Improving irrigated agriculture through integrated water resources management in Pusur Watershed, Central Java

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Abstract. Pusur watershed supplies water for about 3,000 ha irrigated farmlands of 12,000 smallholders. However, water shortages affecting the crop development and production are common in the farmlands within the Pusur Watershed, especially during the 3rd cropping season (June-October). This research conducted a survey to describe water resources availability, hydraulic network performance, cropping calendar, canal water access, and crop development condition with objectives to improve water management and reduce water conflict in the irrigated region. The participatory and rapid appraisal results identified different condition of canal water access and crop development within the sampling area. The result found that the pusur watershed is very elongated shape and the largest area was covered by 44.24 % of rice. Water availability of all dams in Pusur Watershed are decreasing from rainy season to dry season about 8 until 19% in every year. Many farmers has a good access in hydraulic structure condition and water distribution efficiency, but most of them has canal water lack for crop during the 3rd cropping. An analysis of water balance simulation showed a degraded conditions of crop development most located in downstream areas whereas crops look growing-up normally in most of upstream zones.

1. Introduction

Pusur watershed, located at Klaten and Boyololi Regency, Central Java. The Pusur River, which is a tributary of Bengawan Solo River, takes its source on Merapi Volcano slope. Its catchment is elongated in a northwest to southeast, measuring about 32 km in length and averaging only about 1.7 km in width. This shape, inherited from Merapi volcano-building processes millions of years ago, reflects the characteristics of the valley developed on the slope of the volcano. Elevations in the watershed range up from 830 m above sea level to 100 m.

The variation of the elevation slopes shows three main sections: (i) an upstream section from 830 m to 380 m with a slope around 5%, (ii) from 380 m to 200 m a slope around 2.5% and (iii) from 200 m to 100 m a slope around 0.05%. The spring belt that surrounds Merapi is located on the first slope break around an elevation of 380 m. This slope break demarcates 2 distinctive land uses: agroforestry upstream the break slope and irrigated areas downstream.

During dry season, surface water resources mainly depends of springs flow located around Merapi. It includes Cokro spring (total discharge 1,200 L s⁻¹) that supply Pusur River while Sigedang spring (225 L s⁻¹) that supply Kapilaler canal. These water resources are jointly used for irrigation and non agricultural purpose.
An agriculture water demand is intended to supply the irrigation system consisting of the Kapilaler irrigation area (425 ha) and 2 clusters of irrigation areas along the Kali Pusur stream, each of which is located upstream and downstream of the Cokro stream.

The flow of the upstream springs irrigates a relatively small part of upper cluster that comprises 11 small irrigated schemes (around 500 ha), while the flow of Cokro spring allows to crop a significant part of the downstream cluster that has 7 irrigated areas (around 3,235 ha).

Due to its high rainfall (between 3,000 mm and 1,500 mm), Pusu watershed cannot be considered as a region affected by absolute water shortage; water resources are theoretically sufficient to meet needs according to FAO assessment. In fact, Pusur Watershed supplies water for about 3,000 ha irrigated area with 12,000 smallholders.

However since 1990s, increasing population growth and water use competition (private commercial water companies, state-based water distributors and tourism) have been frequently resulting in problem access to water for irrigation farming communities and private household. Several region located in Pusur River basin are frequently suffering from water shortage during the 3rd cropping season (July-October) which is affecting the crop development and production. Some tense situations related to the river and irrigation canal water access issues have already occurred in the near past not only between water user groups within the same region but also between groups of different region.

In line with Integrated Water Resources Management (IWRM) approach, the general objective is to conduct a survey to describe water resources availability, hydraulic network performance, cropping calendar, canal water access, and crop development condition with objectives to improve water management and reduce water conflict in the irrigated region a survey

2. Materials and methods

2.1. Time and location

The survey was carried out during the dry season of 2012 (July to October). The location for data collection was carried out in the upper reach of the Pusur river, to be precise, Jetak’s Dam, which is located in the hills where the land cover is well conserved until today. The survey was implemented at 8 Pusur Irrigated Region which are located in Tulung, Polanharjo, Delanggu and Juwiring District, Klaten Regency, Central Java Province. A set of 8 region covering near to 90% of total Pusur irrigated areas, was identified to implement the survey by following the River course over about 20 km from upstream to downstream zones i.e. Kemiri, Plosowareng, Taman, Wantil, Bagor, Dolikan, Bogem and Jetak area.

