Economic and Social Study on Rainwater Harvesting in Karanganyar Regency, Central Java, Indonesia

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(インドネシア中部ジャワ・カランガンヤ地区における集水農業に関する経済および社会学的研究)

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SUMMARY

Climate change impacts on human life are inevitable, with the agricultural sector being significantly affected. As a country where more people rely on agriculture, Indonesia has begun to feel the impact of climate change. First research about farmers' perceptions regarding the differences in pest attack frequency, water sufficiency and harvest failure between the past and the present were analyzed. Data was collected using a survey technique, which involved administration of questionnaires to a sample of respondents selected from a specified population. Chi Square analysis was used to identify whether the variables of past and present are different or not, Pearson's Chi Square analysis was used to identify significant correlation of rejected variables, and Cramers V analysis was used to identify the correlation's strength. Finally the suitable method to address the expected impact of climate change was suggested. This research was conducted in Karanganyar Regency, Central Java Province, Indonesia. The interview was done in December 2011.

The chi square analysis found that crop patterns, water resources and the incidence of short droughts had not changed from the past to the present, while harvest failure, pest attack frequency and water sufficiency had changed. Pearson's chi square and Cramers V analysis shows that in the past, harvest failure had a direct correlation with pest attack frequency and short droughts, while pest attack frequency had a direct correlation with short droughts, indicating that short droughts might have had an indirect correlation with harvest failures. Harvest failure also had direct correlation with water sufficiency. In the present, harvest failure was found to have direct correlations with pest attack frequency and water sufficiency. Present correlation of pest attack frequency become negative might be caused by the pesticide application. Today's

pesticide quality is increasing, that can control the pest attack. When weeds were included in the correlation analysis, harvest failures could possibly have an indirect correlation with weeds and water sufficiency through pest attack frequency.

Harvest failure has increased significantly and has been the main climate change impact on agricultural productivity in this area. There were several reasons identified for harvest failure. First, if there is not enough water or lack of water, there are commensurate increases in weeds which lead to an increase in pest attacks, which can cause harvest failure. Further, if rain is uncertain or late at the beginning of the wet season, farmers often delay their first crop season, which then affects the second crop season which can lead to crop failure due to lack of water. Farmers need to be able to start their first crop season in October to ensure the success of the second crop season. Therefore, it is suggested that alternative water sources such as small farm reservoir be developed. Small farm reservoirs can supply water at the beginning of the wet season, thereby mitigating any rainfall concerns, and can also help with flood systems to prevent excessive weed growth if there are water shortages in either the first or second crop seasons.

In advance, second research about the suitability of small farm reservoirs was conducted in the same area. The aims are to analyze which is suitable and acceptable based on economic change between tarpaulin and concrete in small farm reservoir application and to find out proper way to make rainwater harvesting technology adaptable for more farmers. This research was conducted in Wonosari Village, Gondangrejo Sub-District, Karanganyar Regency, Central Java Province, Indonesia. In the research area, four small farm reservoirs with irrigated rain-fed paddy fields were selected for detailed observation and analysis. The owners of those small farm reservoirs were interviewed using a structured and a semi-structured questionnaire covering a broad range of socioeconomic aspects related to the application of small farm reservoir. The interviews were conducted in June - August 2014. Economic analysis was carried out based on two consecutive seasons, 2012/2013 (only first crop season in case that small farm reservoir was not built) and 2013/2014 (two crop seasons; first crop season and second crop season in case that small farm reservoir was available). Benefit-cost ratio analysis was used to determine if the project was economically acceptable.

It was clarified by previous research in the same area by Ariyanto *et al*. (2015) that the presence of small farm reservoir enabled farmers to cultivate paddy twice a year, because small farm reservoir could supply irrigation water during short drought and dry season in the second crop season. In addition, the optimum irrigation area must be estimated as proposed by Ariyanto *et al*. (2016) in order to gain the maximum benefit of small farm reservoir, because benefit cost ratio values for actual irrigation areas decided by farmers are lower than one, and not acceptable for almost all small farm reservoirs. Furthermore, the results indicate that it is important to identify the catchment area appropriately, in order to maximize the SFR benefits. Increasing the catchment area can increase the benefit cost ratio value through the water storage index. The benefit cost ratio value can be estimated from the lining material, the catchment area, the harvest ratio, and the small farm reservoir volume before the construction commences.

Based on the analysis of the concrete and tarpaulin benefit cost ratio values, concrete is recommended as lining material of small farm reservoir. Nevertheless, the high cost of constructing a small farm reservoir with concrete cannot be paid in a lump sum by common farmers, who rely only on farming. Thus, the subsidy or supporting system such as loan with long payback period with small interest from government is required to make this technology more accessible.

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I. INTRODUCTION

1.1 Background

Water scarcity has become an increasingly severe global problem due to factors such as climate change, water pollution, and the unsustainable consumption of water resources (Zhan et al., 2009). This scarcity demands the maximum use of every drop of rainfall (Zreig et al., 2000) and many methods have already been developed to deal with this. Rainwater harvesting (RWH) seems to be a beneficial method for minimizing water scarcity in developing countries (Helmreich and Horn, 2009; Dile et al., 2013; Akter and Ahmed, 2015) and is a particularly useful adaptation to environmental stresses at the local scale (Pandey et al., 2003).

This technology not only improves agriculture production but also could be a way to utilize available areas to collect rainwater for human activities (Yuan et al., 2003). RWH is one measure that enhances the resilience of human society towards a water shortage problem (Lee, 2016). Given these benefits, RWH is suitable for small farmers who are threatened by climate's unpredictability, unstable markets, and insecure conditions due to social, economic, and state politics (Fox et al., 2005).

Over thousands of years, indigenous RWH and management regimes were used and have adapted to climate change (Pandey et al., 2003). Commonly, there are two types of RWH as follows: domestic usage, which usually uses rooftops as the catchment area (Abdulla and Al-Shareef, 2009; Mun and Han, 2012; Sturm et al., 2009), and agricultural usage, which uses the open field as the catchment area (Panigrahi et al., 2001; Li et al., 2006; Xiao et al., 2007).

Based on water management, the design of RWH systems is important to determine the optimum volume of RWH. Specific research on the design of RWH systems for agriculture is still limited. Ariyanto et al. (2016) showed that the RWH volume could be calculated with some available data, such as irrigation area, crop pattern, catchment area, and climatic data. Conversely, based on the available RWH volume, crop, catchment area, and climatic data, the optimum irrigation area could also be calculated.

The next part of an RWH design is selecting the lining material, which can be a soil base, tarpaulin seal, or concrete. Based on strength, concrete is the better option, but it is often not economically viable due to high construction costs. Machiwal et al. (2004) showed that dry stone masonry is more cost-effective than concrete, although this material design is dependent on the socio-economic conditions in the target area.

RWH has been proved to be an economically promising technology by many researchers (Fooladmand and Sepaskhah, 2004; Liang and Pieter van Dijk, 2011; Contreras, 2013; Komariah and Senge, 2013; Dile et al., 2013; Zingiro et al., 2014; Lage and Verburg, 2015; Zhou, 2015). The most commonly used methods to calculate the feasibility of RWH are yield comparisons, gross margin analyses, and investment analyses (Senkondo et al., 2005). In an investment analysis, the net present value (NPV) and internal rate of return (IRR) are often used to analyze the feasibility of an RWH system (Senkondo et al., 2005; Morales-Pinzon et al., 2014; Matos et al., 2015).

There are two researches that have been conducted relate with climate change and rainwater harvesting to overcome climate change. Both researches were brought for one main purpose, to help Indonesian agriculture that risky to climate change. Indonesian agriculture is dominated by rain-fed agriculture. With traditional way only rely on rainfall will not bring any change. Rainwater harvesting technology seems to be a good method for today’s water problem for Indonesian agriculture.

1.2 Research Objectives

Research I; Indonesian Farmers’ Perception on Climate Change; Case study in

Karanganyar Regency, Central Java Province, Indonesia

a. Analyze whether there have been any change in crop pattern, pests, water availability and harvest failure etc. during four decades.
b. Propose suitable method to address the expected impact of climate change.

Research II; Evaluation on Rainwater Harvesting Suitability in Indonesia; Case Study of Four Small Farm Reservoirs in Wonosari Village, Central Java, Indonesia

a. Analyze which is suitable and acceptable based on economic change between tarpaulin and concrete in small farm reservoir application
b. Find out proper way to make rainwater harvesting technology adaptable for more farmers.

II. RESEARCH I

2.1 Materials and methods

2.1.1 **Location**

Data for this study was collected in Karanganyar Regency (77,379 ha), Central Java, Indonesia (Figure 2.1). This regency has 17 sub districts and a density of 1,086 people per km^2. In 2014, approximately 30% of the total area was paddy field, with only 5% having irrigation channels. In other words, most agriculture relies on rainfall or rain-fed sources.

