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To cite this article: Muhammad Rasyid Ridla Ranomahera and Henk Ritzema 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **437** 012033

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Seeking alternatives of water-saving irrigation: sprinkler irrigation for smallholder sugarcane farmers in East Java, Indonesia

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Abstract. Sugarcane farmers in Lumajang in East Java Province have a strong preference of using furrow irrigation instead of sprinkler irrigation. To evaluate the possibility of smallholder sprinkler irrigation as an alternative water-saving irrigation method, the aim of this research is to examine the socio-technical dimension of current irrigation practices of smallholder sugarcane farmers, emphasizing the extent of farmer perspectives and knowledge. As comparison to furrows, a smallholder sprinkler system was designed and evaluated. The sprinkler was expected to fit smallholders' acreage, has low investment costs, is easy to build by locals, and is easy in its operation. The responses, perspectives and expectations of farmers to this smallholder sprinkler system are also discussed. The results indicated that smallholder sugarcane farmers perceive furrow irrigation as the best and low-cost irrigation method. They have already spent money on furrow irrigation investment; however, that investment was seen as a burden for their budgets because smallholders perceived sprinkler irrigation as an expensive irrigation method. In addition, the sprinkler could not satisfy their main expectation because it delivered less water than furrows, meaning the soil was not saturated. This mind-set underlines the slow acceptance process of a relatively new irrigation technology implementation for smallholders in Indonesia.

Keywords: smallholder, sugarcane, sprinkler, furrow irrigation, East Java

1. Introduction

Sprinkler irrigation for sugarcane farmers in Indonesia is not popular, although it has been applied in several developing countries worldwide since many decades ago [1]. The large-scale commercial sprinkler irrigation system is widely known and has been implemented in many sugarcane estates around the world. A sprinkler system offers the possibility of controlling water discharge precisely to meet crop water requirements, delivers water efficiently, and leads to water savings. However, in East Java, Indonesia, sugarcane is mostly cultivated by smallholder farmers in fragmented small plots [2], [3]. Unfortunately, applying a large sprinkler irrigation system on the small plot would bring about technical, practical, and economical challenges. The furrow irrigation practice is widely implemented by smallholders because it is cheap and easy to operate, but it is considered as an inefficient irrigation method due to its excessive water use.

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Furrow irrigation has been practiced for years for irrigating sugarcane fields in Lumajang Regency, East Java. On the other hand, it requires excessive water use on the field. Sugarcane growth needs adequate water, at least in the five months after planting to secure the potential yield [4]. An efficient way of utilizing water for irrigation is needed. Cornish (1998) stated that sprinklers and drips offer better irrigation efficiency and uniformity, which lead to water savings. Other advantages are the possibility of reduction in labour and energy costs [5]. Research on pressurized irrigation systems for smallholder farmers has been conducted in several countries of Sub-Saharan Africa and South Asia, but mostly with drip irrigation [6] – [10]. In addition, Postel *et al*. (2001) identified that there is a need for an affordable pressurized irrigation system for smallholder farmers that is designed for small plots and can deliver water efficiently and uniformly to the field just as well as a large commercial system [8].

First, the aim of this research is to examine the socio-technical dimension of furrow irrigation practices of smallholder sugarcane farmers in Lumajang. Second, this research was conducted to evaluate the possibility of irrigation technology alternatives, here being sprinkler irrigation for smallholder sugarcane farmers in Java. This study emphasizes the extent of farmer perspectives and knowledge of current furrow irrigation. As a comparison to furrow irrigation, a local modified sprinkler system was designed, introduced, and evaluated. The sprinkler was expected to be appropriate to the acreage of smallholders, low in cost, easy to build by locals, as well as easy to operate. Furthermore, the responses and perspectives of farmers to this smallholder sprinkler system were examined. The research results can be used as a source of information for farmers, sugar mills, local irrigation authorities, and researchers for developing smallholder sprinkler irrigation for sugarcane in East Java.

2. Materials and Methods

2.1. *Time and location*

The research was conducted from January – April 2018 at Jatiroto Sugar Mill in Lumajang Regency, in the Province of East Java, Indonesia, where rice and sugarcane fields dominate the agricultural area (Figure 1).