Survey activities have been carried out, including observing fluctuations in the water level of the pusur river for a full hourly period of one year in the upstream area by installing the Automatic Water Level Recorder AWLR. Agricultural data and information including cropping patterns and easy access for farmers to hydrological structures were obtained by interviewing the Participatory Rural Appraisal PRA method.

2.2. Material

Data and map were analyzed in this study i.e : (i) Daily Rainfall Data of Tulung, Polanharjo, Delanggu and Juwiring District, Period of 2003 to 2019, Public Work of Klaten [1]; (ii) Daily Discharge Data of Pusur River, AWLR of Jetak’s Dam, period of 2012; (iii) Daily Discharge Irrigation Data of 8 Dams : Kemiri, Plosowareng, Wantil, Taman, Bagor, Dolikan, Bogem, Jetak Dam, period of 2003 to 2012, Public Work of Klaten Regency [1]; (iv) Map of Drainage Network at a scale of 1:25,000, Agency of Geospatial Information (BIG) [3]; (v) Map of Dam Location at a scale of 1:100,000, Public work of Klaten Regency; (vi) Map of Rain gauge Station at a scale of 1:50,000, Public Work of Klaten Regency [1].
2.3. Method
Method of this study consist of watershed characterization, water availability analysis and Water Balance Analysis [4]. Watershed characterization consist of: GIS analysis of digital topography map and ALOS satellite imagery analysis. This analysis identifies geomorphological characteristic and land cover distribution [5]. Water availability analysis consist of daily river discharge data analysis of pusur river and 15-thedaily irrigation discharge data analysis.

Water Balance or Water Supply-Demand were analyzed using Water Crop Requirement Analysis (FAO irrigation & drainage bulletin N°56) [6-8]. This analysis need the data i.e: surface of irrigated area, 15 daily irrigation discharge, annual cropping pattern, daily rainfall and Potentian Evapotranspiration (PET) [9].

3. Results and discussion

3.1. Biophysical characteristic of Pusur Watershed
The depiction of its biophysical characteristics developed below by considering its geo-morphology, topography, hydrography as well as the spatial variability of the types of soil and land use.

The catchment has a total area of 33.43 km²; it’s elongated in a northwest to southeast direction, measuring about 32 km in length and averaging only about 1.7 km in width. Elevations in the watershed range from 8 to 900 m above sea level.

The descriptive parameters of its geo-morphological features are presented in table 1. The low value of the compactness index indicates very elongated shape.

Table 1. Descriptive parameters of the geo-morphological characteristics of Pusur Watershed.

| Parameter                        | Unity      | Value   |
|----------------------------------|------------|---------|
| Area                             | Km²        | 33.43   |
| Perimeters                       | Km         | 61.35   |
| Compactness index                | -          | 2.99    |
| Length of the equivalent rectangle | Km      | 29.77   |
| Width of the equivalent rectangle | Km        | 1.12    |
| Global Slope Index               | m Km⁻¹     | 24.8    |
The watershed is covered by 3 main types of soil which are located according to land elevation, namely Tropudults above 700m (7.25%), Tropaquert between 450 m and 700m (24.25%), Eutropept below 450 m (68.5%).

Rice fields, settlement area and agro-forestry land are the 3 main types of land use as presented in table 2. The spatial distribution of the main types of land use is illustrated in figure 2.

Table 2. Total area of the main types of land use within Pusur Watershed.

| Type of Land Use  | Area (Km²) | %     |
|-------------------|------------|-------|
| Agro-forestry     | 7.18       | 21.47 |
| Shrub             | 1.31       | 3.93  |
| Mixed Garden      | 0.21       | 0.62  |
| Settlement        | 9.94       | 29.74 |
| Rice field        | 14.79      | 44.24 |
| Total             | 33.4       | 100.00|

Figure 2. Distribution of the main types of land cover within Pusur Watershed.