2.1.2 Methods

Data was collected using a survey technique, which involved administration of questionnaires to a sample of respondents selected from a specified population (Babbie, 2010). The population in this research was farmers who had started farming before 1970s, as it was assumed that these farmers had already experienced some climate change phenomena over the past four decades. Seventy farmers from 13 sub-districts were interviewed in December 2011. A structured questionnaire was developed to obtain information about the farming conditions over the past four decades in terms of crop patterns, pests, weeds, water availability, and harvest failures. The questions focused on the changes or differences in conditions from before 1970 (the past) and after 1990 (the present). The hypotheses for this research were as follows:

Null hypothesis (Ho)	: There have been no changes in the conditions from the past to the present
Alternative hypothesis (Ha)	: Conditions have changed between the past and the present

A chi-square analysis was used to analyze the hypotheses. The significance level was set at .05, so the null hypothesis was accepted if the p-value was less than the significance level. Pearson's chi square analysis was used to analyze the variables to assess the rejection of Ho, to identify the correlations between the variables. Variables that had "past and present" categorical data were analyzed against variables from the same time period (e.g., in the past with the past and in the present with the present). Cramers V analysis was used to analyze the rejected variables from Pearson's chi square analysis to identify the strength of the correlation. And the direction of the correlation was confirmed with matrix check; positive correlation defines as one variables increase, the other variable increases, and negative correlation defines as one variable increases, the other variable decreases.

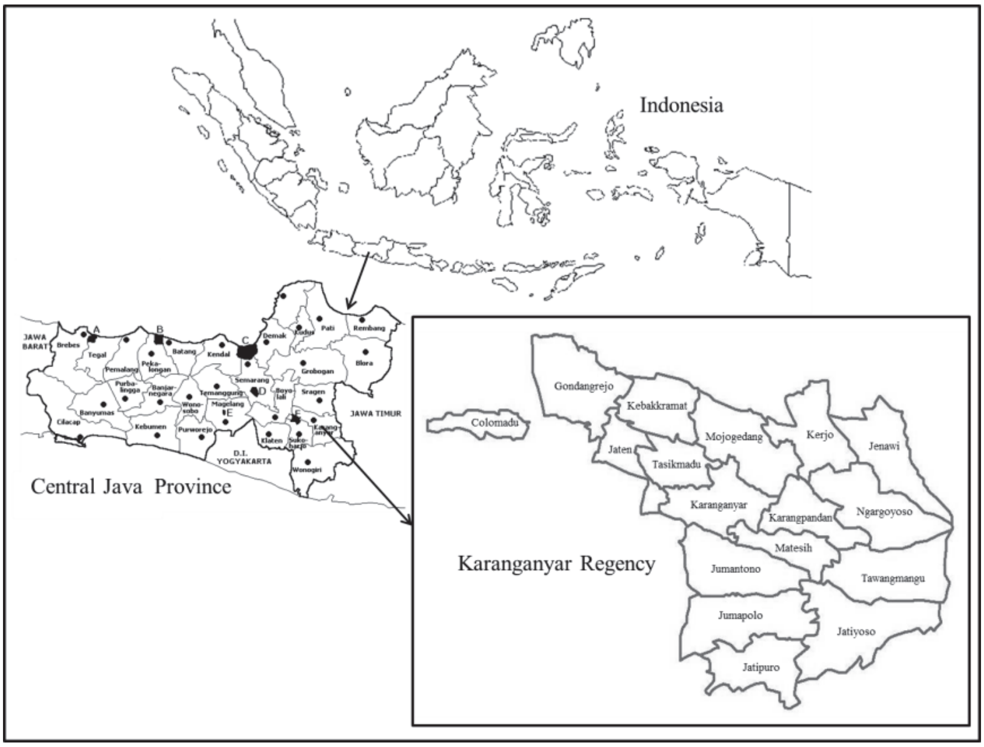

Fig. 2.1 Research location

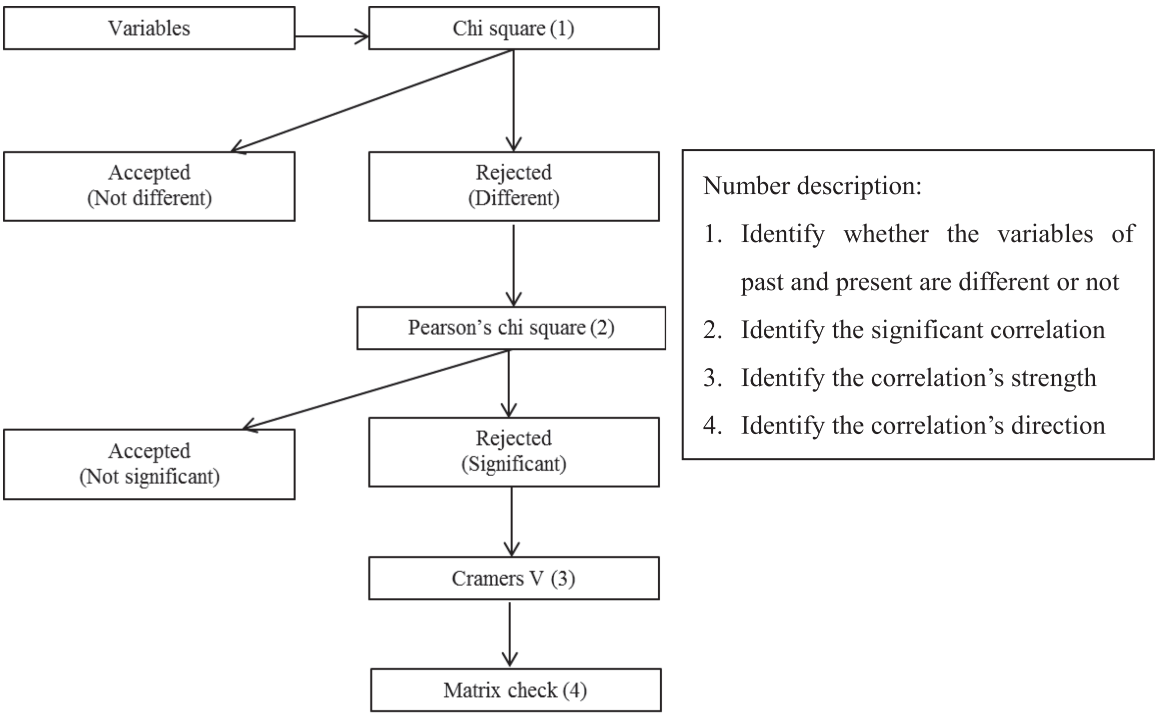

Fig. 2.2 Statistical analysis flow

2.2 Results

2.2.1 Respondent characteristics

More than half the respondents (68.6%) were of productive age from 50-64 years old. However, because of economic problems, nonproductive respondents (31.4%) older than 65 years old still needed to work (Table 2.1). Over half the respondents (51.4%) had only an elementary school education and a further 18.6% had never attended school (Table 2.1). For people born before the 1970s, education awareness at that time had been minimal as there had been no government enforcement. The development of farming has been hampered to some degree by small paddy field area landholdings. In the past, only 38.6% of respondents had a land area less of than 0.25 ha (Table 2.2); however, in the present, this has increased to 67.1% because farm lands have been sold or given/divided up for their children and/or other family members.

Table 2.1 Age and educational background (unit: %)

Item	Categories	Total
Age (year)	0 – 14	0.0
	15– 64 (Productive)	68.6
	≥ 65	31.4
Educational background	None	18.6
	Elementary school	51.4
	Middle school	15.7
	High school	11.4
	Academy/university	2.9

There has been a change in farming activity as a main job (Table 2.3). In the past, 84.3% of respondents had worked in farming as their main job, which has increased to 92.9% in the present. This was because 8.6% of the respondents had retired from the civil service and other positions and decided to focus on farming after retirement. Some respondents did have side jobs, the rate for which has shown an increasing trend from 25.6% in the past to 42.8% in the present (Table 2.3). Engaging in off-farm employment is often needed to guarantee an adequate family income (Leeuwen and Dekkers, 2013).

Table 2.2 Landholding (unit %)

Landholding (ha)	Past	Pres.
0 – 0.25	38.6	67.1
0.26 – 0.5	31.3	14.3
0.51 – 0.75	4.3	4.3
0.76 – 1	12.9	5.7
≥1	12.9	8.6

Table 2.3 Occupation (unit: %)

Type	Main job		Side job	
	Past	Pres.	Past	Pres.
Farmer	84.3	92.9	8.5	10.0
Farm worker*	0.0	0.0	4.3	4.3
Labor	5.7	1.4	10.0	11.5
Livestock	0.0	0.0	1.4	5.7
Civil service	10.0	5.7	1.4	4.2
Trader	0.0	0.0	0.0	7.1
None	0.0	0.0	74.4	57.2

*Work on a farm that does not belong to them

2.2.2 Crop

As rice both satisfies personal needs and can be easily grown, it has remained the main farm crop, with the number of farmers growing rice having increased from 37.2% in the past to 47.2% in the present (Table 2.4). In the present, 17.1% of respondents have attempted to diversify their crops due to the rainfall uncertainty in the wet season, with 35.7% planting other crops in addition to rice. Due to the changes in the weather, 94.3% of respondents were unable to clearly pinpoint the best planting time, with many delaying planting time by up to one month or until November when it was felt that the rain was reliable. Qodriyatun (2016) found that in this area, erratic rainfall often influenced planting times. With recent technological developments, 85.7% of respondents felt that seed quality had improved. The availability of good quality seeds encouraged 91.4% of respondents to change to better seeds.

