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The Effectiveness of Plastic Mulch for Maintaining the Potato Farmland in Dieng Plateau Using Soil Biological Quality Index

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Abstract

Dieng farmers apply plastic mulch to reduce erosion and to prevent the loss of nutrients. This study aimed to determine the effectiveness of plastic mulch in maintaining the quality of potato farmland using the Soil Biological Quality Index (QBS-ar) based on the existence of microarthropods. Soil sampling was conducted in six different locations, i.e., flat area with mulch, sloped area with mulch, the flat area without mulch, sloped area without mulch, flat forest area, and sloped forest area. Microarthropods were obtained from soil samples using a Berlese Funnel method. Soil quality was analyzed using QBS-ar index which was calculated based on Eco-morphological Index (EMI). The results showed that the value of QBS-ar index in potato farmland with the use of plastic mulch was much higher than in farmland without plastic mulch in bothflat and sloped area. Compared to the soil in the forest area, the value of QBS-ar index in farmland with the use of plastic mulch, especially in the flat area, was relatively similar. Hence, the use of plastic mulch for potato cultivation in the hilly area is effective in maintaining soil quality. This finding would be beneficial for developing a soil conservation strategy to achieve sustainable agriculture in Dieng agricultural area.

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INTRODUCTION

Dieng plateau has a problem regarding land degradation. Most of Dieng residents are farmers who grow various crops including potato. The farmers clear-cut perennial plants and replaced them with crops which resulted in soil erosion and uncontrollable chemical fertilizers utilization. Without proper management, the cultivation of potato in Dieng might increase erosion and land degradation that far from the efforts to achieve sustainable agriculture (Pradana et al., 2015).

One of the farmers efforts to maintain land qualities is by using plastic mulch. The use of plastic mulch can protect the soil from direct raindrops so that, it can prevent the loss of nutrients. Besides, plastic mulch is physically able to keep the soil temperature more stable and maintain the moisture around the plant roots (Annisa et al., 2014). The use of plastic mulch for agricultural cultivation requires a monitoring program. The organisms that can be used as monitoring agents are soil microarthropods because they are very sensitive to changes in soil environmental conditions. There had not been enough research regarding the effect of using plastic mulch towards the presence of microarthropods. The research that has been done only focus on its effect on the plant. The use of plastic mulch in study by Permana et al. (2017) showed that it can significantly increase the growth and yield of soybean crops. Meanwhile, the research conducted by Haque et al. (2018) showed that plastic mulch has the effect on increasing the growth and yield of plants in saline soils where plant growth is generally poor. Therefore, this study was important to examine the condition of soil quality under the plastic mulch using a microarthropod soil as monitoring agents.

Few parameters can be used to monitor the land quality such as by observing the physical or chemical aspects of the soil. However, it is also important to consider the biotic environment such as the presence of microarthropods inside the soil as parameter. This organism has an important role in producing nutrients for the soil. Soil microarthropods are the main structure of food webs as a decomposer. It also contributes to soil aggregation by producing organic matter (Gardi et al., 2002). The numbers of soil microarthropods are quite large, and their role in land formation and transformation is very beneficial. Their life cycle and their natural history in the field can help to assess the ecological condition of the soil (Gardi et al., 2002).

Microarthropods is a useful monitoring agent due to its highly diversity taxonomically and ecologically, especially in eudaphic forms of microarthropods which is unable to survive in various disturbances i.e cultivation practice (Parisi, 2005). Recently, an integrated approach has been proposed in the form of Soil Biological Quality Index (QBS-ar). This index is based on the concept of higher quality soils means a higher number of microarthropods groups that can adapt to the soil habitat. (Paolo et al., 2010).

Microarthropods can be used as an indicator to measure the soil quality because they are very sensitive to the change of soil environmental condition. According to Parisi et al. (2005), the biological indices of soil quality can be discovered by observing the microarthropods found in the soil. Microarthropods have a significant role in the soil food chain. Their purpose is to distribute the energy from microfauna to microfauna on a higher trophic level (Culliney, 2013)arthropods may represent as much as 85% of the soil fauna. They comprise a large proportion of the meso- and macrofauna of the soil. Within the litter/soil system, five groups are chiefly represented: Isopoda, Myriapoda, Insecta, Acari, and Collembola, the latter two being by far the most abundant and diverse. Arthropods function on two of the three broad levels of organization of the soil food web: they are plant litter transformers or ecosystem engineers. Litter transformers fragment, or comminute, and humidify ingested plant debris, which is deposited in feces for further decomposition by micro-organisms, and foster the growth and dispersal of microbial populations. Large quantities of annual litter input may be processed (e.g., up to 60% by termites. Microarthropods are one of the most important inhabitants even in strongly disturbed soils (Dunger & Voigtlander, 2005).

