination of root mean square (RMS). The larger the change of RMS value, the more sensitive is the attribute in utilization of land for agriculture. All the operational processes, right from sustainability analysis to Monte Carlo simulations was done with the help of modified Rapfish software to a RApALU software.

4. Results and discussion

The research results were discussed in multidimensional perspective, including ecological, socio-economical, socio-cultural and technological dimensions.

Table I.
Classification of sustainability status of land utilization for agricultural

Index value	Category	Remarks
Less than 25	Bad	Not sustainable
25–50	Less satisfactory	Less sustainable
51–75	Satisfactory	Sufficiently sustainable
More than 75	Excellent	Very sustainable

Sources: Modified after Bourgeois and Jesus (2004); Bohari *et al.* (2008)

4.1 Analysis of sustainability of land utilization for agriculture – ecological dimension

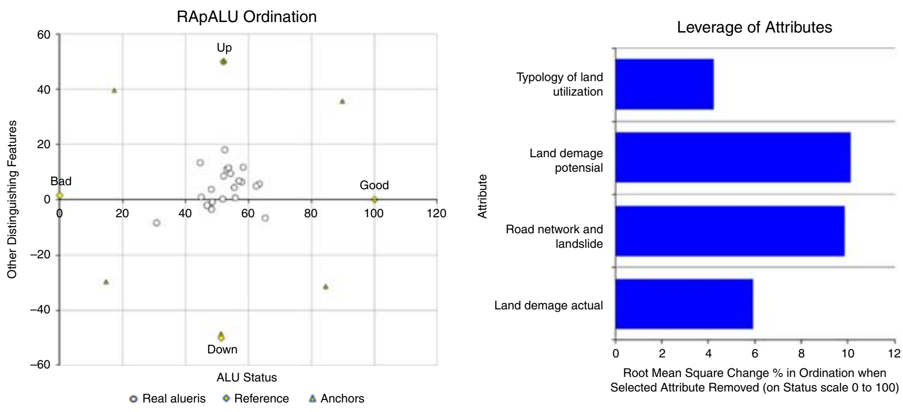
In the study area, the analysis of index and status of sustainability of land utilization for agriculture in the hilly mountainous regions in Kulonprogo for ecological dimension shows a diversity of the index value of sustainability between landform units, ranging from category Less sustainable to Sufficiently sustainable. There were seven landforms units that categorized as Less sustainable (33.33 percent). The rest (14 landforms units) were categorized Sufficiently sustainable (66.67 percent) (Figure 2).

The magnitude of landform units with sustainability status of Less sustainable in the study site primarily was caused by land geophysical condition factors, especially related to the high rate of damage to the land due to erosion and landslides. The H5D0 (Andesite-Breccia Complex Denudational Hills) landform unit has the lowest sustainability index of land utilization in ecological dimension, i.e., 29.32 (Table AII).

Among four examined attributes, namely, the typology of land utilization, the potential land damage, the land network and landslide events and the actual land damage levels, two attributes are sensitive in influencing the sustainability (Figure 3), they are the potential land damage with the score of 10.10 and the landslide events in the land network with the score of 9.87. The score of potential land damage is relatively high in the study site because it is a hilly mountainous region with complicated topography, ranging from plains to mountains with slope variation ranging from flat to steep. The slope stability was varying due to topography complexity. Morphogenetically, the study site was formed from denudational, structural and fluvial processes (Sartohadi, 2005; Juhadi, Tjahyono and Arifudin, 2014). Within hilly mountainous area dominated with dry land, the potential of erosion was quite high because of high rainfall intensity, steep slopes and poor cropping patterns. Prolonged erosion has reduced soil fertility and even reduced or eliminated top soil layers (Syam, 2003).

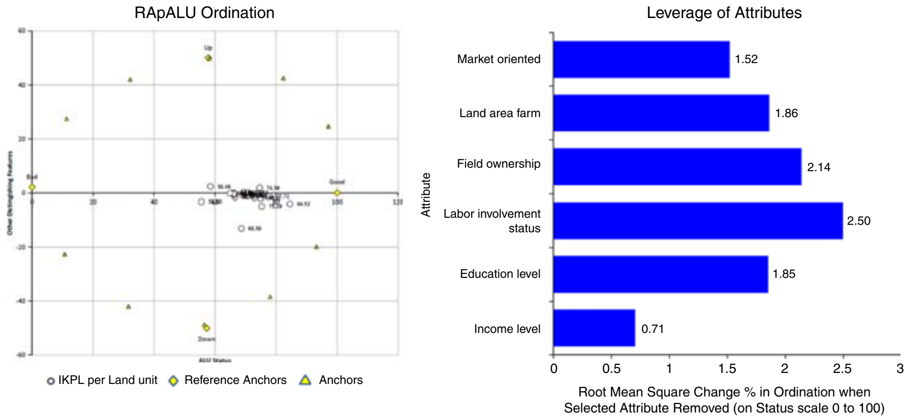
4.2 Sustainability of land utilization for agriculture in socio-economical dimension