Table 2.4 Change of farming (unit: %)

Items	Categories	Past	Pres.
Cropping pattern	Instead of Rice	21.4	17.1
	Rice and others	41.4	35.7
	Rice	37.2	47.2
Start planting time	Similar	5.7	
	Uncertain	94.3	
Type of seeds	Same	8.6	
	Change	91.4	
Quality of seeds	Decreased	5.7	
	Similar	8.6	
	Increased	85.7	
Harvest failure	None	44.3	34.3
	Rare	55.7	41.4
	Often	0.0	24.3
Cause of harvest failure	None	44.3	34.3
	Water shortage	15.7	4.3
	Pests	40.0	61.4

Harvest failure was one of the main hurdles with 55.7% having suffered it in the past. However, in the present, harvest failure experiences have increased to 65.7%, with 24.3% of farmers saying that this had often been a problem. Harvest failures have mainly been caused by pest attacks, which have increased from 40.0% in the past to 61.4% in the present. Asnawi (2015) found that harvest failure increased the threat of malnutrition in children in rural Indonesia.

2.2.3 Weeds and pests

Present weed emergence was felt to be same compared to the past by 62.9% of the respondents; however, 34.2% felt that the weeds have increased, with only 2.9% respondents feeling they have decreased (Table 2.5). Pest attacks have been seen to be more frequent in the present (77.2%), a significant rise from only 15.7% in the past. The most dominant pest is the planthopper, which had been a problem to 20.0% of respondents in the past but which has increased to 80.0% in the present. Further, whereas 18.6% of respondents had had no pest problems in the past, this has decreased to only 1.4% in the present. Conversely, rat problems were higher in the past (74.3%) than in the present (5.7%).

Table 2.5 Weeds and pests (unit: %)

Items	Categories	Past	Pres.
Weeds	Decreased	2.9	
	Same	62.9	
	Increased	34.2	
Pest's type	Rat	74.3	5.7
	Planthopper	20.0	80.0
	Rice Stem Borer	5.7	0.0
	Grasshopper	0.0	1.4
	Caterpillar	0.0	12.9
	Bird	0.0	0.0
Frequency of pests attack	None	18.6	1.4
	Rare	65.7	21.4
	Often	15.7	77.2
Pesticide application	None	2.9	
	Decreased	7.1	
	Same	7.1	
	Increased	82.9	

The increase in weeds and pests has led to an excessive use of pesticides (Tirado *et al.*, 2010), as it is believed that pesticides can stabilize agricultural production and decrease crop losses due to weeds, insects, plant diseases, rodents, and other pests (Fabro and

Varca, 2012). Eighty-two point nine respondents have increased pesticide doses in the present to control weeds and pests and to keep rats away from the paddy field area.

2.2.4 Water

Temperature increases associated with climate change means that more moisture is absorbed from the oceans into the atmosphere, resulting in an increase in global precipitation. Accordingly, the spatiotemporal rainfall variations have increased, with some areas receiving greater rainfalls, and others receiving less (Parker and Shapiro, 2008). Most farming activities depend on rainfall for water, which was felt to be abundant in the past by 54.3% of respondents; however, this confidence in the rain has decreased to 14.2% in the present (Table 2.6). Short droughts were felt to be more frequent in the present by 15.7% of the respondents.

Table 2.6 Water resource's condition (unit %)

Items	Categories	Past	Pres.
Water resource	Rainfall	97.1	92.9
	Irrigation	2.9	7.1
Water sufficiency	Deficient	10.0	42.8
	Sufficient	35.7	42.8
	Abundant	54.3	14.2
Short drought	None	25.7	20.0
	Rare	60.0	50.0
	Often	14.3	30.0

2.2.5 Statistical analysis

The null hypothesis for crop patterns, water resources and short droughts was accepted because the p-value was less than the significance level (0.05), at 1.46, 1.35, and 5.04 respectively, so there were no differences between these variables in the past and in the present (Table 2.7). However, the null hypothesis for harvest failure, frequency of pest attacks and water sufficiency was not accepted because the p-value was above the significance level (0.05) at 19.36, 54.49 and 31.09, respectively, indicating that there had been changes in these variables from the past to the present.

Table 2.7 Chi square

Category	$X^2_{(P=0.05)}$	X^2
Crop pattern	5.99	1.46
Water resource	3.84	1.35
Harvest failure	5.99	19.36*
Freq. of pest attack	5.99	54.49*
Water sufficiency	5.99	31.09*
Short drought	5.99	5.04

*Rejected variable

Short drought was included in to Pearson's chi square analysis because it has p-value close to rejected variables. Based on Table 2.8, harvest failure in the past was found to have a positive worrisomely strong correlation with pest attack frequency and short drought, while in the present there were negative moderate strong correlations found with pest attack frequency and water sufficiency. Pest attack frequency in the past was found to have a strong positive correlation with short droughts. Weeds were found to have a positive strong correlation with pest attack frequency and a negative strong correlation with water sufficiency. From these correlation results, is can be seen that the main impact of climate change has been harvest failure (Figure 2.3). In the past, harvest failure had a direct correlation with pest attack frequency and short droughts, while pest attack frequency had a direct correlation with short droughts, indicating that short droughts might have had an indirect correlation with harvest failures. Harvest failure also had direct correlation with water sufficiency.

Table 2.8 Pearson Chi Square, Cramers V and direction of correlation

Variable	Statistical analysis	Harvest failure		Freq. of pest attack		Water sufficiency	
		Past	Pres.	Past	Pres.	Past	Pres.
Freq. of pest attack	Pearson's chi square	0.001	0.037				
	Cramers V	0.462 (WS)	0.270 (MS)				
	Direction of correlation	(+)	(-)				
Water sufficiency	Pearson's chi square	0.291	0.018	0.102	0.709		
	Cramers V		0.292 (M)				
	Direction of correlation		(-)				
Short drought	Pearson's chi square	0.000	0.123	0.004	0.734	0.140	0.164
	Cramers V	0.471 (WS)		0.332 (S)			
	Direction of correlation	(+)		(+)			
Weed*	Pearson's chi square		0.896		0.011		0.002
	Cramers V				0.306 (S)		0.351 (S)
	Direction of correlation				(+)		(-)

* To analyze the correlation with the weed, the "past and present" categorical data for harvest failure, pest attack frequency and water sufficiency was changed to "decreased, same and increased" categorical data.

Symbol description: M: Moderate, S: Strong, MS: Moderately strong, WS: Worrisomely strong

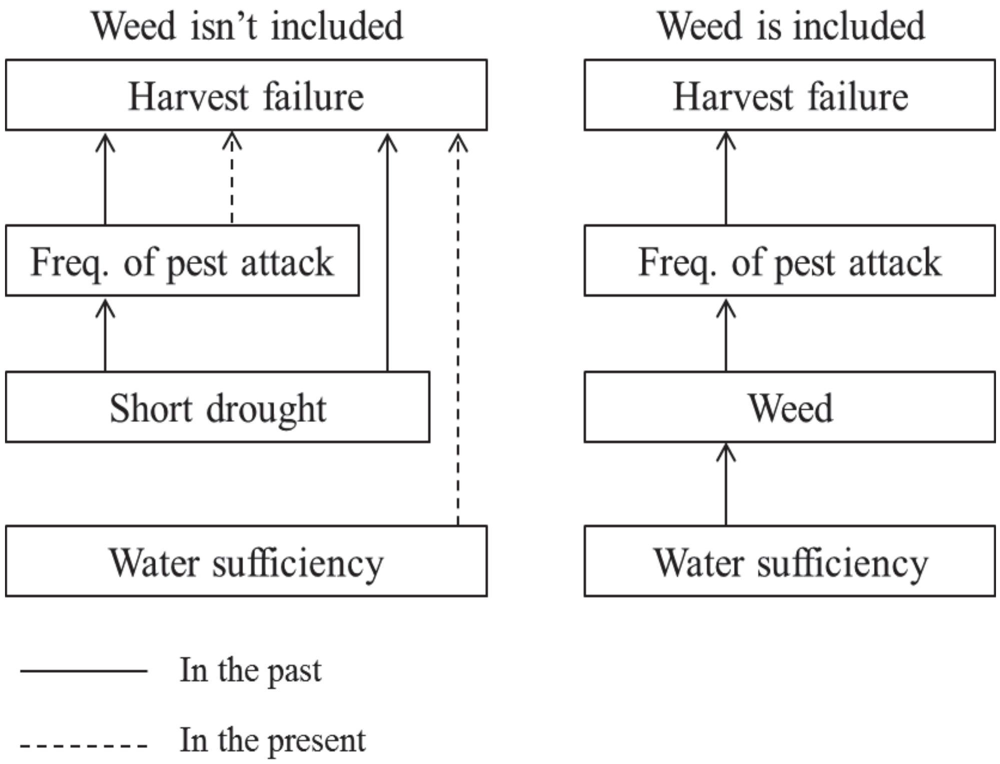

Fig. 2.3 Correlation chart (Based on Table 2.8)

Correlation flow (Figure 2.3) was divided to with weed and not because in the Pearson's chi square the weed analysis also differentiated due to the different categorical data. So in this correlation flow was made within the same categorical data.

