Irrigation water management to increase planting index in Boyolali Regency, Indonesia

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Abstract. Climate change will have a negative impact on water resources, agriculture, forestry, health and the vulnerability of public infrastructure and the extinction of various species. Water sources as the main means of agriculture, especially rice fields are the main thing in irrigation. Water sources for irrigation of paddy fields in Boyolali include weirs, trenches, springs that are collected in the form of ponds and a small part is a reservoir. Within 2 years after operation, the use of ponds of water for irrigation was able to accelerate yield increases. With various models of water sources, the cropping patterns include paddy-paddy-paddy, paddy-paddy-palawija (crop planted as 2nd crop in dry season), paddy-palawija-palawija and paddy-palawija-fallow. Water management arrangements in each area that use irrigation channels have an Association of Farmers Using Water who is tasked with making a schedule for the distribution of irrigation between blocks, especially if there is water scarcity such as during the dry season. Types of activities that are usually coordinated by farmer groups are pest control, channel maintenance, and irrigation arrangements. For channel maintenance, usually coordinating with the officers of association of water user farmer and development coordinators in their respective villages.

1. Introduction
A region that has a lot of easy water source be used as a development of irrigated technical or region rice field with cropping patterns without fallow. However, climate change can affect the availability of water at the water source and will certainly affect the utilization of the alternative irrigation network. Changes in precipitation patterns affect the hydrological systems, water resources, land degradation, changes in the capacity of irrigation, time of planting, planting season, cropping pattern, crop damage, the area of planting and harvest acreage, productivity, change of habitat and damage to biodiversity [1]. Thus the need for a strategy to anticipate the climate change concerns the direction, policies, guidelines and adaptive agricultural technology on climate change. Conceptually, the adaptation strategy of climate change for crops is the optimization of land/water/irrigation resources, the adjustment of cropping, the adjustment of planting time, the adjustment of crop rotation, the adjustment of the varieties, the development of adaptive technologies that are environmentally friendly [2].

The availability of permanent and feasible to use irrigation network in irrigated rice field, rain-fed rice field, and dry land is the operational strategy for the improvement of the crop index which is directly related to the increase in food production and revenue as well as improving the welfare of farmers [3].

2. Materials and methods
The event was held in Boyolali Regency, Central Java Province, Indonesia in 2016. The method of activity was to survey the source of irrigation water in 14 districts with field counselor and managers of water resources as the informants. The Data were analyzed descriptively.
3. Results and discussion

Boyolali is a region with dry land, rain-fed and irrigated rice fields agro-ecosystem. The condition of rainfall in 2016 as shown in Figure 1. The rainy season occurs in the months of January to April with a rainy day around 13-22 days in each month. Whereas the dry season occurs in the months of July to September. The most dominant food crop commodities are rice, corn, cassava, peanut and soybean with regard to local agro-ecosystems and water sources for irrigation.

![Figure 1. Climate Data in 2016 [4]](image1)

The result of the survey and the focused discussion with field counselor is dominant cropping patterns; paddy-paddy-paddy, paddy-paddy-palawija (crop planted as 2nd crop in dry season), paddy-palawija-palawija and paddy-palawija-fallow. The beginning of the planting period of October 2015 – September 2016 was the month of November (KATAM in October II-III for the southern region of Boyolali, while for the northern region of Boyolali is the Nov III-Dec I). While data verification of water resources, which is a flow irrigation of rice fields listed in Table 1.