3.2. Characteristic of Pusur irrigated area

A set of 8 region covering near to 90% of total Pusur irrigated areas, was identified to implement the survey by following the River course over about 20 km from upstream to downstream zones i.e. Kemiri, Ploso Wareng, Taman, Wantil, Bagor, Dolikan, Bogem and Jetak area. The need of water for all those region are mainly supplier by Pusur River waters through dam equipped with a lateral gate and an inlet primary canal. Figure 1 shows the location of irrigated region along the Pusur River course.

The smallest irrigated area is Kemiri with 44 ha and the biggest one is Ploso Wareng with more than 1,000 ha. Depending on the area location from the dam point, primary canals have different lengths from a few hundred meters up to more than 1,500 m for some of them. For the 8 region we account 143 blocks that are mainly irrigated through open canals. The size of irrigation blocks varies from less than 1 hectare for the smallest ones up to about 10 ha for the biggest one (Ploso Wareng area).
Table 3. General features of Pusur irrigated region.

| No | Area     | Ha  | Dam location | Canal length (m) | Number of irrigation |
|----|----------|-----|--------------|------------------|----------------------|
|    |          |     |              | Primary | Secondary |                   |
| 1  | Kemiri   | 90  | Upstream     | 1,000   | 1,350     | 15                  |
| 2  | Ploso Wareng | 1,100 | Upstream     | 650     | 11,100    | 35                  |
| 3  | Taman    | 211 | Middle stream| 175     | 2,740     | 7                   |
| 4  | Wantil   | 500 | Middle stream| 610     | 3,590     | 17                  |
| 5  | Bagor    | 451 | Downstream   | 1,200   | 5,200     | 13                  |
| 6  | Dolikan  | 323 | Downstream   | 1,680   | 4,160     | 23                  |
| 7  | Bogem    | 290 | Downstream   | 1,010   | 5,360     | 22                  |
| 8  | Jetak    | 44  | Downstream   | 890     | 180       | 11                  |
|    | Total    | 3,014 |              | 7,215   | 33,680    | 143                 |

3.3. Water availability characteristic of Pusur irrigated area

Water availability condition of Pusur Irrigated Area represented by daily discharge of Pusur River recorded using by Automatic Water Level Recorder (AWLR) has been installed at Jetak’s Dam since November 2011. Pusur river discharge during the period of December 2011 until November 2012 varied from 0.06 m³ s⁻¹ on dry season until 11.03 m³ s⁻¹ on wet season.

![Daily discharge of Pusur River](image)

**Figure 3.** Daily discharge of Pusur River.

Irrigation data available in Public Work (PW) of Klaten Regency correspond to discharge average values over a period of 15 days. The PW data covers the 1998 to 2008 inter-annual series. Depending on the climatic season (rainy season vs. dry season) and the area size, primary canal inlet discharge values may vary a lot, from 22 L s⁻¹ in dry season for the smallest area (Jetak, 44 Ha) up to 955 L s⁻¹ in rainy season for the biggest one (Ploso Wareng, 1,100 ha). In the dry season (June to October), the Pusur River is no longer supplied by the watershed surface but is supplied from the Ingas springs in the upstream area of Ploso Wareng. So, between the two seasons, canal inlet discharge decrease from 9 up to 19% according to the area. Such discharge deacrease would affect the available water quantities from canals to irrigate crops during the 3rd cropping season (dry period, June to October). Average values of canal inlet discharge (over a period of 15 days) of the 8 studied region are shown in the table 4.
Table 4. Water discharges (average values over a period of 15 days) during the rainy and dry seasons at the head of the primary canal within the Pusur studied region.