Sustainability of land utilization for agriculture in socio-economical dimension based on empirical data was varied in several landforms, with index values ranging from 55.50 to 84.52, and this means that the sustainability status was categorized Adequate to Good. This is different to analysis of ecological dimension. In the socio-economic dimension, there were three landform units (14.29 percent) that have been categorized as good, whereas 18 landform units (85.71 percent) were categorized as sufficiently sustainable (Figure 4).



Source: Juhadi (2013)

Figure 3. Index and sustainability status, and sensitive attributes influencing the sustainability in ecological dimension



Source: Juhadi (2013)

Figure 4. Index and sustainability status, and sensitive attributes influencing the sustainability in socio-economic dimension

The sustainability index value in socio-economic dimension of some landforms was also high, i.e., more than 80. The lowest value was 55.50, i.e., H2D0 (Sentolo formation denudational hilly complex) landform unit which was categorized as sufficiently sustainable. In general, the distribution of the index values and the sustainability status of land utilization in socio-economic dimension in each landform was categorized as sufficient (Table AII).

Four sensitive attributes influencing the sustainability index value in socio-economic dimension were labor involvement; tenure; farming land area; and education level. The distribution of the index values and the sustainability status of land utilization in socio-economic dimension of the upper part of the hilly mountainous region which is dominated by mixture plantation are categorized as good, whereas the low slopes which are commonly used as moor land or field are categorized as sufficient.

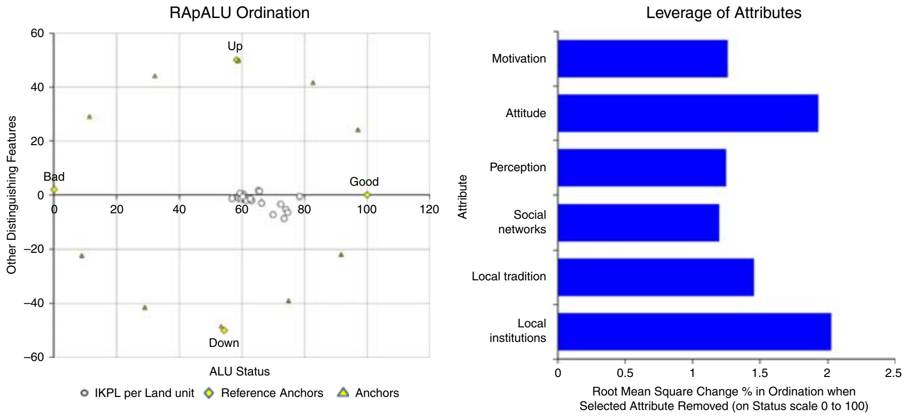
In general, in economic dimension, majority of the study areas are categorized as sufficient. The high or low value of sustainability index of land utilization in socio-economic dimension is influenced by several factors, such as the diversity of sources of income from a number of agricultural commodities and income from non-agriculture sector.

4.3 Sustainability of land utilization for agriculture in socio-cultural dimension

The sustainability indices of land utilization for agriculture in socio-cultural dimension in various landform units in the study area that were calculated using RApALU program that showed scores ranging from 56.83 to 78.38, which means that they are in category range of sufficient and good. The sustainability index value in category sufficient was very dominant, being found in 20 landform units (95.24 percent). Conversely, the landform unit that is categorized as good is only 1 unit (4.76 percent) (Figure 5).

Analysis on 21 landform units in general showed that they are categorized as sufficient, and only 1 landform unit in category good, i.e., H3D0 (Jonggrangan Formation Denudational Hilly Complex) (Table AII). Socio-cultural aspects that have been gone well in societal life on the study area seemed have positive trend for the sustainability of land utilization. This is proven from the availability of land resources that resulted in category sufficient for the sustainability index value.