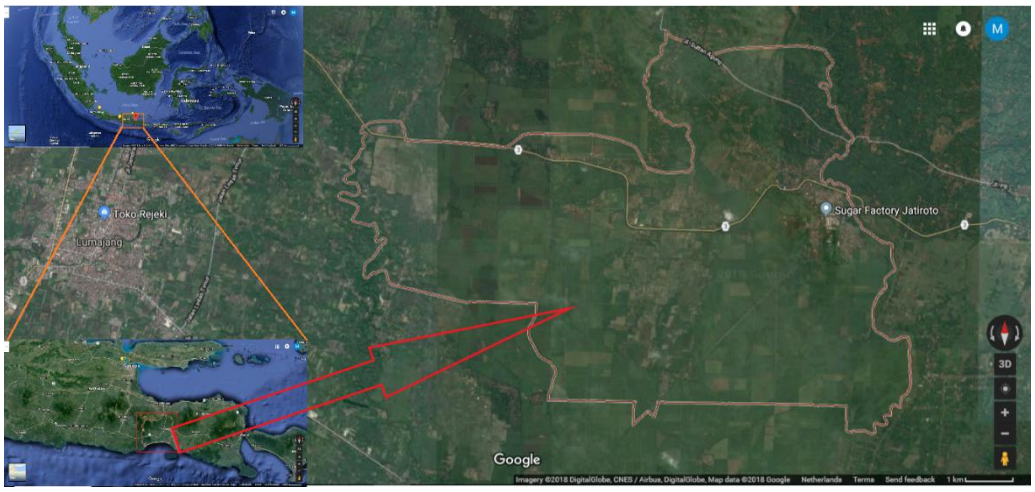

Figure 1. The research location, surrounding of Jatiroto Sugar Factory at Lumajang

2.2. *Research questions*

Several research questions to be answered were developed for this research:

1) What are the current irrigation practices and perspectives of farmers on furrow irrigation in smallholder sugarcane plots in Lumajang?
2) What knowledge, perspectives, and expectations do farmers have about sprinkler irrigation?

3) What are the differences in field performance and farmers' perspectives of irrigating smallholder sugarcane fields with furrow irrigation and sprinkler irrigation in Lumajang?

2.3. *Research methods*

This research employed a qualitative and quantitative approach. The qualitative approach was used for analysing and interpreting in-depth interviews and field observations. The in-depth interviews probed the real-world condition of smallholders' irrigation activities, and the qualitative approach was the proper method to gain people's perspectives on specific issues from their points of view [11]. The quantitative approach was used for analysis of interview responses.

These are some of the methods used in this research:

1) Library research
   This method consists of activities of literature review as well as designing and building the sprinkler. Secondary data, such as rainfall, climate, and sugarcane plantation data were collected. 20 years of monthly rainfall data were collected from local weather station. Limited availability of climatic data at the research location was solved by CropWat 8 for Windows software to analyse the crop water requirement (CWR) for sugarcane. The CWR value is locally specific only for this location and was used for designing the sprinkler system. The plantation data constituted estate area, ownership, and sugarcane yields.
2) Interview
   In-depth semi-structured interviews were conducted to gain the understanding and perspectives of farmers regarding their current irrigation practice and their expectations for sprinkler irrigation. Some short videos related to sprinkler irrigation were presented to farmers. Seventeen farmers and five sugar mill employees were selected as respondents. The selection criteria is that respondents must be experienced with irrigation practices. The interview duration varied from 40 minutes to 70 minutes per respondent. The interview was conducted face-to-face and one-by-one at the houses of each respondent. The interview was also noted and recorded by audio and video.
3) Field observation
   Field observation was conducted to grasp the real situation on the field as explained by farmers during interviews with them. Some field visits were made during field observation to acquire more details of the situation.
4) Data analysis
   For data analysis, seventeen interview recordings were collected. The recordings were transcribed into a matrix which consists of the questions and the name of the farmer. Descriptive analysis was performed to answer the research questions. In addition, some farmer responses were also quantified to explain trends. Field observation results were used to support the interview matrix as additional information.