| Variable                                | Kemiri | Ploso Wareng | Taman  | Wantil | Bagor  | Dolikan | Bogem  | Jetak  |
|-----------------------------------------|--------|--------------|--------|--------|--------|---------|--------|--------|
| Area (Ha)                               | 90     | 1.1          | 211    | 500    | 451    | 323     | 295    | 44     |
| Discharge During Rainy Season (L s⁻¹)  | 46     | 955          | 138    | 214    | 205    | 150     | 117    | 26     |
| Discharge During Dry Season (L s⁻¹)    | 40     | 770          | 114    | 194    | 187    | 138     | 107    | 22     |
| Discharge Decrease (%)                  | 13%    | 19%          | 17%    | 9%     | 9%     | 8%      | 9%     | 15%    |

On-field visits to observe and appraise hydraulic structure and crop development conditions in wet and dry season found that the rice remains the main crop in Pusur basin region throughout the rainy and dry seasons (more than 95% of total area areas). Only farmers from Kemiri area are growing corn during the 2nd and 3rd cropping season. Water shortage from canals for crop irrigation usually occurs during the dry season (July to October) and during the land preparation in November to initiate the 1st cropping if the beginning of wet season are delayed. Farmers from most of region are still growing rice in dry season using mainly water from irrigation canal. Only in Kemiri area, rice is substituted by corn during the 2nd and 3rd cropping season. In some region like in Bagor, Bogem and Jetak, the rice is still cultivated during the dry season but only 25 up to 50% of areas of perimeter. Within those region farmers usually apply additional pumping during the dry season to compensate water shortage from irrigation canals and to fulfill correctly the crop water requirements. In the dry season, farmers in the Ploso Wareng area get additional water supply (200-250 L s⁻¹) from the Brambangan and Krusuk areas.

Table 5. Main crops and cropping calendars observed in the studied region.

|                   | Kemiri | Ploso Wareng | Taman  | Wantil | Bagor  | Dolikan | Bogem  | Jetak  |
|-------------------|--------|--------------|--------|--------|--------|---------|--------|--------|
| November – February (Rainy season 01) | Rice   | Rice         | Rice   | Rice   | Rice   | Rice    | Rice   | Rice   |
| March – June (Rainy season 02)         | Corn   | Rice         | Rice   | Rice   | Rice   | Rice    | Rice   | Rice   |
| July – October (Dry season)            | Corn   | Rice         | Rice   | Rice (50%) | Rice (50%) | Rice (25%) | Rice   | Rice   |

| Note : Main crops cover more than 85% of total area |

Most farmers such as interviewed think that hydraulic structures along the primary and secondary irrigation networks are generally working in good conditions. It seems that water schedule is correctly distributed within the region that farmers follow the water calendars between the different irrigation blocks such as applied by Perkumpulan Petani Pemakai Air (P3A) as shown in table 6. During the irrigation network observations, the team could confirm the respondent opinion (and PW information) regarding hydraulic structure conditions. Except the Kemiri area, which presents strong degradations for some hydraulic structures like gates (inlet/outlet) and canal surface (cement/soil compacted), most structures of irrigated region are working normally.

Table 6 recapitulates the farmers’ perceptions about canal water access conditions to fulfill correctly or not the crop water requirements during the dry season. Most of dams are currently full of sediments but lateral water intakes are not affected by soil deposits. Over 8 region identified, strong damages were observed only in Kemiri (dam, canal and gates). For the others 7 region, the hydraulic structures are still working in good conditions. Consequently, further rehabilitation works should be prioritized in Kemiri area.
Table 6. Farmers’ perceptions on irrigation canal water access and crop development conditions in Pusur River basin region.

| DAM Location | Perimeter | Hydraulic structure conditions | Water distribution efficiency | Canal water lack for crops | Crop development conditions | Additional pumping |
|--------------|-----------|--------------------------------|------------------------------|---------------------------|----------------------------|-------------------|
| Upstream     | Kemiri    | Bad                            | Bad                          | Yes, during the 3rd cropping | Good only for 70% of area | No                |
|              | Ploso Wareng | Good                        | Good                         | No                         | Good for 100% of area     | No                |
| Middlestream | Taman     | Good                           | Good                         | No                         | Good for 100% of area     | No                |
|              | Wantil    | Good                           | Good                         | No                         | Good for 100% of area     | No                |
| Downstream   | Bagor     | Good                           | Good                         | Yes, during the 3rd cropping | Good only for 50% of area | Yes               |
|              | Dolikan   | Good                           | Good                         | Yes, during the 3rd cropping | Good for 100% of area     | Yes               |
|              | Bogem     | Good                           | Good                         | Yes, during the 3rd cropping | Good only for 50% of area | Yes               |
|              | Jetak     | Good                           | Good                         | Yes, during the 3rd cropping | Good only for 25% of area | No                |