The reason why QBS-ar is easy to use to assess the soil quality is that it does not require a complex identification of taxonomy. The assessment is only based on the biological morphology according to the adaptation level of soil habitat. Then, each group of microarthropods is given scores based on Ecomorphological Index (EMI). The calculation results are only seen from the adaptation of microarthropods to their new habitat without classification to species level. Thus, the costs and labors needed are reduced (Paolo et al., 2010). This research was really necessary to determine the effectiveness of using plastic mulch towards the cultivation of potato farms using the QBS-ar index, so that in the future the data obtained can be used as a reference for better farmland management.

METHODS

Study area

The study area was located in the Dieng Plateau Kejajaran District, Wonosobo Regency, Central Java. The sampling locations were chosen based on the usage of plastic mulch as an alternative agricultural technique both in flat and slope land condition. Forest land in Dieng Plateau was chosen as reference stations for comparison purpose. The sampling location was divided into six research locations:

MF: potato agricultural land with the use of plastic mulch located on flat land.

MS: potato agricultural land with the use of plastic mulch located on the land with slopeof 28°.

NF: potato agricultural land without the plastic mulch located on flat land.

NS: potato agricultural land without the plastic mulch located on the land with slope of 28°.

FF: a flatted forest with a high amount of vegetation.

FS: a forest with slope of 35° and a high amount of vegetation.

Soil sampling

The boundary of the sampling area was decided according to the width of the land, representative area, and potato uniformity. There were five sampling points, every sample was taken from the middle of the station. There were two soil samples taken from eachstation, one for microarthropod identification and the other for soil physical-chemical analysis. Soil samples were taken using a small shovel measuring 10 cm depth and 10 cm in diameter. The sample can only be taken at ≥ 40% of soil humidity.

Extraction of microarthropods and identification

The microarthropod samples were obtained using the Berlese-Tullgren funnel (Parisi et al., 2005). For trapping the microarthropod, 40W of light was placed on the top of the funnel to increase the soil temperature up to 35°C. A 500mL plastic bottle filled with 75% alcohol was placed under the funnel to trap the microarthropod that comes down. This process took around seven days to complete. The process of identifying and grouping the taxa was performed by observing the micro-morphology using a microscope and identification book.

Data analysis

QBS-ar (Biological Soil Quality) index was used to analyze the soil microarthropods data. The QBS-ar index is based on a direct relationship between soil quality and the number of microarthropods adapted to soil habitats. The identification process uses a biological form approach towards morphological class according to their level of adaptation to the soil environment (Gagnarli et al., 2015). The scoring of EMI values, wich ranged from 1 (zero adaptation to the soil) to 20 (maximum adaptation to the soil) was defined according Parisi et al. (2005) and Menta et al. (2017).

The soil physico chemical data was analyzed using Person correlation. The parameters analyzed included pH, temperature, moisture, N-total, organic matter conten and C/N ratio of the soil.

RESULTS AND DISCUSSION

The quality of the potato farmland soil in flat land with the use of plastic mulch was better than in that one without plastic mulch. It is shown in Table 1 that the value of QBS-ar index of farmland with plastic mulch was much higher (70) than the one without plastic mulch (45). It seems that the plastic mulch protects the soil effectively from the harsh of an abiotic environment. Mahmudi et al. (2017) stated that plastic mulch could preserve soil temperature which is useful for soil microorganisms to decompose organic matter. The increase in the number of microorganisms is strongly related to the existence of microarthropods. According to Coleman et al. (2004), microarthropods have an important role in plant litter fragmentation. The result of this fragmentation causes the surface area to expand, thus increasing the activities of microbes.

In sloped potato agricultural land, the QBS-ar index value with the use of plastic mulch is also higher (56) than that the one without the plastic mulch (43) (Table 1). This is indicated that the plastic mulch can retard the nutrients from eroding in the sloped land. Thus, the soil quality can be maintained. It is supported by Fahrurrozi (2009) who stated that the soil can be protected from rainfall by using the plastic mulch, because it keeps the nutrients from drifting. Unlike in the farmland with plastic mulch, the existence of microarthropods in the farmland without plastic mulch is relatively easily to go extinct because they were drifted due to soil erosion. The abundance of soil microarthropods is associated to soil quality. Larasati et al. (2016) stated that microarthropods will continuously maintain the nutrient cycle process.

Table 1. The comparison of QBS-ar index value in flat area with plastic mulch (MF), sloped area with plastic mulch (MS), flat area without plastic mulch (NF), sloped area without plastic mulch (NS), flat area in the forest (FF), and sloped area in the forest (FS).