Leverage analysis showed a similar result with MDS analysis in that the sensitive attributes influencing the socio-culture dimension were local institution, attitude, tradition, and society perception. Among the four sensitive attributes, local institution scored the



Source: Juhadi (2013)

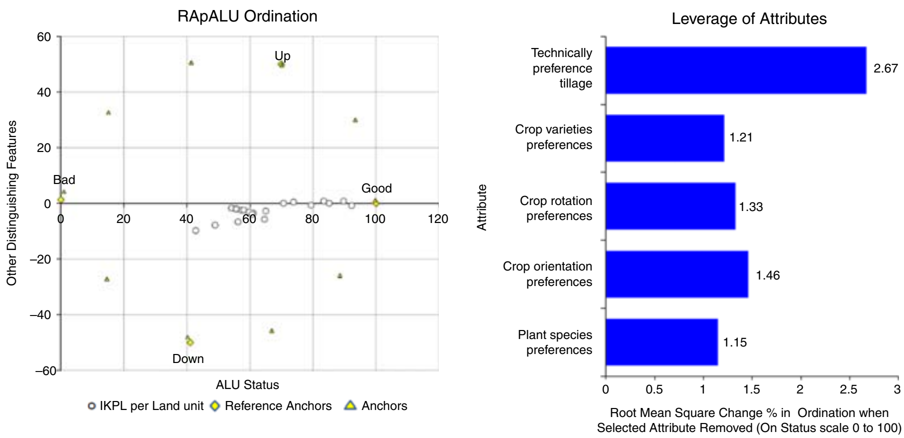
Figure 5.
Index and status of sustainability, and sensitive attributes influencing the sustainability in socio-cultural dimension

highest, i.e., 2.02. When compared with economical dimension analysis, result showed that the similar trend, that is, positive trend with the sustainability index value were in the range of sufficient to good (Figure 6).

4.4 Sustainability of land utilization for agriculture in technological dimension (farmer's preference)

Land Utilization Sustainability Index (LUSI) analysis for technological dimension showed a variation of the sustainability index and status for each landform. RApALU analysis for technological dimension showed that 19 landform units (90.48 percent) have the sustainability index of more than 50.01 percent (Table AI).

This means that from technological dimension point of view, the land utilization in the study area is categorized as relatively good. The LUSI for technological dimension that categorized as less sustainable were found in two landform units, i.e., H4D0 (Andesite Denudational Hilly Complex) and H3D5 (Jonggrangan Formation Denudational Hilly Middle Slopes). There were



Source: Juhadi (2013)

Figure 6.
Index and sustainability status, and sensitive attributes influencing the sustainability in technological dimension

four of five aspects of technology implementation in terms of land utilization showed middle-good result, namely, farmer's preference in plant various practices, plant orientation, plant rotation and selection of plant species, while the aspect of soil processing method is adequate. This matter because land characteristic on study area has erosion and landslide sensitivity, hilly dry land and middle-high rainfall (Gunadi *et al.*, 2004; Hadmoko *et al.*, 2010; Juhadi *et al.*, 2011; Juhadi, 2013).

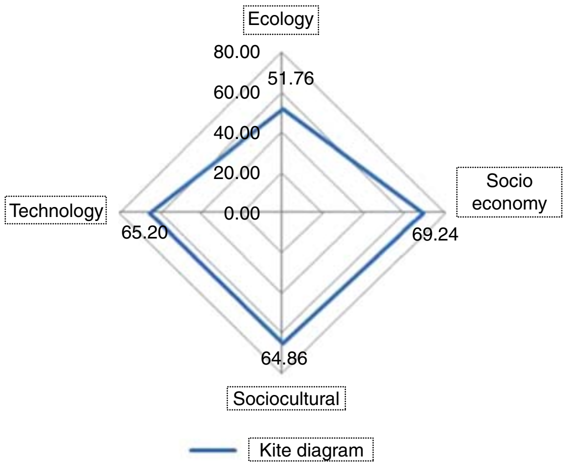
The condition of land utilization in technological dimension spatially also showed that most of them in category sufficient. But several locations especially in Sub-District Kokap are in category less sustainable. Most areas studied in this research are categorized sufficient to very good in terms of the sustainability index of land utilization for agriculture in technological dimension. The farmers seem have used basic principles of land conversion in managing their agricultural field.

The sustainability indices in ecological, socio-economic, socio-cultural and technological dimensions are shown in Figure 7.

Kite diagram shows the scores ranging between 0 and 100 percent with interval of 25 percent, and with criteria of bad, insufficient, adequate and good. If the score moves outward, then the sustainability status is going better. On the contrary, if the index score moves inward, then the sustainability status is going worse. Based on kite diagram analysis, it was shown that overall the sustainability index of land utilization for agriculture in the study area fell in the range of 30–94 percent. It means that the sustainability index of land utilization for agriculture in the study area is in the criteria of less sustainable to good. Of four examined dimensions, the socio-economic dimension showed the better sustainability level, with Land Utilization Sustainability Index of 69.24 percent and therefore is categorized as sufficiently sustainable. It was followed by technological dimension (65.20 percent), socio-cultural dimension (64.86 percent) and lastly, ecological dimension (51.7 percent). However, these values are still categorized as sufficiently sustainable.

