The increase of rice cropping index supported by river dam irrigation in dry land

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Abstract. This study aimed to determine the increase of rice cropping index from 1 to 2 in several rice varieties supported by river dam irrigation on dry land during the second growing season. The research was conducted in dry land in Pacarejo, Semanu, Gunungkidul, Yogyakarta, Indonesia, in March-July 2019 during second growing season. The increasing of rice cropping index utilized supplementary irrigation from river dam to maintain soil moisture. Rice varieties used were Inpari 24, Inpari 30, Inpari 32, and Inpari 33, complete with a package of technological components. The result showed 139 mm of rainfall with 11 rainy days, so that the most of crop water requirements came from river dam irrigation. Inpari 24 gave the highest grain yield (442.8 kg/1,000 m²) which was not different from Inpari 30 but different from Inpari 32 and Inpari 33. Inpari 24 carbon absorption was 503.8 kg/1,000 m², consisting of 207.4 kg/1,000 m² in grain, 218.6 kg/1,000 m² in straw, and 77.9 kg/1,000 m² in root which was different from Inpari 32 (p<0.05; n=3). B/C Inpari 24 was 1.18 and farmers profit was Rp. 1,006,600/1,000 m². The profit of rice cultivation in all rice varieties were higher than groundnut with higher irrigation costs.

1. Introduction

The population is increasing by 1.49% per year, causing pressure on rice fields to increase production [1]. This condition is exacerbated by climate change [2], land conversion [3,4] and land fragmentation. Therefore, alternative solution is needed. One of the solutions is by utilize the dry land as food production can be supported by the use of dry land [3].

The dry land in Indonesia is covering 144.5 million ha area approximately [3] which potential to support food availability [5] with limited water conditions [6]. Dry land highly dependent on rainfall [3], so that rainfall plays a major role in yield [7,8]. Utilization of dry land must be supported by supplementary irrigation [9]. It reduces drought stress [10], so it increases dry land productivity [11]. Thus, water limitation is followed by water use efficiency technology [12].

Water harvesting is a water management strategy which can reduce the risk of flooding and drought [13,14]. Condition of catchment area affects water properties, water distribution, and hydroecological balance, usually upstream conditions affect water conditions downstream [15]. Harvesting water in the pond is an alternative option [16] like a river dam.

The increase of cropping index affects rice production [17], it is requiring a special strategy related to soil, water, and crop management [18]. One of the strategies is using the superior rice varieties. They
have the potential to provide support [19] and, as a component of technology, it is cheap and easy to be adopted [20,21].

Increasing rice production has the potential to be carried out on dry land through increasing the cropping index, utilizing supplementary irrigation, and using suitable rice varieties. Therefore, this study aimed to determine the increase of rice cropping index from 1 to 2 using several rice varieties supported by river dam irrigation on dry land during the second growing season.

2. Material and methods

2.1. Research location

The research was conducted in dry land, located in Pacarejo, Semanu, Gunungkidul, Special Region of Yogyakarta, Indonesia at 8°17’N, 110°36’20”E with altitude of 171 meter above sea level. It was conducted in March – July 2019 during second growing season. The existing cropping pattern was rice/maize/groundnut/cassava-maize/groundnut/soybean/cassava-cassava/no plant.

The average of annual rainfall was 1,971 mm with 5 months of wet and 5 months of dry consecutively. Soil was classified as Mediteran [22] with clay texture. Climate and soil properties can be seen in Table 1.

| Type of land | pH | TOC (%) | TN (%) | CEC (cmol(+)/kg) | pF 2.54 | pF 4.20 | P (mm) | T (°C) |
|--------------|----|---------|--------|-----------------|---------|---------|--------|--------|
| Dry land     | 6.31 | 1.18   | 0.08   | 34.30           | 39.32   | 14.27   | 1,971  | 27.5   |

2.2. Water catchment area for river dam

On dry land, the main requirement for increasing the rice cropping index is the availability of supplementary irrigation. River dam irrigation requires an adequate catchment area as a source of water. The catchment area of river dam irrigation was determined based on the direction of water flow.

2.3. Treatments and experimental design

The technology components of superior rice varieties were easily adopted by farmers, so that it was positioned as a treatment in this research. The superior rice varieties in this research were Inpari 24, Inpari 30, Inpari 32, and Inpari 33 [23] which treated using a randomized completely block design (RCBD) with 3 block replications.

