Water deficits in Bogowonto

Evaluation of hydrological effects of stakeholder prioritized response options for the agricultural water deficits in Bogowonto, Indonesia

by

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Contents

Preface

This master thesis is written as part of my Master program Civil Engineering and Management at the University of Twente. This research aims to involve stakeholders in the decision process on measures which decrease the agricultural water deficit in Indonesia. The study is carried out during a collaborative internship at the Gadjah Madah University, Yogyakarta and the Faculty of Engineering Technology, Enschede.

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Summary

Evaluation of hydrological effects of stakeholder prioritized response options for the agricultural water deficits in Bogowonto, Indonesia.

Indonesia is a tropical country situated in South-East Asia that faces water scarcity during the dry season. The yearly returning agricultural water deficits caused by periods of insufficient rain, lack of water retention capabilities, degraded irrigation infrastructure and inefficient management of the irrigation weirs result in sup-optimal cropping conditions for the farmers who depend on the irrigation water flows. The National Middle Term Development Plan (RPJPN) of the Indonesian government includes options to increase the water availability and reduce the agricultural water demand. However, the RPJPN does not include the opinions of the local stakeholders in the decision process on measures which reduce the water deficits, nor does it include a specific assessment for the present and future hydrological conditions of Bogowonto.

The overall objective of this study is to select potential measures for the Bogowonto catchment to decrease the agricultural water deficits by following a participatory approach to obtain preferred measures and by applying a water allocation model which addresses the spatial and temporal variations in the agricultural water deficit. This study includes the construction of a water allocation model with multiple scenarios for climate variability (i), results from participatory meetings for the up-, mid- and downstream irrigation weirs (ii) and statements on stakeholder prioritized measures to assess the agricultural water deficit (iii). Based on this, the historical (1992-2012) and future (2025-2045) agricultural water deficits are simulated and a set of measures is proposed based on the prioritization of the stakeholders and a multi-criteria analysis. These results can be of great value if the government is recipient to include the opinion of local stakeholders in the process of decreasing the agricultural water deficit. Moreover it can provide direction for future catchment plans of Bogowonto.

Main findings of this study are:

- For the upstream irrigation weir the agricultural water deficit varies around 350 [330-370] mm for the driest simulated year. The brackets show the minimum and maximum value as modeled by the climate scenarios for the driest year. The months May-June and October-November are the largest contributors to the cumulative annual water deficit, as a direct result of the low rainfall in these periods and the high agricultural water demand. For five out of the twenty simulated years the agricultural water deficit exceeds 50 mm/year. In other words, every four years the annual water deficit exceeds 50 mm. This value is significantly lower compared to the mid- and downstream irrigation areas, mainly because the upstream area receives more precipitation.
- For the midstream irrigation weir the agricultural water deficit is 750 [620-810] mm for the driest simulated year. The peaks of this cumulative annual water deficit take place during May, June and October. Sixteen out of twenty years have a water deficit which exceeds 50mm per year. To put it differently, almost every year the annual water deficit exceeds 50 mm.
- For the downstream irrigation weir the future agricultural water deficit is 650 [750-520] mm per year for the driest simulated year. The peak of the cumulative annual water deficit takes place

during October. Thirteen out of the twenty years have a water deficit which exceeds 50mm per year. In other words, every one and a half year the annual water deficit exceeds 50 mm.

- The participatory sessions illustrated the rehabilitation of the irrigation infrastructure was preferred out of all simulated measures by all stakeholders, which can be explained by the current degraded status of the irrigation infrastructure in Bogowonto. Secondly the stakeholders from the mid- and downstream irrigation weirs preferred the construction of an upstream reservoir that would satisfy the larger irrigation demand during periods of insufficient rain like May, June and October. Enrolling a new cropping pattern was not preferred by the stakeholders, due to the lack of successful examples at neighboring farms and alternatives like the reservoir and irrigation efficiency were much more popular.
- The stakeholders in this study are the farmers at the irrigation weir, the employees of the irrigation weir and the local government. Other measures which were proposed by the stakeholders like small rain fed reservoirs, heightening of river banks to stop the annual floods or stopping illegal extraction by farmers from surface- or groundwater have not been selected for simulation. These measures are outside the scope of this research, or RIBASIM was not able to simulate such a measure or the level of scale was inappropriate. During the final participatory session the local government proposed the combination of the measures 'irrigation efficiency + reservoir', since none of the measure was able to reduce the annual water deficit to such an extend it satisfied the stakeholders.
- For the upstream irrigation weir the maximum water deficit decreases from 350 [330-370] to 0 mm for the driest simulated year. During none of the 20 simulated years a water deficit is present. This means no water deficits are expected for the future.
- For the midstream irrigation weir the maximum water deficit decreases from 750 [620-810] to 250 [220-260] mm considering the driest simulated year. In addition, three out of the twenty annual simulated years still exceed 50 mm per year. To put it in another way, roughly every seven years a water deficit takes place which exceeds the annual water deficit of 50 mm.
- For the downstream irrigation weir the maximum water deficit decreases from 650 [750-520] to 90 [80-100] mm for the driest simulated year. It is expected every seven years the annual water deficit still exceeds the 50 mm.

These results lead to the following recommendations for the operational management of Bogowonto catchment:

- Firstly the measures "irrigation efficiency" and "construction of the reservoir" are able to positively contribute in the reduction of the agricultural water deficit for 2025-2045 and are supported by the majority of the stakeholders which effectuates a positive implementation of these measures.
- Secondly is it recommended to perform research on the current quality of the irrigation channels and decide which parts should be replaced to achieve an irrigation efficiency of at least 65% in 2035.
- Thirdly if one is considering the construction of the reservoir, it is recommended to perform research to the exact location and dimensions of the reservoir, which should be communicated to the local community in an early stage. In this way added value for the local community can be developed and a win-win scenario is established for the farmers, civilians and government.

1 Introduction

Paragraph 1.1 covers the motivation for this research. The specific contribution of this research is covered by the research objective described in paragraph 1.2. Consequently, the research questions are presented in paragraph 1.3. Finally, paragraph 1.4 presents an outline of the subsequent chapters.

1.1 Motivation

Indonesia is a tropical country situated in South-East Asia that faces water scarcity during the dry season. With agriculture being one of the largest water consumers, 54% of the total agricultural water demand is used for the production of rice (Bulsink, 2010). During periods of insufficient rain the need for irrigation water becomes more urgent. This irrigation water is crucial for crop growth to overcome dry periods. Also due to the high population pressure on Java, it is expected more water is necessary in the time to come. From 1945 to 1995 the population on this most densely populated island of Indonesia increased from 47 million to 113 million (Verburg, 1999). Irrigation works have been build during the last decades to keep up with this growing water demand. However, the degraded infrastructure and sub-optimal control of the irrigation works resulted in large water deficits for the agriculture. The lack of real-time data for managing these irrigation weirs and the degraded condition of the irrigation works have resulted in a poor future perspective for some catchments in Indonesia (Balai PSDA Probolo, 2014).

In accordance with Article 4 of Law Number 25 year 2004 on National Development Planning, the National Long Term Development Plan (RPJPN 2005-2025) aims to achieve the development goals as mandated in the Preamble to the Constitution of 1945. A part of this is the Agriculture Ministry's Strategic Plan which addresses the agricultural challenges for the current period of 2010 to 2014 (Peraturan Menteri Pertanian, 2011). To cope with the degraded agricultural infrastructure and sub-optimal management, the Ministry of Agriculture targets to achieve self-sufficiency on the long term for Indonesia for rice, corn, soybeans, sugar and beef by providing more subsides for technical developments and better regulations on fertilizer needs and seeds. A program for infrastructure and facilities revitalization is still running to help improving the current degraded infrastructure of irrigation.

Although the Agriculture Ministry's Strategic Plan mentions a lot of opportunities to boost the agricultural sector, it lacks the enforcement to successfully execute these plans. Many agricultural works have not properly been maintained or upgraded during the last decades. For example the building of a planned reservoir is postponed due to conflicts with the local community (BBWS Serayu-Opak, 2014). This shows improvements can be made in communication and interaction with the local community in the decision making process. Secondly the current models that are used to calculate the water supply and demand simulate the complete Serayu-Opak catchment. Due the size of this catchment less attention is given to the local problems and needs present at a catchment scale. A more detailed analysis of the hydrology of a catchment might help in a better understanding of the current system.

The overall purpose of this study is to select potential measures for a catchment in Indonesia to decrease the agricultural water deficit by a participatory approach and by applying a model which simulates spatially the water supply and demand within this catchment (paragraph 1.2). Water demand in the context of agriculture, is the as the amount of water needed for the optimal growth of the cultivated crop. Water supply is the amount of water which is available for the irrigation of the crops including processes like evaporation, infiltration and the water needs of other consumers. Water deficit is the difference in water supply and demand, often expressed in mm. Simulating the spatial and temporal distribution of the water deficit and applying a participatory approach to find community supported measures, helps to decrease the water deficits. This approach also provides opportunities to model future water needs and supplies under different climate variability scenarios. These future scenarios can include measures that are suggested by the local community to decrease the agricultural water deficit. This will result in new insights which might be useful for long-term master plans for the Ministry of Agriculture and help our hydrological understanding of the behavior of agricultural water deficits in tropical areas.

For this study the catchment of Bogowonto is selected, located in central-Java. This area is already intensively studied through a collaborative PhD-program between the University of Twente and the Gadjah Mada University (Marhaento, 2014). This collaborative program provides valuable contacts and data for setting up this research. Because for other catchments in Indonesia no data, contacts or budget is available, this research will make use of the already provided data and contacts at the Gadjah Mada University in Indonesia and the University of Twente. Part of this research has been executed at the BBWS Serayu-Opak, a governmental organization which is in charge of the water resource management in this area. They are eager to understand the hydrological conditions of this catchment to apply appropriate measures to ensure the best water resources conditions for its civilians, industry and agriculture, now and in the future.

A more detailed description of the research objective is presented in paragraph 1.2. The resulting research questions are presented in paragraph 1.3. Paragraph 1.4 presents an overview of all chapters in this research.

1.2 Research objective

The overall objective of this study is formulated as:

> Select measures to decrease the annual agricultural water deficit for Bogowonto catchment for the period 2025-2045 by modeling proposed measures of stakeholders in RIBASIM and discussing these measures with the same stakeholders from the up-, mid- and downstream irrigation weirs.

The selection of the period from 2025-2045 is for pragmatic reasons. The Intergovernmental Panel on Climate Change (IPCC, 2013) provides climate projections for 2035 and available time series of hydrological data in Bogowonto have a length of 20 years, hence the period of 2025-2045 is chosen. The stakeholder proposed measures are seen as possible options for decreasing the agricultural water deficit in Bogowonto. These measures are retrieved during interviews and participatory sessions with farmers, local employees of the irrigation weir and the local government.

1.3 Research questions

The following research questions have been formulated to meet the research objective:

1. What are the current (1992-2012) and future (2025-2045) agricultural water deficits for the Bogowonto catchment?
   a) What is the annual and monthly agricultural water deficit for 1992-2012 for the up-, mid- and downstream irrigation weirs?
   b) What are appropriate scenarios to address future climate variability for 2025-2045 for central-Java, Indonesia?
   c) Between what ranges varies the agricultural water deficit for 2025-2045 for the up-, mid- and downstream irrigation weirs?

2. Which measures are preferred by the up-, mid- and downstream stakeholders in the Bogowonto catchment to decrease the annual agricultural water deficit for 2025-2045?
   a) Who are the main stakeholders for the up-, mid- and downstream irrigation weirs regarding irrigation management?
   b) Which measures are proposed to decrease the annual agricultural water deficit?
   c) What are the effects of individual measures to the simulated agricultural water deficit under different future scenarios for water availability and demand?
   d) To what extend do the simulated measures satisfy the interests of the stakeholders?

1.4 Research outline

To construct a water balance model, hydrological data for the Bogowonto catchment and technical data for the present water resource infrastructure are necessary. Chapter two describes the study area (2.1) and present irrigation infrastructure (2.2). Also this chapter gives an overview of the data requirements for the model and assesses the quality of the available data (2.3).

The applied methods to answer each research question are presented in chapter three. For assessing the first research question, which addresses the present and future agricultural water deficit, a water balance model should be selected. This model should be able to simulate the agricultural water deficits in Bogowonto (3.1). Subsequently the model is implemented for the Bogowonto catchment and available data are adjusted and implemented (3.2). The second research question addresses possible measures which decreases the agricultural water deficits. By interviews and participatory meetings the preferences of the stakeholders are retrieved (3.3). Furthermore by multi criteria analysis three measures are selected for simulation in the water allocation model (3.4).

Chapter four present the results of the model simulations for the agricultural water deficits in Bogowonto. To assess the quality of the model, a validation is done by comparing the simulated and observed discharges (4.1). The annual and the monthly water deficits for 1992-2012 (4.2) and 2025-2045 (4.3) are shown for multiple climate variability scenarios. This final paragraph will provide an overview when and where water deficits are present.

Chapter five presents the results of the executed interviews and participatory meetings and shows the simulated effects of the stakeholders proposed measures on the future water deficit. First a selection of the stakeholders for these sessions is carried out (5.1). Secondly, during interviews and participatory meetings their problems and proposed solutions regarding water resources management in Bogowonto are collected (5.2). This is done for three locations: up-, mid- and downstream. For each location - measures are simulated in the water balance model and the effect of each measure is presented to the same stakeholders again (5.3). During a participatory session at each location, a consensus on the preferred solution is retrieved. Based on the preferences of the stakeholders from the up-, mid- and downstream locations and by a multi-criteria analysis, the final solution package is presented and simulated (5.4).

Chapter six addresses the discussion. Finally chapter seven outlines the conclusions (7.1) and the scientific and operational recommendations (7.2).

2 Study area and data

First a general introduction is given of the hydrological and geographical characteristics of this catchment (2.1). The next paragraph looks at water related infrastructure and analyzes which irrigation weirs and crop types are present at these irrigation weirs (2.2). The last paragraph presents the available hydrological data for this research (2.3), as input for the model in chapter three.

2.1 Bogowonto catchment

The Bogowonto river is one of the largest rivers in Central Java and plays a crucial role in supplying irrigation water for thousands of hectares of paddy rice. Figure 2.1 shows that the Bogowonto catchment is situated in the middle of the island of Java and is shared by four districts: Purworejo, Magelang, Kebumen and Kulon Progo. The Bogowonto catchment extends over 597 km^2 and is situated between latitude $7^0$23’ – $7^0$54’ South and longitude $109^0$56’ – $109^0$10 East. The Bogowonto river and its main tributary, the Kodil River, flow from the slopes of Mount Simbung (3.375m above sea level), forming the boundary with both the Serayu and Progo river basins. Volcanic cones characterize the upper catchment, with slopes exceeding over 40%. The middle and lower parts have denudated hills and mountains. This results in large loads of sediment being transported by the Bogowonto river (Ministry of infrastructure, 2003). In the downstream estuary the river mouth is sometimes closed by the alongshore sediment transport. This causes local floods, sometimes displacing hundreds of households (BBWS Serayu-Opak, 2014).