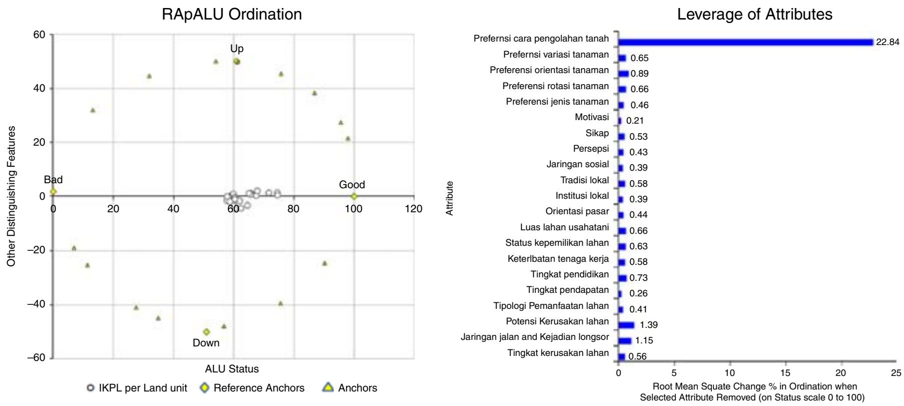
4.5 Analysis of sustainability of land utilization for agriculture – multidimensional

A multidimensional RApALU analysis using a ordination technique through the MDS method has resulted in LUSI value for each landform unit (Figure 8).



Source: Juhadi (2013)

Figure 7.
Kite diagram value of agricultural land use sustainability index



Source: Juhadi (2013)

Figure 8. Index and sustainability status, and sensitive attributes influencing the multidimensional sustainability

The LUSI value for each landform unit was obtained based on the valuation against 21 attributes that were covered in four dimensions, i.e., ecological dimension (four attributes), socio-economic dimension (six attributes), socio-cultural dimension (six attributes) and technological/farmer's preference (three attributes). The result of the study on 21 landform units showed that 2 landform units have sustainability indices of category good, i.e., D1F8 (Fluvio-Coluvial Foot Plains) and H3D2 (Jonggrangan Formation Denudational Hilly Ridge) because they fell within the range of 75.01–100. It is because the D1F8 landform unit is mainly utilized as paddy fields and secondary crop fields, and therefore, the society always try to make efforts to maintain the land productive and keep it away from land damage, whereas D1F8 (Jonggrangan Formation Denudational Hilly Ridge) landform unit mainly utilized is forest areas and perennial plantations and therefore useful to produce wood and fruit as one of the pillars of economic sources of the societal income. Therefore, this area is maintained and always be preserved, and despite routine harvest, the society always carry out continuous rejuvenation.

A Leverage analysis in a multidimensional way showed that the most sensitive attributes in influencing the sustainability of the land utilization for agriculture in the study area is the tillage. This is because the geobiophysical characteristics of the study area is very complicated due to the high vulnerability to erosion and landslide (Dibyosaputro, 1999; Gunadi *et al.*, 2004; Sartohadi, 2005; Hadmoko, 2009; Juhadi *et al.*, 2011; Priyono, 2012). Empirical data also strengthen the previous study, in that majority of the study area is highly potential to experience land damage. Therefore, the problem of land management in this area needs special attention.

Analysis model RApALU (Figure 2) can identify and find in detail from a number of studied aspects. Among studied aspects, the aspect showing sensitive and not sensitive influence to land degradation will be clearly visible.

RApALU analysis showed that all attributes examined against the sustainability status of the land utilization for agriculture in the hilly mountainous region in Kulonprogo Regency, Province of Yogyakarta Special Area, is relatively accurate so that it can provide more reliable and more accountable analysis result. This can be seen from stress value and determination coefficient value (R^2). This figure is obtained automatically in the MDS analysis using RApALU software . Kavanagh and Pitcher (2004) suggested that the analysis result is considered accurate and accountable when the stress value is lower than 0.25 or 25 percent and the determination coefficient value (R^2) is close to 1.0 or 100 percent (Table II).

The stress values for all analyzed dimensions, either individually or collectively (multidimensional), showed a very good result, i.e., the stress values were far from 0.25 percent and the RSQ values were close to 1. The MDS analysis using RApALU program showed that all examined attributes were accurate and accountable. The analysis also showed that the result was not significantly different to Monte Carlo analysis and MDS analysis (Table AII).

