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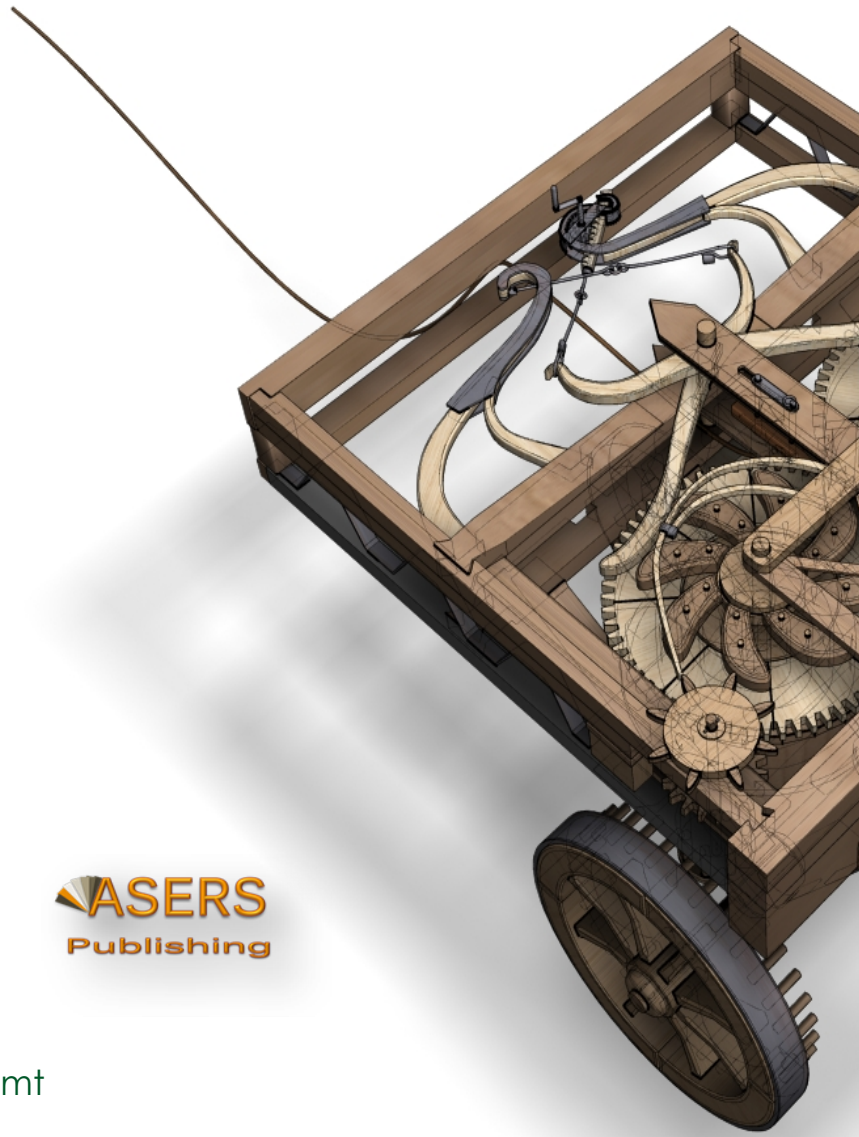

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Strategies for Environmental, Economic, and Social Sustainability of Potato Agriculture in Dieng plateau Central Java Indonesia

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Abstract:

Environmental problems in Dieng Plateau area, Central Java, Indonesia have no longer conformed to the principles of ecology, in which the use of fertilizers and pesticides is very high and productivity has decreased. Potato farming system causes the land condition becomes critical which could negatively affect the system of sustainable agricultural development. This study aims to analyze sustainable agriculture management in Dieng Plateu using indicators of economic, environmental and social. This study employed a combination of quantitative and qualitative method. Quantitative method was used to answer questions regarding economic, social, and environmental aspects. The economic aspect of sustainable agriculture included income, productivity and calculation of return cost ratio, and technical efficiency. Calculations on the use of organic fertilizer and manure, erosion hazard level and quality of water were included in the environmental aspect. The social aspect included education level, and housing conditions. Qualitative method was used to analyze the institutional model related to the conditions of Dieng area. The findings showed that potato farming indicators index was 48.57 and classified as unsustainable.