![Figure 2. Data of harvested area (ha), productivity (kw ha\(^{-1}\)) and production (tons) of commodities: rice, corn, cassava, peanut and soybean in Boyolali. [5]](image2)
Table 1. The problem of the irrigation water source in Boyolali Regency (data of rice field raw area)

| No | District     | Rice field raw area (ha) based on the BPS 2016 | Water resources and water resource issues                                                                                                                                                                                                 |
|----|--------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1  | Ampel        | 571.06                                        | Water sources come from rain, spring (Simaron) and dam (Sigereng, Padas Plorot, Pule, Siaji Yagan, Mudal, Sisabuh, Keboan and Widodari). The problem is the decreasing water discharge due to the use of the springs for drinking water. |
| 2  | Andong       | 2228.7                                        | Water sources come from rain, Bade reservoir and well pumps. The problem is the decrease in discharge of water from the Bade Reservoir due to the silting of the reservoir.                                                                                                                   |
| 3  | Banyudono    | 1,515.08                                      | Water sources come from some weir of Pepe river and Pengging springs (Drono, Karangkulon, Gisik and Umbul Pengging). The problem is the silting of the river, the destruction of the weir as well as the presence of garbage in the river.                                    |
| 4  | Boyolali     | 294.60                                        | Water sources come from water spring in the form of a pond or reservoir (Umbul Tlatar and Karangboyo reservoir) and dam (Tempel, Pusung, Ampera). The problem that occurs is the silting of the reservoir with the uncontrolled growth of water hyacinth, the siltation of irrigation networks with the amount of land, irrigation networks tertiary yet entirely concreted so that small avalanches happen on the wetland. |
| 5  | Karanggede   | 1,682.34                                      | Water sources come from weir of Serang river and Braholo (dam of Surowangsang, Klumpit, Sempurul, Kedung Jambe and Parean). The problem is the absence of primary networks reparation so that the areas of rice field that are irrigated in the dry season is not optimal. |
| 6  | Kemusu       | 652.43                                        | Water source comes from rain and pump from the River Braholo. However, in the planting season II to meet the cropping pattern paddy-palawija-fallow, some farmers pump water from the Braholo River.                                                                                                                   |
| 7  | Klego        | 1,568.10                                      | Water sources come from rain, the reservoir (Braholo river swipe) and small dam (Panggolo, Kedung Gandrung, Pancoran, Selogan, Grujak and Seretan) from the Braholo river. The problem is the silting of Bade reservoir for about 3 m, so that the water discharge is reduced. The reduction of the water discharge affects the extent of rice field which is narrowed in the dry season. |
| 8  | Mojosongo    | 942.75                                        | Water sources come from springs (Umbul Tlatar) and weirs of Pepe River (Nglayud). The problem that occurs is not yet severe. Just needs a repair on the network of tertiary irrigation.                                                                                                                   |
| 9  | Ngemplak     | 1,401.98                                      | Water sources come from weirs of Pepe River (Kedung Batang Dam) and Cengklik Reservoir (River swipe of Butak River). The problem is silting of reservoirs with plenty of water hyacinth and soil that accumulate in the reservoir. Generally, the water user farmer of the reservoirs is requested to clean the water hyacinth that exists in the reservoir. Besides the silting, blockages in the secondary irrigation network that connects the reservoir to the agricultural land also occurred. |
| 10 | Nogosari     | 2,479.83                                      | Water sources come from the dam of Cemara river (Kedungboyo dam) and Cengklik reservoirs. The problem that occurs is the silting the river caused by the increase of the sediment height of about 3 m at Cemara River. As the silting is occurred, the water discharge of Kedungboyo Dam was reduced in the dry season and the extent of rice field that are irrigated increasingly narrow. While in Cengklik Reservoir, the increasing of the extent of water hyacinth and siltation are occurred. |
11 Sambi 2,204.49 Water sources come from the dam of Butak river near the springs (Umbul Ranacak) in the District of Semarang (Wonontoro dam). The problem is the retrieval of irrigation water with the pump in the path of the irrigation network in Semarang Regency, so that the irrigation water network for Boyolali Regency is reduced.

12 Sawit 1,275.25 Water source comes from springs that accommodated then distributed into arranged irrigation network (Umbul Mangup, Umbul Pundung, Umbul Soka, Umbul Ledok, Umbul Nglese, Umbul Gombang) The problem is river silting due to the sediment. With the presence of sediment, the water which is stored is reduced, resulting in an extent of irrigated rice fields increasingly narrow in the dry season.