The average annual precipitation over the Bogowonto basin reaches to above 3.000mm/year and exceeds 5000 mm/year at the slopes of Mount Simbung (Ministry of infrastructure, 2003). Therefore the mid-and downstream areas are more sensitive to water deficits. At the coastal plain the annual precipitation is lower compared to the average precipitation, caused by the lower altitude and the influence of ocean winds. The mean annual discharge at the river mouth is 589 m^3/sec for the period 2002-2011 (Marhaento, 2014). More details on the spatial distribution of the rainfall for the Bogowonto catchment can be found in appendix A.

The land use is dominated by forest and agriculture (Marhaento, 2014). The upper part is known for its rich variety of cropping types like peanuts, soya beans and chili. Also the up- and midstream sections are known for wood production, especially the exploitation of the Pioneer tree (BBWS Serayu-Opak, 2014). In general there are two types of forest, dependent on their ownership. The first is state forest, i.e. a homogenous forest which is owned by a state owned company. The second is community forest, forest owned by public, mostly dominated by mixed-planting multipurpose trees which can be used for wood production, palm oil and many other purposes. Agriculture is dominated by lots of paddy fields. Further upstream, more dry land crops like chili can be found. A map showing the distribution of these land use types for Bogowonto is presented in appendix B.

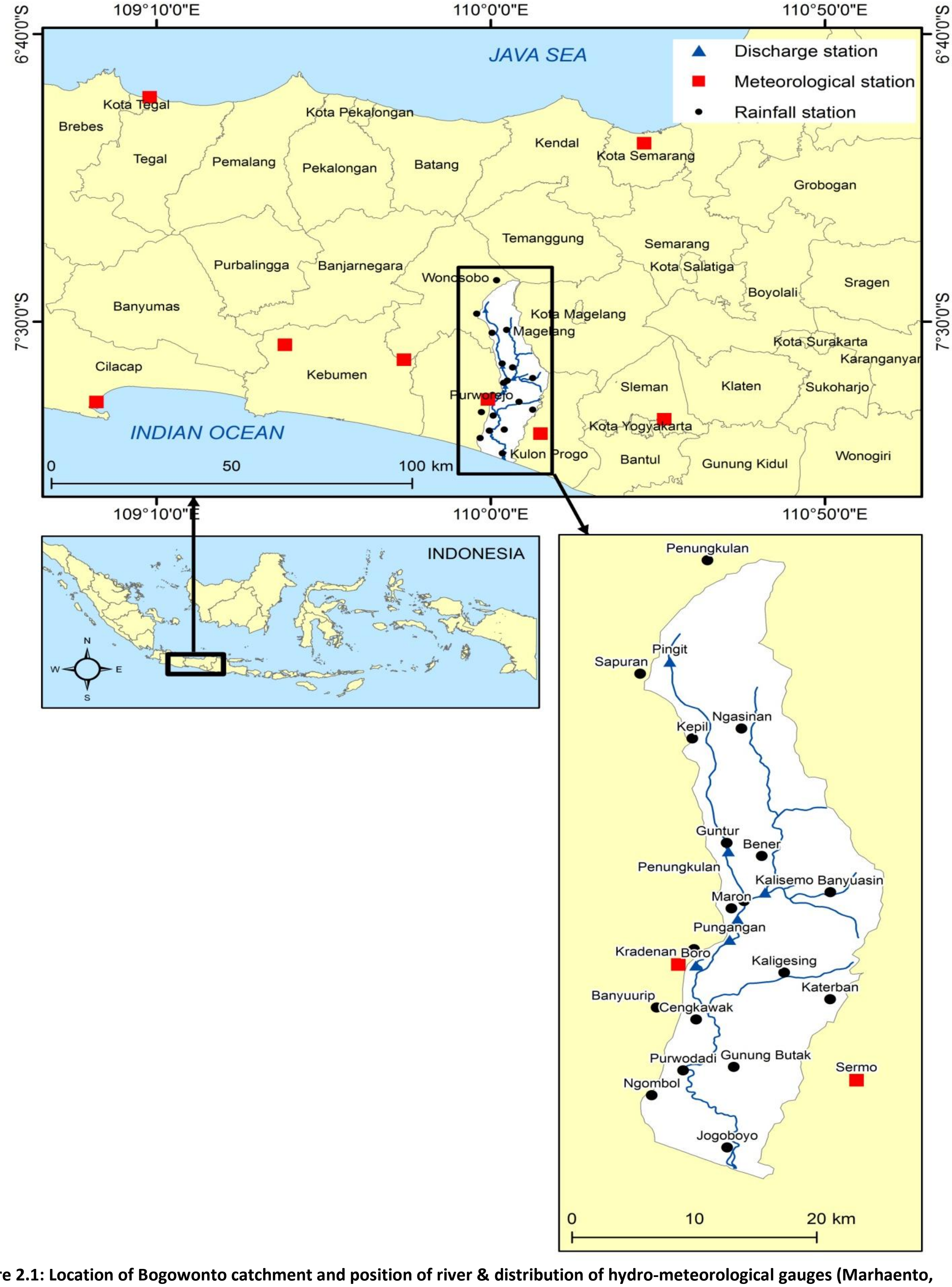


Figure 2.1: Location of Bogowonto catchment and position of river & distribution of hydro-meteorological gauges (Marhaento, 2014). Black = rainfall stations, red=meteorological station, blue=discharge station.

2.2 Present irrigation infrastructure

This paragraph introduces the three selected irrigation weirs (2.2.1) and covers the irrigation weir specifications and the cropping types on each irrigation weir (2.2.2).

2.2.1 Irrigation weirs Bogowonto river

A schematization of the Bogowonto river and branches is presented in figure 2.2. Ten irrigation weirs are shown in figure 2.2, recognizable by the green box or green line. Balai Probolo (2014) states that probably 1-3 additional small weirs are present in this area, but they have not been included in their administrative management, due their insignificant water consumption (estimated less than 100 ha of irrigated land in total) (Balai PSDA Probolo, 2014). Compared to the largest irrigation intake Boro of 5136 ha, it is assumed that these un-managed irrigation nodes can be neglected. In figure 2.2 the five green boxed irrigation weirs show which irrigation weirs are schematized in the model. These weirs have been selected based on two criteria: data availability and size of the irrigation field. Weirs smaller than 300 ha (Pingit, Semagung, Kaliduren, Kandon) are considered insignificant due their small water demand (Balai PSDA Probolo, 2014). No weirs larger than 300 ha without data are present in this area.

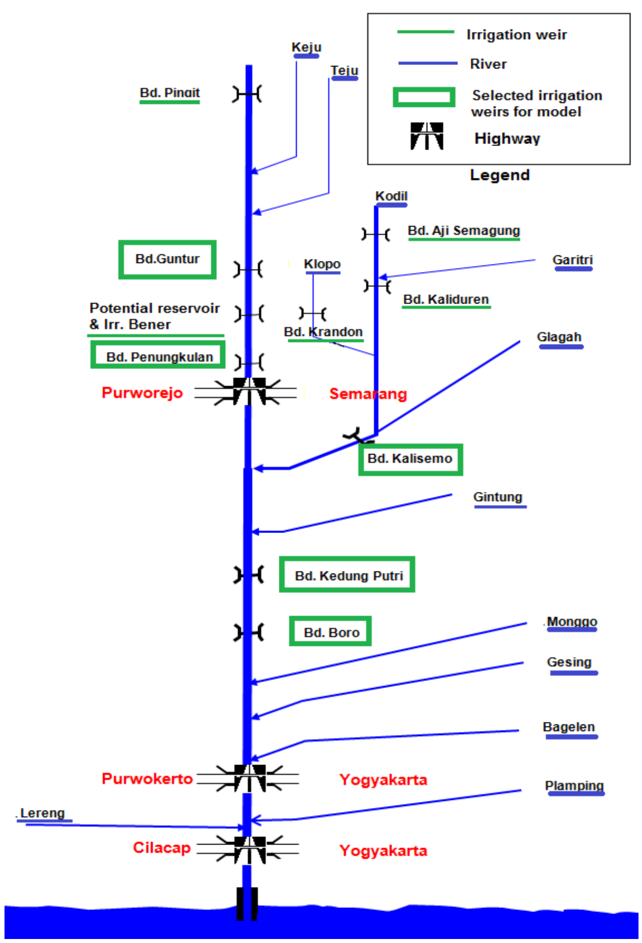


Figure 2.2: Schematization irrigation weirs along the Bogowonto river.

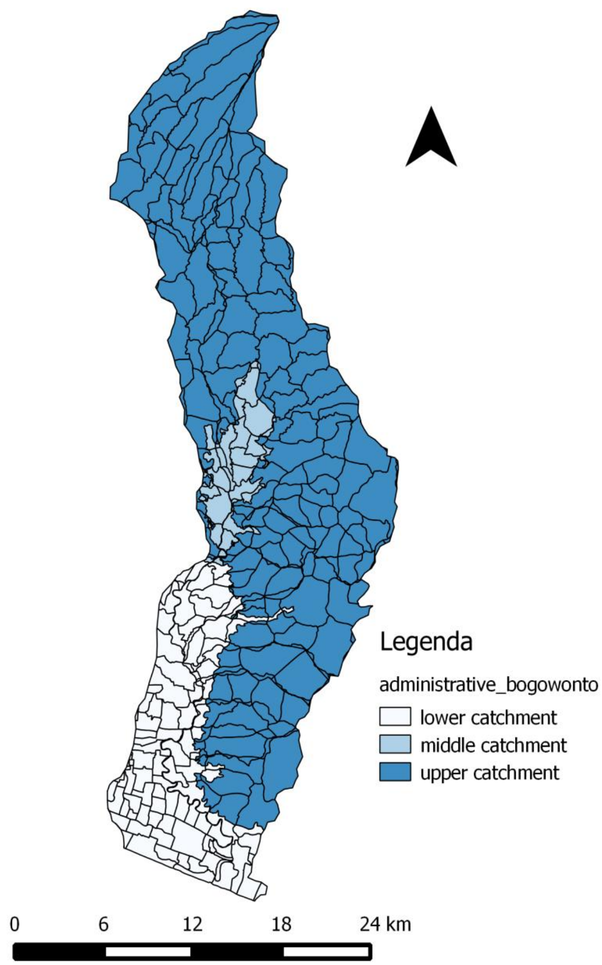


Figure 2.3: Division in up-mid-and downstream area, based on DEM (Marhaento, 2014).

2.2.2 Up-mid and downstream irrigation weirs and crop type

The upstream part of the Bogowonto river is situated in the district of Wonosobo. In this area the Pingit, Guntur and Penungkulan irrigation weirs are situated. In the upstream area the river is characterized by large rocks and a strongly variable discharge due to intensive rainfalls (figure 2.4a). West of the Bogowonto river, the branches of the Kodil and Glagah contribute to the main flow (figure 2.2). Dry-land crops are most common here, however also paddy fields can be found (figure 2.4b). The irrigation surfaces of these weirs are around each around 300 ha.

Figure 2.4a: Bogowonto river north of Pingit weir **Figure 2.4b: Farmer at Guntur irrigation area with paddy rice**

In the mid-stream part of Bogowonto, the weirs Kalisemo and Kedung Putri are situated. The second weir is by far the largest midstream weir irrigating 4340 ha of land (figure 2.5a and 2.5b) (Balai PSDA Probolo, 2014). Typical dry-land crops found here are chili, peanuts and soya beans. A lot of irrigation water is used for paddy fields.

Figure 2.5a: Weir at Kedung Putri in main river **Figure 2.5b: Paddy rice field at Kedung Putri**

In the downstream part of the Bogowonto river, the Boro weir is situated. This is the largest weir of the Bogowonto catchment serving 5136 ha of paddy fields (Balai PSDA Probolo, 2014). Via an enormous network of secondary and tertiary irrigation channels all of these paddy fields are reached. Most of the paddy rice is found in this region, due the flat land. Finally, multiple small creeks confluence with the Bogowonto river downstream of the Boro wear (figure 2.2). The Lereng channel connects the

Bogowonto river with the Cokroyasan river. This channel is used to divert the excessive discharge during very wet periods to the Indian Ocean.

Figure 2.6a: Irrigation intake downstream of Boro weir

Figure 2.6b: Example of instabilty and erosion of outer slopes embenkment primary irrigaton channel Boro

In general the Bogowonto catchment contains many larger and smaller sized weirs for the irrigated paddy fields. Dry land crops are most found in the upstream part. The quality of the current infrastructure for irrigation is poorly due sedimentation in the irrigation channels and leakage through degraded dikes (figure 2.6b). As can seen in figure 2.1, multiple measurement stations for precipitation, discharge and temperature are present in this area. The quality and quantity of these periods of this hydrological data will be assessed in the next paragraph.

2.3 Hydrological data

This paragraph presents the available hydrological data for this study. The best data will be selected for simulation of the current (1992-2012) and future (2025-2045) water deficit in Bogowonto. The precipitation, evaporation and discharge data are presented in sections 2.3.1-2.3.3. The analysis of the inflow and runoff series for the water districts in Bogowonto is performed in section (2.3.4).

2.3.1 Precipitation

Daily precipitation data (mm/day) have been obtained from the Balai PSDA Probolo office in Purworejo for in total 18 rainfall stations for the combined provinces of Purworejo (mid- and downstream) and Wonosobo (upstream) for the period 1990-2011. The spatial distribution of these 18 rainfall gauges is shown in figure 2.1. Precipitation data from BBWS Serayu-Opak (2014) only contained maximum rainfall rates, and therefore Balai PSDA Probolo is the only source of data.

In general the quality of the measurements of these rainfall gauges is considered moderate, since incomplete data result in uncertainty whereas a zero value should be interpreted as 'Not a Number' or indeed 0 mm of rainfall. To assess whether such an uncertainty is present, the data are compared with a nearby rainfall station for a decisive answer. In case the value is incorrect, the incorrect value is replaced by the average value for that time step of the complete data set.

Table 2.1: Rainfall stations Bogowonto. NC=Not Complete data, periods are missing, C=Complete data (Marhaento, 2014)**.**

Station Name	Type of station	Data periods	Resolution	Conditions
Banyuurip	Rainfall	1992-1997, 2003-2011	Daily	NC
Banyuasin	Rainfall	1990-2011	Daily	NC
Bener	Rainfall	2008-2011	Daily	NC
Cengkawak	Rainfall	1992-2011	Daily	C
Guntur	Rainfall	1990-2011	Daily	NC
Gunungbutak	Rainfall	1990-2011	Daily	C
Jogoboyo	Rainfall	1991-2011	Daily	C
Kaligesing	Rainfall	1990-2011	Daily	NC
Katerban	Rainfall	1990-2011	Daily	C
Kedungputri	Rainfall	1990-2011	Daily	C
Kepil	Rainfall	1990-1999	Daily	C
Maron	Rainfall	1990-2011	Daily	C
Ngasinan	Rainfall	1990-2011	Daily	NC
Ngombol	Rainfall	1992-2011	Daily	NC
Penungkulan	Rainfall	1999-2011	Daily	C
Purwodadi	Rainfall	1992-2011	Daily	C
Purworejo	Rainfall	1990-2011	Daily	NC
Sapuran	Rainfall	1990-2011	Daily	C
Kradenan	Meteorology	2002-2011	Daily	C

2.3.2 Reference evaporation

Four actual evaporation series are available, shown in figure 2.7 (Balai PSDA Probolo, 2014; Gracia, 2014).