In the present, harvest failure was found to have direct correlations with pest attack frequency and water sufficiency. Present correlation of pest attack frequency become negative might be caused by the pesticide application. Today's pesticide quality is increasing, that can control the pest attack. When weeds were included in the correlation analysis, harvest failures could possibly have an indirect correlation with weeds and water sufficiency through pest attack frequency.

2.3 Discussion

The climate in this area is classified as tropical monsoon, so a typical year has a wet season from October/November to March/April and a dry season from April/May to September/October. In general, there are two crop seasons for rain-fed agriculture, the first from October/November to January/February, and the second from February/March to June/July. In most cases, most farmers prefer to cultivate rice in both crop seasons. However, in the second crop season, there is a risk of harvest failure because it is at the end of wet season or at the beginning of the dry season when the rainfall is often insufficient.

Many farmers stated that in the past they started planting at the beginning of the wet season, but in the present they often delayed the first crop season because of uncertain rainfall at the beginning of the wet season. Planting delays in the first crop season can cause increased insecurity for the second crop season because if planting is started late, the growing season is later into the dry season when there is increased uncertainty about rainfall. Recently, farmers have cultivated only in the first crop season because the second crop season has a high risk of harvest failure due to lack of water. Farmers need to start planting for the first crop season from the beginning of the wet season so as to be able to cultivate in the second crop season when there is a lower risk of water deficits.

The main problem is that the water required for cropping is totally reliant on rainfall, a condition that has not changed from the past. Therefore, alternative water sources must be provided to ensure that planting can commence at the beginning of the wet season. The water requirement from planting to rooting would not be great as the rainfall would be stable from the following month; therefore, small water sources such as small farm reservoirs (SFR) could be sufficient. SFRs use rainwater harvesting technology (RWH) which has been successful in some areas in Indonesia. There are two common types of RWH. The first is for domestic usage and usually uses the rooftop as the catchment area (Mun and Han, 2012). The second type is for agriculture, which uses an open field as the catchment area (Li *et al*., 2006; Xiao *et al*., 2007).

SFRs are easier to build on the farm area as the RWH can supplement irrigation needs (Ariyanto *et al*., 2016). This technology can be used to deal with the uncertain unstable rainfall at the beginning of the wet season. SFRs can also be water sources at the end of the second crop season to mitigate water deficits. Rainwater harvesting technology to overcome climate change was also mentioned in the Research and Development of Agriculture, Ministry of Agriculture guidebook as one of the methods to adapt to climate change in the agricultural sector (2011). This guidebook explained that one type of RWH was the SFR.

Table 2.6 shows the number of farmers who felt that short droughts occurred more often in the present than in the past. The statistical analyses showed that the short drought frequency almost have changed because the p value (5.04) is close to significant level as shown in Table 2.7. The statistical analysis, however, showed that "water sufficiency" is different between the past and the present which become more deficient, as shown in Table 2.7. By relying only on rainfall, water deficiencies can more easily occur because of recent erratic rainfalls at the beginning of the wet season, which can lead to harvest failure, as shown in Table 2.4. The statistical analysis shown in Table 2.8 shows that there have been several conditions affecting harvest failure in the past and in the present; however, harvest failure events have increased in more recent times. Figure 2.3 demonstrates that harvest failure has been the main climate change impact on farming. Furthermore, increased water sufficiency could also lead to increased weed problems, which could in turn lead to an increase in pest attacks, which then leads to full or part harvest failure. Through this effect direction, SFR application would be so helpful in overcoming harvest failure.

In the study area, the farmers always use a flood system when planting rice as it can prevent weed growth, some pests and plant diseases (Catling and Islam, 1999). If a water shortage is experienced during rice cultivation that uses the flood system, there is an increase in weed growth and pest attacks. Therefore, SFRs could keep the paddy fields flooded when there are water shortages. Rahmadiyanto et al. (2014) demonstrated that utilizing SFRs can save water as well as mitigate water shortages. The ability of farmers to adapt to climate change can affect regional and national economies which are highly dependent on agricultural production (Laux *et al.*, 2010).

2.4 Conclusion

Climate change has begun to affect Indonesian agricultural production. This study examined whether there has been any noticeable changes over the past four decades in terms of pest attack frequency, water sufficiency and harvest failure. The chi square analysis found that crop patterns, water resources and the incidence of short droughts had not changed from the past to the present, while harvest failure, pest attack frequency and water sufficiency had changed. Harvest failure has increased significantly and has been the main climate change impact on agricultural productivity in this area. There were several reasons identified for harvest failure. First, if there is not enough water or lack of water, there are commensurate increases in weeds which lead to an increase in pest attacks, which can cause harvest failure. Further, if rain is uncertain or late at the beginning of the wet season, farmers often delay their first crop season, which then affects the second crop season which can lead to crop failure due to lack of water. Farmers need to be able to start their first crop season in October to ensure the success of the second crop season. Therefore, it is suggested that alternative water sources such as SFRs be developed. SFRs can supply water at the beginning of the wet season, thereby mitigating any rainfall concerns, and can also help with flood systems to prevent excessive weed growth if there are water shortages in either the first or second crop seasons.

III. RESEACRH II

3.1 Materials and methods

3.1.1 Study site

This research was conducted in Wonosari Village, Gondangrejo Sub-District, Karanganyar Regency, Central Java Province, Indonesia (Figure 3.1). From 495.6 hectares of this area, 147.0 hectares is occupied by paddy field. There is no irrigation channel yet here, so all paddy field areas are rain-fed (Gondangrejo, 2015). This situation makes their farming susceptible to the change of climate. Research by Rozaki *et al*. (2016)[a] showed that there were different farming conditions between past and present due to climate change in this area. The 10-day rainfall in the research site is presented in Figure 3.2.