3. Results and Discussion

3.1. *Overview of Smallholder Landholdings*

The FAO AQUASTAT Survey (2011) in Indonesia reported that more than 40% of Indonesian farmers hold land of less than 0.5 ha, which is in line with this research's finding [12]. In this research, the acreage was classified into four groups (Table 1). Table 1 shows the number of farmers as per the 2018 milling season, the mean acreage landholdings for each farmer, and the acreage classification. The "0-0.5 ha" landholdings group resulted in an average of 0.3 ha per farmer. The "> 2.0 ha" group indicated a large gap of landholdings among all groups. For this group, the average landholding for each farmer was 3.61 ha, which is economically feasible for sugarcane farming. However, in this research, it was found that landholdings were not the primary rationale for the farmers to grow sugarcane. For them, growing sugarcane in a very small plot was not a drawback.

Table 1. Overview of landholdings of Jatiroto Sugar Mill farmers

Parameters	Landholdings category			
	0-0.5 ha	**0.5-1.0 ha**	**1.0-2.0 ha**	**> 2.0 ha**
No. of farmers	2419	1659	1219	902
No. of farmers (%)	39	27	20	14
Total acreage (ha)	717	1189	1699	3252
Total acreage (%)	10	17	25	48
Average landholdings (ha)	0.3	0.72	1.39	3.61

Source: R & D division of Jatiroto Sugar Mill, (2018), analysed by author

The sum of total acreage (%) of the "0-0.5 ha" and the "0-1 ha" groups is 27% (1906 ha) of land held by 63% (4078 farmers) of total farmers, mostly in a rental scheme, which results in a small landholding for each farmer, approximately 0.5 ha per farmer. On the other hand, the sum of total acreage (%) of the "1–2.0 ha" and "> 2 ha" landholding groups results in a bigger acreage, 73% (approximately 5000 ha), which is only cultivated by 34% of farmers. The small landholdings generated low revenues from the annual yields.

3.2. *Current practices and perspectives of farmers on furrow irrigation*

In the rural area of Jatiroto, smallholders are able to irrigate their small plots sufficiently because of the rooted understanding between rice and sugarcane farmers. This tolerance was built based on the extent of drought tolerance between sugarcane and rice crops. However, during scarce water periods, rice crops will obtain irrigation priority, as explained by one respondent.

> *Farmer #4 said during the interview, "Well, the sugarcane farmer must concede to rice farmer for irrigation turns. In July, we still got the turn for water, but we had wait for three days after the* tuwowo *finished irrigating the rice fields. However, in August-September it was impossible!"*

According to the point of view of farmers, furrow irrigation was the most preferred and cheapest way to irrigate. They confirmed that by using furrow irrigation, they do not use the water pump, which means a lower energy cost. They wished that their plots can be watered from the irrigation canal. To get an incidental water turn, sugarcane farmers must request from the water guardian and pay a "fee" of approximately IDR 150,000 per irrigation turn. When farmers were asked about their views and perspectives of furrow irrigation, the responses were varied (Table 2).

Table 2. Eight top perspectives of farmers on current furrow irrigation practices

Response	**No. of responses (farmers)**
Crucial because it positively influences sugarcane yield	7
Better than sprinkler irrigation for wetting the soil adequately	5
A cheap way of irrigation	3
Furrow irrigation can extend the irrigation interval than sprinkler irrigation	2
Water is not uniformly distributed within the plot	1
Easy to perform	1
Water fee can be paid later at the harvesting season	1
I do not know (or irrelevant answer)	1

When an open question, "What do you think about furrow irrigation?" was asked to respondents, it yielded diverse responses. Generally, all respondents agreed on the importance of irrigation related to

positive yield and furrow method was the best as they had practiced the method for years. During the interviews, the sprinkler video was shown as part of the interview, and they started comparing the method with the furrow irrigation. Five respondents answered with a statement that the furrow method is still the best and cheaper than the sprinkler because it perfectly saturates the soil with little cost. Some respondents stated that the furrow irrigation was advantageous due to the plot location being at a close distance to the tertiary canal.