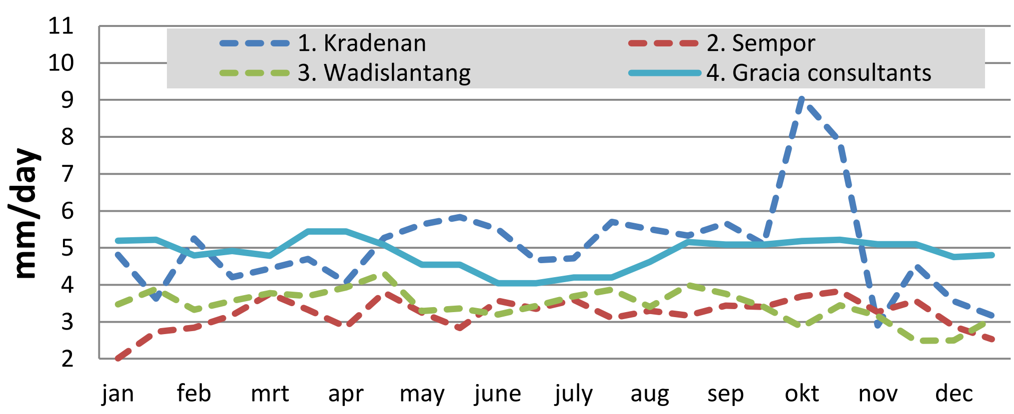


Figure 2.7: Reference evaporation for 4 locations in Serayu-Bogowonto for the year 2005.

Kradenan is located just west of the city of Purworejo, close to the Boro weir. Sempor and Wadislantang are located at big natural lakes in the vast area of Serayu-Bogowonto. For the Gracia time series the exact measurement location is unknown, but inside the Bogowonto catchment and assumed to be at an altitude between 50-300m above sea level in the Bogowonto catchment (Gracia, 2014).

Sempor and Wadislantang are 100km away from the Bogowonto catchment. Moreover they are located near large lakes, and therefore not representative for the evaporation above land. Thus Sempor and Wadislantang are not suited for this research.

The climate station Kradenan is located just across the western border of Bogowonto and therefore already more suited than Sempor and Wadislantang. However in 2005 during the months October and November an extreme value in evaporation is recorded of 8.5mm/day (yearly average all time series: 3.85mm/day). It is unknown whether this is an extreme value or a measurement error. However, no physical explanation can be found for this sudden increase in evaporation (BBWS Serayu-Opak, 2014) and therefore this evaporation series is not suited for this research.

The last available series is from Gracia Consultants (2014) (figure 2.7), which is currently used in the official model by BBWS Serayu-Opak for the Serayu-Bogowonto watershed in Indonesia. This time series shows the expected seasonal fluctuation in evapotranspiration, showing the natural increase in evaporation during the wet season and the other way around for the dry season.

In summary the evaporation series of Gracia Consultants is the best available evaporation series due its location and plausible values.

2.3.3 Discharge

For six locations in Bogowonto daily discharge measurements are available (in m^3/sec).

Table 2.2: River flow stations in Bogowonto catchment (Marhaento, 2014)**.**

Station Name	Type	Data periods	Resolution	Conditions
Pungangan	AWLR station	2002-2011	Daily	C
Boro	Dam	2002-2011	Daily	C
Kalisemo	Dam	2005-2011	Daily	C
Kedungputri	Dam	2002-2011	Daily	C
Penungkulan	Dam	2005-2011	Daily	C
Pingit	Dam	2005-2011	Daily	C

The locations of these river flow stations can be found in figure 2.1 These discharge series will be used for validation of the model. For most stations, only data from 2005 to 2011 is available.

2.3.4 Model input: Precipitation and runoff series water districts (WD)

In addition to the precipitation and discharge measurements, Muchamed (2014) calculated the cumulative precipitation and runoff in m^3/sec for different segments of Bogowonto. In general these segments, i.e. Water Districts (WD), are equal to the number of irrigation weirs in this area. RIBASIM needs these WD to calculate the water allocation. However, this catchment has been sub-divided into six WD, although in this catchment nine irrigation weirs are present. It is assumed these six WD only consider the largest six irrigation weirs.

Based on a previous model schematization, the Bogowonto catchment is sub-divided into six water districts (paragraph 3.2.4). For each water district, a time series for rainfall and runoff (m^3/sec) for 1992-2012 is available from previous model schematization (Muchamad, 2014). The model is explained in paragraph 3.1.

2.3.4.1 *Water districts*

In a previous schematization in RIBASIM, Bogowonto is sub-divided into six water districts (WD) (Muchamad, 2014). A map of these WD can be found in appendix C. Table 2.3 presents the surfaces in km^2 of each WD. Each water district generates its own specific runoff, which is a fraction of the precipitation of that WD.

Table 2.3: Surface area water districts Bogowonto

WD	Surface (km^2)
Wad_Up_ Bogowonto (6901)	73
Wad_Down_ Bogowonto (6902)	17
Wad_Down_ Guntur (6904)	14
Wad_Up_ Kedungputri (6903)	160
Wad_Mudalrejo (6906)	39
Wad_Up_ Boro (6905)	155
Total	459
Total DAS Bogowonto	597

Since the hydrologic border is different to the irrigation districts border (figure 2.8). The hydrologic border is based on the elevation profile. However the downstream part of Bogowonto is really flat and water from the Cokroyasan irrigation weir is partly used for fulfilling water demands in the southern part of Bogowonto (Wad_Up_Siwatu). This area is approximately 150 km^2 and explains the discrepancy in area.

2.3.4.2 *Precipitation water districts*

The distribution of the half-monthly rainfall averaged for the six water districts is presented in figure 2.9a by a box plot. During the wet season (October-April), precipitation can be up to 550 m^3/sec per water district. During the dry season (May-September) rainfall can be zero for several consecutive months.

This time series could not be validated because no data are available for this study about the design of the water districts, or which rainfall stations were used, or which formulas and assumptions have been applied to convert the precipitation into runoff. The most common method for converting precipitation data into cumulative rainfall for a specific water district is by the Thiessen Polygon method (Cheng, 2011). It makes use of polygons, whereby the boundaries of each polygon defines the area which is closest to the location of given precipitation rate. For Bogowonto this resulted in into six separate water districts. After all the runoff and precipitation for these six water districts cannot be reconstructed, in this case resulting in more difficulty to make solid conclusions based on these data. To deal with these conditions, Muchamed consultant (2014) was asked to clarify how these data were constructed. Unfortunately no answer was found (BBWS Serayu-Opak, 2014; Muchamad, 2014; Sutarto, 2014). Although this may be true, figure 2.9a reveals that the time series follows the expected annual dry-wet pattern and no unusual outliers have been marked (figure 2.2 and 2.3), except for the drop of the average rainfall in the 2nd part of December and 1th part of January for the period 1992-2012. This drop is remarkable during the wet season, but does not result in water deficits for the agriculture. Given these points it is chosen to apply this runoff and precipitation data, since no other data is available for this research. Differences between the six water districts are assessed in appendix A. These results suggest that the rainfall in WD6901 is significant larger compared to the five other water districts. Coupled with the larger rainfall in the upstream area, this is considered a plausible observation.

2.3.4.3 Runoff water districts

Similar to the precipitation series, also six runoff series are available (Muchamad, 2014) (figure 2.9b). In the wet season (October-March) the average runoff varies from 70 to 150 m^3/sec. During the dry season (April until September) the runoff varies from 10 to 70 m^3/sec. Because it is not possible to display all the data of the six water districts, these figure shown the data distribution for the average of the six water districts.

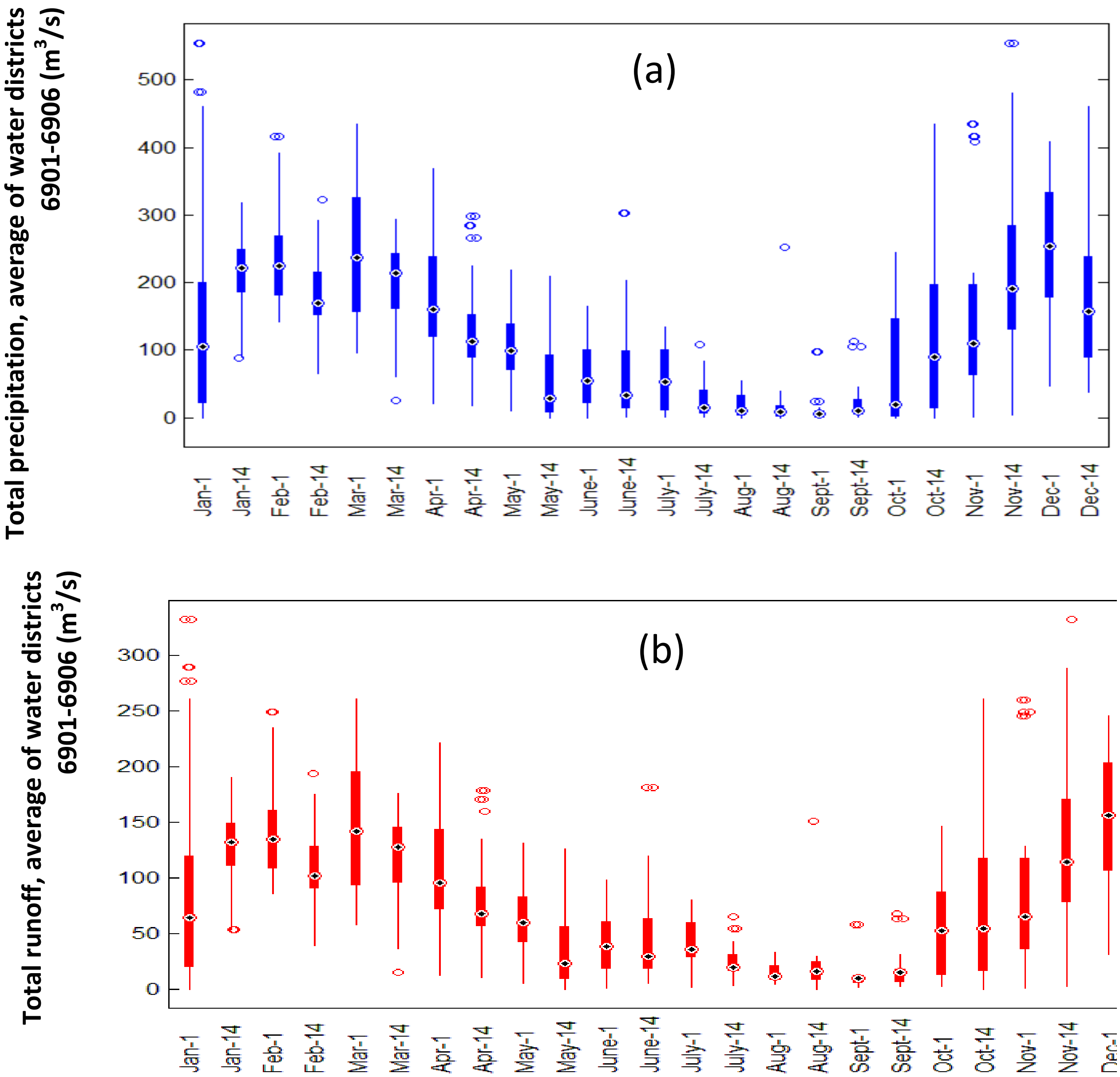


Figure 2.9: Half-monthly precipitation distribution averaged over the six water districts, Bogowonto 1992-2012 (a) and half monthly runoff distribution averaged over the six water districts, Bogowonto 1992-2012 (b)

3 Method

To simulate the current and future water deficits for Bogowonto and select measures to decrease the water deficits, this chapter starts with the outline and implementation of the water allocation model (3.1 and 3.2). This model specifically concerns the simulation of the current and future agricultural water deficits shown in figure 3.1. Subsequently, interviews and participatory sessions are applied to obtain measures which decrease the agricultural water deficits (3.3). A selection of these measures is simulated and discussed with the same stakeholders, to obtain a consensus on the best package of measures. This chapter closes with the procedure for selecting criteria to evaluate the proposed measures of these stakeholders (3.4).

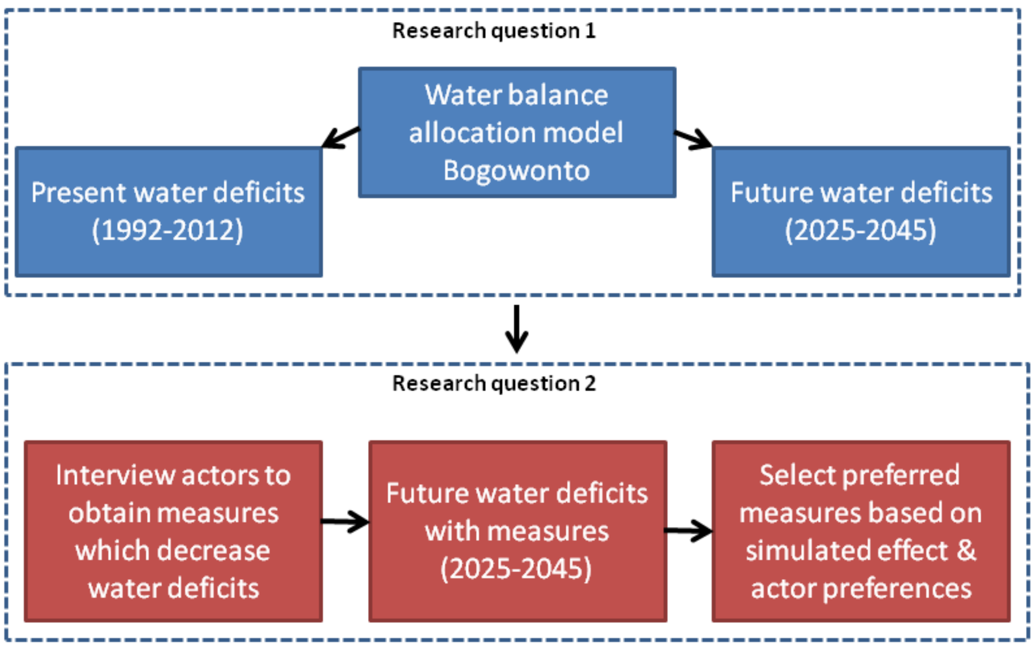


Figure 3.1: Research approach

3.1 Water balance model

This section presents the model choice (3.1.1), data requirements of the model (3.1.2.), model operation (3.1.3) and model output analysis (3.1.4).

3.1.1 Model choice

A large number of hydrological models are available for simulation of the water balance. For this research three models are analyzed: River Basin Simulation (RIBASIM), Water Evaluation And Planning (WEAP) and Soil and Water Assessment Tool (SWAT).

