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Utilization of Deep Groundwater to Support Rice Cultivation in Dry Land

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ABSTRACT

Land limitations cause dry land to become an alternative for food fulfillment, especially rice. This research aimed to investigate the use of deep groundwater for rice plants irrigation in dry land in the second growing season in terms of production, economy and social aspects. The research was conducted in dry land of Gunungkidul D.I. Yogyakarta Indonesia, in the second growing season. Rainfall was observed to determine the time of irrigation. Sidenuk, Inpari 33 and Inpari 42 varieties, complete with rice production technology components, were tested using a Randomized Completely Block Design with 3 replications. Interviews were conducted to explore the economy and farmers perceptions. The results showed additional irrigation from groundwater in supporting rice planting in the second growing season, with Inpari 42 providing the highest yield of dry grain harvested of 7.2 tons ha-1, straw of 9.6 tons ha-1, carbon absorption in grain of 3.9 tons ha-1, carbon absorption in straw of 4.3 tons ha-1, profit in Indonesian Rupiahs of 17,670,000 and R/C of 2.41. Farmers' constraints on rice planting in the second growing season, especially in terms of capital, control of plant pests and organic fertilizer.

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1. INTRODUCTION

The need for rice increases in line with the increase in population. Rice is related to the economy, social and politics, so it remains a priority. Suboptimal land such as dry land is a priority for rice. Abiotic (drought and low fertility) and biotic (pests and diseases) constraints are inherent in dry land (Makarim et al., 2007). The problem is exacerbated by climate change and seasonal shifts that cause uncertainty in the rainy season. Climate change causes changes in the hydrological cycle with uncertain rainfall (Sutrisno, 2016). The use of dry land for rice will automatically be related to these problems.

Indonesia has 144.5 million ha of dry land, so it has great potential to support food availability and sufficiency (Mulyani, 2015). Dry land has varying levels of productivity, determined by climate conditions and stability, intensity and distribution of rainfall and soil properties (Hayashi et al., 2018). Dry land relies on water from rainfall as the main water source, with limited quantities and distribution, so the danger of drought will always be a threat (Sutrisno, 2016). Decomposition of soil organic matter occurs rapidly, resulting in low soil organic matter content, furthermore low soil fertility levels (Abdurachman et al., 2008). Utilization of dry land will require additional technology and resource support, especially water resources (Anshori, Riyanto, et al., 2021), for example supplementary irrigation.

The key to utilizing dry land depends on the availability of water for plants. One way is to utilize groundwater for plant growth, development and production. Liu et al. (2014) stated that there is a relationship between the environment, economy and society in the planting system, so that food security and socio-economic stability are achieved. Optimal planting considers the close relationship between water, energy and economic aspects. Furthermore, water supply management is directed to maximize economic, social and environmental benefits (El-Gafy et al., 2017). This research aimed to investigate the use of groundwater for rice irrigation in dry land in the second growing season in terms of production, economy and social aspects.

2. RESEARCH METHODOLOGY

The location selection was based on climate conditions, rainfall distribution and farmer habits. The location has an average annual rainfall of 2,118.9 mm per year, there are differences between the rainy and dry seasons. Farmers usually plant rice in the rainy season, in the first growing season, when rainfall is maximum. Most farmers plant palawija and vegetables in the second and third growing seasons (Figure 1). The location includes the areas of Gunungkidul, D.I. Yogyakarta, Indonesia, at coordinates 7.98549°N and 110.7053°E, with an altitude of about 232 meters above sea level. Research on rice planting using deep groundwater wells was conducted in the second growing season.

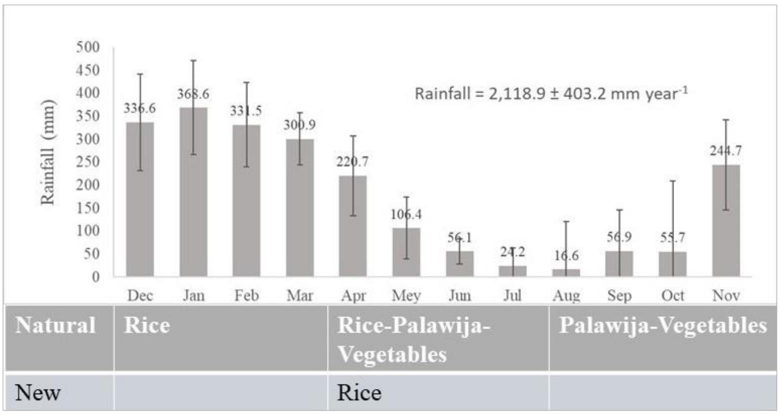

Figure 1. Natural and new of the cropping pattern in Ponjong

Rice planting technology is determined based on climate conditions, farmer habits and input of required technology components. Sidenuk, Inpari 33 and Inpari 42 were used in the study (Table 1). Each variety was repeated five times, using different farmer's land or plots, so that it formed a Randomized Completely Block Design (RCBD) with 3 treatments and 3 replications. Rice productivity was calculated based on the weight of dry grain harvested from 2.5 x 2.5 meters tiles. Seeding was carried out on March 29, 2020, rice planting on April 16, 2020, and rice harvesting on July 15, 2020. Rice was harvested at 90 days after transplanting (DAT).