Keywords: environment; economy; social; agricultural sustainability; Dieng plateau

JEL Classification: O13

Introduction

The concept of agricultural sustainability was first introduced at the end of the 1980s as a responsive attitude towards early development strategy which mainly oriented the target of rapid economic growth which is absolutely caused degradation of the economy's productive capacity and environmental quality. The indicators used to determine the success of sustainable agricultural development of the economic aspect is farm income, return cost ratio and productivity (Hayati, Ranjbar, and Karami 2010, Dantsis 2010). Aspects of the environment use some indicators in terms of the use of fertilizers, pesticides, irrigation systems, and farm management (Dantsis 2010). Researches on sustainable agriculture have been done by Hayati, Ranjbar, and Karami (2010), Ceyhan (2010), Rigby, Woodhouse, Young, and Burton (2001), Rao and Rogers (2006), Roy and Chan (2011), Bos *et al.* (2007), Majewski (2013), Niemmanee, Kaveeta, and Potchanasin (2015), Veisi, Liaghati, and Alipour (2015) by using of different indicators on each aspect.

Sustainable agriculture has been implemented by the Government of Thailand, Malaysia, India and Bangladesh after their agricultural environmental damage in which the form of damage to the soil conditions are getting worse, pollution, health problems resulting from the use of pesticides (Faroque 2013, Ahmad 2001, Rao 2002, Niemmane, Kaveeta, and Potchanasin 2013). The practice of agricultural sustainability in Indonesia is the implementation of agricultural sustainability development program. Environmental damage and potato farmers' right in Dieng constitute a compelling matter in the government willingness to run sustainable agricultural development through the natural preservation and the improvement of socio-economic condition. The development of potato cultivation diminishing environmental quality in this area becomes the main problem (Lavigne and Gunnell 2003).

The citizens around the plateu have less concern about land management in Dieng. Based on the explanation in a local government regulation of spatial planning (2011), it can bee seen by many potato cultivations conducted irresponsibly by using chemical fertilizer and pesticide harming the surrounding. Land erosion along Serayu riverside and the increasing number of using manure contaminating some lakes and reservoirs in Dieng indicate that some environmental damage has occurred in this area. Those matters are as the impact of bad farming system neglecting ecology system and this can be observed by massive exploitation and high application of manure and pesticide on the lands. In biophysical environment, it also decreases hydrological function as hinterland area, soil fertility, and comfortable existence.

1. A brief overview of sustainable agriculture

1.1 Sustainable agriculture

Sustainable agriculture is a utilization of renewable and un-renewable resources for agricultural production by minimizing negative effects on the environment. This includes the use of available resources, the optimization of production quality and quantity, and the consideration of the environmental sustainability function.

Sustainable agriculture involves successful management of resources for agriculture to satisfy human needs while maintaining or enhancing the quality of environment and conserving natural resources (Technical Advisory Committee of the CGIAR 1988). Allahyari (2009) defines that agricultural sustainability is the successful agriculture resource management to supply human needs, to preserve the environment, and to improve biological resource. According to Rao and Roger (2006), agricultural sustainability is an agricultural implementation providing daily needs, nutrients and other related needs for a short time. Food and agricultural organization (FAO) has developed and defined the development concept of agricultural sustainability and rural development (PBPP) as natural conservation and management orientating the change ecology and institution aiming to fill human needs for present generation and future generation.

Some studies have shown the relation between sustainable agricultural implementation and food security (Arshad and Shafqat 2012). The success of sustainable-agriculture project has shown the solution needed to overcome food insecurity. The solution is not in the form of land expansion and the use of pesticide, but in the form of agricultural sustainability utilization using technology and ecosystems consideration.

Majewski (2013), measuring the agricultural sustainability using synthetic farm sustainability index (SFSI), reveals that a syntactic sustainability index can be achieved by agricultural infestation and programs enhancing environmental performance. Saptana (2007) explains that sustainable agricultural development will be more optimal if it is combined with the commitment to build partnerships among businessmen. It is because agricultural-based partnerships can guarantee to create efficiency and growth, justice and equalization, and environmental insight requiring the best institutional consolidation of farmers, private sectors and the government.