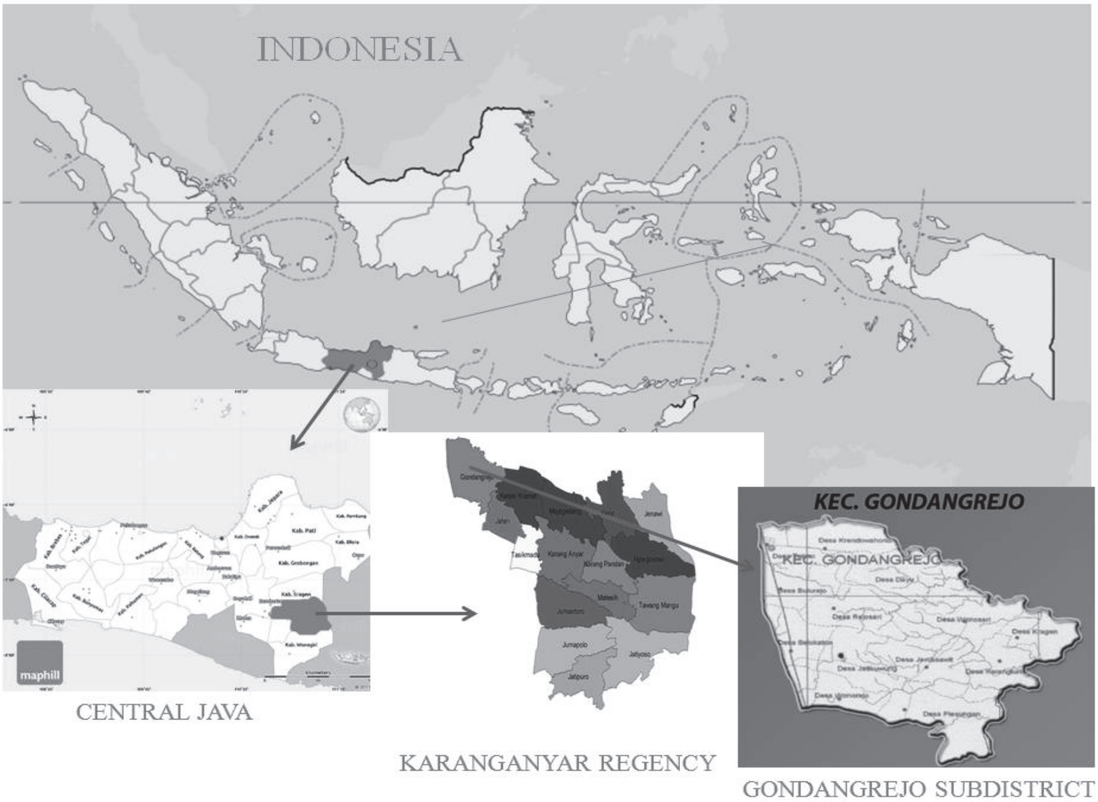

Fig. 3.1 Research location

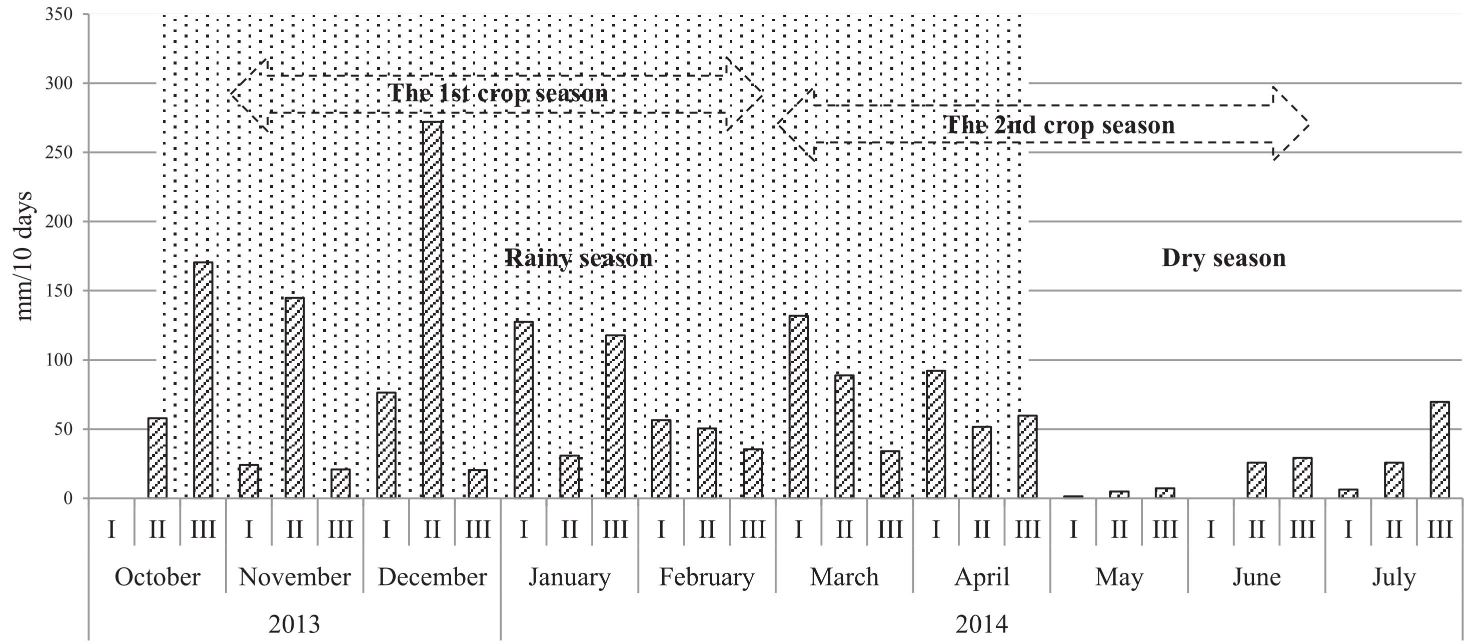

Fig. 3.2 Ten-day precipitation in the research site during the study interval 2013/2014

The climate of this area is classified as tropical; the dry season lasts from April/May to September/October and the rainy season from October/November to March/April, in a typical year. Each month consists of three 10-day intervals. According to the Indonesian Agency for Meteorological, Climatological and Geophysics (BMKG), the rainy season starts when the 10-day rainfall exceeds 50 mm for two consecutive 10-day intervals. In addition, a short drought period is defined as an isolated period within a rainy season, when the total rainfall is less than 50 mm per 10-day interval. Climate data were obtained for the research location from October 2013 until July 2014.

As can be seen in Figure 3.1, the rainy season started from the 2nd 10-day interval of October 2013, and the following dry season started from the 1st 10-day interval of May 2014. During this rainy season, six short droughts occurred. In this area, there are generally two crop seasons per year. The 1st crop season (CS1) lasts from November to February, for which planting takes place by rain-fed farming during the rainy season. The 2nd crop season (CS2) is from March to June, but CS2 is risky and often fails without irrigation, because the dry season starts during this crop season.

3.1.2 Methods

In the research site, four SFRs which irrigated rain-fed paddy fields, were selected for detail observation and analysis. Specifications of each SFR are listed in Table 3.1. The owners of those SFRs were interviewed using structured and semi-structured questionnaire which covered a broad range of socioeconomic aspects related with the application of SFR. The interview was conducted in June until August 2014.

This research presents two different lining types of SFRs, i.e. tarpaulin and concrete. The suitability and acceptability of two linings will be analyzed mainly in economic terms by using physical and economic data of SFRs. The construction cost of SFR was calculated based on the general price of tarpaulin and concrete in this area including the cost for excavating the SFR by employed human power.

Economic analysis was carried out based on two consecutive seasons, 2012/2013 (only CS1 in case that SFR was not built) and 2013/2014 (two crop seasons; CS1 and CS2 in case that SFR was available). Income possibilities on the farming are varied with farm resources, the market for farm products, and human capital (Jervell, 1999). In this research, family members who were involved in the farming enterprise were not accounted in expense analysis. And the net incomes of the CS2 in 2013/2014 were obtained in the two cases of actual irrigation area and estimated optimum irrigation area. Benefit cost ratio (*B/C*) analysis is used to determine whether the project is economically acceptable or not (Equation (1)). This analysis is the systematic method of calculating the ratio of project benefits to project costs at a discounted rate.

$$\frac{\mathrm{B}}{\mathrm{C}} = \frac{\sum_{t=1}^{n} B_t(1+i)^{-t}}{\sum_{t=1}^{n} C_t(1+i)^{-t}} \qquad (1)$$

Where, B_t and C_t is the benefit (receipt) and the cost (disbursement) at time t, respectively. If the *B/C* is greater than one, the project is economically acceptable. If the ratio is less than one, the project is not acceptable. A ratio of one indicates a break-even situation for the project (Badiru and Omitaoumu, 2007).

Table 3.1 Specification of each SFR (Ariyanto, 2016)

Dimensions: unit	SFR1	SFR2	SFR3	SFR4
Catchment area (A_c) : m^2	817	4,184	4,068	1,826
SFR volume (V_{sfr})$=L*W*H$:m^3	35.1	132.5	182.6	113.6
Length(L),Width(W),Height(H) of SFR :m	9,3,1.3	25,5,1.06	22,5,1.66	20,4,1.42
Land holding area (A_i) :m^2	3,500	4,200	5,700	3,500
Optimum irrigation area (A_{opt})* :m^2	962	4,080	5,624	3,499
Harvesting ratio (H_r)**	0.3	0.1	0.24	0.31
Water storage index (WSI) = $V_{sfr}/(H_r * A_c)$: m	0.13	0.32	0.19	0.2

*A_{opt} was estimated by the model simulations for actual SFRs during CS1-CS2

**H_r was estimated by dividing water inflow to SFR (m^3) with total rainfall (m^3).

Fig. 3.3 SFR1

Fig. 3.4 SFR2

Fig. 3.5 SFR3

Fig. 3.6 SFR4

3.2 Results

3.2.1 Reservoir construction

The SFRs size (Table 3.1) is determined based on the water balance between inflow from the catchment area and water demand of irrigation area under proper water management of SFR (Ariyanto *et al.*, 2016). The average excavation cost is assumed to be IDR 18,181 per m^3 from the inquiring survey in the test site (Table 3.2). In case of SFR1 with volume of 35.1 m^3, the expense for digging SFR1 by human power needed IDR 638,181 (=18,181 IDR/m^3 × 35.1 m^3). To use family member as main labor in construction will significantly save expenses (Teshome *et al.*, 2010).

The construction expense of SFR tarpaulin was calculated through the excavation cost mentioned above added with tarpaulin cost. The tarpaulin cost comes from the tarpaulin size multiplied with local tarpaulin price; IDR 18,000 per m^2. The tarpaulin size is summation of the inside surface of SFR and surrounding of SFR with 1m width. In case of SFR1, the tarpaulin size is 82.2 m^2 (=24×(1+1.3)+9×3) (Table 3.2). The expense of SFR1 tarpaulin is IDR 2,117,781(=IDR 638,181+18,000 IDR/m^2×82.2m^2). The construction expense of SFR concrete was composed of the excavation cost, stone masonry with thickness of 15cm for the wall and screed concrete with thickness of 2cm for the bottom. This model was calculated based on local price of stone masonry and screed concrete, which is IDR 600,000 per m^3 and IDR 800,000 per m^3, respectively. SFR1 needed the stone masonry of 4.68m^3 (=24×1.3×0.15) and screed concrete of 0.54m^3 (=9×3×0.02) (Table 3.2). This model is the best way to make SFR durability longer and the price is cheaper than total concrete with steel frame. Based on local survey, with good maintenance this model can stand until 10 years or more. After 10 years, this SFR can be repaired, whose cost is not high compared to construction because only the broken part is repaired. The expense of SFR concrete for SFR1 is IDR

3,878,181 (=IDR 638,181+600,000 IDR/$m^3 \times 4.68m^3$+ 800,000 IDR/$m^3 \times 0.54m^3$) (Table 3.2).