The Stress values were ranging only from 2 to 20 percent, whereas the determination coefficient (R^2) values were ranging from 84 to 99 percent. The stress values and the determination coefficient values were presented in (Table II). This result supported Kavanagh (2001) findings that the analysis is considered adequate when the stress value is less than 0.25 (25 percent) and the determination coefficient value (R^2) is close to 1.0. It means that errors in the analysis have been minimized, either during the attribute scoring process, the variation in scoring due to dissenting opinion was relatively small, the data analysis process performed repeatedly was relatively stable, and the data entry mistake and loss data were minimized or avoided. The distribution of multidimensional sustainability index and status of land utilization for agriculture showed that study areas were in category sufficient to very good (Figure 8).

One of the implications of this research is that this model could be used to quickly measure the arrangement of an area that is experiencing environmental problems so that the land use planning process could be done more effectively and efficiently. These problems could be both related to natural physical problems or social problems. Generally, if the physical problem is natural, then the focus is on the location of the problem. While social problems are focused on different perception, opinion, or habits/customs.

The parameters used in each variable could be chosen by the researchers themselves according to location. As far as known by the researcher, the methods used have not been well integrated, they are still separated, for example, only physical problems, if social problems have not been measured properly. For example, the problem of forests could be due to market demand from outside, thus encouraging/giving pressure to the community to exploit nature with improper methods. This model is not perfect yet, it could be developed further because environmental problems are very complex and could be different from one location to another.

5. Conclusion

RApALU analysis can be used as preliminary analysis to comprehend general and overall description on the status of the sustainability index of land utilization for agriculture in hilly mountainous regions. The study confirmed that RApALU analysis can help determine the status of the sustainability of land utilization in intricate areas. The RApALU technique was able to comprehensively identify important factors affecting sustainability status of various dimensions. RApALU analysis is a method which still can be developed extensively, such as by expanding and sharpening the dimensions to be used as required in the research or by increasing the number of attributes for each dimension.

Table II. RApALU analysis result for values of stress and determination coefficient (R^2)

Parameter	Sustainability dimension				
	Multidimensional	Ecological	Economic	Socio Cultural	Technological
Stress	0.200	0.118	0.128	0.089	0.027
Squared Correlation (RSQ)	0.841	0.949	0.973	0.978	0.998
Number of iteration	4	3	4	3	3

Source: Primary data analysis (Juhadi, 2013)

Of four examined dimensions, the socio-economic dimension showed the better sustainability level, with average Land Utilization Sustainability Index of being categorized as sufficiently sustainable. This is followed by technological dimension, socio-cultural dimension and lastly was ecological dimension; however, all were still categorized as sufficiently sustainable.

Out of 21 attributes analyzed in a multidimensional way, the most sensitive attribute on the sustainability of land utilization was tillage. The problem of land management in the study area needs special attention, especially the geo-biophysical characteristics of the area is very complicated due to the high vulnerability to erosion and landslide. If the method of land management is not using/giving less attention to the land conservation principles, then the land damage will be potentially hazardous in the future.

Commonly, the hilly mountainous regions are highly vulnerable to some aspects of land geophysics, and they normally will have high potential to be damaged too. The level of the land damage is triggered by societal member activities in utilizing the land for agriculture and for other purposes. The current research that use RApALU analysis found that the sustainability status of the land utilization for the four examined dimensions, either individually or collectively showed a relatively good result. This phenomenon indicated that the severely damaged land (due to erosion and landslide) in the study area was not merely caused by land geophysical factors but more be caused by non-natural factors, especially human factor.

References

Adiningsih, J.S. and Karama, A.S. (1992), “A sustainable upland a farming system for Indonesia”, Center for Soil and Agro Climate Research (CSAR) Agency for Agricultural Research and Development, Bogor.

Adnyana, M.O. (2001), “Business systems development sustainable agriculture”, Center for Agricultural Socio-Economics Research and Development, Bogor, FAE, Vol 19 No. 2, pp. 38-49.

Alder, J., Pitcher, T.J., Preikshot, Kaschner and Ferrias (2000), “How Good is good?: a rapid appraisal technique For evaluation of the sustainability status of fisheries of the North Atlantic”, in Pauly, D. and Pitcher, T.J. (Eds), *Methods for Evaluating The Impact of Fisheries on North Atlantic Ecosystem*, Fisheries center Report, Fisheries Center, Univ. of British Colombia, Vancouver.

Arifin, T. (2008), “Akuntabilitas dan keberlanjutan pengelolaan kawasan terumbu karang di selat lembeh”, Kota Bitung (Accountability and Sustainability Management of Coral Reefs Area in Lembeh Strait, Bitung City), Disertasi, Sekolah Pasca Sarjana Institut Pertanian Bogor.