Sharma and Shardendu (2011), Dillon, Hennessy, and Hynes (2010), Roy and Chan (2011) used indicator economic, social and ecologi with different parameter to indicated how sustainability. Bagheri (2010) conducted a study to potato farmers in Ardabil province in Iran aiming to examine the perception of potato farmers towards sustainable agriculture. The research reveals that the farmers will gain benefits of sustainable-agriculture practices as the positive effects of resource conservation, negative effects of chemical substances minimization and pest invasion arising from continuous cultivation. Besides, there is a relationship between socio-economy of farmers and sustainable agriculture implementation. Niemmanee, Kaveeta, and Potchanasin (2015), carrying out the study about sustainable agriculture in Thailand, states that the practices of monoculture commercial plan orienting the export causes worsened land condition, pollution, increase of farmers' loan, and health degeneration due to intensive pesticide use. Furthermore, the study suggests that farmers need to reduce the use of chemical fertilizers and pesticides and replace them with organic materials such as manure and other agricultural residues. Also, they should implement production system management, secure training, and learn more about agriculture. In this case, agricultural sustainability is considered to be the best solution although no distinctive method can be applied uniformly in all regions and countries. Every country is to find its own way to reach agricultural sustainability in social economic and ecology condition.

1.2 Indicators of sustainable agriculture

Several previous studies have measured agricultural sustainability using different indicators. Sands and Pod more (2000) used environmental sustainability index (ESI) to analyze the agricultural sustainability and applied it on livestock in USA.

Andreoli and Tellarini (2000) used manometer and energy to compare the sustainability on livestock in Italy. More specifically, Gowda and Jayamariah (Gowda and Jayamariah 1998, Hayati, Ranjbar, and Karami 2010) used nine indicators including integrated nutrient processing, input productivity, productive quality, integrated pest management, integrated water management, input self-sufficiency, security crops, family food sufficiency, and independent information.

There are three components of sustainable agriculture, including ecology, society and interactive integrated economy. However, Norman *et al.* (1997) criticizes the concept because the components mentioned are dependent and inconsistent. Some components are probably sacrificed to achieve a certain goal. In addition, some indicators might not work practically for the farmers nowadays. Next, some usual marks normally show a progress of some sustainability but sometimes they fail to find out the problem solving of these matters.

1.3 Agricultural development in Dieng highland

The massive intensification and intensification were initiated in 1980 for potato commodity in Dieng highland. Potato farming changed the mountain becoming a big escalated horticultural cultivation till the top of hillsides (Sumedi 2013, Fadlillah, and Widyastuti 2016, Rudiarto, and Doppler 2013). Monumental potato plantation was started by new farmers bringing potato seed from Bandung. By introducing a better method of cultivation, potato seed, addition of manure, herbicide, fungicide, and regular watering process, this new cultivation resulted in good and economic productivity. Therefore, this method became popular throughout villages in Dieng. From 1980 to1986 most farmers started loving this method because potato seed was relatively inexpensive and farmers could harvest three times a year. Moreover, potato was long-lasting and unseasonable plant. It reached its peak in 1987 but then it began to fall. By 2000's, potato cultivation had been experiencing decreasing remarkable decrease, and so did the soil fertility (Rudiarto and Doppler 2013).

The extortionate demand of Dieng potato and the availability of pesticide and insecticide stimulated the farmers' addiction towards monoculture farming system. Ecological condition or highly influences the growth of plants. Improper environment leads to slim productivity. Potato cannot grow ell if we cultivate them in low lands. Even though new variety of potato can survive in medium lands (around 500 masl), ideal areas to produce potato are highlands or mountain 1000- 3000 masl. Therefore, Dieng highland, 2000 masl, is an ideal place.

Potato cultivation in Dieng is generally characterized as monoculture system to maximize profit. However, some people try to apply intercropping system by planting cabbage, corn, and tobacco. A plantation with mounds system is lengthened along the slopes and it causes more erosion. Therefore, it causes the soil less fertile. Potato cultivation in Dieng is located on the slope of 45 degrees. The farmers, believing that potato must be produced on overlays, refused all conservations carried out by the local government of Banjarnegara and Wonosobo.