3.2.2 Net income

The common thing of farming economic analysis is the limitedness of data availability (Hatibu and Mutabazi, 2006). Each farmer has different way in managing their farm land, because there is no particular standard procedure. So the expenses are not only influenced by land area, but also by farming's management. Farmers who owned these SFRs had various techniques to draw up water from SFR; pump machine, siphon and bucket. All SFR owners had pump machine except SFR1 owner, but he could use pump machine which was provided by Sebelas Maret University. SFR which was located higher than irrigation area could use siphon technique and didn't need pump machine (SFR3). Bucket was also used for drawing up the water, whose technique was used additionally for drawing up water when the amount of irrigation water was not much. Farmers utilized the water stored in SFRs carefully under the consideration of the crop and weather conditions.

The main benefit of the SFR construction is that the possibility to get higher yield in the CS2 as long there is enough water in the SFR. In Kenya, farmers who have not adopted RWH only have 40% chance to get harvest. Thus the adoption of RWH technologies would increase the chance of producing a good harvest (Ngigi *et al*., 2005). Research by Hatibu *et al.* (2006) showed that farmers who have not adopted rainwater harvesting can only grow sorghum or maize with great difficulties. When farmers under the same situation adopted rainwater harvesting, therefore they were able to produce paddy or vegetables.

Table 3.2 SFR construction cost

Type	Dimensions	Unit	SFR1	SFR2	SFR3	SFR4
Excavation	① Volume	m^3	35.1	132.5	182.6	113.6
	② =18,181×①	IDR	638,181	2,409,090	3,320,000	2,065,454
Tarpaulin	③ Size	m^2	82.2	248.6	253.64	196.16
	④ =18,000×③	IDR	1,479,600	4,474,800	4,565,520	3,530,880
Concrete	⑤ Wall size*	m^3	4.68	9.54	13.45	10.22
	⑥ =600,000×⑤	IDR	2,808,000	5,724,000	8,067,600	6,134,400
	⑦ Bottom size**	m^3	0.54	2.5	2.2	1.6
	⑧ =800,000×⑦	IDR	432,000	2,000,000	1,760,000	1,280,000
SFR-Tarpaulin	⑨ =②+④	IDR	2,117,781	6,883,890	7,885,520	5,596,334
SFR-Concrete	⑩ =②+⑥+⑧	IDR	3,878,181	10,133,090	13,147,600	9,479,854

*Stone wall **Screed concrete

Table 3.3 Net income of the CS1 in 2012/2013

Items (Unit)	SFR1	SFR2	SFR3	SFR4
① Actual cultivated area (m^2)	3,500	4,200	5,700	3,500
② Actual Production(kg)	680	750	1,000	860
③ Productivity (=②/①)(kg/m^2)	0.19	0.18	0.18	0.25
④ Income(=②×4,000 IDR/kg)(IDR)	2,720,000	3,000,000	4,000,000	3,440,000
⑤ Cost(IDR)	675,000	867,000	972,500	956,000
⑥ Cost per production (=⑤/②)(IDR/kg)	993	1,156	973	1,112
⑦ Net income(=④-⑤)(IDR)	2,045,000	2,133,000	3,027,500	2,484,000

Table 3.4 Net income of the CS1 in 2013/2014

Items (Unit)	SFR1	SFR2	SFR3	SFR4
① Actual cultivated area (m^2)	3,500	4,200	5,700	3,500
② Actual Production(kg)	700	800	1,040	750
③ Productivity (=②/①)(kg/m^2)	0.20	0.19	0.18	0.21
④ Income(=②×4,000 IDR/kg) (IDR)	2,800,000	3,200,000	4,160,000	3,000,000
⑤ Cost(IDR)	705,000	937,000	1,047,500	886,000
⑥ Cost per production (=⑤/②)(IDR/kg)	1,007	1,171	1,007	1,181
⑦ Net income(=④-⑤)(IDR)	2,095,000	2,263,000	3,112,500	2,114,000

Table 3.5 Net income of the CS2 in 2013/2014

Items (Unit)	SFR1	SFR2	SFR3	SFR4
① Actual cultivated area (m^2)	781	1,733	2,968	3,270
② Actual Production(kg)	150	350	520	700
③ Productivity (=②/①)(kg/m^2)	0.19	0.20	0.18	0.21
④ Income(=②×4,000 IDR/kg)(IDR)	600,000	1,400,000	2,080,000	2,800,000
⑤ Cost(IDR)	177,400	415,500	553,250	822,750
⑥ Cost per production (=⑤/②)(IDR/kg)	1,183	1,187	1,064	1,175
⑦ Net income(=④-⑤) (IDR)	422,600	984,500	1,526,750	1,977,250

Table 3.6 The average cost (IDR) for producing rice (1kg)
(unit:IDR/kg) per Crop Season (CS)

Type	2012/2013	2013/2014	
	CS1	CS1	CS2
Tillage/Machine	350	350	401
Seed	84	61	47
Fertilizer	72	93	106
Pesticide	63	94	93
Labor	486	489	448
Pump	-	-	51
Total	1,055	1,087	1,145

Net incomes of three cases are presented in Table 3.3 to 3.5. Net income was calculated from income minus cost. The price of rice is assumed to be 4,000 IDR/kg based on the local market. Table 3.6 shows the average cost for producing one kg rice for each crop seasons, which was calculated from the average actual cost for all SFRs farming. Labor is the highest cost because planting, harvesting and weeding relied on employed human power. Tillage was the rental price of tilling machine, which was the highest in the CS2 of 2013/2014, because the production was lowest of all crop seasons. Pump is the price of gasoline which is consumed for pumping water from SFR only in the CS2 because irrigation was not needed for cultivating the paddy field in the CS1.

3.2.3 Acceptability

In the research site, farmers planted rice only during the 1st crop season (CS1) in the period of 2012/2013 before the construction of SFR. Meanwhile, farmers could plant in CS1 and CS2 of the period of 2013/2014 after SFR constructed. In the CS2 of 2013/2014, SFR owner planted some parts of their landholding, because they were afraid the water stored in SFR was not enough to irrigate. Research by Ariyanto *et al.* (2016) proved that optimum irrigation area was larger than SFR owners had planted. Optimizing cultivation area is necessary to obtain maximum benefit. Table 3.7 shows the net income estimated from the optimum irrigation area.The production from optimum irrigation area in CS2 of 2013/2014 (Table 3.7②) is estimated by multiplying the productivity of CS2 of 2013/2014 in Table 3.5③ with optimum irrigation area (Table 3.7①). Furthermore, the cost from optimum irrigation area in CS2 of 2013/2014 (Table 3.7⑤) is estimated by multiplying the cost per production of CS2 of 2013/2014 in Table 3.5⑥ with estimated production (Table 3.7②).

Table 3.7 Estimated net income from optimum irrigated area of CS2 in 2013/2014

Items (Unit)	SFR1	SFR2	SFR3	SFR4
① Optimum irrigated area (m^2)	962	4,080	5,624	3,499
② Estimated production(kg)	185	824	985	749
③ Productivity (=②/①)(kg/m^2)	0.19	0.20	0.18	0.21
④ Income(=②×4,000 IDR/kg)(IDR)	739,052	3,296,018	3,941,348	2,996,086
⑤ Cost(IDR)	218,513	978,211	1,048,342	880,368
⑥ Cost per production(=⑤/②)(IDR/kg)	1,183	1,187	1,064	1,175
⑦ Net income(=④-⑤)(IDR)	520,539	2,317,807	2,893,006	2,115,717

Table 3.8 Estimations of B/C

Materials	SFR1		SFR2		SFR3		SFR4	
	Actual	Optimum	Actual	Optimum	Actual	Optimum	Actual	Optimum
Tarpaulin	0.66	0.83	0.51	1.14	0.69	1.28	0.92	1.01
Concrete	0.79	1.03	0.75	1.69	0.84	1.58	1.15	1.29

Table 3.8 shows the result of *B/C* analysis by using the equation (1), from both actual and optimum irrigation areas. Discount rate is 9% which was taken from BRI (Bank Rakyat Indonesia). SFR tarpaulin is estimated to stand for 3 years, while SFR concrete stands for 10 years. And the depreciation period is decided to be 10 years. The cost to replace the tarpaulin sheet every 3 years i.e. 4th year, 7th year and 10th year was included in the running cost for SFR tarpaulin, while the running cost for SFR concrete was assumed to be zero because the cost to clean the SFR every year was considered to be done by family members.

The benefit is defined to be the difference of total net income between before and after SFR constructs. Net income before SFR constructs is regarded as net income of 2012/2013, when farmer planted only in CS1. On the other hands, net income after SFR constructs is regarded as the net income of 2013/2014, when farmer could plant in both CS1 and CS2. Both tarpaulin and concrete linings were assumed to produce the same yield and income.

Table 3.8 shows that all SFRs of tarpaulin with actual irrigation area are not acceptable with less than one of *B/C* value, while three SFRs (SFR2,SFR3,STR4) with optimum irrigation area are acceptable with more than one of *B/C* value. On the other hands, SFR of concrete with actual irrigation area is acceptable only for SFR4, while all SFRs with optimum irrigation area are acceptable based on the *B/C* values. These results suggest that optimum irrigation area is necessary to be estimated on applying SFR. Furthermore, it is clarified that *B/C* values of all cases of SFR concrete are higher than SFR tarpaulin.