Table 1. Technology components applied to rice cultivation

Technology component	Description
Superior varieties	Sidenuk, Inpari 42, Inpari 33
Seed	Labeled
Seedling	15 to 20 days after sowing
Planting distance	Jajar legowo 2:1, 2-3 seedling per hole
Soil cultivation	Mechanization with two-wheel tractor
Fertilization	Nitrogen 46% 100 kg ha^{-1}, NPK 15-15-15 300 kg ha^{-1}
Irrigation	Intermittent, Irrigation with deep groundwater well
Control of plant pest	Integrated
Harvesting	Mechanization with *pedal threser*

Interviews were conducted with 10 farmers to determine farmers' perceptions of technology components in the second growing season. Interviews were also conducted to explore farmers' economy. Farmers' perceptions and economic conditions as a basis for improving rice cultivation in the second growing season, as a replication effort, and further for sustainability.

3. RESULTS AND DISCUSSIONS

Rainfall during the second rice growing season was 344 mm (Figure 2), not enough for the ideal rainfall for rice plants. According to Oldeman and Frere (1982) rice plants require sufficient water for growth and development. The water shortage is met by a water pump from a deep groundwater well, with a discharge of around 30 liters per second. Irrigation is carried out with a puddle height of around 15 to 20 cm. The appearance of the well and the plant growth until harvest can be seen in Figure 3.

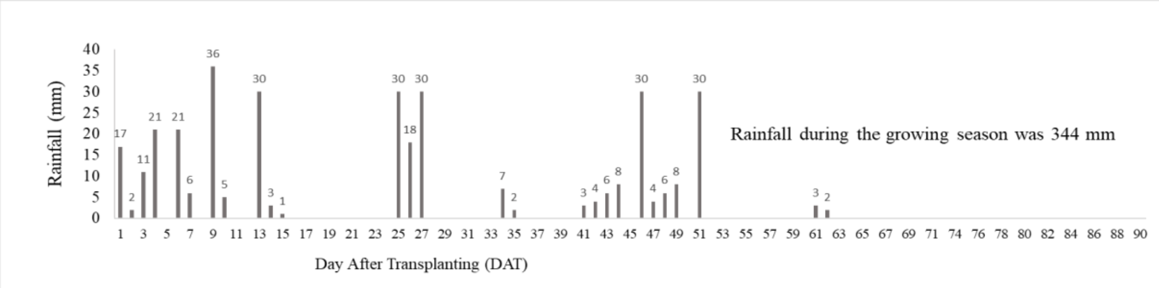

Figure 2. Rainfall during the second growing season

Rainfall until 62 DAT, amounting to 344 mm, is not enough for rice plants. Deep groundwater wells are a very valuable resource for farmers, reducing the risk of crop failure due to lack of water (Anshori et al., 2020 ; Viandari & Anshori, 2021). Rice is saved from drought due to lack of rainfall. Irrigation is carried out when rice plants need additional water. 10 times irrigation from deep ground wells is carried out to support the growth of rice plants until harvest. Irrigation is not carried out when rice plants are sufficient by rainwater.

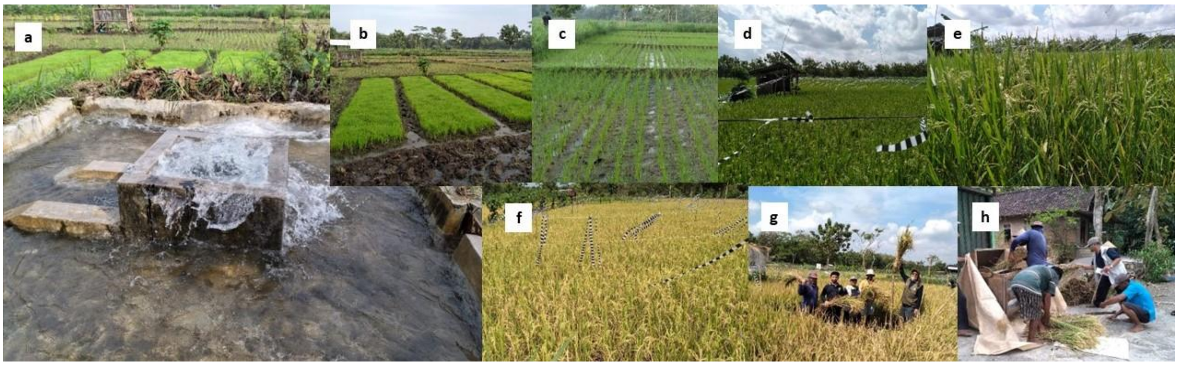

Figure 3. Water sources from deep groundwater wells (a); Rice seedbed (b); Rice plants (c, d, e); Rice plants ready to harvest (f); Rice harvest (g, h)

The highest productivity of Inpari 42 rice, reaching 7.2 tons ha^{-1}. The lowest Sidenuk variety with 6.7 tons ha^{-1} (Table 2). In addition to grain, the rice harvest produces dry straw (Anshori et al., 2023), which can be used as a source of animal feed, which is a source of organic fertilizer. The rice planting index is more than 0.5, indicating that the grain produced is quite high. In addition to being supported by irrigation sources, high rice productivity is also supported by the application of appropriate technological components.