2. Methodology

The sample of this study was selected though multiple stage sampling method. This means that samples were taken from populations, but not all populations became samples. The first step was determining the sample of the regions in Dieng highland by applying purposive sampling, meaning that the sample was based on data area in Dieng highland producing abundant potatoes. Those areas were of Wonosobo and Banjarnegara regions. The data used in this study was obtained from the respondents using questionnaires and from the interviews with experts.

The second step was determining the samples of district by purposive sampling. Kejajar and Garung district were the two biggest-potato-producing areas in Wonosobo in the last three years. Batur district is the biggest-potato-producing area in Dieng. The third step was determining the selected sample village using purposive sampling. The selected villages are potato-producing villages in 3 districts (Kejajar and Garung in Wonosobo and Batur in Banjarnegara). Deciding a number of samples by quota sampling was the fourth step. The respondents were 200 farmers. The analysis of sustainable agricultural performance was measured using three aspects as variables including economic aspect, environmental aspect, and social aspect. Economic aspect was measured by three indicators including potato productivity per hectare, farm income, return cost ratio and technical efficiency. Environmental aspect was measured using indicators including organic fertilizer, per hectare, water quality, erosion hazard level. Social aspect was measured using indicators including education level, housing condition, skill training and participation in organization.

2.1. Economic aspect

2.1.1. Farming production function model

$$Y= \beta.X_1^{\beta_1}. X_2^{\beta_2}.X_3^{\beta_3}. X_4^{\beta_4}. X_5^{\beta_5}. X_6^{\beta_6}. X_7^{\beta_7}. e^{\pi} \quad (1)$$

To estimate the parameters that affect the production of potatoes was done in a form of linear regression. This model was also used to determine in which stage of production of potatoes in Dieng area.

$$Ln\ Y = Ln\ \beta_0 + \beta_1\ Ln\ X_1 + \beta_2 Ln\ X_2 + \beta_3 Ln\ X_3 + \beta_4 Ln\ X_4 + \beta_5 Ln\ X_5 + \beta_6 Ln\ X_{6+} \beta_7 Ln\ X_{7+} e \quad (2)$$

where: Y = production of agricultural commodities, β0 = intercept / constants, β1 …β4 = coefficient of regression toward each independent variable, X1 = area of agricultural land, X2 = the use of chemical fertilizers, X3 = fungicide, X4 = the use of insecticides, X5 = labor (person-days), X6 = fertilizer use CM; X7 = hybrids, e = stochastic disturbance.

Furthermore, to analyze the effects of equally used production factors on the production of potatoes, F-test was use. T-test was used to examine the influence of each production factor on the production.

2.1.2. Return to scale

Return to scale determines the condition of activities to be increasing, constant or decreasing. There are three alternatives including decreasing return to scale if $\beta_1 + \beta_2 < 1$, constant return to scale, if $\beta_1 + \beta_2 = 1$, increasing return to scale, if $\beta_1 + \beta_2 > 1$ (Soekartawi 2006).

2.1.3. Technical efficiency

The level of technical efficiency was measured using the formula proposed by Soekartawi (2006).

$$ET = Y_i / \hat{Y_i} \quad (3)$$

where: ET = technical efficiency; Yi = output at- *i*; $\hat{Y_i}$ = amount of production based on the observation of all i obtained through frontier production function of Cobb Douglass

2.1.4. Net income

The farmers' net income is the average income received from one harvest in rupiah (Soekartawi 2006, 1990). The income of the farmers was formulated as follows:

$$TR = Y_i . P_{yi} \quad (4)$$

where: TR = total revenue; Y = productivity; Py = payment of Y.

2.1.5. Return cost ratio

Return cost ratio analysis measured the income or payment (Soekartawi 2006). It also reveals the money gained from each expanse value. The bigger the R/C value, the bigger the income. This means that the farming succeeds. Return cost ratio is formulated as follow:

$$a = R/C \quad (5)$$

where: R= Py.Y; C = FC + VC; a= {(Py.Y)/ (FC+VC)}.