Several smallholders also invested funds on irrigation equipment. The typical investments were made on the tools of (medium) water pump and piping system. Figure 2 below illustrates the irrigation equipment owned by smallholders.

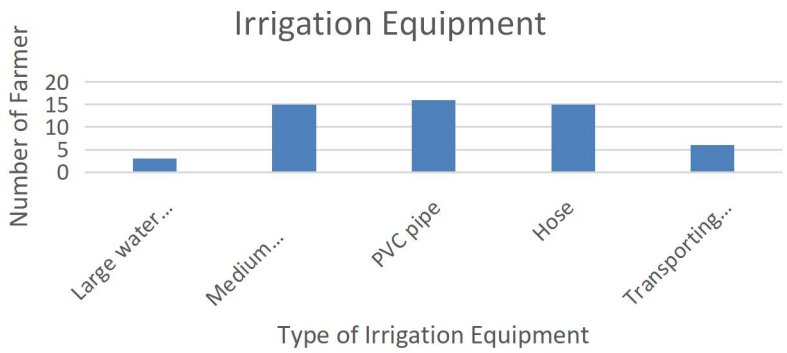

Figure 2. Irrigation equipment possessed by smallholders for furrow irrigation

Fifteen interviewed farmers responded that they invested in some irrigation equipment such as medium water pumps, PVC pipes, and hoses. These are the standard tools for performing furrow irrigation. The amount of PVC pipes depends on the acreage of the plot. The total cost for a new set, for example, consists of a new pump costing IDR 4,500,000, 40 pieces of Ø = 3-inch PVC pipe costing IDR 1,350,000, and a 50-meter medium quality hose costing IDR 600,000. In total, the smallholders budgeted IDR 6,450,000. Some smallholders had more than one water pump and more than 40 PVC pipes to deal with fragmented plot locations. Four respondents had five water pumps and 100 PVC pipes each. A smallholder detailed his effort during an interview.

> *The statement by Farmer #4 during interview confirmed his efforts in buying irrigation equipment: "Since I became involved in sugarcane farming business in 2005, to make my sugarcane crop grow better, I rented a pump along with the hoses, pipes, and even the workers. Starting in 2013, I bought five medium water pumps, one by one, because my plots expanded. Now I have 30 ha of sugarcane. Do you think those pumps are quite enough for me? I need more but last harvesting season was not that good, so I hold my plan. I hope this season (2018) will be much better."*

Commonly, a bore-well is used for irrigating up to 2 ha of sugarcane plots. A medium water pump, 40 PVC pipes, and two workers are typically involved in performing irrigation of a sugarcane plot per day. Farmers with larger plots (> 1 ha) prefer to have their own; therefore, presently, the willingness of farmers to invest in water pumps and pipes are greater than in the past. This is reflected in the following graph.

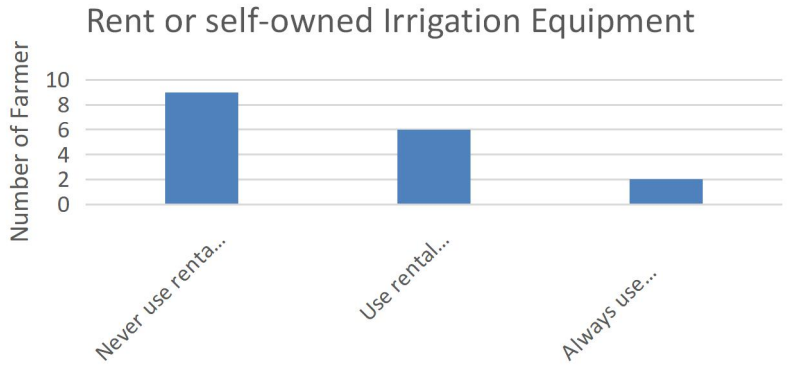

Figure 3. Irrigation equipment ownership scheme of smallholders

The figure shows the number of farmers according to their ownership of irrigation equipment. Most of the interviewed farmers carried out irrigation using their own equipment. This situation indicates that farmers had allocated budgets for irrigation investment. Those who had their own equipment argued that this creates flexibility and freedom in performing irrigation. The inflexibility of rental service underlined the shift from rental to self-owned irrigation equipment. However, investment for sprinkler irrigation tools is seen as a burden for their budget. They thought that the sprinkler irrigation system is expensive and not affordable. This may be linked to a lack of information and knowledge on the advantages and disadvantages of sprinklers in this region.