13 Simo 2,117.8 Water sources come from weirs of Cemara river (Pulung, Kedung Jangan and Kedung Banteng) and rain. The problem is, the damaged tertiary irrigation channels. As a result, in the dry season, areas of irrigated rice fields which usually planted with rice changed into palawija (especially corn). However, damage to the tertiary irrigation network can be handled by farmers by doing community service of repairing tertiary irrigation. For the damage (loss of the lock of secondary or primary channel door) has not got serious treatment from the related department.

14 Teras 1,423.03 Water source comes from weirs of Pepe river that its water flow passing through the main street of Solo – Boyolali (Penjalinan, Pelmburan, Nglayud, Dlimas, Ngemplak, Gunungtigel, Karangkulon, Magangan and Ngemplak dam). The existing problem is the retrieval of irrigation water from the secondary irrigation network by many farmers, so that there was no clear division of water. The springs that are located in the District of Teras already converted to drinking water, so that acreage in some villages declined in the planting season III.

15 Wonosegoro 1,883.80 Water sources come from weir of Serang river (Penggung, Kedungkopyah and Tretes dam), Repaking river (Kalikidang Dam, Kaliciling Dam, Repaking Dam) and Kebomati river (Kebomati dam). The problem is, the damaged tertiary irrigation channels. As a result, in the dry season, areas of irrigated rice fields which usually planted with rice changed into palawija (especially corn). However, damage to the tertiary irrigation network can be handled by farmers by doing community service of repairing tertiary irrigation. For the damage (loss of the lock of secondary or primary channel door) has not got serious treatment from the related department.

The availability of water in the rice fields depends on the local weather conditions, precipitation, watershed and river's humidity. Therefore, the extent of rice field that can be planted with rice in El Nino year or dry season is narrower than in the rainy season or La Nina year [6]. Besides the water of the river that was dammed, the source of irrigation water from the springs are accommodated in the form of the reservoir [7]. Besides the reservoir, there is a dam of the trench - the building of water conservation (small weir in the natural trenches) that can withstand water and increase the water level to be distributed as irrigation water [8]. In terms of hydrology, there are three terms of drought, namely agro-meteorology drought, hydrological drought and socio-economical drought. Therefore, in anticipating climate change, maintenance of the irrigation network is a strategy in the field operation concerning the agro-meteorological, hydrological and socio-economical drought.

Irrigation water is generally obtained from surface water such as a river, lake, or swamp, as well as a source of underground water. In principle, the calculation of the availability of water is sourced from data of the climate (precipitation and climatology) and river discharge. The data of river discharge are used to determine the flow fluctuations throughout the year. The availability of irrigation water is generally divided into two, namely the availability of water in the land and availability of water in the intake building. Irrigation water requirement is the amount of required water for the growth of rice from planting until harvesting and also the loss that deals with the distribution and use of water [9]. Theoretically, crop irrigation is required as a complement, if rainfall is not sufficient to compensate the water loss of the plant caused by evapotranspiration by considering time, volume and appropriate intervals. By calculating the water balance of the land in the zone of the rooting daily, thus the volume...
and interval of irrigation can be planned [10]. The availability of water determines the cropping patterns, planting time, commodities and varieties. To alleviate poverty in the agricultural land where the source of the water is very rare, to increase production through the development and utilization of reservoir, dam trench, long storage, and building of other water reservoir [3] The Shelter and the utilization of the abundant water is operational strategies which applied to increase food production on rain-fed rice field.

In Boyolali, the sources of irrigation water are weir, dam of the trench, springs that accommodated in the form of the pond and only fractions are the reservoir. One of the districts that have more than two little springs (umbul) as a source of irrigation is a District of Sawit. While the district that has the source of water from the dam is District of Banyudono. Both districts have asynchronous planting time. With the dam, the rice fields that can be irrigated (Banyudono District) are about 1,300 ha (87 % of the raw area), while the entire extent of rice fields are around 1,500 ha.