2.4. Cultivation details

Rice was planted using jajar legowo system with proportion of 2:1. The transplantation used 4−5 seedlings of 15 days after sowing (DAS) on the land with no tillage condition. The fertilizer rate was 200 kg ha⁻¹ of 46% N and 300 kg ha⁻¹ of 15:15:15 NPK. The fertilizer was applied as the basic fertilizer on 15 and 30 days after transplanting (DAT). Sprayed of liquid fertilizer was at 10, 20, and 40 DAT.

The weeds, pest, and diseases were controlled by integrated method. Irrigation was carried out from river dam every 3 to 4 days until 71 DAT with the water level around 15-20 cm. The Soil water content was not less than permanent wilting point on pF 4.20. Rice was harvested at 91 DAT for Inpari 30, Inpari 33 and Inpari 24, just Inpari 32 at 97 DAT.

2.5. Sampling and measurement of parameters

Harvested dry grain, straw, and roots were taken after harvest drying. The carbon content of grain, straw, and roots were determined based on the carbon content in the tissue. The feasibility of cultivation was calculated based on B/C following [24]. The measurement of organic carbon is related to the system sustainability [25].
2.6. **Statistical analysis**
The significant treatments of rice variety was determined by the F test and Duncan Multiple Range Test (DMRT) at <0.05 level of significance [26].

3. **Results and discussion**

3.1. Water availability
Supplementary irrigation can come from deep wells, shallow wells, reservoirs, long storage, and ditch or river dams. River dam uses water harvesting techniques, the source of water is from upstream catchment. The water flow from the catchment area is collected by the river dam as a pool of water (Figure 1). The upstream hydroecological conditions affect the downstream water conditions as statement [15].

![Figure 1. Research location and river dam irrigation catchment area](image)

Water catchment covers area of 454 ha and the runoff water was collected in a river dam. A water pump was used to lift water from a river dam which collected in a water tank, then distributed through pipes for irrigation of rice crops. The water pump debit was 5 litres second	extsuperscript{-1}. The 2 ha of rice cultivation was fulfilled by irrigation from river dam.

3.2. Rainfall and cropping pattern
Rainfall during the first growing season was 1.319 mm. Most of the rainfall occurred in the first growing season. The farmers planted upland rice/maize/groundnut/cassava in which the crop water requirements were fulfilled from rainfall (Figure 2). Rainfall determines the cropping pattern according to [27].

Rainfall in the second growing season, during the increase of rice cropping index, was 139 mm. Rainfall was distributed on March III to April III, with 11 rainy case which was low for rice cultivation. Lack of rainfall water was fulfilled from river dam irrigation (Figure 2) which irrigated every 3-4 days with water level of 15-20 cm that sufficient to meet the water requirement of rice crop. It made the moisture content was not less than permanent wilting point at pF 4.2.

The third growing season, during the dry season, farmers planted vegetables with irrigation from river dam. Cassava was harvested at the third growing season, in the dry season. Irrigation from the river dam increases the rice cropping index 1 to 2 and the cropping index 2 to 3.
3.3. Rice yield components and carbon absorption

Grain, straw, root, and carbon absorption of rice variety and groundnut can be seen in Table 2. Inpari 24 gave the highest dry harvest grain yield of 442.8 kg 1,000 m$^{-2}$ which was not different from Inpari 30 but significantly different from Inpari 32 and Inpari 33. The weight of Inpari 24 dry straw was 487.3 kg 1,000 m$^{-2}$ and dry root was 181.7 kg 1,000 m$^{-2}$. They were significantly different only from Inpari 32. The highest carbon absorption in Inpari 24 was 207.4 kg 1,000 m$^{-2}$ for grain which was not different from Inpari 30 but significantly different from Inpari 32 and Inpari 33. Inpari 24 carbon absorption was 218.6 kg 1,000 m$^{-2}$ for straw and 77.9 kg 1,000 m$^{-2}$ for roots, they were significantly different only from Inpari 32 (p<0.05; n = 3) (Table 2). Inpari 24 and Inpari 30 have high yield potential [23] and high carbon absorption, so they are feasible to develop. In addition, high carbon absorption promotes the stability and sustainability of the agricultural system [28,25]. Inpari 24 and Inpari 30 are suitable for increasing the rice cropping index from 1 to 2 on dry land in the second growing season.