Arsyad, S. (2006), *Konservasi Tanah & Air (Soil and Water Conservation)*, IPB Press, Bogor.

Banowati, E. (2016), “Empowerment of the inhabitants of pesanggem to poverty reduction and the acceleration of the recovery forest resource Muria”, *Jurnal SPATIAL – Wahana Komunikasi dan Informasi Geografi*, Vol. 16 No. 2, pp. 39-46.

Barlowe (1986), *Land Resources Economic*, Prentice Hall Inc., Raleigh, NJ.

Bohari, R., Pramudya, B., Alikodra, H.S. and Budhisantoso, S. (2008), “The analysis of the sustainability of the coastal area of the beach of Makasar of South Sulawesi”, *Jurnal Torani*, Vol. 18 No. 4, pp. 314-324.

Bourgeois, R. and Jesus, F. (2004), *Participatory Prospective Analysis: Exploring and Anticipating Challenges with Stakeholders*, Report No. 1437-2016-118895, available at: https://ageconsearch.umn.edu/record/32731

Brady, M. and Kosasih, A. (1991), “Controlling off-site forest destruction during oil field development in Sumatra, Indonesia”, *Proceeding Indonesian Petroleum Association*, Vol. 20, p. 485.

Dibyosaputro, S. (1999), “The landslide area in Samigaluh sub-district, area of Kulon Progo Regency, Yogyakarta special region”, Research Report, Research Institution, UGM, Yogyakarta.

FAO (1976), “A framework for land evaluation”, FAO Soils Bulletin 32, Rome.

FAO (2007), "Land evaluation: towards a revised framework", FAO discussion papers, Rome.

Fauzi, A. and Anna, D.S. (2005), *Modeling of Fisheries and Marine Resources for Policy Analysis*, PT, Gramedia Pustaka Utama, Jakarta.

Fauzi, A. and Suzy, A. (2005), *Pemodelan Sumber Daya Perikanan dan Kelautan untuk Analisis Kebijakan (Modeling of Fisheries and Marine Resources for Policy Analysis)*, Gramedia Pustaka Utama, Jakarta.

Goodland, R. (1995), "The concept of environmental sustainability", *JStor: Annual Review of Ecology and Systematics*, Vol. 26, pp. 1-24.

Green, P.E., Carmone, F.J. and Smith, S.M. (1989), *Multidimensional Scaling: Concepts and Applications*, Allyn and Bacon, London.

Gunadi, S., Sartohadi, J., Hadmoko, D.S., Hardiyatmo, H.C. and Giyarsih, S.R. (2004), "Competitive grant research report XI/2 for higher education, budget year 2004: integrated land conservation areas prone to avalanche disaster in Kulon Progo Regency, Yogyakarta", Research Institution, Gadjah Mada University, Yogyakarta.

Hadmoko, D.S. (2009), "Les mouvements de versant dans les mont menoreh", Java,Indonésie: variabilité spatio-temporelle, impacts, déclenchement, etanalyse de la susceptibilité. *These De Doctorat* De L'université Paris I – Panthéon – Sorbonne Ecole Doctorale De Géographie.

Hadmoko, D.S., Lavigne, F., Sartohadi, J., Hadi, P. and Winaryo, W. (2010), *Landslide Hazard and Risk Assessment and Their Application in Risk Management and Landuse Planning in Eastern Flank of Menoreh Mountains*, Springer Science+Business Media B.V, Berlin.

Huang, J.J., Tzeng, G.H. and Ong, C.S. (2005), "Multidimensional data in multidimensional scaling using the analytic network process", *Pattern Recognition Letters*, Vol. 26 No. 6, pp. 755-767.

Juhadi, J. (2013), "Spacio ecological dimensions of agricultural land utilization in hilly mountainous area girimulyo, kokap and pengasih Kulon Progo Regency Yogyakarta special province", unpublished dissertation, School of Postgraduate, Faculty of Geography, Gadjah Mada University, Yogyakarta.

Juhadi, Tjahyono, H. and Arifudin, R. (2014), "Analisis spasial tipologi kerusakan lahan berbasis sistem informasi geografis (spatial analysis of land damage typology based on geographic information system)", *Jurnal Tata Loka*, Vol. 16 No. 4.

Juhadi, J., Yunus, H.S., Sartohadi, J. and Poerwanto, H. (2011), "Assessing vulnerability base on spatial geobiophysics and community behavior: case study on hilly-mountenous of kulonprogo regency, Yogyakarta, Indonesia", in Yunus, H.S., Sekaranom, A.N. and Larasati, A. (Eds), *Proceeding International Conference on the Future of Urban and Peri-Urban Area*, ISBN: 978-979-3969-43-5, Yogyakarta, Department of Environmental Geography, Faculty of Geography, Gadjah Mada University, pp. 112-123.