Farming productivity analysis was measured by the farmer's expanse per hectare whereas environmental analysis on this research is measured by the amount of manure and inorganic fertilizer used. Land erosion in Dieng highland results in the application of chicken manure (CM), 100 kg/ha. The inorganic fertilizer used in Dieng is TSP, Urea and Phonska. The standard of using inorganic fertilizer is 300 kg/ha for TSP and 150 kg/hectare for Urea. Water quality condition compared to standard water quality standards is specified in government regulation. Erosion hazard level influencing environmental conditions in Dieng Plateau can be seen from the level of land degradation, the erosion level indicator. Influence of the attrition rate as an indicator of the level of land damage is based on the condition of the area as a conservation area. Protected areas function shift into potato cultivation can increase erosion.

2.2. Environmental aspect

In measuring environmental aspect, this study uses the indicators: (1) the use of chemical fertilizer / hectare; (2) the use of fertilizers CM / hectare; (3) Water Quality Condition; (4) Erosion Hazard Level.

(1). Use of Chemical Fertilizer / hectare

Indicators of Environmental Aspects as one of the elements to assess sustainability of farming potatoes one seen from the use of chemical fertilizers per hectare (Ceyhan, 2010). Standards are used as a benchmark is a Table 1, which is the result of the calculation of Wonosobo District Agriculture Office, in cooperation with the Central Bureau of Statistics of Wonosobo. Assessment is done with the criteria, according to the standard, above standard or substandard.

(2). Use of Fertilizers CM / hectare

Use of Fertilizer CM / ha is an indicator in the assessment of environmental aspects (Ceyhan 2010). Standards are used as a benchmark is a Table 1, which is the result of the calculation of Wonosobo District Agriculture Office, in cooperation with the Central Bureau of Statistics of Wonosobo. Assessment is done with the criteria, according to the standard, above standard or substandard.

(3). Water Quality Condition

Determination of water quality compared to standard water quality standards stipulated in Government Regulation.

(4). Erosion Hazard Level

To determine the environmental conditions in the Dieng Plateau can be seen from the level of land degradation, the erosion level indicator. Determination of the attrition rate as an indicator of the level of damage to land is based on the stipulation of the area as a conservation area. The land use change from protected areas into land potato cultivation can increase erosion. The level of erosion can be calculated using the universal soil loss equation (USLE) developed by Wischmeier and Smith (1978).

$$A = R \times K \times LS \times C \times P \quad (6)$$

where: A = the amount of the alleged erosion; R = rain; K = soil erosion; LS = slope factor; CP = factor utilization and processing plants.

Evaluation of danger of erosion was formulated by Hammer (1981).

$$TBE = A / TSL \quad (7)$$

where: TBE = erosion hazard level; A = annual potential erosion rate (tons/ha/yr); TS = erosion allowed (tons/ha/yr)

To determine the category of erosion hazard level, calculation results are categorized as low (<1.00), middle (1.00-4.00), and high (> 10.00). Social aspect is measured by education level categorized into low, medium and high; conditions house live in category of good, average and poor; frequency of training in categorized into frequent, ever and never; participation in organization categorized into good, average, and poor.

2.3. Social aspect

Social aspect is measured by some indicators of education level; conditions house live, frequency of training and participation in organization categorized into good, average, and poor. Education level of educational attainment is divided at three categories, namely low, medium and high. Conditions of housing can be categorized into three, namely good, average and poor. Frequency of training that is described as the following in the trainings related to conservation of the environment that supports sustainable agriculture programs is categorized into frequent, ever and never. Participation in the organization can be categorized into three, namely good, average and poor.

To analyze the sustainability category potato farming four steps were conducted including the calculation of each aspect based on the scale x frequency; the sum of the calculation scale x frequency for each aspect; sub-total calculation of each aspect; the final value of the calculation.