Microarthropods group	Potato Agricultural Land				Forest Land	
	MF	MS	NF	NS	FF	FS
Collembola	20	10	10	8	20	20
Hemiptera	-	-	-	-	1	-
Coleoptera adults	10	-	-	-	15	20
Coleoptera larvae	-	10	10	10	-	-
Holometabolous larvae	-	-	-	-	-	10
Hymenoptera	5	5	5	5	5	5
Diptera adults	-	-	-	-	1	1
Diptera larvae	-	-	-	-	10	-
Araneae	5	-	-	-	5	-
Acari	20	20	20	20	20	20
Psocoptera	-	1	-	-	-	-
Symphyla	10	10	-	-	-	-
QBS-ar	70	56	45	43	77	76

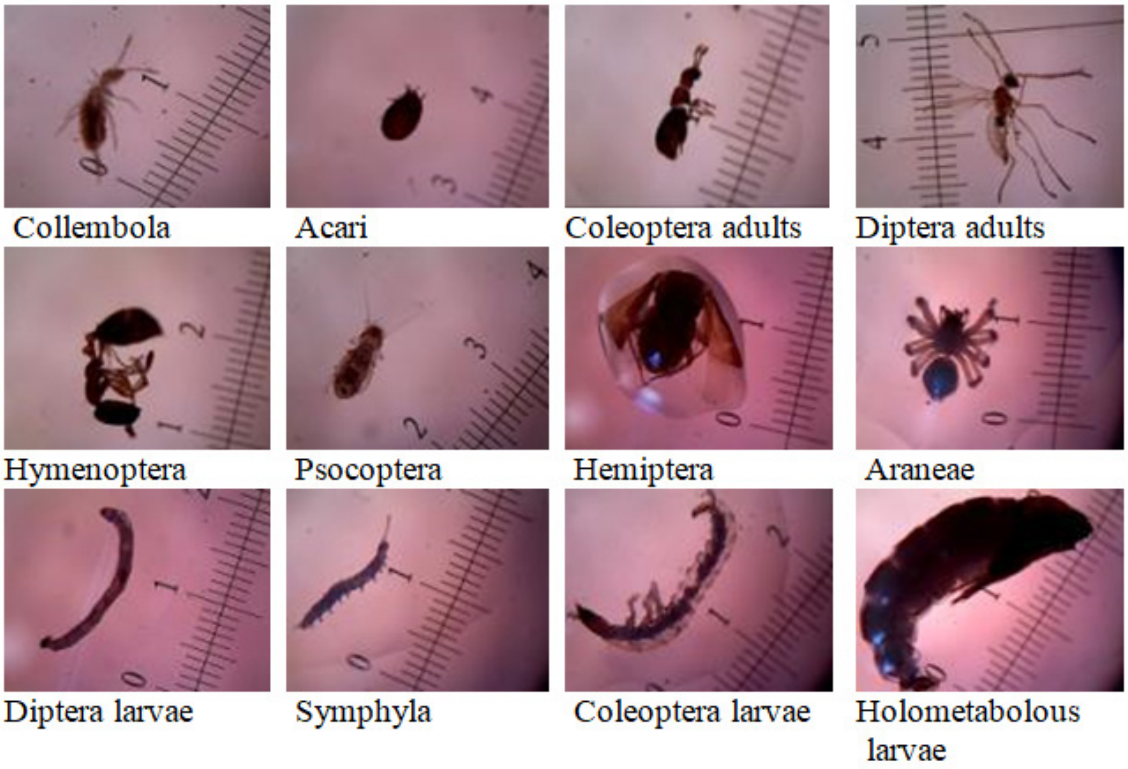

Figure 1. Microarthropods found in potato agricultural land and forest land.

The results showed that the QBS-ar index value in the forest are higher (76- 77) than those in potato agricultural land (43 -70), regardless the presence of plastic mulch and any variation of slope (Table 1). This might be because of the soil in Dieng potato agricultural land is exposed to chemical fertilizers and pesticides intensively. According to Isnaini (2006), the use of chemical fertilizers in the long term causes the levels of soil organic matter to decrease, soil structure to be damaged and environmental pollution. If it continues, this could reduce soil quality and environmental health. Moreover, the high value of the QBS-ar index in the forest is related to the

Tabel 2. The physico-chemical parameter of soil in potato agricultural land and forest of Dieng