Kepas (1985), "The critical uplands of ecosystem in java: an agro-ecosystem analysis", Agency for Agricultural Research and Development (KEPAS), 72pp.

Kavanagh, P. (2001), *Rapid Appraisal of Fisheries (Rapfish) Project.Rapfish Software Description (for Microsoft Excel)*, University of British Columbia, Fisheries Centre, Vancouver.

Kavanagh, P. and Pitcher, T.J. (2004), "Implementing microsoft excel software of rapfish: a technique for the rapid appraisal of fisheries status", Fisheries Centre Research Report 12(2), University of British Columbia, Vancouver.

Lefroy, R.D.B., Bechstedt, H.-D. and Rais, M. (2000), "Indicators for sustainable land management based on farmer surveys in Vietnam, Indonesia, and Thailand", *Elsevier – Agriculture, Ecosystems and Environment*, Vol. 81 No. 2000, pp. 137-146.

Mather, A.S. (1986), *Land Use*, Longman Publishing Group, New York, NY.

Nababan, B.O., Sari, Y.D. and Hermawan, M. (2017), "Analisis keberlanjutan perikanan tangkap skala kecil di kabupaten tegal jawa tengah (teknik pendekatan rapfish) – (analysis of small scale fishery sustainability in Tegal regency, Central Java Rapfish approach)", *Jurnal Sosial Ekonomi Kelautan Dan Perikanan*, Vol. 2 No. 2, pp. 137-158.

Nurmalina, R. (2008), "Anallysis of sustainability index and status of rice availability system in several region in Indonesia", *Jurnal Agro Ekonomi*, Vol. 26 No. 1, pp. 47-79.

Pitcher, T.J. and Preikshot, D. (2001), "RAPFISH: a rapid appraisal technique to evaluate the sustainability status of fisheries", *Fisheries Research*, Vol. 49 No. 3, pp. 255-270.

Priyono, K.D. (2012), "The typology of pedogeomorphic landslide occurrence in on hilly-mountenous of Kulonprogo regency, Yogyakarta", unpublished dissertation, School of Postgraduate, Faculty of Geography, Gadjah Mada University, Yogyakarta.

Rohimat, I.S. (2015), *Sustainability Status of Agroforestry in Private Lands: Study in A Case Rancah, Ciamis, West Java Regency*, Agroforestry Technology Research Center, Bogor.

Sartohadi, J. (2005), "The study of the arrangement of DAS river attack in Kulon Progo Regency", Research Report, Cooperation between Directorate General of Water Resources and PT. Puser Bumi Consultants, Yogyakarta.

Sena, C.D. and Marcos, A. (2009), "A theoretical essay on sustainability and environmentally balanced output growth: natural capital, constrained depletion of resources and pollution generation", BAR, Curitiba, Vol. 6 No. 3, pp. 213-229.

Syam, A. (2003), "Sistem pengelolaan lahan kering di daerah aliran sungai bagian hulu (management systems dryland watershed in upper section)", *Jurnal Litbang Pertanian*, Vol. 22 No. 4, pp. 162-171.

Sys, C.E., Van Rust, E. and Debaveye, J. (1991), "Land evaluation part II, methodes in land evaluation", Agricultural Publications No. 7, General Administration for Development Cooperation Place Du Champ The Mars 5 Bte 57-1050, Brussel.

Van Sickle, J. (1997), "Using mean similarity dendrograms to evaluate classifications", *Journal of Agricultural, Biological, and Environmental Statistics*, Vol. 2 No. 4, pp. 370-388.

Further reading

Michon, G., D.Yu., S. and Jafarsidik, Y. (1989), "Shorea javanica cultivation in sumatra: an original example of peasant forest management strategy", *Dalam Management of Tropical Rain Forest. Utopia or Chance of Survival*, Namos Verlagsgesellschaft. Hal, Baden, pp. 59-71.