3.2.4 Analysis of relation between B/C and SFR dimensions

Benefit is directly influenced by irrigation area, because the crop yield is in proportion to irrigation area. And irrigation area is decided by the volume of SFR and inflow from catchment area (*Ac*). On the other hands, the construction cost of SFR per its volume decreases along with the increase of SFR volume (V_{SFR}), because the construction cost is almost in proportion to lining area. Therefore, *B/C* value is expected to have correlation with two variables of *WSI* and *Ac* as the following equation (2).

$$\frac{B}{C} = a \times H_r A_c + b \times WSI + c \qquad (2)$$

WSI (m) is a storage index proposed by Ariyanto *et al.* (2016) that expresses a SFR storage capacity (V_{SFR}) per a catchment area weighted the harvesting ratio (H_r), and the amount of rainfall stored by the SFR (Eq.(3)).

$$WSI = \frac{V_{SFR}}{H_r \cdot A_c} \qquad (3)$$

Where, H_r is the harvesting ratio which is assumed to be a constant as following equation (4), although it is influenced by the amount of rainfall (*R*), and soil and landscape characteristics of the catchment area (Ariyanto *et al.*, 2015).

$$H_r = \frac{Q_{inflow}}{R \cdot A_c} \qquad (4)$$

Where, Q_{inflow} is inflow from catchment area into SFR during rainfall and *R* is rainfall.
Table 3.9 shows from the results of multiple correlation analysis that there is an extremely strong regression among three variables; *B/C*, *WSI*, and H_rA_c with more than 0.98 of multiple correlation coefficient in both cases of tarpaulin and concrete.

Furthermore, it is revealed that the partial regression coefficients (a) of H_rA_c in both cases are almost same, but a partial regression coefficient (b) of *WSI* in SFR concrete is around three times bigger than tarpaulin. It suggests that the increase of SFR volume (V_{SFR}) heightens the *B/C* value in concrete lining more than tarpaulin under the same catchment area (A_c).

Table 3.9 Multiple regression analysis

Materials	a	b	c	r
Tarpaulin	0.55×10^{-3}	1.27	0.493	0.987
Concrete	0.56×10^{-3}	3.31	0.386	0.983

Fig. 3.7 and Fig. 3.8 express the relation among the three variables *B/C*, H_rA_c, and *WSI* based on the above multiple regression analysis. These figures show that B/C values increase along with the increase of H_rA_c and *WSI.* If the catchment area (A_c) and volume of SFR (V_{SFR}) are decided under the assumption that farmer cultivates the optimum irrigation area, the *B/C* values can be estimated accurately. So, whether the SFR construction will produce positive result or not can be known before construction commences.

3.2.5 Adoption

Adoption is the main purpose in technology development, because it is the indicator that the technology is useful and accepted. The process is not easy because internal and external factors are complicated and affect the decision of adoption. In standard investment theory, the best investment strategy is the one that brings the highest economic profit. Economists make the point that when a new technology is introduced, its success depends on it being economically viable (Fox et al., 2005).