Parameter	Potato Agricultural Land				Forest Land	
	MF	MS	NF	NS	FF	FS
N total	0.29	0.15	0.23	0.41	0.38	0.35
Organic matters	2.60	2.07	1.74	1.80	3.34	3.25
The ratio of C/N	9.12	13.56	7.69	4.41	8.74	9.2
Soil pH	6.1	6.5	6.1	6.5	6.7	6.9
Soil Temperature	17.6	16.6	17.2	16.8	10.8	10.2
Soil Humidity	88	89	100	91	50.6	50.6

vegetation condition. The vegetation in the study site is relatively better than in potato cultivation area, regarding the plant's diversity and density. Wang et al. (2013) stated that vegetation affects the ability of the soil to hold water to prevent erosion and landslides. Vegetation root systems can significantly improve the stability of the soil and act as anti-erosion agent (Zheng et al., 2007). The activity of soil organisms is strongly dependent on the condition of vegetation. Plants play a role in supplying organic matter to the soil either through the production of litter or root exudates while soil organisms are responsible for most biological processes related to nutrient cycles and decomposition of organic matter (Widyati, 2013).

Table 3. The correlation (Rs) of Soil Biological Quality Index (QBS-ar) with soil physico-chemical parameter

Parameters	Correlation (Rs)
N total	0.243
Organic matters	0.968*
C/N	0.359
Soil pH	0.492
Soil Temperature	-0.543
Soil Humidity	-0.928*

Note: (*) refers to significant correlation at 5% level.

The correlation analysis indicates that organic matters have a significant correlation to QBS-ar index (Rs = 0.968) (Table 3). The correlation coefficient shows a positive value, meaning that the higher the organic matters, the higher the QBS-ar index value. This is possible because the usage of plastic mulch can prevent the soil nutrients, some of which are organic matters, from drifting. The result of the research conducted by Gagnarli et al. (2015)in some vineyards in Piedmont (Italy showed that the QBS-ar index is higher in a grape farm using organic management than that of using integrated pest management (IPM). The research conducted by Husna et al. (2016) also stated that the richest microarthropods taxa were found in the farms that contain high organic matters.

Suin (2003) showed that soil organic matters determine soil organism density, including soil microarthropods. Soil organic matters are including litter and soil organisms, whether decomposed or not. The distribution of organic matters in soil affects the existence of soil microarthropods since it is associated with the source of nutrition.

The only soil physico-chemical factors which has a significant correlation except soil organic matter, is soil humidity (Table 3). The correlation between soil humidity and QBS-ar index value indicates a negative correlation (-0.928). Both extremely high or extremely low humidity environment condition can cause a negative impact on microarthropods. A desiccated condition also decreases the population of microarthropods since majority animal has a small tolerance limit of environmental humidity. Abiotic factors such as soil humidity could affect the presence of soil microarthropods taxa (Larasati et al., 2016).

According to Hamdani (2009), using plastic mulch can maintain more stable soil temperature and preserve humidity around the roots of plants. In addition, the administration of mulch and legume inoculant can affect the number of bacteria in root nodules and can affect the growth of soy plants of Grobogan variety (Ni'am & Bintari, 2017). Furthermore, plastic mulch is also able to keep water (in soil) from excessive evaporation (Noorhadi & Supriyadi, 2003). Research by Samiyarsih et al. (2018) stated that relatively high humidity causes the pathogen *Sphaceloma babatas* to penetrate, infect, and damage tissue in sweet potato plants.

This study proves that the usage of plas-

tic mulch on potato farming system can improve the soil quality. It is indicated from the higher QBS-ar index value in the farmlandwith the plastic mulch compared to the one without plastic mulch in both flat and sloped land.According to Fahrurrozi (2009), the usage of plastic mulch is more effective. Plastic mulchcan be used to protect soil physically from direct raindrops, to loosen the texture of soil, toprevent nutrients from drifting, to prevent the splashing of soil granules on plants, to prevent soil water from evaporating, and to decelerate the release of carbon dioxide in the soil resulted from respiratory activities by microorganisms.

The usage of plastic mulch is useful for maintaining soil quality through modification of soil temperature,prevention of weed growth, reduction of evaporation as well as soil compaction and erosion. Under plastic mulch, soil properties such as temperature, moisture content, rainfall density, aggregate stability and availability of nutrients can be improved. Growth and yield of plants are also positively affected by plastic mulch due to modification of soil microclimate (Lalitha et al., 2010).

This research would be beneficial for developing a sustainable agriculture through a strategy of soil conservation in Dieng area in order to prevent soil degradation and soil erosion. Hence, the farmers could be benefited in economy, ecology and in terms of socio-cultural aspects.

CONCLUSION

According to Soil Biological Quality Index (QBS-ar) based on the existence of microarthropods, application of plastic mulch on potato cultivation is effective to maintain the soil quality in order to conserve soil in Dieng agricultural land.

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