Table 1. Sustainability category of potato farming

Index Value	Criteria
0.00 -25	Poor (unsustainable)
25.1- 50	Less (less sustainable)
50.01- 75	Enough (quite sustainable)
75.01-100	Good (very sustainable)

Source: Soetriono and Suwandari Anik 2016

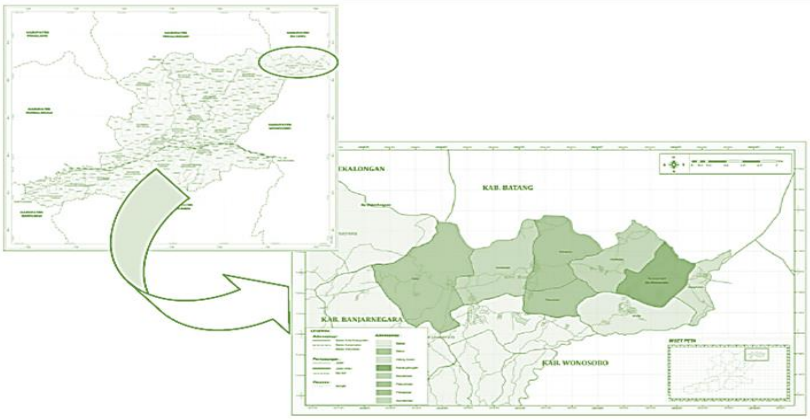
2.4. Analysis performance analysis recovery team Dieng area.

Performance analysis of existing institutions that manage Dieng area was conducted to determine how it performed during this time, so that further needs to be done to determine the new institutional models.

3. Result and discussion

Based on the calculation results on the Map of Administration and Region Boundaries with the help of Geographical Information Systems, it shows that the total area of Dieng is 54,974.24 Ha

Figure 1. Map of Administration and Region Boundaries



3.1. Economic aspect

3.1.1. Production function

The production function based on the calculation above is as following:

$$\ln Y = \ln 3.624 + 0.779 \ln X_1 + 0.035 \ln X_2 + 0.029 \ln X_3 + 0.028 \ln X_4 + 0.060 \ln X_5 + 0.048 \ln X_6 + 0.046 \ln X_7 \quad (8)$$

From the equation, it can also be shown that the return to scale of potato farming is as following:

$$\sum\beta = 0.779 + 0.035 + 0.029 + 0.028 + 0.060 + 0{,}048 + 0.046 = 1.025 \quad (9)$$

The value of returns to scale is 1.025, meaning that potato farming condition is at the stage of increasing returns to scale.

3.1.2. Return cost ratio

According to the result of field experiment through analyzing the average of return cost ratio, it was found that 19 respondents' cultivation was sustainable. Return cost ratio calculation showed that the average was 1.224 meaning that the potato cultivation on the observed areas was appropriate for economic side. In details, the farmers' payment was used 18.48 % for seed, 25.39 % for fertilizer, 30.55 % for salary, 0.53 % for insecticide, 4.31 % for fungicide, 15.36 % for rent, and 8.98 for other expenses.

3.1.3. Farm income

The farm income calculated in this research was gained from farmer's income obtained from potato agriculture as the main crop and cabbage and carrot as additional plants. From the research conducted in 200 farmers in Wonosobo and Banjarnegara regions, it can be known that the average income of farmers is IDR 10.531 million, the maximum income is IDR 47.906 millions and the minimum IDR (56.5) millions.

The calculation of farmers' income revealed that the income or production value trimmed outcome during growing season. This income was compared to farmer analysis standard and farmer income 5 years ago. The areas having income more than income standard are Mlandi, Dieng, Jojogan, Sumberrejo, and Karangtengah. Potato farmer analysis standard was IDR 18.235 million (1.381 US$) per hectare. Some villages have income below standard. It was probably caused by two problems including low productivity per hectare and the same price of potatoes of all areas.

3.2. Production productivity per hectare

3.2.1. Technical efficiency

The efficiency of the technique is the ability to produce maximum output with minimum input using certain technologies. In this study, potato production function was estimated using computer packages frontier 41. The results of estimation techniques used n = 200, obtained technical efficiency was 0.886.

The value of technical efficiency less than one indicating that potato farming in the researched area was not efficient, meaning that the use of the input was possible to be improved to increase production.

3.3. Environment aspect

3.3.1. Used of CM-fertilizer

From environmental aspect, CM-fertilizer use indicator in Dieng highland was used because hara layers were almost completely removed. Therefore, the function of manure CM became the place where potatoes grow. The use of CM fertilizer per hectare in Garung district was 7.486 kg/ha, in Kejajar district was 5.672 kg/ ha, and in Batur district was 5.834 kg/ha.