RIBASIM is a generic water balance model to link hydrologic features to water-consuming activities in a river basin. The tool can be used to evaluate a variety of measures related to infrastructure and operational management (Krogt van der, 2008). The most important application of RIBASIM is the evaluation of alternative water resource developments in a basin (Krogt van der, 2008). WEAP has been developed by the Stockholm Environment Institute. The model operates on a monthly time step and applies the basic principles of water balance accounting. Similar to RIBASIM the user specifies various sources of supply, withdrawals, water demands and ecosystem requirements (Yates, 2005). SWIM is a continuous semi distributed ecohydrological model, integrating hydrological processes, vegetation, nutrients (nitrogen and phosphorus) and sediment transport at the river basin scale (Krysanova, 2005). Because the models have comparable functions, the RIBASIM model is preferred since for this model an old schematization of the Serayu-Opak watershed is available. Data on inflow, weirs, reservoirs, domestic, industrial and agricultural irrigation in version 6.3 provides a good foundation for the construction of a new schematization in RIBASIM version 7.0. Keeping in mind RIBASIM is still the most used program to evaluate future water allocation in Indonesia (BBWS Serayu-Opak, 2014), explanation and discussion of output results will be more easy.

3.1.2 Data requirements model

The following data is required for an optimal performance of the model.

Table 3.1: Data requirements RIBASIM model Bogowonto catchment

Data	Availability	Source
Inflow series (runoff) in $m^{3/}$sec for six WD	Yes	Muchamed (2014)
Precipitation in mm for six WD	Yes	Muchamed (2014)
Cropping schedules all irrigation nodes + irrigated area (ha)	Yes	PSDA Probolo (2014)
Groundwater flows (m^3/sec)	No	-
Reference evaporation series (mm/day)	Yes	Gracia (2014)
Public water demand	Yes	Muchamed (2014)

Except for the groundwater data, all required data is available for a correct simulation. Because in Bogowonto no groundwater stations are installed yet and data for groundwater extractions is not available for this study, this study does not include groundwater flows.

3.1.3 Model operation

As shown in the previous paragraphs RIBASIM needs hydrological and technical data, which in general can be divided into: water demand, water availability and infrastructure which include operation rules for the operation of the irrigation weirs (figure 3.2). During the simulation the model will use a half-monthly time step to calculate the new distribution of the water in the network. This time step is appropriate for simulation agricultural water deficits, since only 2 or 3 weeks without water have a significant effect on the growth of the crops.

The simulation process proceeds in time steps. For each time step the water balance is computed based on the supply of water at the boundaries of the system, the demand of water from the various users, the operation rules for the various structures like surface water and groundwater reservoirs, weirs and the water management policies at basin level (Krogt van der, 2008). Appendix D shows a description of how the water balance in RIBASIM is modeled.

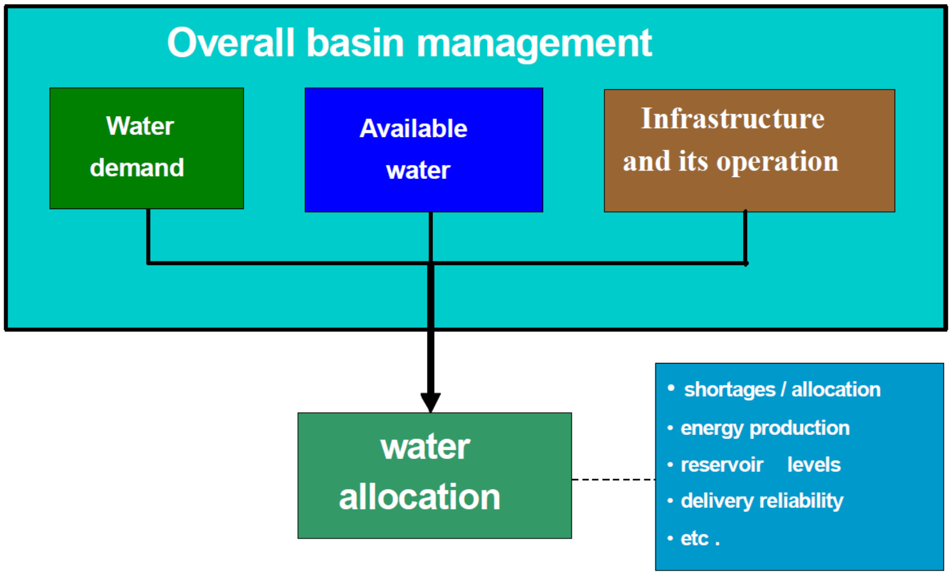


Figure 3.2: Overall input-output diagram RIBASIM (Krogt van der, 2008)

3.1.4 Model output analysis

For this research the water supply, the agricultural water demand and the water deficit (m^3/sec or mm) are useful parameters to address the 14-days average agricultural water deficit. The results will show the annual cumulative water deficit in mm and the half monthly water deficit in mm for the up-, mid- and downstream irrigation weir.

3.2 Model implementation

First the available data as presented in chapter 2 needs to be checked on extremes and errors (3.2.1). Subsequently, it is explained how the infrastructure, water demand and water supply are schematized (3.2.2- 3.2.4). The simulation period and scenarios (3.2.5) and model validation (3.2.6) are outlined in the final two paragraphs.

3.2.1 Data preparation

The precipitation and runoff time series for 1992-2012 are already provided by Muchamed consultants (2014). However, these data needs to be checked on extreme or wrong values. Chapter two already showed the monthly distribution of these data and concluded no outliers are present in this data.

3.2.2 Schematization infrastructure

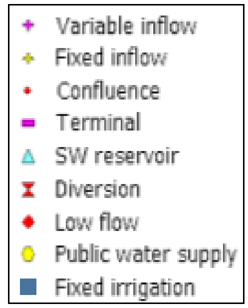
The river is schematized with Surface Water (SW) links (figure 3.3b). The catchment is divided into six water districts (WD). For each of these WD a precipitation and runoff time series is needed. In the river network demand nodes for domestic, industrial and agricultural use can be added. An overview of all link and node types and the schematization of the Bogowonto river are presented in figure 3.3a and 3.3b.

3.2.3 Water Demand

This paragraph discusses three nodes representing water demand: domestic, industrial and agricultural.

3.2.3.1 Domestic demand

Muchamed (2014) provided the most recent data on the explicit public water supply for Purworejo, the central city in Bogowonto. This demand only takes into account the water needs of Purworejo, because the water for domestic use in Wonosobo is extracted outside Bogowonto. It is assumed the population has a linear correlation with the water demand (table 3.2a and 3.2b).



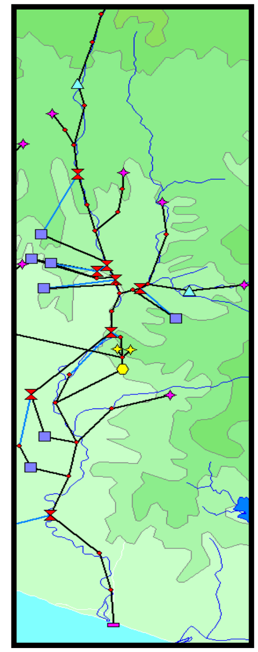


Figure 3.3: Available nodes and links in RIBASIM and schematization river network Bogowonto.

3.2.3.2 Industrial demand

In the area of Bogowonto no significant industries are present. Also no significant industrial growth is expected for the coming 30 years. So the industrial demand is assumed to be zero (Hasi Analisis, 2010).

Table 3.2a: Population Purworejo (Hasi Analisis, 2010)

Year	**2010**	**2035**
Population Purworejo	727.668	783.721

Table 3.2b: Explicit demand Public Water Supply (PWS) Purworejo (Hasi Analisis, 2010)

Year	**2010**	**2035**
Explicit demand Public Water Supply Purworejo (m^3/sec)	1.07	1.24

3.2.3.3 Agricultural demand

The larger the irrigated paddy fields, the higher the agricultural demand. In contrast to the domestic demand, the agricultural demand shows a clear seasonal fluctuation. The first cropping season starts in October and end in January (4 months). The water demand is extra high during the first half month of a new cropping season, because the land needs a pre-saturation of 50-100mm (BBWS Serayu-Opak, 2014). The second cropping season starts in February and last until June (5 months). During the third cropping season from July to September (3 months) only dry-land crops like chili, peanuts and soya beans are cultivated. These crops do not require additional irrigation but use little amount of rainfall in the dry season. The agricultural demand for 2010 and 2035 are given in table 3.3 (Muchamad, 2014). As seen a small decrease in demand is predicted, due to the decline of the agricultural area by 4%. This is explained by the expected conversion of agricultural land into residential area (Muchamad, 2014). These values will be used for simulating of the water demand of the irrigation weirs. The model takes into account the varying irrigation water demands of the crops during the different stages of the growing season.

Table 3.3: Annual water demand for 2010 and 2035 irrigation nodes Bogowonto

Location	Annual water demand 2010 (m^3/sec)	Annual water demand 2035 (m^3/sec)
Irr_Penunkulang	0.285	0.280
Irr_Guntur	0.211	0.212
Irr_Kalisemo	0.295	0.289
Irr_KedungPutri	2.738	2.543
Irr_Boro	2.852	2.688
Total Bogowonto	6.381	6.123

3.2.4 Water Supply

In this study for the water supply we use the district runoff and precipitation for the inflow nodes, as specified in paragraph 2.3.4.3. These series are available for each of the six water districts in Bogowonto in mm/14 days for the period 1992-2012.

This study does not account for groundwater extraction because no data is available on these groundwater extractions. This will result in a small overestimation for the demand on the remaining resources (irrigation demand).

3.2.5 Simulation period and scenarios

To construct several scenarios for the water demand and supply for the Bogowonto catchment to address climate variability, this study makes uses of IPCC (2013) scenarios to modify the historical measured time series on precipitation and runoff. According to the IPCC (2013) on average the precipitation in South-East Asia will increase in the dry and the wet season. The amount of increase depends on the climate model. For this study the RCP4.5 scenario is chosen to address variations in precipitation and temperature. Four scenarios for the period 2025-2045 will be constructed: Overall wetter (1), wetter wet season and a drier dry season (2), drier wet season and a wetter dry season (3) and overall drier (4). More information on this climate scenarios and how the new scenarios for the water availability are constructed, is presented in Appendix F.

The calculated values for domestic, industry and agriculture are used as input for the historical (1992-2012) and future (2025-2045) simulation period demand. The water demands of 2010 for domestic, industrial and agricultural use are assumed to be representative for the historical simulation period 1992-2012. The water demands for domestic, industrial and agricultural use of 2035 are assumed to be representative for the simulation period 2025-2045. No water demand data for 2002 was available for this study. In addition also no data on irrigation surface area and efficiency was available and therefore the water demand during the first 10-15 years is likely to be overestimated, assuming a gradually increase of the irrigation area during this period.

Table 3.4 presents five scenarios for 2025-2045 with varying water availability for the wet (October-March) and dry (April-September) season. The precipitation and runoff series for scenario C, D, E and F are constructed by multiplying each value of the historical time series by in- or decrease of precipitation and reference evaporation (in %), including the seasonal differences between the wet and the dry season.

Table 3.4: Scenarios RIBASIM model. P=Precipitation, E=reference evaporation. Historical time series = precipitation and runoff per district for 1992-2012 (Muchamad, 2014)**. Modified time series= The historical time series are adjusted according to IPCC (2013) prognoses for P and ET to simulate climate variability for 2025-2045**

Water availability input				**Water demand input**	**Measures**			
					Reference	Measure 1	Measure 2	Measure 3
HISTORY 1992-2012	**Scenario A.** **Reference situation** Historical time series			Water demand (2010)	A0	-	-	-
FUTURE 2025-2045	**Scenario B.** Historical time series	ΔP Oct-Mar = 0% Apr-Sep = 0%	ΔE Oct-Mar = +0% Apr-Sep = 0%	Water demand (2035)	B0	B1	B2	B3
	Scenario C. Modified time series	ΔP Oct-Mar =+12% Apr-Sep = +7%	ΔE Oct-Mar = +3% Apr-Sep = +3%		C0	C1	C2	C3
	Scenario D. Modified time series	ΔP Oct-Mar= +12% Apr-Sep = -3%	ΔE Oct-Mar = +3% Apr-Sep = +1%		D0	D1	D2	D3
	Scenario E. Modified time series	ΔP Oct-Mar = -2% Apr-Sep = +7%	ΔE Oct-Mar = +1% Apr-Sep = +3%		E0	E1	E2	E3
	Scenario F. Modified time series	ΔP Oct-Mar = -2% Apr-Sep = -2%	ΔE Oct-Mar = +1% Apr-Sep = +1%		F0	F1	F2	F3

These scenarios are able to simulate the water deficit on an annual and two weekly timescale. Scenarios C (wettest) and F (driest) are useful to analyze the lower and upper boundaries of the water deficit as a result of fluctuations in rainfall. Scenario D addresses extremes by simulation a wetter wet period and a drier dry period. Scenario E is the reverse of scenario D. Comparing the annual water deficits will reveal the years with the largest water deficits and which years are responsible for the three largest water deficits at the up-mid- and downstream irrigation weir. Comparing water deficits at a two-weekly timescale will reveal which months during the year contain the largest water deficits.

Each measure will be simulated individually for each scenario to analyze the impact of the measure and to assess the sensitivity of the effects of the measure to climate variability. In this way a comparison between the sensitiveness of the measures to climate variability can be made. Also the effect of the measures on an two-weekly and annual time scale will be simulated without any climate variability scenarios (scenario B), wherefore the effect of individual measures can be compared.

3.2.6 Model validation

For the irrigation nodes Kedung Putri (midstream) and Boro (downstream) discharge data is available to validate the model performance. To address the model performance, two objective functions are considered: mean absolute per cent error (MAPE) and root mean square error (RMSE).

$$MAPE = \frac{1}{N}\sum_{J=1}^{n}\left|\frac{Q_{obs}(j) - Q_{sim}(j)}{Q_{obs}(j)}\right| * 100\% \tag{1}$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(Q_{sim}(j) - Q_{obs}(j))^2} \tag{2}$$

Where:

N	Number of time steps (-)
J	Time step (-)
Q_{obs}	Observed o discharge (m^3/sec)
Q_{sim}	Simulated discharge (m^3/sec)

The first function is more suitable for low flows simulations (Yu, 2000), whereas the second function is more appropriate for simulating high flows (Mediero, 2011). The RMSE and MAPE will be calculated for the complete data period. Furthermore graphs will present several adjacent years containing, at least one long dry season.

3.3 Interviews

This paragraph addresses the objective (3.3.1), target group (3.3.2), procedure and planning (3.3.3) and illustrates how the interviews are conducted and processed (3.3.4).

3.3.1 Objective

Based on the research objective possible water deficit decreasing measures should be obtained from the stakeholders and ranked in accordance to their preference for the up-, mid- and downstream irrigation weirs. To achieve this research objective, the following three steps are considered:

- Invite stakeholders on agricultural water management for interviews, for each of the three selected irrigation weirs (3.3.2).
- Explore water resource related problems and possible solutions which decrease the agricultural water deficit.
- Rank the top-3 measures for each location according to the preference of the stakeholders.