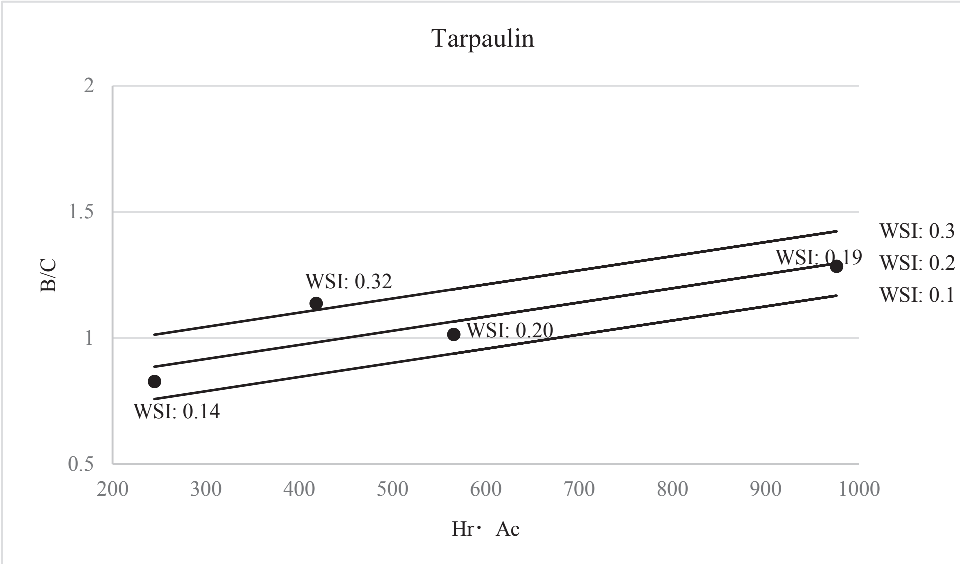

Fig. 3.7 The relation of *B/C*, *WSI*, and $H_r \cdot A_c$ of SFR tarpaulin

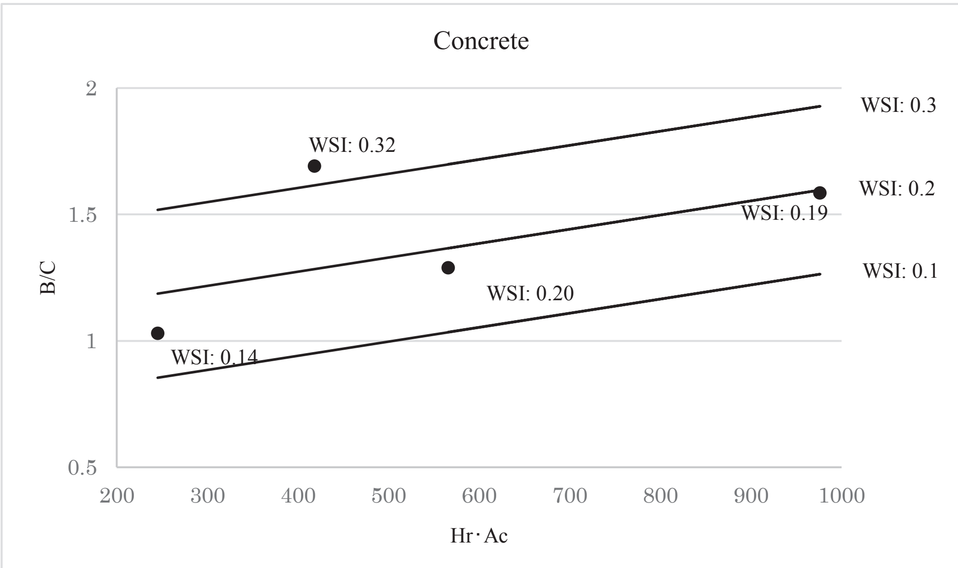

Fig. 3.8 The relation of *B/C*, *WSI*, and $H_r \cdot A_c$ of SFR concrete

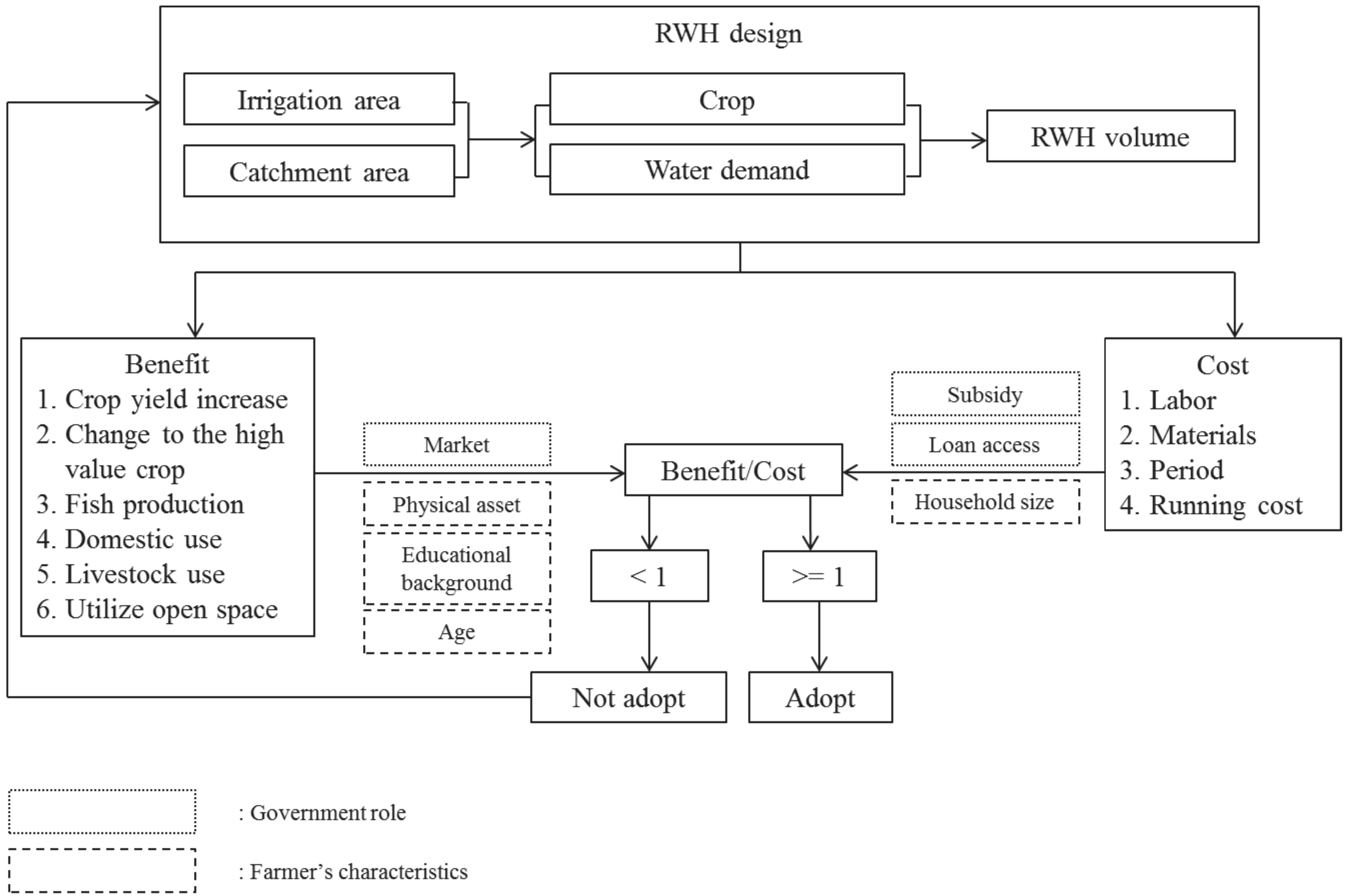

Fig. 3.9 RWH adoption diagram

The more informed people are of the benefits of RWH, the more motivated they will be, and adoption of RWH systems will increase. The positive benefits of RWH are the need to be informed, such as through extension programs (Fox et al., 2005; He et al., 2007; Zingiro et al., 2014; Wu et al., 2015).

The economic benefit is affected by the starting point of RWH construction: catchment area, water storage, and irrigation facilities. They are the basic factors that impact the costs of RWH and supplemental irrigation in agriculture (Yuan, 2003). The required investment is assumed to be covered through a loan, since it is unlikely that a small landholding farmer would otherwise be able to provide the capital necessary for the investment (Fox et al., 2005). Access to a loan is one of the critical inputs required by small-scale farmers to implement new agricultural technologies (Brehanu and Fufa, 2008). Without access to a loan, RWH is often unaffordable to an individual farmer (He et al., 2007).

The limit of extension, credit, and assistance will also hamper the adoption of an RWH system (Wu et al., 2015). Baguma and Loiskandl (2010) showed that a subsidy provision was statistically significant for the adoption of RWH technologies in rural Uganda. Several countries, such as in Spain, Brazil, and Australia, also have tried to provide a subsidy when adopting RWH technology for domestic (Domenech and Sauri, 2011). It is the role of government to provide subsidies to small landholding famers for the construction of RWH systems (Balooni et al., 2008).

Adoption is not always about showing the positive aspects of the technology, but also any negative impacts or challenges that may emerge during its implementation. Researchers and development agents more often confront farmers with only the positive aspect of a technology, while farmers are also concerned about the failure of technology. In some cases, even once the positive results has been shown to farmers, their skepticism regarding the use of RWH technologies prevails, particularly in low-precipitation areas. This is because the socio-economic features of the farmers may certainly influence the perception and attitudes towards RWH systems (Domenech and Sauri, 2011; Kumar, 2016). In other words, we need to understand the farmers' goals and decision-making dilemma under risky and uncertain conditions given that food self-sufficiency is the primary goal for most subsistence farmers (Ngigi et al., 2005).

The adoption RWH technologies by farmers is affected by their educational background, physical assets, household size, farm income, group membership, active labor force size, contact with extension, participation in a government project, and positive attitudes towards RWH. The adoption will increase with the support of credit access and advisory and technical training. The close relationship of researchers or government advisors increases the adoption rate (He et al., 2007; Wakeyo, 2013; Zingiro et al., 2014; Kimani et al., 2015; Wu et al., 2015; Kumar et al., 2016).

3.3 Conclusion

It was clarified by the previous research of Ariyanto *et al*. (2015) that the presence of SFR enabled farmers to cultivate paddy twice a year, because SFR could supply irrigation water during short drought and dry season in the 2nd crop season. And the optimum irrigation area must be estimated by the procedures proposed by Ariyanto *et al*. (2016) in order to gain the maximum benefit of SFR, because *B/C* values for actual irrigation areas decided by farmers are lower than one, and not acceptable for almost all SFRs as can be seen in Table 3.8.

Also the above results provide the important suggestions that catchment area (A_c) is important factor, in order to gain the maximum function of SFR. The increase of the catchment area (A_c) can heighten the *B/C* value through the increase of water storage index (*WSI*). The *B/C* value can be estimated by Figure 3.7 and 3.8 from the lining material, catchment area (A_c), harvest ratio (H_r), and SFR volume (V_{SFR}) before the SFR constructs. It is also clarified from the analysis of the *B/C* values that the concrete is recommended more than tarpaulin as lining material of SFR. The construction cost of SFR tarpaulin is lower, but its running cost is higher compared to SFR concreate because tarpaulin cannot stand long time and need to be replaced every three years with additional lining cost. On the other hands, the construction cost of SFR concrete is high but the running cost is very low, because it can stand ten years and after construction needs to be cleaned only by farmer's labor when the soil sediment has been accumulated in the SFR.

According to these results, concrete lining is recommended to increase the benefit more than tarpaulin lining. However, due to the high cost for construction of SFR concrete which cannot be paid in a lump-sum by common farmers who only relay on farming, the subsidy or supporting system such as loan with long payback period with small interest from government is required to make this technology become easy to be adapted (Rozaki *et al.*, 2016)[b]. To counter the skepticism of RWH among farmers, the positive and negative results of RWH must be non-discriminatory. This will improve the farmers' awareness of RWH, and the intention to adopt this technology may come.

CONCLUSION

The impact of climate change in many parts of the world, such as frequent droughts, rising temperatures, and unpredictable rainfall, have required people to find suitable ways to adapt to these potential problems (Below *et al.*, 2010). In agriculture, reductions in yield and increases in weeds and pests have become common climate change problems (Nelson *et al.*, 2009; Ingram, 2014), all of which have contributed to food and economic insecurity (Hwan *et al.*, 2013). As Indonesia is one of the biggest agricultural countries in the world, the rise in food insecurity due to climate change has become of serious concern here (Amien *et al.*, 1992; Measey, 2010). Research in Indonesia has found that serious consideration is now needed to minimize the impact of climate change (Dewi *et al.*, 2014; Mayasari and Suroso, 2014). However, to date, most research has only focused on the environmental effects such as CO_2 emissions (Gernowo *et al*., 2012; Hasegawa and Matsuoka, 2015), the impact on Arabica coffee production (Widayat *et al*., 2015), and the effects on rice yields (Amien *et al*., 1996).

There has been little research, however, on the impact of climate change on farmers. First research proved that farmers often delayed the first crop season because of uncertain rainfall at the beginning of the wet season, which then meant that the second crop season was delayed and was therefore more insecure as the cropping period was deeper into the dry season. Therefore, it is proposed that small water resource such as SFRs be constructed on farms to mitigate water concerns and give farmers the confidence to start the first crop season at the beginning of the wet season. The SFRs would also be able to provide adequate water for paddy field flooding, which would prevent weed growth and pest attacks, thereby ensuring the harvest success.

Second research shows the suitability of SFR. The presence of SFR clearly can make twice crop season a year. This happens because the CS2 has enough water supply during short drought and during the dry season period. In order to SFR can give maximum function, enough catchment area is important. Increase the catchment area can increase the B/C through the increase of water storage index. The availability of catchment area and harvest ratio data can be used to analyze the B/C before construct the SFR. Therefore whether SFR will produce positive result or not can be known from the beginning.

Optimum irrigation area need to be calculated to optimize irrigation area in order can get maximum benefit, which can be seen in Table 3.8 that B/C for actual irrigation area is acceptable for SFR concrete of SFR5 only, while B/C for optimum irrigation area is acceptable for all SFRs both tarpaulin and concrete except SFR1 of tarpaulin scenario. Based on those results, concrete is recommended as lining material of SFR. The construction cost of SFR tarpaulin is lower, but its running cost is higher compared to SFR concrete, because tarpaulin needs to be replaced every three years with additional lining cost. On the contrary, the construction cost of SFR concrete is high, but the running cost is very low because it can stand for ten years and only requires periodic cleaning after construction, which can be done by the farmer and his family. Nevertheless, the high cost of constructing an SFR with concrete cannot be paid in a lump sum by common farmers, who rely only on farming. Thus, the subsidy or supporting system such as loan with long payback period with small interest from government is required to make this technology more accessible.

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