The current furrow irrigation has been practiced for years on rice and sugarcane fields in Lumajang. Therefore, farmers perceive that furrow irrigation is the only method that can satisfy crop water requirements, indicated by the saturated soil. As a result, those sugarcane farmers refuse and overlook the sprinkler technology. The main reasons are that first, sprinklers cannot adequately saturate the soil as furrow irrigation does, and second, sprinklers shorten the irrigation interval. In addition, farmers never quantified the volume of water entering their plots because they thought that it is unnecessary. However, Vos and Linden (2011) gave an example: in Peru, where rice and sugarcane farmers also competed for water use, the volumetric water fee system was proven to boost water use efficiency at the field level [13].

3.3. *Farmer perspectives and expectations of sprinkler irrigation*

The lack of pressurized irrigation technology dissemination leads to assumptions by farmers that there are no other irrigation methods except furrow irrigation. According to the interview results, thirteen respondents said that they did not know about sprinkler irrigation. During the interviews, three sprinkler irrigation videos were shown to the respondents. They were excited and asked several questions about sprinklers, for example on the throwing radius, the type of pump, the water source, and the cost. The other three respondents indicated that they had seen sprinklers used at the Jatiroto sugarcane nursery. A respondent also confirmed at another sugar mill. However, the sprinkler used at the nursery has a significant difference in size and the operation mechanism.

Showing the sprinkler irrigation videos to respondents opened up their curiosity on the technology. When asked about their thinking and perspectives of sprinkler irrigation, various responses came from them. Each farmer responded interactively and delivered more than one answer. Sometimes they asked back to gain understanding about sprinkler operation. Asking what sprinklers can do for their sugarcane was the response that they gave most often. The top fifteen responses are described in Table 3.

Table 3. Perspectives of farmers on sprinkler irrigation (top 15 responses)

Responses	No. of responses (farmers)
How large is the coverage radius?	8
Can I use my existing water pump?	7
Seems comfortable in operation - it is turned on and left.	6
If the price is high, I will say NO.	6
Needs more frequent applications (especially for new plants).	6
Similar to rainfall - the water sprays uniformly.	5
Where is the water coming from?	5
What is the fuel for the pump?	4
Sophisticated, but I fear it may be damaged or stolen by others.	3
Seems labourless.	3
Faster and efficient water application.	3
Will be good if this is portable.	2
Can it rotate?	2
Where can I buy this sprinkler?	1
How do I operate this sprinkler?	1

The greatest response of farmers on their perspectives on sprinkler involved asking again about the sprinkler coverage radius, because this is considered significant for sugarcane irrigation. They also said that the investment cost of sprinklers might be expensive. Hence, they asked about the sprinkler performance. The second-greatest response was the possibility of using their existing water pumps so that additional budgets could be avoided. Some respondents agreed that if the investment cost of a sprinkler system is out of their financial limits, it would be hard for them to implement the system. Attention to shortening the interval irrigation also arose.

In the perspective of farmers, sprinkler irrigation cannot perform better than furrows in term of wetting the soil, which is linked to a shorter irrigation interval. For the practicality aspect, with a sprinkler, a farmer will irrigate more frequently than with a furrow. They also argued that sprinklers may reduce labour through easy operation, but irrigation needs to be performed more often, which becomes contrary to the labour cost reduction. An interesting response appeared, with some asking about the fuel for the pump; as a sprinkler is a sophisticated tool for them, they thought that it would need a different kind of fuel for its operation. Also, due to its modern appearance, a sprinkler may attract burglars.