Table 2. The dry of harvest grain, straw and root and the carbon absorption of grain, straw and root

| Commodity / Rice variety | Dry Harvest grain kg 1,000 m$^{-2}$ | Carbon absorption |
|-------------------------|--------------------------------------|-------------------|
|                         | Grain                                 | Straw             | Root              |
| Groundnut               | 205.3±12.1#                          | 319.0±3.1*        | 54.9±3.2#         | 158.2±1.5*        |
| Inpari 32               | 382.3± 4.3a                          | 414.2±4.4a        | 156.4±3.8a        | 179.4±2.0a        | 185.8±2.0a        | 67.1±1.6a        |
| Inpari 33               | 414.3±7.1b                          | 467.5±11.4b       | 174.1±3.4b        | 192.4±3.3b        | 209.7±5.1b        | 74.7±1.5b        |
| Inpari 30               | 434.7±13.3bc                         | 468.2±20.2b       | 174.4±11.8b       | 203.1±6.2bc       | 210.0±9.1b        | 74.8±5.1b        |
| Inpari 24               | 442.8±7.2c                          | 487.3±10.9b       | 181.7±5.0b        | 207.4±3.4c        | 218.6±4.9b        | 77.9±2.1b        |

Note: The numbers that followed by the same letter in the same column show no significantly different in the DMRT of 5%. #: pod, *: leaf, stem and root of groundnut

Groundnut yielded 205.3 kg 1,000 m$^{-2}$ pod and biomass (leave, stem, and root) of 319.0 kg 1,000 m$^{-2}$ with carbon absorption in pod 54.9 kg 1,000 m$^{-2}$ and biomass 158.2 kg 1,000 m$^{-2}$, these were lower than all rice varieties (Table 2). In the second growing season, rice crops provided higher yields and carbon absorption than groundnut.

3.4. Economic feasibility

Economic feasibility analysis was used to determine the priority scale of cultivation. Revenue was obtained from selling grain rice and peanut pod. The costs of rice and peanut cultivation in the second growing season included the costs of seeds, fertilizers, pesticides, labor and water for irrigation (Table 3).
Table 3. Economic analysis for all rice varieties and groundnut in second growing season

| Component                        | Inpari 24 | Inpari 30 | Inpari 33 | Inpari 32 | Groundnut |
|----------------------------------|-----------|-----------|-----------|-----------|-----------|
| Material (seed, fertilizer, pesticide) | Rp. 1,000 m² | 154,000 | 154,000 | 154,000 | 272,000 |
| Labor                            | 360,000 | 360,000 | 360,000 | 360,000 | 360,000 |
| Water for Irrigation             | 340,000 | 340,000 | 340,000 | 340,000 | 80,000   |
| Total cost                       | 854,000 | 854,000 | 854,000 | 854,000 | 682,000 |
| Receipt                          | 1,860,000 | 1,827,000 | 1,738,800 | 1,604,400 | 1,435,000 |
| Profit                           | 1,006,600 | 973,000  | 884,800  | 750,400  | 723,000  |
| B/C                              | 1.18      | 1.14      | 1.04      | 0.88      | 1.02     |

Profits and B/C for Inpari 24 rice varieties were the highest compared to Inpari 30, Inpari 33 and Inpari 32. Overall, rice cultivation in increasing the rice cropping index on dry land in the second growing season was more profitable than groundnut. The B/C of rice cultivation was higher than groundnut, except for Inpari 32. Rice cultivation requires higher irrigation costs, it requires capital for irrigation cost.

4. Conclusion
The increase of rice cropping index in dry land at the second growing season can be carried out with supplementary irrigation from river dam. Inpari 24 produced the highest grain and grain's carbon absorption, but it was not different from Inpari 30. Straw and root biomass were not different in Inpari 24, Inpari 30 and Inpari 33, but was higher than Inpari 32 and groundnut, as well as their carbon absorption. Inpari 24 and Inpari 30 were more suitable for increase of rice cropping index due to their higher grain yield and carbon absorption. Economically, the profit of rice cultivation in all rice varieties were higher than groundnut, but higher in irrigation costs. Farmers need capital for irrigation cost.

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