**Figure 3.** The source of irrigation water in Sawit District (Umbul Mungup II, Umbul Ledok, Jetak Dam and Baran Dam)

**Figure 4.** The source of irrigation water in the Banyudono District (Drono Dam and Gisik (a slightly sloping trail by the sea extending between the lowest sea boundary and other patterned terrain such as steep cliffs or grasslands) of the Pepe River) and in the Districts of Andong (artesian and pump well)

Of the 19 (nineteen) there are 4 (four) districts that have the widest dry land and rain-fed rice field namely Cepogo, Juwangi, Musuk and Selo. In the fourth district, the most dominant cropping patterns are rice in the rainy season and horticulture in the planting season II and III. Rain-fed rice field that the cropping index could potentially be developed from 100 to 200 with a source of irrigation from artesian wells in every area of 1000 m$^2$ is in the Andong District. The existence of the irrigation water and the channel type is indicated in Table 2. Types of irrigation channels which is; permanent is 63.16% and simple is 36.84%, the channel conditions are quite good (68.42%), good (15.79%) and damaged 15.79%. The presence of irrigation water each year in 66.67% of the territory of Boyolali is sufficient and the rest (33.33%) is still lacking (Nogosari, Simo, Wonosegoro, Andong). The presence of irrigation water each year in 66.67% of the territory of Boyolali is sufficient and the rest (33.33%) is still lacking (Nogosari, Simo, Wonosegoro, Andong).

In determining the planting season in most of the region (Ampel, Nogosari, Simo) stick to the principle of local wisdom (pranoto mongso) by reading natural phenomena such as autumn, cottonwoods are flown, the growth of tubers and others. In setting the water management in each region that uses irrigation channels, the officer’s association of water user farmer made the schedule of the division of irrigation between blocks in the dry season. The relationship between farmer group and the association has been running well in the context of the maintenance of the channel. Irrigation water is required in a sufficient amount to meet the needs of evapotranspiration, percolation and lost on the channel. This means the water needs ranged from the available water until field capacity which depends on the physical quality of the soil. The adequacy of water and technology of irrigation is able to guarantee
the planting pattern in a year and setting time of planting, as a result the use of water increased. Commodity that is cultivated also have economic value and scale agribusiness [11]. A variety of local wisdom cannot be fully used as a reference in determining the beginning of the planting season due to climate change and the more difficult it is to find indicators marker of the season. Fluctuations in precipitation is very dynamic due to the emergence of climate anomalies to cause a shift of the beginning of the rainy season and dry season. Chief among the culprits of the loss of opportunities in food production and agriculture is the poor condition of the supporting infrastructure [12]. The rehabilitation of the irrigation network of the 3-million-hectare damaged area, or 52% of the total irrigation area, able to expand irrigation services thereby increasing the cropping index of 0.3 or more [3].

Table 2. The existence of the irrigation water and the type of irrigation channels in Boyolali Regency, 2016