Farmers were also asked about their expectations of sprinkler technology, even though they had no experience of it. Their expectations were meaningful to adjust the sprinkler design to meet their needs without sacrificing its potential performance. The top seven responses by farmers are described in the table below.

Table 4. Expectations of farmers on sprinkler irrigation (7 top responses)

Responses	No. of responses (farmers)
I hope it will be cheap	6
I want to try if the sprinkler trial is successful	4
Possibility to be implemented in rainfed or dry crop areas	4
I do not know (or irrelevant answer)	2
Should be easy to use	1
More efficient (on irrigation cost and performance)	1
I hope it can reduce weeds	1

The sensitiveness of smallholders on the sprinkler price was the top response. They expected that if they decided to invest for sprinklers, they would not spend so much money. Unforeseeable situations of their future income at harvest time made them very prudent on budgeting. Based on their experiences in previous years, some unexpected conditions may possibly happen at harvest time; for example, sugar prices may drop, fire may burn the ready-to-harvest sugarcane, and rain may fall. These conditions caused significant reductions in the income of sugarcane farmers. Some respondents expected a sprinkler experiment to prove scientifically the advantages of sprinklers. If the experiment is successful, then farmers will follow. Other expectations also arose, for example ease of use, possibility of weed reduction, and so on.

In discussing farmer perceptions on sprinkler irrigation, several conditions should be noted. First, it should be understood that sprinkler irrigation is a new and modern object for sugarcane smallholders in Lumajang. Most of the respondents have had no experience with sprinklers (in terms of knowing about, seeing, and using them). The perceptions of smallholders on sprinklers in this research were built based on their limited information and knowledge of pressurized irrigation technology. Second, furrow irrigation has become rooted and embedded in their agricultural activities and social system. Their understanding of furrow irrigation is obtained informally, mostly learning by imitating. For some smallholders, their knowledge was acquired from daily interactions with other farmers. Senior farmers are considered as experienced and having more knowledge; what they say and do related to sugarcane farming will most likely be followed by other farmers. Yet, in fact, no senior farmers implemented sprinkler irrigation. Therefore, other smallholders cast doubts about sprinklers, which is reflected in their arguments questioning sprinkler performance and investment cost for the sprinkler system.

The responses of farmers to sprinkler irrigation can be categorized into three groups. First is the group of farmers who perceive their current practice of furrow irrigation is the best method that gives them plenty of agronomic and economic benefits; this group sees sprinkler irrigation as a burden to their budget. Second is the group of farmers who perceive that sprinklers are better but keep doubting its advantages. They request other stakeholders such as the government, researchers, and sugar mills to conduct a sprinkler demonstration. Third is the group of farmers who want to try sprinklers because of their potential benefits, but do not have the capital to invest. This group asks about the possibility of a government project that would give them free sprinkler systems.

The sprinkler irrigation is perceived by most of the respondents as a relatively expensive method, yet one that offers a comfortable way of watering. They apparently said that the operation of sprinklers seems to be convenient compared to the how furrow irrigation currently works. Once a sprinkler is set to work, there is no longer the muscle work of manual digging of furrows within a plot to direct water, as is carried out while performing furrow irrigation. Less labour is also required to irrigate a larger area with equal irrigation time as furrow irrigation, yet this only works out for a relatively large area. Two workers for each pump in a bore-well is the most common setting for plot acreages of less than 1

ha. For a large plot, the operation setting is not changed, but the irrigation time for the whole plot increases. Smallholders want technology that is easy to use and gives better yield improvement with low investment costs. However, discussing low investment costs is complicated, as there is no clear differentiation between low costs and high costs. Therefore, the price of a new medium water pump (IDR 4,500,000) is used as the upper line of "low costs" for smallholders as stated by most of them during this research.