The maximum use of CM-fertilizer was up to 27,000 kg/ha in Garung district, 30,000 kg/ha in Kejajar district and 45,000 kg/ha Batur district, while the use of Urea and TSP fertilizer was 300 kg/ha and 150 kg/ha respectively. The amount of CM fertilizer in the researched area was more than 50-70 times.

The condition happening at this time in Dieng highland is the large land converted to different role more increasingly with land cover vegetation condition which is annual plant supported by natural condition which actually conservation area, therefore, the possibility of the erosion occurring and the chance of the larger critical-land are very high (Andriana 2007). The cultivation technique utilized by potato farmers does not indicate the efforts of the farmers care about environmental preservation. It can be known from their attitude to use insecticide and abundant fertilizers.

From the interview result of Dieng-highland-caring team, Atmojo, Ir. Dwi an information was obtained, that the farmers tend to not care about environmental damage because they thought that it is a government responsibility. The result of the interview with farmer groups showed that the farmers understand the concept of sustainable agriculture, but potato farmers have to protect potato cultivation, the problem of environment and conservation was neglected. The priority of farmers is how to produce big and more potatoes.

3.3.2. The application of unorganic fertilizer

The analysis of TSP and urea fertilizer supply by potato farmers in Dieng revealed that 42% was used below standard fertilizer and 58% was used over standard fertilizer. It can be observed that environmental condition in Dieng highland has been out of protection function shown by thinning soil, and more erosion, 436.077 ton/year/ha at Kejajar, 407.390 ton/year/ha at district Garung and 494.217 ton/ha/year at district Batur.

Basically, the respondents realized that the impact of this condition was worsened potato productivity and rising demand of potato in Dieng highland. Market accessibility lead to the degradation of environment. The farmers

had not found any substitute. Cabbages and carrots were produced in this area but were not as beneficial as potatoes.

3.3.3. Level of erosion hazard

Based on erosion hazard classification rate, each researched district was categorized in as extremely high. Research conducted by Andriana (2007) in Dieng area in 2007 revealed that TBE result was 48.32 tons/ha/year. Erosion hazard level at Kejajar district was 45.427 ton/year/ha in 2016, at Garung 42.436 ton/ha/year and in Batur district was 51.48 ton/year/ha.

3.3.4. Quality of water

Water condition of Serayu watershed was heavily polluted. This showed that the water quality in the Dieng plateau region was alarming for agricultural activities if not managed properly.

3.4. Social aspect

Social analysis focused on health issues affected by over-doze pesticide. In 2004, the department of health in Wonosobo conducted an experiment to see the effect of using more pesticide and there was no more expedition about this issue up to now. This analysis must be done to identify the farmers' health, and detect some effects of over doze pesticide. The observation showed that there were some impacts experienced by 200 respondents including 14 people having dizziness syndrome, vomit, and itchy syndrome. Unluckily, the cause was unclear. The difficulties were faced in figuring out the impact of applying pesticide and insecticide on some respondents because many workers were from other districts, not original farmers.

Calculation of the index was 48.57. Based on the criteria of sustainability level, the condition of farming in Dieng area was included in the category of less sustainable this means that potato farming in Dieng area was already in the stage of no sustainability concerning the economic, environmental and social aspect. The lack of continuity of the economic aspect, with productivity indicators, return cost ratio, farm income showed that potato farming did not provide a guarantee of economic life of the farmers. Environmental aspect including erosion hazard level calculation in district Kejajar, Garung and Batur showed a very high level of danger conditions. The use of chemical fertilizers and manure CM (manure) will greatly affect the condition of the soil, and soil productivity, as well as causing damage to the environment. Based on the calculation of the social aspect, low level of education features prominently, only 143 farmers finished primary school (elementary school)/do not complete primary school and never went to school.

Based on the results of judging of the performance Restoration Coordination Team Dieng Wonosobo district which reached 42.25 means included in the category of performance being. This criterion means that, as a public institution with a vision to save the environment Dieng could not perform optimally programs, from the aspect of productivity, responsibility, responsiveness and accountability.

Conclusion

Poor condition of potato agriculture can be improved by following the standard of potato farming concept and considering environmental aspect. Productive function theory–diminishing return to scale-is suggested for potato farming or production. It has been proven that providing more efforts decrease the productivity.