Despite suitable conditions of hydraulic structures observed in the region and the good system of water distribution pointed out by the key respondents, problems of water shortage from irrigation canal were brought up in Bagor, Bogem and Jetak region. As mentioned above, water shortage usually happen during the dry season (3rd cropping cycle) when farmers feel obliged to apply additional pumping to fulfill the crop water requirements (mainly rice) and to avoid crop yield losses. However, in most of region located in downstream areas, water lacks from irrigation canal are so considerable that farmers cannot cultivate the entire area of region: 50% of area in Bagor and Bogem and only 25% in Jetak area are cultivated in dry season.

According to farmers located in these region, one of the main causes of this hard situation could be related to the unfairness in the Pusur River water access during the dry season. Considering the surface of region, some respondents from downstream areas hold oneself penalized by the quantities of water allocated, which would be much smaller than those delivered in upstream region (Kemiri, Ploso Wareng and Taman). Their perception on such inequity in River water access can be illustrated by comparing the unit inlet discharges (inlet discharge at the head of primary canal divided by the area) of each area (figure 4).

For most region located in downstream areas of Pusur River basin, the unit inlet discharge values in dry season remain lower to 0.45 L s⁻¹ ha⁻¹ whereas there are still superior to 0.50 L s⁻¹ ha⁻¹ in upstream areas. The biggest difference of unit discharge is observed in Ploso Wareng area (1,100 Ha) for which one the unit inlet discharges remain higher to 0.85 L s⁻¹ ha⁻¹ that’s to say more than the double of unit inlet discharges delivered in Wantil, Bagor, Dolikan and Bogem region.

Suitability between primary canal inlet discharge and crop water requirements via the simulation of crop water balance to better appraise the crop hydrous development conditions in rainy and dry seasons. Based on PW discharge data series and farmers cropping information collected during the survey, the analysis focus on the comparison between the available waters from irrigation canals and the crop water requirements. The information as follows was taken into account (figure 4).

1) The most representative cropping calendars:
   - from 15 October to 15 November until 15 February to 15 March for the 1st cropping cycle,
   - from 15 February to 15 March until 15 June to 15 July for the 2nd cropping cycle, and
   - from 15 June to 15 July until 15 October to 15 November for the 3rd cropping cycle.
2) The main crops are those that grow in more than 90% of the perimete area:
   - rice crop in Ploso Wareng, Taman, Wantil, Bagor, Bogem and Jetak region,
   - in Kemiri area, the rice is substituted by corn for the 2nd and the 3rd cropping cycle.
3) As regards the cropping patterns, the main information deal with:
   - an average water height of 100 mm for the rice land preparation,
- a minimal water height of 25 mm and a maximal water height of 75 mm for the rice maintenance water,
- an average soil water content of 150 mm,
- a crop cycle length of 110 to 115 days for rice and corn crop,
- a stop of irrigations 15 to 20 days before harvesting.

Sources: Public Work Klaten.

**Figure 4.** Inlet discharges per hectare. Average values (series: 1998-2012).

4) The crop water balance was analyzed using the methodology in the Bulletin of FAO no 56 (Allen, *et al.*, 1998) [6]. The crop water balance was simulated throughout the 3 cropping cycles and over a period of 10 years, from 1998 to 2007. The Net Irrigation Depth (NID) daily values were cumulated over a 15 days period in order to be compared to the canal inlet discharge values taking into account the network convey efficiency (80%).