Table 2. Rice harvest yield in the second growing season

Component	Unit	Rice variety		
		Sidenuk	Inpari 33	Inpari 42
Plant height	cm	87	95	97
Grain	ton ha^{-1}	6.7	7.1	7.2
Straw	ton ha^{-1}	8.2	9.7	9.6
Carbon in grain	ton ha^{-1}	3.6	3.8	3.9
Carbon in straw	ton ha^{-1}	3.7	4.4	4.3
Yield index	-	0.82	0.73	0.75

From the environmental side, there is absorption of carbon from the air, into biomass of rice and straw (Anshori, Suswatiningsih, et al., 2021). Carbon dioxide is absorbed by plants during photosynthesis to form plant tissue. Carbon dioxide is a type of greenhouse gas. Thus, it directly reduces the greenhouse effect, increasing the earth's temperature and global warming.

Economically, profit in Indonesian Rupiahs (IDR), Inpari 42 provides a profit of IDR17,670,000, higher than Sidenuk IDR14,310,000, or 23.5% higher. Meanwhile, the profit of Inpari 33 is 20.5% higher than Sidenuk. The profits of Inpari 42 and Inpari 33 are almost the same or only differ very little. According to Soekartawi (2016) in the condition that all cost components are the same, the difference in profit comes from the production.

Table 3. Economic analysis of rice cultivation in the second growing season

Economic component		Rice variety	
	Sidenuk	Inpari 33	Inpari 42
		IDR ha^{-1}	
Material	1,670,000	1,670,000	1,670,000
External labor	3,600,000	3,600,000	3,600,000
Internal labor	4,800,000	4,800,000	4,800,000
Water for irrigation	2,500,000	2,500,000	2,500,000
Total cost	12,570,000	12,570,000	12,570,000
Revenue	26,880,000	29,820,000	30,240,000
Income	19,110,000	22,050,000	22,470,000
Profit	14,310,000	17,250,000	17,670,000
R/C	2.14	2.37	2.41
B/C	1.14	1.37	1.41

The cost of rice farming in the second growing season requires farmers to spend additional costs for irrigation by utilizing deep wells using pumps (Anshori et al., 2020). Farmers' capital capabilities to finance irrigation vary. This is one of the obstacles for farmers to plant rice in the second growing season. The labor devoted to cultivating the land until harvest is 57% labor from within the family. Activities that require labor from outside the family such as cultivating the land, planting and harvesting.

Farmers' income by planting rice in the second planting season is influenced by the variety of rice planted. The Inpari 42 variety provides the highest income, but of all the varieties planted, it provides a B/C value of more than one, so planting rice in the second growing season, with the additional cost of deep well irrigation, still provides benefits for farmers. According to (Anshori, Iswadi, et al., 2021), it is important for farmers to pay attention to the choice of varieties that provide higher productivity, in order to obtain higher income.

Farmers' perceptions vary regarding rice planting in the second growing season, especially related to the obstacles that will be faced (Anshori et al., 2020). Lack of capital is experienced by farmers with limited capital. Additional capital is needed for irrigation costs, which require costs for fuel and irrigation labor. Farmers who do not fully rely on income from agriculture, feel reluctant because planting rice in the second growing season requires more intensive attention, or feel that it takes up a lot of time, thus reducing activities outside of agriculture.

Table 4. Constraints by farmers in planting rice in the second growing season

Components of rice planting technology	Farmers' response
Rice planting in the second growing season with suplementary irrigation	Some farmers expressed limited capital
Organic fertilization	Some farmers do not have sufficient supplies of organic fertilizer
Integrated control of plant pests	Some farmers still want to use synthetic chemicals, especially for weed control before planting

Organic fertilization is needed in the second growing season of rice (Anshori et al., 2023). Organic fertilizer will increase the physical, chemical and biological fertility of the soil (Stevenson, 1982 ; Sukristiyonubowo et al., 2020). Specifically, organic fertilizer will increase the soil's ability to retain water. However, not all farmers have sufficient supplies of organic fertilizer. Organic fertilizer comes from livestock pens. The number of livestock by farmers varies, so the availability of fertilizer varies according to the number of livestock farmers. Some farmers also still object to implementing integrated control of plant pests. Farmers still rely on pesticides, especially for weed control before planting or tillage.

4. CONCLUSIONS

Rice planting in the second growing season is supported by groundwater irrigation in providing the highest yield for Inpari 42, in the form of 7.2 tons ha^{-1} of harvested dry grain, 9.6 tons ha^{-1} of straw, carbon absorption in grain of 3.9 tons ha^{-1}, carbon absorption in straw of 4.3 tons ha^{-1}, profit of IDR17,670,000 and R/C of 2.41. Farmers have constraints in planting rice in the second growing season in terms of capital, control of plant pests and organic fertilizer.

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