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Appendix

Dimension and attribute	Data procurement method	Parameter	Data type
Ecological dimension			
Damage level on potential land	Map analysis and satellite imagery, field check	Land utilization typology, morphology, morphostructure, morphogenesis, morphoarrangement	Secondary
Damage level on actual land	Soil drilling, patch boxes, map analysis and satellite imagery	Soil thickness, distribution of loose rocks, plot density, open land	Primary
Road networks and landslide occurrences	Observation, measurement and map analysis	Landslide spots around road networks per landform units	Secondary
Land utilization typology	Observation and map analysis, field check	C-factor value, land utilization type on each landform unit	Secondary
Social cultural dimension			
Local Institution	Structured interview with questionnaire	Policies regarding conservation aspect	Primary
Local tradition	Structured interview with questionnaire	Traditions regarding conservation aspect	Primary
Social tradition	Structured interview with questionnaire	Social networks regarding conservation aspect	Primary
Perception	Structured interview with questionnaire	Comprehension of conservation	Primary
Attitude	Structured interview with questionnaire	Attitude toward land conservation acts	Primary
Motivation	Structured interview with questionnaire	Motivation toward land conservation acts	Primary
Social economic dimension			
Family revenue	Structured interview with questionnaire	Agricultural Revenue and expenditure outside agriculture	Primary
Education level	Structured interview with questionnaire	Formal education level	Primary
Involvement of family labor	Structured interview with questionnaire	Workdays	Primary
Land ownership status	Structured interview with questionnaire	Origin of land ownership	Primary
Agricultural land acreage	Structured interview with questionnaire	Class of land ownership acreage	Primary
Market orientation	Structured interview with questionnaire	Plant type percentage for trading commodity	Primary
Technological dimension			
Land utilization type	Structured interview with questionnaire and field check	Compatibility of vegetation type with land conservation aspect	Primary
Plant rotation	Structured interview with questionnaire and field check	Plant rotation technique used, according to land conservation aspect	Primary
Plant orientation	Structured interview with questionnaire and field check	Chosen vegetation, oriented to land conservation aspect	Primary
Plant variation	Structured interview with questionnaire and field check	Plant variation, according to land conservation technology	Primary
Soil processing technique	Structured interview with questionnaire and field check	Soil processing technique, done according to conservation technology	Primary

Table AI.
Dimensions and attributes of sustainability of land utilization for agriculture at hills-mountains region

Table AII. Sustainability index of land utilities

No.	Landform unit	Code	Sustainability index of land utilities: Socio-economic dimensions	Socio-cultural dimensions	Technological dimensions	Ecological dimensions	Multi dimensions	Criteria
1	Colluvium fluvio footplain	D1F8	74.56	72.36	83.38	62.76	76.89	Good
2	Igir of denudational hill Jonggrangan formation	H3D2	74.91	69.93	92.24	51.98	75.53	Good
3	Denudational andesit hills complex	H4D0	84.52	60.40	42.80	51.03	62.60	Moderate
4	Denudational breccias andesit hills complex	H5D0	77.72	66.25	65.00	29.32	70.14	Moderate
5	Denuadational hills complex Jonggrangan formation	H3D0	70.03	78.38	70.66	44.06	71.73	Moderate
6	Denuadational hills complex Sentolo formation	H2D0	55.50	74.02	89.69	43.06	66.63	Moderate
7	River valley	L0F9	66.50	63.05	61.02	55.21	65.04	Moderate
8	Topslope of denudational hills breccias-andesicitic	H5D4	66.01	58.79	54.09	57.05	60.30	Moderate
9	Topslope of denuadational hills Jonggrangan formation	H3D4	66.18	60.67	57.19	54.44	61.70	Moderate
10	Topslope of structural hills breccias-andecitis	H5S4	66.08	59.68	55.62	45.78	60.53	Moderate
11	Topslope of structural hills Sentolo formation	H2S6	66.08	59.68	55.62	56.83	61.18	Moderate
12	Colluvium footslope	B1D7	66.08	59.68	55.62	61.72	62.32	Moderate
13	Footslope of denudational hills andesicitic	B4D7	58.46	73.42	73.80	56.60	66.88	Moderate
14	Footslope of denudational hills breccias-andesicitic	B5D7	75.29	59.35	56.18	66.08	66.51	Moderate
15	Middleslope of denudational hills andesicitic	H4D5	64.88	61.30	58.00	47.66	61.56	Moderate
16	Middleslope of denudational hills breccias-andesicitic	H5D5	70.51	65.19	85.09	47.12	72.91	Moderate
17	Middleslope of denudational hills Jonggrangan formation	H3D5	72.86	56.83	48.89	51.13	57.89	Moderate
18	Middleslope of denudational hills Sentolo formation	H2S5	69.06	60.25	59.65	51.23	63.77	Moderate
19	Denudationnal hills breccias-andesicitic	H5D1	69.45	65.61	64.62	52.46	67.89	Moderate
20	Denudationnal hills Jonggrangan formation	H3D1	70.84	74.60	79.37	53.67	74.89	Moderate
21	Denudational topslope Sentolo formation	H2D3	68.58	62.62	60.61	47.68	62.10	Moderate

Source: Juhadi *et al.* (2011)

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