5) Impacts of water deficit on crop yields were estimated according to criteria:
   - Irrigation index (100) or irrigation keeping soil water content over threshold of transpiration reduction: The fulfillment rate of crop water requirements by water supplies from irrigation canals is very high and, consequently, the level of water constraint on crop development (and yield losses) is considered as Very Low (VL)
   - Irrigation index (75) or 75% of the reference irrigation is applied: The fulfillment of crop water requirements by water supplies from irrigation canals is high and, consequently, the level of water constraint on crop development (and yield losses) is considered as Low (L)
   - Irrigation index (50) or 50% of the reference irrigation is applied: The fulfillment of crop water requirements by water supplies from irrigation canals is medium and, consequently, the level of water constraint on crop development (and yield losses) is considered as Medium (M)
   - Irrigation index (25) or 25% of the reference irrigation is applied or no irrigation: The fulfillment of crop water requirements by water supplies from irrigation canals is very low and,
consequently, the level of water constraint on crop development (and yield losses) is considered as High (H).

Tables 7 and 8 summarize the level of water constraint on crop development (and yield losses) recorded between 1998 and 2007 under crop water balance simulations.

**Table 7.** Level of water constraint on crop development (and yield losses) under crop water balance simulations in Kemiri, Ploso Wareng and Taman region (upstream areas).

| Perimeter | Calendar | Crop | Level of water constraint on crop development and yield losses (*) |
|-----------|----------|------|-----------------------------------------------|
|           |          |      | 1998  | 1999  | 2000  | 2001  | 2002  | 2003  | 2004  | 2005  | 2006  | 2007  |
| Kemiri    | Nov-Feb  | Rice | VL    | L     | VL    | VL    | VL    | L     | L     | L     |
|           | Mar-Jun  | Corn | VL    | VL    | VL    | VL    | VL    | L     | VL    | VL    |
|           | Jul-Oct  | Corn | L     | VL    | VL    | VL    | VL    | L     | L     | VL    |
|           | Nov-Feb  | Rice | VL    | VL    | VL    | VL    | VL    | L     | VL    | VL    |
| P.Wareng  | Mar-Jun  | Rice | VL    | VL    | VL    | VL    | VL    | VL    | VL    | VL    |
|           | Jul-Oct  | Rice | VL    | VL    | VL    | VL    | VL    | VL    | VL    | VL    |
|           | Nov-Feb  | Rice | VL    | VL    | VL    | VL    | VL    | L     | VL    | L     |
| Taman     | Mar-Jun  | Rice | VL    | VL    | VL    | VL    | VL    | L     | L     |
|           | Jul-Oct  | Rice | VL    | M     | L     | M     | VL    | VL    | VL    | M     | VL    |

(*): VL: Very Low // L: Low // M: Medium // H: High

**Table 8.** Level of water constraint on crop development (and yield losses) under crop water balance simulations in the region located in Pusur basin downstream areas.

| Perimeter | Calendar | Crop | Level of water constraint on crop development and yield losses (*) |
|-----------|----------|------|-----------------------------------------------|
|           |          |      | 1998  | 1999  | 2000  | 2001  | 2002  | 2003  | 2004  | 2005  | 2006  | 2007  |
| Wantil    | Nov-Feb  | Rice | VL    | L     | L     | L     | L     | L     | L     | L     |
|           | Mar-Jun  | Rice | VL    | VL    | VL    | L     | VL    | M     | L     |
|           | Jul-Oct  | Rice | L     | M     | M     | M     | M     | VL    | M     | M     |
|           | Nov-Feb  | Rice | VL    | L     | L     | L     | L     | L     | M     | L     |
| Bagor     | Mar-Jun  | Rice | VL    | L     | L     | M     | L     | VL    | M     |
|           | Jul-Oct  | Rice | VL    | VL    | M     | VL    | M     | L     | L     |
|           | Nov-Feb  | Rice | L     | M     | M     | M     | M     | M     | L     | M     |
| Dolikan   | Mar-Jun  | Rice | L     | L     | M     | M     | L     | VL    | VL    | L     |
|           | Jul-Oct  | Rice | H     | H     | H     | H     | H     |
|           | Nov-Feb  | Rice | VL    | L     | L     | M     | M     | M     | M     |
| Bogem     | Mar-Jun  | Rice | VL    | L     | M     | M     | M     | VL    | M     | M     |
|           | Jul-Oct  | Rice | L     | VL    | M     | VL    | H     | M     | M     | VL    | H     |
|           | Nov-Feb  | Rice | VL    | M     | L     | M     | M     | M     | M     |
| Jetak     | Mar-Jun  | Rice | VL    | M     | VL    | M     | VL    | VL    | M     |
|           | Jul-Oct  | Rice | M     | VL    | L     | VL    | M     | M     | M     | M     |