3.3.2 Target group

These interviews are hold at the Unit Pelaksana Technis (UPT), each with their own office at the up-, mid- and downstream irrigation weir. UPT is responsible for technical performance and maintenance of the irrigation weirs (Balai PSDA Probolo, 2014). For the meetings members of the Agricultural Federation of Water Users Association (GP3A) are also invited. They represent the interest of the farmers and are responsible for good maintenance of the tertiary irrigation channels. In this research the invited stakeholders of the GP3A also were farmers. Together with the office of the government Balai PSDA Probolo (2014), they form the target group of this research. These contacts have been initiated by the Gadjah Madah University.

No industries with large water extraction are present in Bogowonto and therefore no industries are included as stakeholders. Drinking water companies for the different cities also have not been included, since the scope of this research is agriculture and not domestic or industrial use.

3.3.3 Procedure and planning

Firstly, interviews are performed to identify the main stakeholders. Simultaneously to this interviews hydrological data and information on the performance of the irrigation network is retrieved from the local water boards and irrigation weirs. Subsequently the results of the RIBASIM analysis are presented and discussed during meetings with the main stakeholders. In collaboration with the stakeholders a consensus on the best combination of measures is achieved.

The interviews are conducted in central-Java, Indonesia. This encompasses a new culture with unknown issues regarding interviews. The main challenge is to gain trust to ensure a better quality of the interview results. This is done by establishing personal relationships in the organization where the interviews will be hold. These contacts have already been formed by O. Karyanto and H. Purwadi, respectively from the Gadjah Mada University and the BBWS Serayu-Opak. Also the responses of farmers in the interviews are discussed the results with local experts from UGM and BBWS Serayu-Opak, to obtain a better interpretation of the results in the context of the Javanese culture.

3.3.4 Interview processing

The interviews take place at the offices of the UPT. This is a familiar place for the farmers, hence they also gather at this place for the annual meeting on which cropping types will be cultivated in the next year. No preparation for the farmers is necessary regarding the interviews; the meeting is their first time to discuss and formulates answers on the asked questions. During the first interviews basic questions about the crop type, timing of the cropping season and memories of past water deficits are asked. Each of the interviews at the up-, mid- and downstream location is closed with a brainstorm about possible measures that could decrease the agricultural water deficit. The questions of this interview can be found in appendix D. The second meeting can be described as a participatory session, were the future agricultural water deficit are presented and discussed with all participants. The main focus for the discussion will be the timing and the frequency of the simulated water deficits. During this second meeting the results of the proposed measures of the previous interview are discussed to analyze whether the effect of their proposed measures changed their mind.

To obtain possible measures and rank these measures, a simple tool which represents the irrigation field is used were the farmers could specify their cropping type in each season and duration of the growing period for each crop. Also large maps of the area are used to identify problem areas for the water deficit to gain a better understanding of the functioning of the present irrigation system for each irrigation weir.

During these interviews and participatory sessions a large group of farmers and employees of the irrigation weir participated. In Javanese culture this effects the group in such a way, that all of the participants shared the same opinion in most cases. To deal with this issue, individual questions were asked to specific farmers on their opinion about a certain topic. However, it was not possible to obtain the individual opinion of each farmer for each question due to restrictions in time and translation.

Another bias in these interviews is the translation. Sometimes only a summary of the answer is given, which results in a loss of information. To deal with this condition, the interviews are recorded and transcribed and the exact answers of the farmers can be analyzed (appendix H).

If answers need further clarification, the interviewer is not bound by the pre-formulated questions described in appendix D. New questions can be formulated to have the best possible understanding of the opinion of the participants.

The primary results of the interviews and participatory sessions are expected to be:

- Presentation and discussion of the present water deficits (1992-2012)
- Presentation and discussion of the future water deficits (2025-2045)
- List of potential measures formulated by the stakeholders
- Response of the participants to (effect) of each measure (to agricultural water deficit)
- Ranked measures for each location up-, mid-, and downstream.

3.4 Criteria for selection and comparison of measures

A lot of measures will be proposed, but for reasons of simplicity not every measure will be simulated. It is decided that three measures will be simulated. Therefore the following criteria are applied:

3.4.1 Selection of measures for simulation

- Compatibility with RIBASIM: It should be possible to simulate the measure. This means for the water availability no changes in runoff caused by changing land use can be simulated. For the water demand only manipulations can be done for the irrigation nodes. Finally, the model only simulates surface water since no measures regarding groundwater can be simulated.
- Level of scale measure: The measures should in general have the potential to have an impact on the complete catchment, not only on a small spatial scale. This criterion limits the risk of modeling hundreds of small measures, only having local impact but not solving the whole problem.
- Appropriate to answer the research objective: This criterion assesses whether the proposed measure is within the scope of this research. This research focuses on measures which decrease the agricultural water deficit. This can be measures which lower the water demand, or increase the water availability.

These criteria will limit the number of measures. Of these pre-selected measures, the best three measures will be implemented and simulated in the RIBASIM model.

3.4.2 Criteria for comparison measures

Table 3.5 presents the criteria for the comparison of the measures in a multi-criteria analysis.

Table 3.5: Criteria for comparing measures. UPT = Unit Pelaksana Technis, P3A = Coordination Institution for farmers.

	Criteria	Proposed by:	Score A	B	C	D	E
I.	Annual agricultural water deficit in respect to ref. sec. (Q in $m^{3/}s$)	All	Q < 33%	33% < Q < 67%	67% < Q < 100%	Q ≈ 100%	Q > 100%
II.	Economic perspective famers	Farmers	Excellent	Good	Moderate	Insufficient	Poor
III.	Robustness measure (t in years)	Employees UPT	t > 20	15 < t < 20	10 < t< 15	5 < t < 10	t < 5
IV.	Cost efficiency measure	Balai PSDA Probolo	High		Medium		Low
V.	Level of agreement up-, mid- and downstream farmers	Balai PSDA Probolo, farmers	All farmers agree	-	Majority farmers agrees	-	All farmers disagree
VI.	Level of agreement UPT, P3A, local government)	Balai PSDA Probolo	Full consensus	-	Partial agreement	-	No consensus

These criteria have been obtained during the participatory interview sessions at the up-, mid- and downstream irrigation weirs as the most important criteria for the stakeholder (Daru, 1985; Nosikia, 2014; Triyanto, 2014). Who proposed the criterion, how these criterions are defined and finally how they will be assessed is shown below.

I. Decrease of annual agricultural water deficit

This general criterion is unanimous supported by all stakeholders. This criterion assesses whether the future simulated agricultural water deficit in respect to the reference scenario without interventions is decreased by a measure. The score 'E' means the annual water deficit increases, the score 'D' means the annual water deficit remains the equal to the reference scenario, 'C' means the annual water deficit is lowered by a scale 0-33%, 'D' is the annual water deficit is lowered by 33-66%, and a score 'A' means the annual water deficit is lowered by 67% or more compared to the reference scenario.

II. Economic perspective farmers

All up-, mid- and downstream farmers stated "economic perspective", is one of their main interests (Muhon, 2014; Nosikia, 2014; Triyanto, 2014). This criterion is assessed by results from the interviews with farmers in the up-, mid- and downstream part of Bogowonto, for the simulation period 2025-2045. The grade of a good economic perspective is applied if the hydrological cropping conditions are excellent, in other words sufficient water is available and the frequency of the water deficits is zero. Furthermore the opportunity to expand the crop production in ha by cultivating extra crops due to the extravagance of water is also beneficial for the economic perspective of the farmers. On the other hand, if the measure decreases the agricultural demand while their production remains steady, this also creates opportunities to cultivate more crops with the same amount of water. The grade of a poor economic perspective is assigned if not sufficient water is available for the optimal growth of the crops and the frequency of the water deficits is high. In addition there is no opportunity to receive extra water to expand their crop production or to decrease the agricultural water demand by new techniques. A moderate economic perspective is defined if no changes in respect to the reference scenario without measures are seen regarding the increase in water availability or the decrease in water demand by new techniques.

III. Robustness measures

This criterion is proposed by the employees of the irrigation weir, who are responsible for the performance and maintenance of the irrigation weir. The Bogowonto river transports high loads of sediment due to the steep elevation profile and highly erodible soils, affecting the performance of the proposed measures on the long term. Robustness is defined as the minimal long term reward of the system and to what extend it still works under extreme conditions (Dessai, 2007). The farmers mentioned they were very frustrated no good long term management for the irrigation network was established during the past years (Muhon, 2014). This statement was confirmed after more interviews which revealed the unreliable and fluctuating quality of the maintenance of the irrigation network due sedimentation (Triyanto, 2014).

The criterion is assessed by quantitatively analysis of the measure achieves 80% or more of the designed decrease in water deficit after a number of years (table 3.5). The higher number of years the measure decreases the water deficit by 80% or more of the original designed value, the more robust the measure.

IV. Cost efficiency measures

The first proposed criterion by the government is cost efficiency. Cost efficiency is minimizing efforts and maximizing the desired effect. Cost efficiency in this criterion is addressed by analyzing the cost for a reduction of the annual water deficit by for example 50 mm. Since more that 66% of all irrigation weirs are managed by the government, a large budget is needed for the maintenance and renovation of the irrigation infrastructure. This criterion is assessed by a gradual scale which consists of three segments: High, medium and low cost efficiency. Since the interpretation of this criterion is subjected to the type of measures, the interpretation of these scale is explained in paragraph 5.4 were the type of measures are known.

V. Level of agreement up-, mid- and downstream farmers

This second criterion of the government is the agreement on solution for the up-, mid- and downstream farmers. This criterion is assessed by a three point scale: All farmers disagree (E), majority of the farmers agree (C) and total agreement (A). The level of agreement for farmers of the same irrigation weir, is not covered since the farmers at the same irrigation weir all shared the same opinion (Triyanto, 2014).

VI. Level of agreement between farmers, employees irrigation weir and local government

The third criterion of the government is agreement on solution by all stakeholders. This criterion is the degree of conformity of the up-, mid- and downstream farmers, employees of the waterboard and the government about question the measure should be implemented. Also without unanimous support for a measure, it is still implementable, although if all stakeholders agree on which measure to take, the decision making process and implementation will be easier. Similar to the fifth criterion, this criterion is also assessed by a three point scale: No consensus (E), partial agreement (C) and full consensus (A).

4 Results: Water deficits 1992-2012 and 2025-2045

This chapter covers the agricultural water deficits for the period 1992-2012 and the future agricultural water deficit for 2025-2045. The validation results are covered in paragraph 4.1, the water deficit for the period 1992-2012 is presented and discussed in paragraph 4.2 and finally the future water deficit (2025-2045) is presented and discussed in paragraph 4.3.

4.1 Validation results

For the years 1997-2012 the observed discharge is compared with the modeled discharge at the irrigation weirs Kedung Putri and Boro. Before 1997 no discharge measurements are available. In addition for the irrigation weir Guntur no observed discharge series are available, because no river flow station is installed yet (Marhaento, 2014). The results of the two applied objective functions, i.e. MAPE and RMSE, are presented in table 4.1

Table 4.1: MAPE and RMSE validation results for 1997-2012

	Dry season (April-Sep)		Wet season (Oct-Mar)	
Time series	MAPE (%)	RMSE (m^3/s)	MAPE (%)	RMSE (m^3/s)
KEDUNG PUTRI	0.8	18.0	1.3	20.0
BORO	2.6	9.6	2.3	24.0

The correct simulation of low flows is considered to be important since this study is about water deficits. For the dry season (table 4.1), the Kedung Putri and Boro score 0.8% and 2.6% respectively. This means the sum of all water deficits of the measured and simulated water deficit differ by 0.8% and 2.6% respectively. For the dry season the Root Man Square Error (RMSE) for Kedung Putri and Boro is 18.0 m^3/s and 9.6 m^3/s respectively. Although the total water deficit is better simulated for Kedung Putri, this analysis shows individual values are better simulated for the Boro irrigation weir.

Regarding the wet season (table 4.1), the MAPE for Kedung Putru and Boro is 1.3% and 2.3% respectively. The total water deficit for the wet season is slightly worse simulated in comparison to the dry season. The RMSE for Kedung Putri and Boro is 20.0 m^3/s and 24.0 m^3/s respectively, resulting in a substantial bias between the simulated to observed discharge for both Kedung Putri and Boro.

Figure 4.1a and 4.1b present the observed and simulated discharge from 2006-2010. This period is selected because it contains the two driest years, i.e. 2006 and 2010 respectively. For Kedung Putri (figure 4.1a) the peak discharges are overestimated, resulting in an overestimation of river discharge during periods of peak discharge. It is plausible this overestimation explains the high RMSE (table 4.1), since most of the peak discharge take place during the wet season. Figure 4.1a shows the low flows are better simulated compared to the peak discharges for Kedung Putri but they are still far from perfect. For Boro (figure 4.1b) the peak discharges are overestimated and the simulation of the low flows is simulated slightly better compared to the upstream irrigation weir Kedung Putri. Since most of the peak discharges take places in the wet season, the high RMSE for Boro (24 m^3/s) is caused by the underestimation of the peak discharges by the model.

Several explanations can be given for this far from perfect fit. First no calibration is executed, because the conversion of the rainfall into runoff is not included in this water allocation model. To deal with this condition the input data is analyzed by box plots on correctness and outliers are replaced by the mean value of that specific month of whole time series. Furthermore the model uses default values for soil characteristics. Except for choosing the correct surface and crop type, no additional changes have been made in the schematization of the crops. It is possible that these values are not representative for Bogowonto, although these values are recommended by Sutarto & Muchamed (2014). Also it is possible the measured data contains measurement errors. The same yields for reading errors in the collection of these data, as for most measurement devices the water levels are still manually read and not automatically transmitted. In addition, the model itself can contain errors by not fully incorporating all the relevant processes which affect the output variables. In this study groundwater flows are relevant, but not incorporated because these data were not available for this study. In addition not all irrigation nodes are incorporated, resulting in an underestimation of the water demand. To deal with this condition, an estimation is made of the percentage of extractions of groundwater with respect to surface water extractions. Groundwater is only extracted during dry periods (May, June and October). PSDA Probolo (2014) states 1/6 of all farmers have access to groundwater wells. These famers can solve their complete water deficit by pumping this amount of groundwater from springs. Another reason for this not perfect fit is that RIBASIM simulates a fixed irrigation schedule. In reality some farmers have a variable start of their cropping season, since they want for the rain to start. However, this is not incorporated in the model. It is recommended to do further research on the number of farmers who delay the planning of rice if the rainy season is delayed. Finally, the model assumes constant irrigation efficiency for the transport of the water which on average represents the performance of the irrigation weir, but some farmers on the other side of the irrigation intake will be more vulnerable to water deficits compared to farmers close to the irrigation intake, causing conflicting statements regarding the experienced water deficits.

In conclusion, the most important factors for the discrepancy for this result, is firstly caused by the poorly referenced data on rainfall and runoff, resulting in uncertainty about the data quality and propagation of errors and it is unclear which processes have been taken into account regarding the calculation of the runoff per water district. Secondly the model schematization does not include groundwater flows, which results the net water demand on irrigation from the river is overestimated. Finally the model assumes constant irrigation efficiency for all irrigation weirs, while the quality of the irrigation channels contains varies for the large irrigation weir.