Practically, institutional roles and teamwork effectiveness improvement are necessary to realize agricultural sustainability in Dieng Plateau. This research assesses the implementation of agricultural based on three aspects including economic, social, and environmental aspects. Dieng area management strategy is needed with the establishment of management institutions Dieng Plateau Area.

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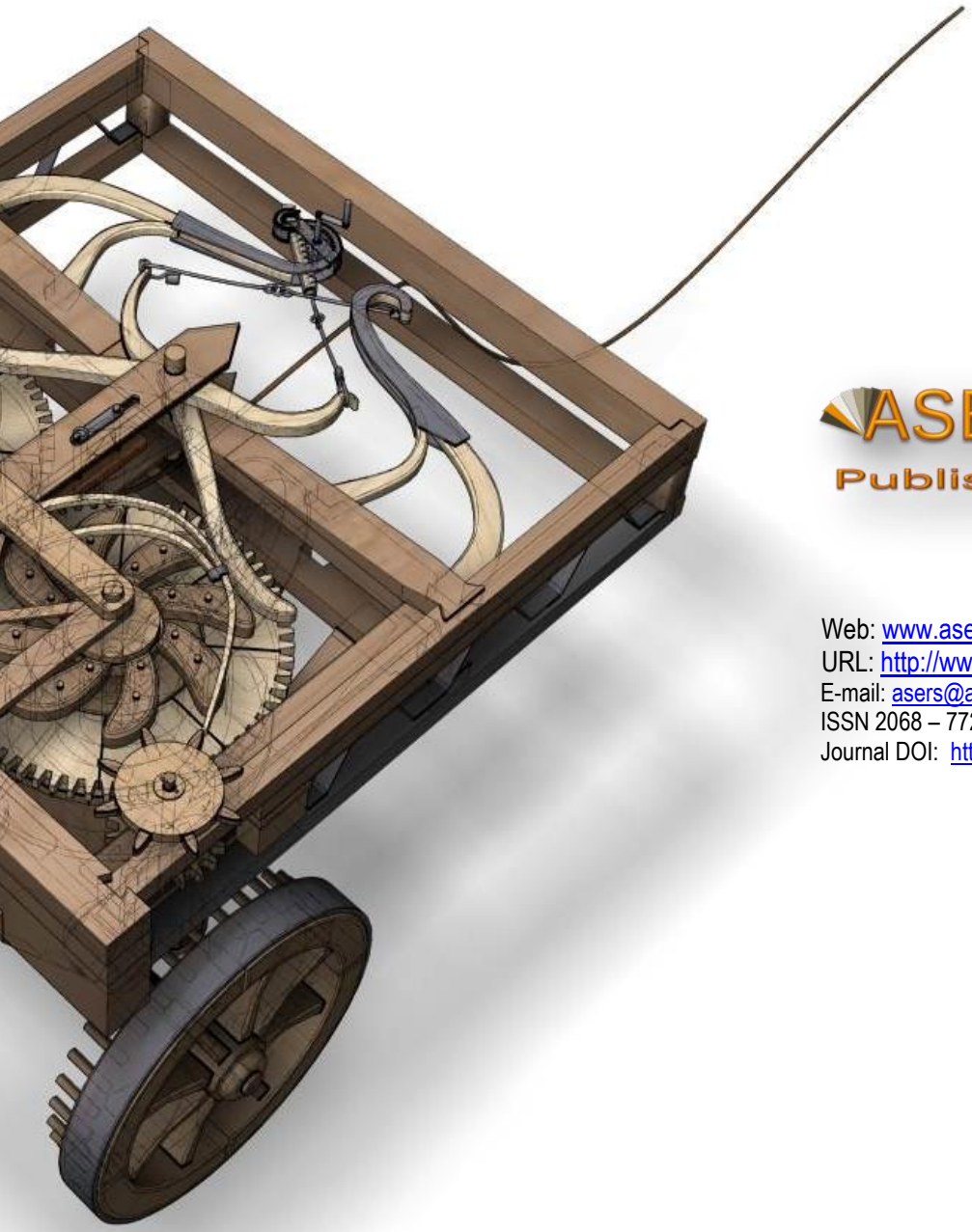

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