Another essential constraint of sprinklers is related to their performance of watering soil to a saturated condition. This constraint can influence the future of pressurized irrigation technology dissemination and adoption. Most respondents expressed that wet and saturated soil satisfies their expectation for irrigation. When saturated, the water is stored as soil moisture for 3-4 weeks, and the next irrigation will be performed after that time. This fact is supported by the statements of smallholders that they mostly perform irrigation four times or at least twice during the growing of sugarcane. This means that for 0-5 months they perform irrigation monthly from 2-4 times. Sprinklers, which deliver less water than furrows, are significant in two ways. First, from the perspective of farmers, less water means that the soil is less wet and not saturated. As a result, the next irrigation might be performed before 3-4 weeks after the previous one. This may increase irrigation occurrences to ten times if the interval is two weeks and will be more for shorter irrigation intervals. Second, considering the point of view of irrigation managers, less water but a greater irrigated area means better irrigation efficiency, as long as this meets the crop water requirements. Which view is better between the two is still debatable.

This explanation reflects that it still takes much effort to convince smallholders that sprinkler irrigation can be an alternative to their current furrow irrigation practices. The work by Burnham *et al*. (2014) indicated that the slow adoption process of a water-saving irrigation system among smallholders in China is because of misaddressing their needs and circumstances with the irrigation technology [14]. Good sprinkler performance is not the only factor to attract them; price, the capital strength of farmers, the perception of farmers, support by relevant stakeholders, and more scientific proof are also other considerable factors to promote sprinkler technology. More research, experiments, and demonstrations would open the possibility of technology adoption as long as the technology can prove positive impacts as returns for irrigation investment.

4. Conclusion

To conclude, farmers have different perspectives between furrows and sprinklers. It is true that furrow irrigation is the superior irrigation method for most sugarcane farmers; this method has been entirely satisfactory to the expectations of farmers for decades in Lumajang, such as the degree of soil wetness and the significant amount of water delivered to the plot. Both expectations are interrelated to each other and makes them feel excited and safe after irrigation. As well, the low costs for performing furrow irrigation has convinced smallholders that furrow irrigation is the best and cheapest irrigation method. Unlike furrows, sprinkler irrigation offers several benefits but do not match what farmers want. They perceive that a sprinkler system is an expensive irrigation system, for which it is hard for them to allocate budgets. Also, the satisfaction of farmers is not met by sprinkler irrigation, as sprinklers deliver less water than furrows, which means the soil is not saturated. Smallholders also expressed that higher investment costs than furrows and operational costs are the drawbacks of sprinklers. From these results, it is suggested that the propagation of information on sprinkler irrigation in this region needs extra effort and support from influential stakeholders, if they consider that sprinkler irrigation is essential to be implemented.

Looking at the field performance comparison between furrows and sprinklers, it can be concluded that both methods complement each other. The notable advantage is that the use of sprinklers enables the irrigation of a larger area than creating furrows with the same amount of irrigation time, which leads to labour cost reduction. On the contrary, the use of sprinklers cannot thoroughly saturate the soil although crop water requirements are met, while furrows can saturate the soil by exceeding the crop water requirement. For irrigation experts, this means that furrow irrigation uses water inefficiently,

and sprinklers use water efficiently. Unfortunately, smallholders in Lumajang take into account neither the sugarcane crop water requirements nor the volume of irrigation water. Moreover, sugarcane smallholders argue that unsaturated soil will lead to a shorter interval to the next irrigation, which leads to more occurrences of irrigation events. In the end, this ends up generating more work and increasing labour cost. It is perceived as a circular trap.

Finally, the possibility of implementing sprinkler irrigation at the current state is less promising, unless the social requirements for the use of sprinkler technology are met, and information about future water scarcity is also disseminated. Although sprinklers offer better efficiency and performance parameters than furrows, more effort is needed to prove that the efficient irrigation method is crucial to be applied in Lumajang. The sprinkler design has to be reviewed to generate better performance parameters. The perceptions of farmers also can be taken into account for evaluating the sprinkler design since they reflect the socio-technical requirements for the sprinkler technology. This research hopefully can contribute to the dissemination of knowledge of sprinkler irrigation in Lumajang Regency. Understanding the socio-economic dimension of water management in the region allows prudent steps to be taken to introduce technology. This work reveals the importance of examining the socio-economic-technical relations of an irrigation system.

Acknowledgments
This research was conducted with funding support from the Indonesia Endowment Fund for Education (LPDP) with contract number PRJ-244/LPDP.3/2016.

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