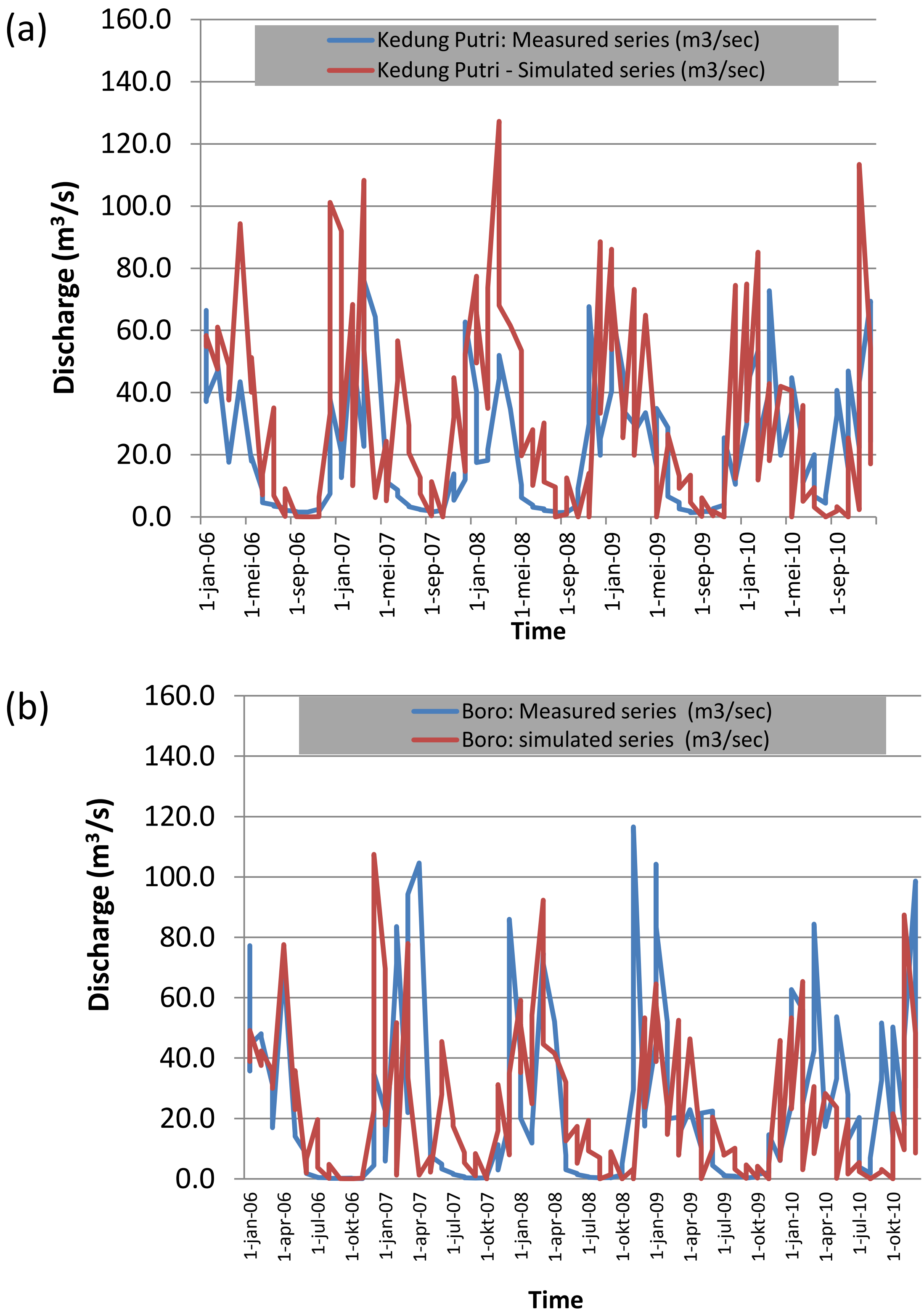


Figure 4.1: Observed and simulated discharge upstream of the mid-stream irrigation weir Kedung Putri for 2006-2010 (a) and observed and simulated discharge upstream of the down-stream irrigation weir Boro for 2006-2010 (b).

4.2 Current agricultural water deficit (1992-2012)

The water deficit is the water demand minus the water availability, expressed in mm. The water deficit is presented for the period 1992-2012 at an annual interval in figure 4.2 and at a monthly interval in figure 4.3. These water deficits are presented for the up-, mid- and downstream irrigation weirs.

The annual water deficits are sorted from the years with the largest to the lowest water deficit. The water deficits in Guntur and Boro are 350 and 750 mm $year^{-1}$ respectively for the driest year (figure 4.2a). However, if the water deficits are corrected with weights proportional to the irrigation surface in ha (figure 4.2b) the mid- and downstream irrigation weirs have by far the largest contribution to the total water deficit in Bogowonto. This is a logical result considering the irrigation areas for these weirs with 326ha, 4341ha and 5136 ha for respectively the up-, mid- and downstream weir.

Figure 4.3 present the monthly analysis of the water deficits, which shows there are two periods with a significant water deficit. The first period is around April-June, i.e. the end of the second cropping season. The rainfall decreases, the land receives less water resulting in a higher need for irrigation water. The simulated water deficits reveal this irrigation demand cannot always be fulfilled. The second period of water deficit takes place in October, i.e. the start of the first cropping season. The combination of a delayed start of the wet season and the high initial water demand for the wet-land crops results in a water deficit for the midstream irrigation weir. However, no water deficit is simulated in the downstream irrigation wear in this same period. It is assumed there is no large difference in runoff, because the irrigation weirs are located close to each other. A more plausible explanation is that upstream of the irrigation weir Kedung Putri, the river flow splits into three parts: Intake for irrigation, intake for Public Water Supply Purworejo and the remaining river flow. The downstream Boro weir benefits from the 14% return flow from Kedung Putri and the 20% return flow to surface water of the Public Water Supply node. This results in a higher water availability, resulting in lower water deficits. However, why the water deficit totally drops to zero for October for the Boro cannot be fully explained.

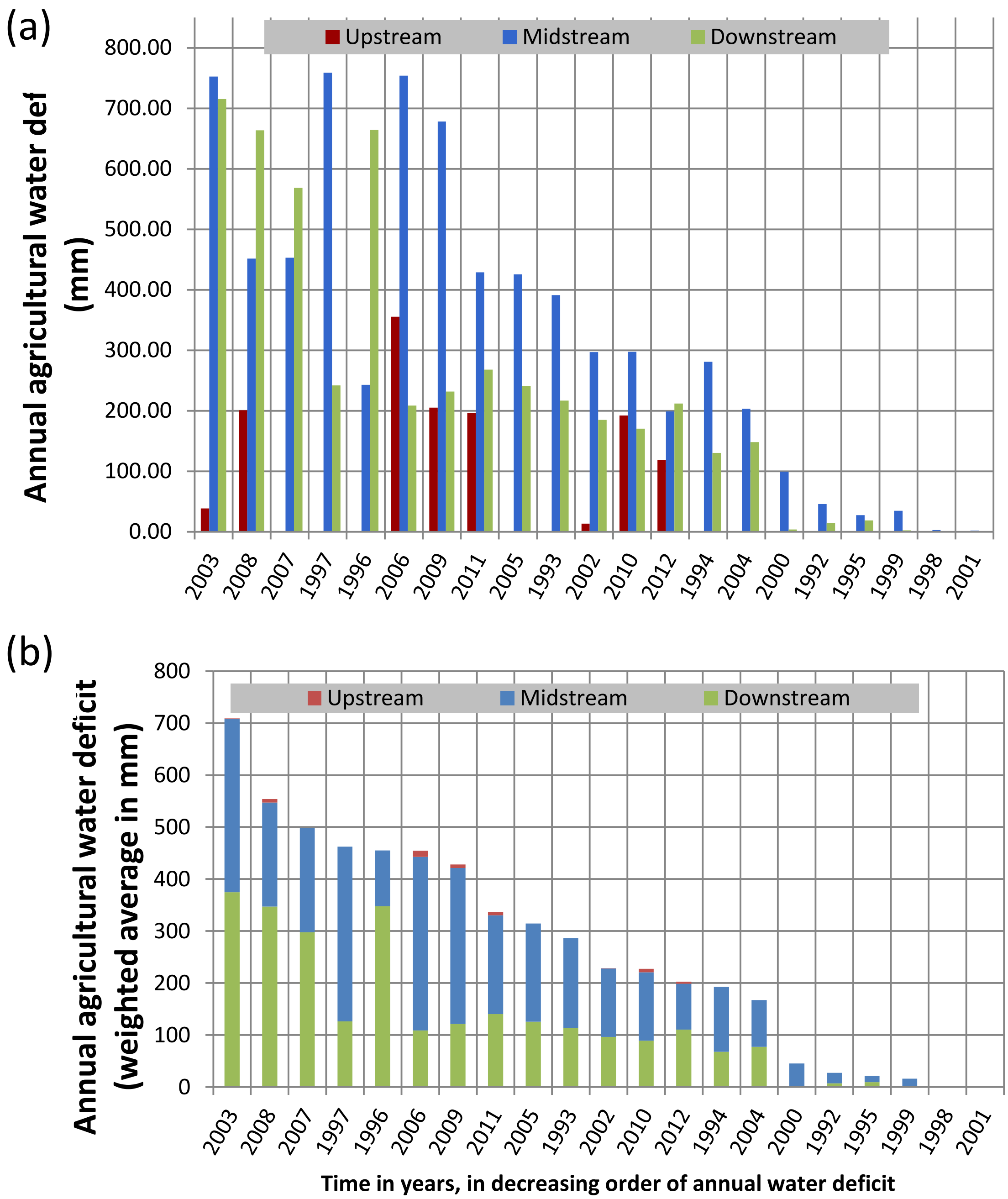


Figure 4.2: Sum of agricultural water deficits for irrigation nodes up-, mid- and downstream (1992-2012) in the Bogowonto catchment (a) and weighted sum of agricultural water deficits for irrigation nodes up-, mid- and downstream (1992-2012) in the Bogowonto catchment. Applied weights are inversely proportional to irrigated surface area irrigation weir (b).

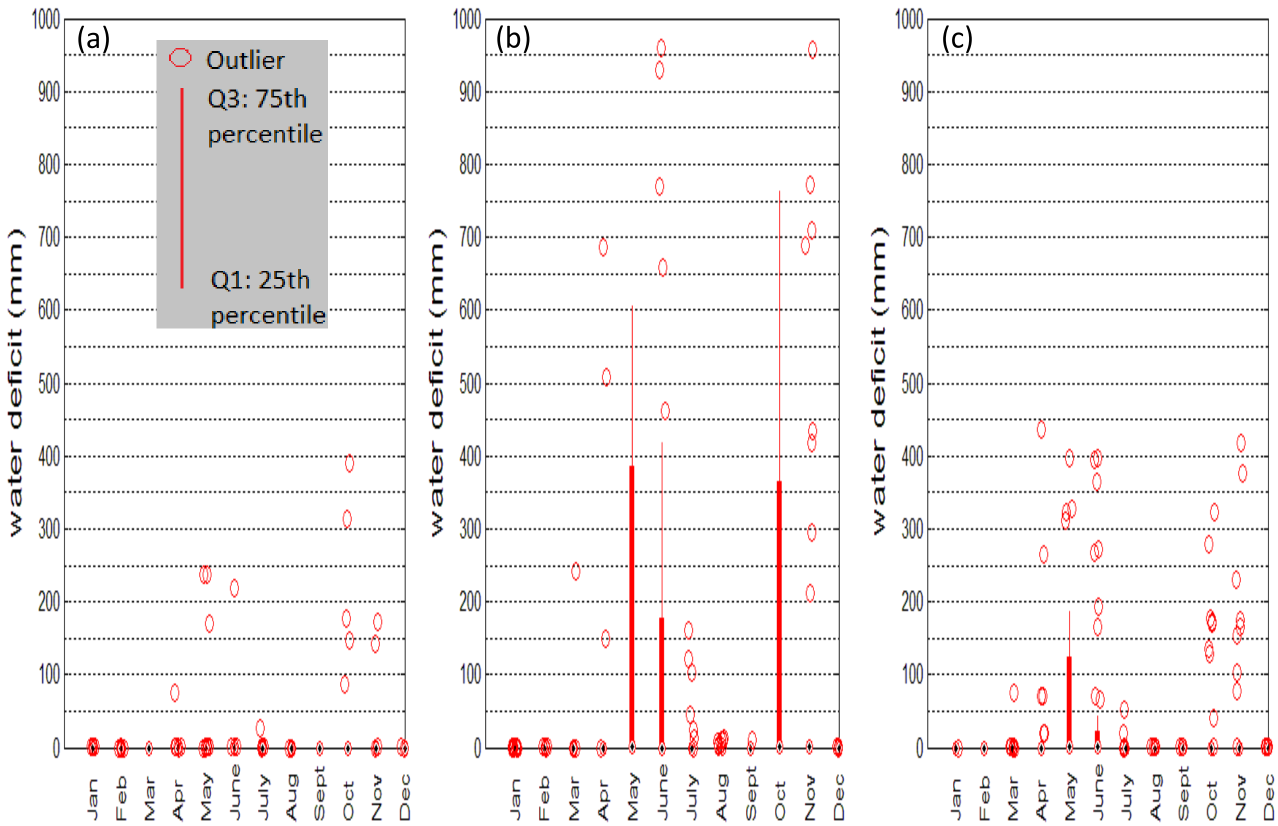


Figure 4.3: Box plot monthly water deficit Guntur (a), Kedung Putri (b) and Boro (c) for period 1992-2012 for reference scenario B (table 4.3).

4.3 Future agricultural water deficit (2025-2045)

Based on the five scenarios for 2025-2045 for the water availability, the water deficit in RIBASIM has been simulated for these years. This has been done for the upstream irrigation weir Guntur (paragraph 4.2.1), midstream irrigation weir Kedung Putri (paragraph 4.3.2.) and downstream irrigation weir Boro (paragraph 4.3.3).

4.3.1 Upstream water deficit 2025-2045

The cumulative annual water deficit (mm) for the Guntur weir for the period 2025-2045 is shown in figure 4.4.

The reference scenario (scenario B) shows the annual water deficit for the scenario if no measures are considered. The year with the largest water deficit is 2030, with an annual water deficit of 350mm. Because the small surface area of this irrigation weir, this deficit is very small compared to irrigation weirs Kedung Putri and Boro, but this water deficit is still causing undesirable water deficits for the farmers at this irrigation weir, with a negative effect on their crop production (Balai PSDA Probolo, 2014).

Five future scenarios for the inflow have been defined, varying from high to low water availability (paragraph 3.2.5.2). The relative effect (in percentages) of these scenarios to the total cumulative water deficit for 2025-2045 is shown in table 4.2. For scenario C with increasing rainfall and runoff in the wet and dry season, this results in an overall decrease of 8% for the agricultural water deficit. For scenario D with increasing rainfall in the wet season and decreasing rainfall in the dry season, the agricultural water deficit drops with 6%. For scenario E with increasing rainfall in the dry season and decreasing rainfall in the wet season, no changes in total water deficit are observed. Finally scenario F with decreasing rainfall in the wet and dry season, the total water deficit grows as expected with 2%.