(*): VL: Very Low // L: Low // M: Medium // H: High

Results from the crop water balance simulations emphasize the good conditions of crop development in Kemiri, Ploso Wareng and Taman area from 1998 to 2007. In Kemiri area (90 ha), such conditions can be explained by the substitution of rice by corn during the 2nd and the 3rd cropping season. Farmers are well aware of water shortage during the dry season and prefer to adapt their cropping system to water resources availabilities by seeding other crops requiring less water than rice like corn, groundnut, beans or cassava (upland crops). In Ploso Wareng area, the entire area (1,100 ha) is cultivated with rice during all the year (3 cycles). However, owing to the good availability of water...
resources from irrigation canal simulation results show there is no water constraint on crop development and yield losses. In Taman area (211 ha) some water constraints can be observed but only during the 3rd cropping cycle with rice crop. According to simulation results, the crop development conditions are pretty different in the region located in downstream areas of Pusur River basin. From Wantil to Jetak area, the water constraint from irrigation canals are significant and affect seriously the crop development conditions.

Water deficits from canals are concerning the 3 cropping cycles throughout the rainy and dry season. In Bagor, Bogem and Jetak region, the situation of crop development could be worse if the entire area of region was cultivated by farmers during the dry season. Due to water shortages in dry season, farmers from Bagor and Bogem only cultivate 50% of the area and those from Jetak only 25%. However, water resources from irrigation canals seem to be very insufficient to fulfill the rice water requirements and farmers must use additional pumping from the surface water table (with significant pumping costs) like in Bagor, Dolikan and Bogem region. In Jetak area, many farmers prefer not to grow crops in dry season.

4. Conclusions
Based on the PRA approach, it is known that various variations in the ease of farmers' access to hydrological buildings and the abundance of water sources in agricultural development in the Pusur Watershed area. Except the Kemiri, most of hydraulic structures seem working in good conditions in the studied region. However, problems of water lacks and crop development were observed in region located in downstream areas of Pusur Watershed, especially during the dry season (June to October, 3rd cropping cycle). Such situation was also highlighted by the results of the crop water balance simulated over a series of 10 years, using the canal discharge data and farmers cropping information. If crops are exclusively irrigated from irrigation canals, the simulation results showed degraded conditions of crop development in the majority of the region located in downstream areas whereas crops look growing to up normally in the region located in upstream zones. In these region, especially in the biggest perimeter of Ploso Wareng area, farmers seem to get the benefit of higher canal discharges during all the year and, in particular, during the dry season.

Especially in kemiri, it has been seen that hydrological structures tend to experience damage which causes loss of irrigation water along the route. As a recommendation, it is better for the government to immediately intervene in handling this matter by involving the active role of P3A in repairing and building irrigation infrastructure so that they have a sense of belonging to be able to take good care of it [10]. According to the information collected in 2019, the Pusur watershed saving activity was carried out by the government in collaboration with the local P3A, including normalizing around the Cokro weir, repairing the Blambangan release weir door as a supplement to increase the discharge to primary irrigation that received flow from the Pusur river and normalization of sedimentation in the tertiary irrigation channel in Kwarasan village to Juwiring district [11].

From the results of the water balance, it shows that several locations in the Pusur Watershed area are starting to lack water. Therefore the recommended recommendation is to increase the conservation of the upstream area of the Pusur river to reduce land degradation in order to be able to maintain sustainable water production in the Pusur watershed area.

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