| No | Kece  | The existence of the irrigation water | The extent of irrigated rice field in Dry Season (ha) | Precipitation | Channel type | Channel Conditions | Irrigation methods |
|----|-------|--------------------------------------|-----------------------------------------------|--------------|--------------|-------------------|-------------------|
| 1  | Ampel | adequate, less                        | 129                                           | Enough       | permanent, simple | adequate, broken | Macak-macak (regulated) |
| 2  | Andong| Less                                  | Less                                          | Permanent    | Permanent      | Good              | Puddle system     |
| 3  | Banyudono | Enough                      | 1,300                                         | Enough       | Permanent      | Enough            | Macak-macak (regulated) |
| 4  | Boyolali | Enough                      | 177                                           | Enough       | permanent, simple | Adequate; broken | regulated puddle and intermittent irrigation |
| 5  | Cepogo | Enough                               | 53                                            | Enough       | Permanent      | Good              | Puddle system     |
| 6  | Juwangi | Enough                               | 150                                           | Less         | Permanent      | Enough            | Puddle system     |
| 7  | Karanggede | Enough                            | 400                                           | Enough       | Simple permanent, simple | Enough | Puddle system puddle and regulated Macak-macak (regulated) |
| 8  | Kemusu | Enough                               | 508                                           | Less         | Permanent      | Adequate; broken | Macak-macak (regulated) |
| 9  | Klego  | Enough                               | 1,370.3                                      | Enough       | permanent      | Enough            | Macak-macak (regulated) |
| 10 | Mojosongo | Enough                            | 101.16                                       | 892.5        | Simple         | Good              | Macak-macak (regulated) |
| 11 | Musuk | Enough                               | 15                                            | 283          | Permanent      | Enough            | Macak-macak (regulated) |
| 12 | Ngemplak | Enough                            | 155                                           | 15           | Permanent      | Enough            | Puddle system     |
| 13 | Nogosari | Less                               | 1,370.3                                      | 283          | permanent      | enough            | Macak-macak (regulated) |
| 14 | Sambi | Enough                               | 101.16                                       | 508          | Simple permanent, simple | Enough | Macak-macak (regulated) |
| 15 | Palm  | Enough                               | 53                                            | 15           | Permanent      | Enough            | Macak-macak (regulated) |
| 16 | Selo  | Less                                 | 15                                            | 283          | permanent      | Enough            | Macak-macak (regulated) |
| 17 | Simo  | Less                                 | 1,370.3                                      | 15           | permanent      | Enough            | Macak-macak (regulated) |
| 18 | Teras | Enough                               | 155                                           | 155          | Enough         | Enough            | Puddle system     |
| 19 | Wonosegoro | Less                               | 155                                           | 155          | Enough         | Enough            | Puddle system     |

One of the irrigation networks that is considered effective in the system of land irrigation is a pond. Pond have a positive impact on increasing food production and agriculture. The pond was done in crowd-sourcing and communal work by empowering farmers around. In operation, the construction of ponds and small dams is more efficient and the cost of maintenance is cheaper, even though farmers own efforts [3]. Irrigation facilities such as reservoir and dam of the trench need to get the attention of the relevant agencies and the community of water users’ farmer in terms of maintenance, repair and rotation of water usage. Silting of small rivers, large rivers and the tertiary channels can be cleaned by
farmer groups by communal work. However, when the damage occurs on the primary and the secondary channel, then the farmer group hopes for a government assistance in the reparation. The condition of the irrigation channel at the time of the survey, mostly in an adequate to good state. The presence of irrigation water each year is sufficient to irrigated region, the condition of precipitation in the current year is adequate to excess in some areas. The calculation of the adequacy of irrigation water is determined by the adequacy of the water. The value of the adequacy of the water is the difference between water availability in a region and in a period of planting with the water needs of the crop in each season [13]. Therefore, to overcome the problem of lack of water in the dry season, there are two keywords namely: appropriate management of the water and the effort to save water. It is necessary to distribute water in turn, if the discharge of irrigation water is limited [14]

4. Conclusion
Climate change can affect the availability of water in water sources and will certainly affect the use of alternative irrigation networks. Changes in rainfall patterns affect hydrological systems, water resources, land degradation, changes in irrigation capacity, planting time, planting season, cropping patterns, crop damage, planted area and harvested area, productivity, habitat change and biodiversity damage. One of the tangible sources of water that influence the system of agriculture is a reservoir and dam of the trench. Pond (*embung* in Indonesia) have a positive impact on increasing food production and agriculture. The utilization of water of the ponds for irrigation is able to accelerate the improvement of the results. The pond was done in crowd-sourcing and communal work by empowering farmers around. With variety of models of the water source, so that the planting pattern in Boyolali is a paddy-paddy-paddy, paddy-palawija, paddy-palawija-palawija and paddy-palawija-fallow. There are officers of association of water user farmer who set the water management in each region which uses irrigation channel charge to make a schedule of the division of irrigation between the blocks, especially if there is a shortage of water such as in the dry.

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