This section does not show the monthly variations of the water deficits, since these water deficits are the same as for the period 1992-2012 (figure 4.3). This is caused by the future scenario for 2025-2045 applies the dataset of 1992-2012 for the water availability. In addition, only small variations in the water demand are present, resulting the values for the annual and monthly water deficit do not differ for these periods.

In summary the scenarios vary from -8 to +2% for the agricultural water deficit for the Guntur weir (table 4.2).

4.3.2 Midstream water deficit 2025-2045

The cumulative annual water deficit (mm) for the period 2025-2045 is shown in figure 4.5. The largest water deficit for Kedung Putri is 770 mm in the year 2030. As expected the wet scenarios C and E result in a lower water deficit for Kedung Putri, whereas scenario F clearly results in a higher water deficit since it is based on less rainfall and runoff. According to table 4.2, the total cumulative water deficit for scenario C decreases with 15%, for scenario D with 6% and for scenario F an increase of 6%. Scenario E with increasing rainfall in the dry season but decreasing rainfall in the wet season, results in a significant decrease for the water deficit for 2030, 2039, 2036, 2042, 2040 and 2041 but is similar to the reference scenario (B) for the remaining years. For the weir Kedung Putri during May (380 mm), June (170 mm) and October (360 mm) the largest water deficits take place (figure 4.3).

As shown above, the scenarios for the water deficit in Kedung Putri vary from -15% to + 6% (table 4.2).

4.3.3 Downstream water deficit 2025-2045

The cumulative annual water deficit for the period 2025-2045 is shown in figure 4.6. In 2036 the water deficit reaches up to 650 mm for the irrigation weir Boro. The year 2036 is the third driest year for irrigation weir Kedung Putri, showing the maximum water deficits takes place in different years. The lower limit of the water deficit is defined by scenario C, whereas scenario F with the largest decrease in precipitation for the dry and wet season marks the upper limit of the water deficit. The effect of these scenarios can seen the best for the driest year (figure 4.6). For Boro the monthly water deficits are 120 mm for May and 30 mm for June. During the rest of the year no significant water deficits are present. The years 2036, 2041, 2029 and 2040 are extreme years with water deficits between 600-710 mm. The remaining 16 years show with water deficits between 0-450 mm. As shown in table 4.2, the scenarios for the water deficits in Boro varies between -18 and +8%.

Table 4.2: Cumulative water deficit (percentage) for 2025

Scenario	B0			C0			D0			E0			F0		
Location	up	mid	down	up	mid	down	up	mid	down	up	mid	down	up	mid	down
Water deficit (%)	100	100	100	92	85	82	94	94	100	100	98	90	102	106	108

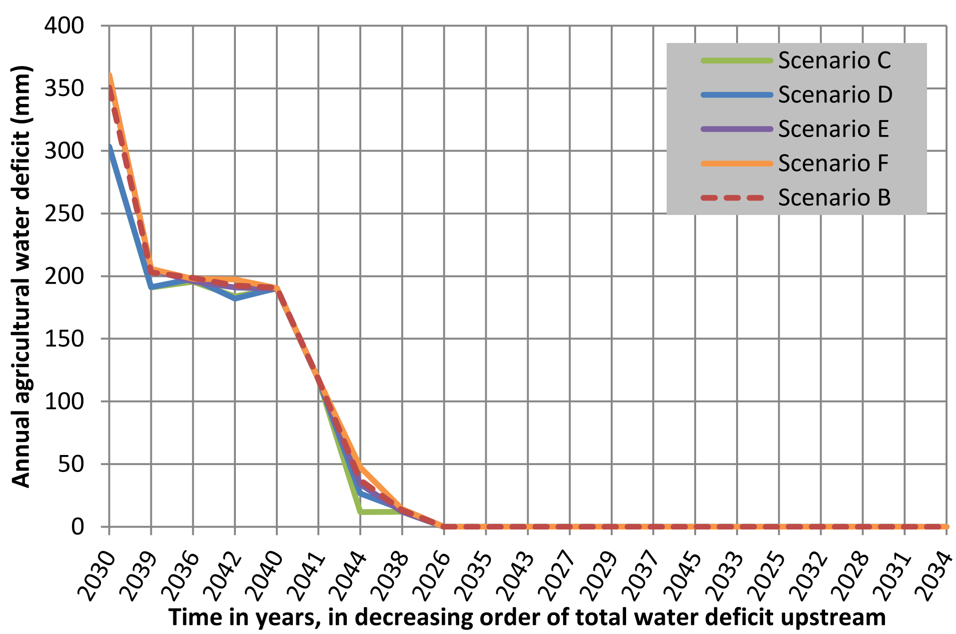


Figure 4.4: Agricultural water deficit for the irrigation weir Guntur for 5 different scenarios for 2025-2045 (see paragraph 3.2.5.2.)

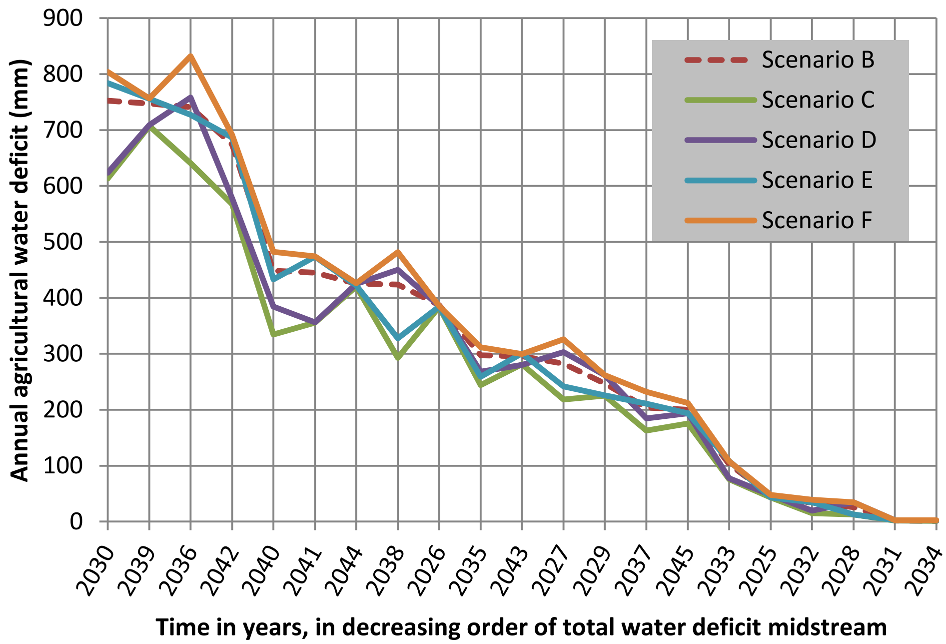


Figure 4.5: Agricultural water deficit for the irrigation weir Kedung Putri for 5 scenarios for 2025-2045 (see paragraph 3.2.5.2.).

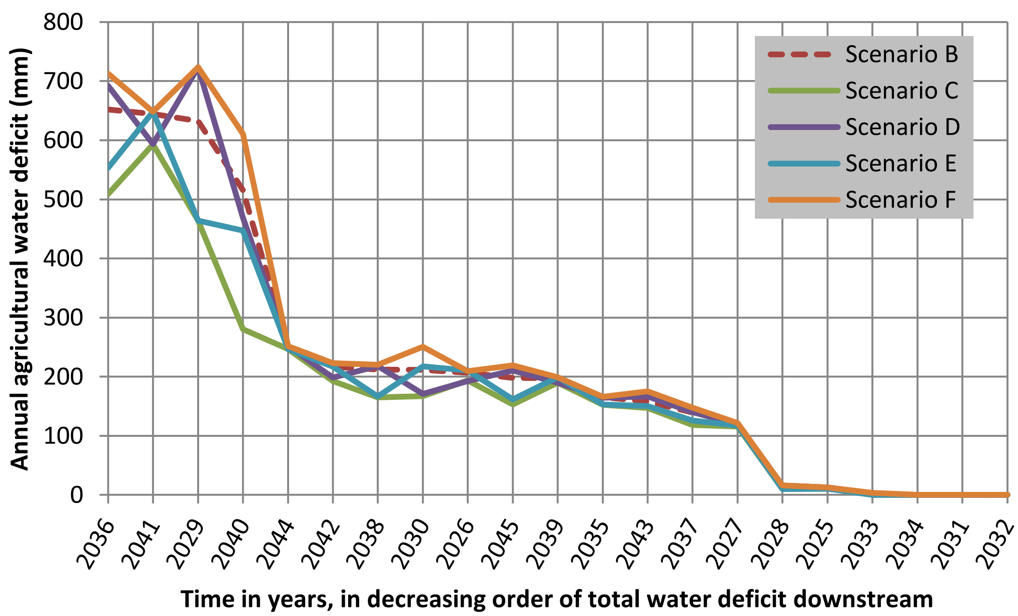


Figure 4.6: Agricultural water deficit for the irrigation weir Boro for 5 scenarios for 2025-2045 (see paragraph 3.2.5.2.)

5 Results: Measure selection and performance

This chapter addresses the type of participants during the interactive sessions (5.1), potential measures for decreasing the water deficit (5.2), the effect of the selected measures on the water deficit (5.3) and the preferred solution package after the effect of all individual measures have been presented (5.4).

5.1 Stakeholders up-, mid- and downstream part

This study is performed at a catchment level. Three irrigations weirs, located in the up-, mid- and downstream part of Bogowonto have been selected to operate as representative markers for the up-, mid- and downstream parts of Bogowonto. The stakeholders are the farmers who make use of these irrigation weirs (PAAA), the operators of these irrigation weirs (UPT) and the local government, who is responsible for these irrigation weirs. These stakeholders and their interests are covered in the paragraphs below.

5.1.1 Farmers irrigation node up-, mid- and downstream irrigation weirs

For the upstream irrigation weir, four farmers with irrigated paddy rice fields have been interviewed. The locations of these paddy fields are all close to the intake of the irrigation weir, due the small size of this irrigation node. All these farmers have been cultivating paddy rice at this irrigation node for 30 years or longer (Muhon, 2014). The interests of these farmers are characterized by high productivity, sustainable irrigation works and high revenues.

For the midstream irrigation weir, three farmers of irrigated paddy rice fields and dry land crops have been interviewed (Nosikia, 2014). Their interests are ranked as follows: Crop productivity, reliable water supply and sustainable irrigation infrastructure.

For the downstream irrigation weir, five farmers with irrigated paddy fields and dry land crops were interviewed (Triyanto, 2014). Crop productivity, a reliable water supply and revenue typify the interest of these farmers.

In general the preferences of the up-, mid- and downstream areas are summarized in the following two criteria. These criteria have been explained in paragraph 3.4 and will be used in the multi criteria analysis for the evaluation of the three measures (5.4):

- Decrease of annual agricultural water deficit
- Economic perspective farmers

5.1.2 Employees local water agency irrigation nodes Guntur, Kedung Putri and Boro

The UPT's at the up-, mid- and downstream irrigation weirs functioned as the official hosts for the conducted interviews in this research. On their behalf the farmers and employees were invited for the meetings. In general five to ten employees, including the director, attended the meetings. They provided valuable feedback and knowledge on the current quality and operation of the irrigation infrastructure. Detailed information on cropping seasons, schedule and irrigation demands also were provided by these employees. Their input has been included in this research because they are considered experts on the operation of the irrigation system. Furthermore they can indicate potential measures at specific locations for improving the irrigation network resulting in a lower water deficit for the period 2025-2045. They preferred robust solutions, since the high concentration of sediment easily decreased the capacity of newly build channels.

The employees of the UPT specified two important criteria. These criteria have been explained in paragraph 3.4 and will be used in the multi criteria analysis for the evaluation of the three measures (5.4):

- Decrease of annual agricultural water deficit
- Robustness performance measures

5.1.3 Regional government

The third participator in these interviews is the regional government, who is responsible for the water resource management in Serayu-Opak, which includes the Bogowonto catchment. The regional government is represented by the Probolo catchment authority and BWSS Serayu-Opak (Balai PSDA Probolo, 2014; BBWS Serayu-Opak, 2014). The Probolo catchment authority is a regional division of the government, managing the spatially distributed smaller water agencies all over Bogowonto and their water resource management. BBWS Serayu-Opak is the provincial department in Central Java, managing their mandate on water resource management on this catchment for this complete province. This is done by master plans and organizing periodic meetings with multiple local catchment management authorities. These actors have been included since the support of these governmental departments is very important in determining the feasibility of measures to decrease the agricultural water deficit.

The director of the Probolo authority specified four important criteria. These criteria have been explained in paragraph 3.4 and will be used in the multi criteria analysis for the evaluation of the three measures (5.4):

- Decrease of annual agricultural water deficit
- Cost efficiency measure
- Level of agreement up-, mid- and downstream farmers
- Level of agreement farmers, irrigation employees and local government

5.2 Potential measures

In this paragraph the proposed measures (5.2.1 and 5.2.2) and the final selected measures for simulation (5.2.3) are covered.

5.2.1 Initial proposed measures by stakeholders

During the first round of interviews at the up-, mid- and downstream irrigations weirs a brainstorm session is done about water resource management problems and potential solutions to solve these problems. These measures are presented in appendix F. The type of stakeholder is specified for each proposed measure. All of these proposed measures are assessed on three criteria (3.4), to check whether they are suited as potential measures to be incorporated in this research.

Of the sixteen proposed measures, two measures passed these selection criteria, both serving the same goal and therefore seen as one measure; increasing the transport irrigation efficiency of the primary, secondary and tertiary irrigation channel by rehabilitation of the present infrastructure of the irrigation channels. It is important to realize that a lot of measures were not selected because these measures might contribute to the solution of floods, salt water intrusion and illegal extraction of groundwater or were not suited for modeling in the RIBASIM model. This research focuses on agricultural water deficits and only includes surface water.

Because it is decided three measures have to be compared, more measures with a completely different nature like increasing the irrigation efficiency are proposed to the same community up-, mid- and downstream.

5.2.2 Additional discussed measures with stakeholders

Although none of the farmers proposed measures regarding crop cultivation, such measures have a high potential, since they directly impact the water demand. The majority of the crops in Indonesia consist of paddy rice. However, if new cropping types or new types of rice with a shorter growing period can be introduced, it can result in a significant decrease of the water demand during present periods of water deficit. To identify possible changes in the cultivation scheme, an interactive tool is used to address possible changes in the cropping pattern of the farmers. The stakeholders supported the simulation of this measure for further research. The outcomes and specifications of these measures can be found in the next paragraph.

The final measure is the construction of an upstream reservoir. Current master plans (BBWS Serayu-Opak, 2014) and schematizations (Muchamad, 2014) show the potential location of an upstream located reservoir. Retrieving community feedback on this measure from the up-, mid- and downstream irrigations weirs is very useful for a potential future implementation in 2020-2025. The stakeholders supported the simulation of this measure for further research.

5.2.3 Selected measures for simulation

Based on paragraph 5.2.1 and 5.2.2 the following measures are modeled in RIBASIM. This paragraph presents the specifications of the measures: increase of irrigation efficiency (i), changes of cultivation scheme (ii) and the construction of a reservoir (iii).

1. Increase of the irrigation transport efficiency

The current situation of the irrigation network is poor at all locations (Muhon, 2014; Nosikia, 2014; Triyanto, 2014). For the neighboring Progo river basin currently a master plan is designed, to give strategic suggestions for the management and operation of this river basin (Sutarto, 2014). This master plan assumes the irrigation efficiency can be increased from 50% to 65% for the year 2035 (Sutarto, 2014). Since the Bogowonto and Progo basins have similar irrigation conditions, the same increase in irrigation efficiency is assumed to be plausible for 2035. The same yields for the semi-technical irrigation nodes. The removal of old or brick irrigation channels and the construction of concrete irrigation channels for the primary and secondary irrigation channels is a possible manner to achieve this increased irrigation efficiency.

Applied changes in RIBASIM:

- Increase the technical irrigation efficiency from 50% to 65% for 2033 for irrigation nodes Guntur, Kalisemo, Kedung Putri and Boro (Sutarto, 2014).
- Increase the semi-technical irrigation efficiency from 45 to 55% for 2033 irrigation nodes Guntur, Kalisemo, Kedung Putri and Boro (Sutarto, 2014).
- Assume a fulltime annual schedule for maintenance of the irrigation channels to remove sediment, not only from February to October (Balai PSDA Probolo, 2014).

2. Change of cropping type and timing

One year consist of three cropping seasons. The first period is from October to January, the second period from February to June and the third cropping period from July to September. The stakeholders were asked to draw their current cropping pattern on the scale model. Subsequently during a group discussion all the participants thought about opportunities with respect to the cropping pattern, which decreased the agricultural water deficit. The structure of this interview, the responses and the current and newly proposed cropping patterns can be found in appendix H. It was proposed a rice type with a shorter growing period could be applied and less water could be stored onto the land, if it did not negatively affect the growth of the crops.

Applied changes in RIBASIM:

- Change the type of rice crops from 5 months to 4 months by cultivating another species of rice (Balai PSDA Probolo, 2014).
- Decrease in pre-saturation for paddy fields from 200 to 50-100 mm, depending on the rice type (Balai PSDA Probolo, 2014)

3. Construction of upstream reservoir

Current plans describe the construction of a upstream reservoir, located upstream of Guntur and downstream of the irrigation node Penungkulan (Balai PSDA Probolo, 2014). Together with this reservoir also an additional irrigation node of 1500 ha is planned. This reservoir serves as a buffer to regulate the downstream flow, i.e. to control the water flow during extreme dry and wet periods.

Applied changes in RIBASIM:

- Implement a reservoir just upstream of the present Guntur weir, of 200 by 200m, with a full reservoir level of 275m. The capacity of the reservoir is designed to be 11 10^6 m^3.

5.3 Future agricultural water deficits with measures (2025-2045)

This paragraph addresses part of the second research question. What are the effects of the selected measures under different scenarios on the agricultural water deficit for the locations Guntur, Kedung Putri and Boro. In other words, this paragraph addresses compares the effect of the measures and the robustness of each measure for the climate scenarios. Paragraph 5.3.1-5.3.3 cover the findings on annual (figures 5.1a-5.3c) and monthly (appendix H) simulated water deficits for the period 2025-2045 for the up-, mid- or downstream irrigation weir. The first measure simulates an increase of the irrigation efficiency, the second measure simulates a shorter cropping pattern including a lower water level on the land for wet land crops and the third measure simulates the effect of the construction of a reservoir.

5.3.1 Upstream

For irrigation node Guntur the measures irrigation efficiency (measure I) and building reservoir Bener (measure III) lower the water deficit for all years (figure appendix-H1). Shortening the second cropping season only lowers the water deficit for some years. The water deficits for the three driest years vary from 200 to 350 mm per year. Building the reservoir is by far the most successful measure which lowers the water deficit, because the simulation shows no water deficit for this upstream irrigation weir after the construction of this reservoir. Increasing the irrigation efficiency lowers the water deficit by roughly 30%.

In decreasing order of robustness, the measures are ranked as follows: reservoir, irrigation efficiency and an alternative cropping pattern. In general all measures are considered robust, since they keep doing what they are designed for during 2025-2045. Figures Appendix H1a shows a steady performance in reducing the water deficit by construction of the reservoir. Increasing the irrigation efficiency contain more years with variations in the water deficit, but the margins are small (figure appendix H1b). The same yields for the cropping pattern, although the measure itself does not perform a steady annual decrease of the water deficit but shows large fluctuations (figure appendix H1c).

The distribution of the monthly water deficits (appendix H) shows no water deficits are present for all months during the years 2025-2045 for the measure 'reservoir' , 'cropping pattern' and 'irrigation efficiency'.

5.3.2 Midstream

For irrigation node Kedung Putri all three measures are successful in lowering the water deficit for the period 2025-2045. The water deficit in the reference scenario is 750 mm for the three driest years. Figure 5.1b shows that increasing the irrigation efficiency and constructing the reservoir decreases the water deficit for the driest years 2030, 2039 and 2036. It has to be noted that these are different years compared to the upstream irrigation weir. A change in the cropping pattern (measure II) does not lower the water deficit for 2030 and 2039, but does lower the water deficit for 2036. As expected, the reservoir reduces the water deficit to almost zero for the driest years. How the reservoir could deal with such a water deficit in the driest year can be explained by the fact that the year 2029 was a very wet year, resulting in a full reservoir at the beginning of 2030.

The effect of the climate scenarios is presented in figure 5.2a-5.2c. The measures are ranked in the same order on robustness compared to the upstream weir: reservoir, irrigation efficiency and change to the cropping pattern. The wettest scenario (C) simulates the lowest possible water deficits and the driest scenario (F) simulates the highest possible water deficits. Scenario D lowers the water deficit for the ten driest years, because it lowers the water deficit in October by modeling more rainfall during the wet season. For the remaining ten ranked years it can be clearly that seen scenario E simulates a decrease of the water deficit for May and June keeping in mind figure 4.3, since this scenario addresses a higher rainfall during the dry season (figure 5.2b). A possible explanation for the excellent performance of the measure ‘reservoir’ for different climate scenarios, is caused by the storage capacity of the reservoir. Less precipitation does not immediately result in a lower water availability, since this can be regulated by the reservoir if sufficient water is available in the reservoir. The other two measures only reduce the amount of water needed, but are directly affected by fluctuations in precipitation and runoff.

5.3.3 Downstream

For irrigation node Boro increasing the irrigation efficiency and the construction of a reservoir are successful measures to lower the water deficit for all years (figure 5.1c). The three driest years are 2030, 2039 and 2036, again different years compared to the upstream irrigation weir, with water deficits varying around 650 mm. Applying a new cropping pattern results for two years even in an increase of the water deficit, meaning this specific measure is less suited for this location.

The effect of the climate scenarios is presented in figure 5.3a-5.3c. The same explanations and conclusions as the midstream irrigation weir apply for this downstream irrigation weir regarding robustness. One minor difference is the effect of climate scenarios D and E. For Boro only a water deficit in May and June is present (figure 4.3), wherefore scenario E lowers the water deficit more compared to scenario D.

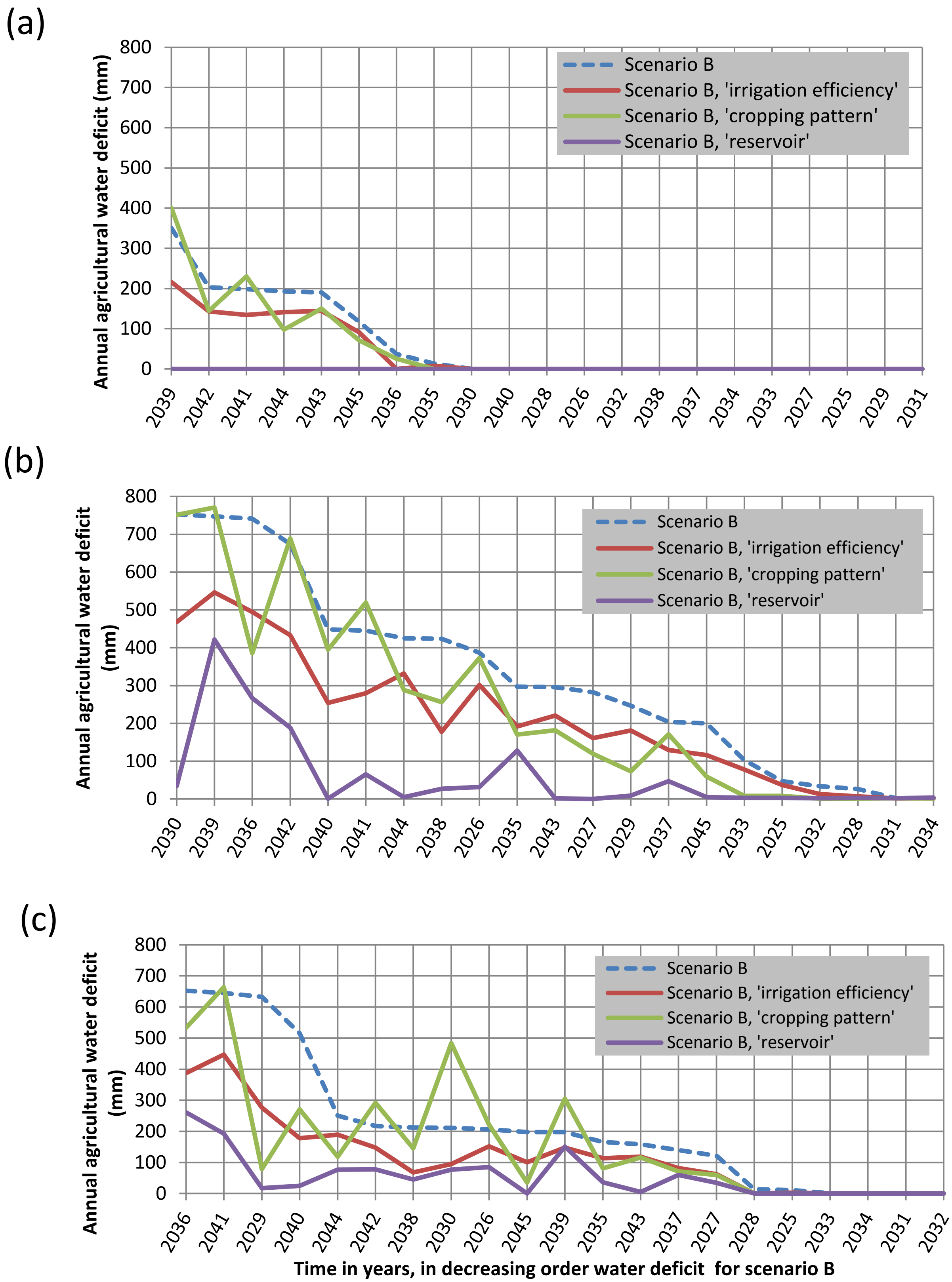


Figure 5.1: Annual agricultural water deficit upstream (a0, midstream (b) and downstream (c) in Bogowonto catchment for period 2025-2045.

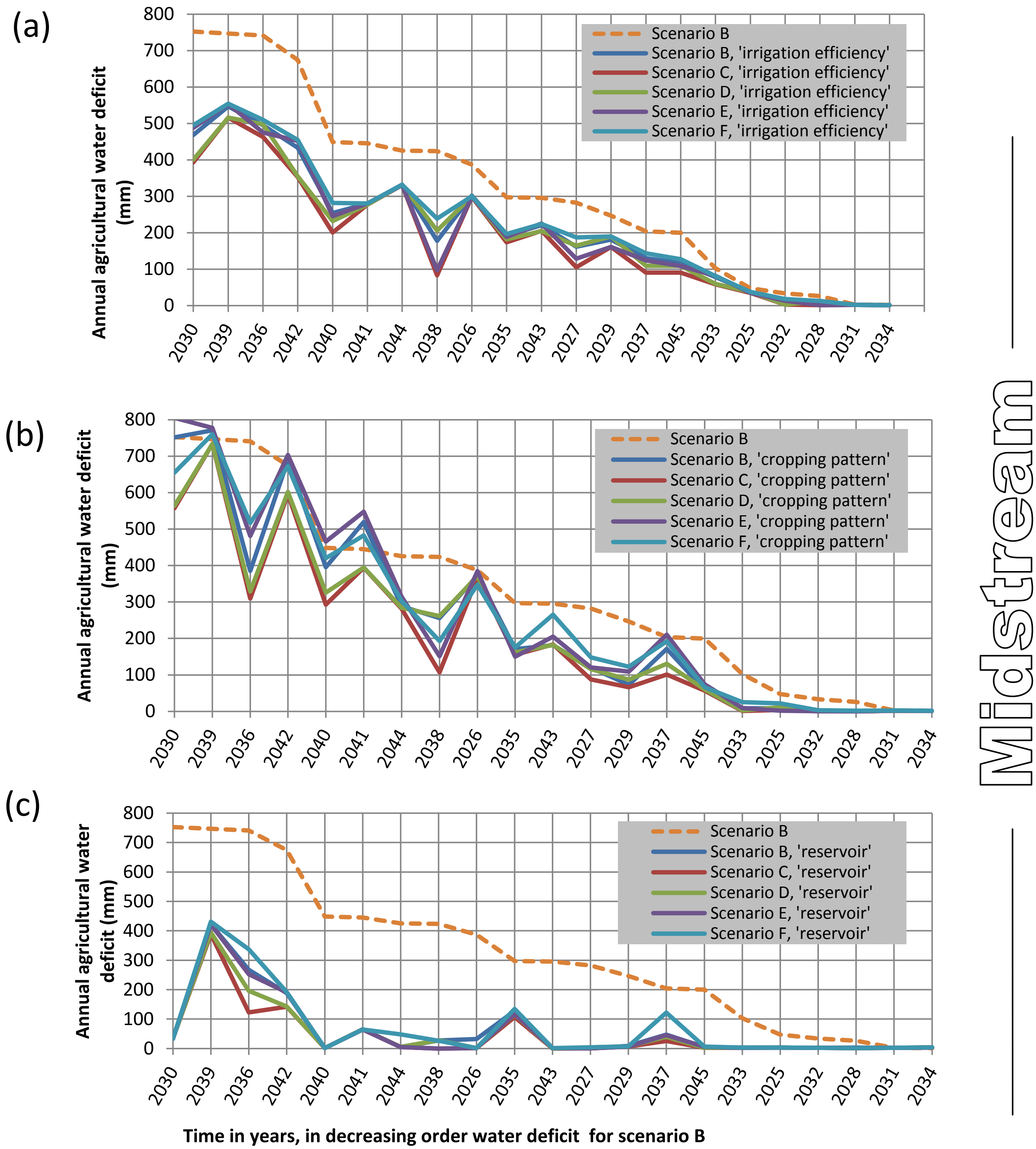


Figure 5.2: Annual agricultural water deficit in midstream Bogowonto catchment including climate scenarios for climate variability for period 2025-2045 measure 'irrigation efficiency' (a), measure 'change cropping pattern' (b) and measure reservoir(c).

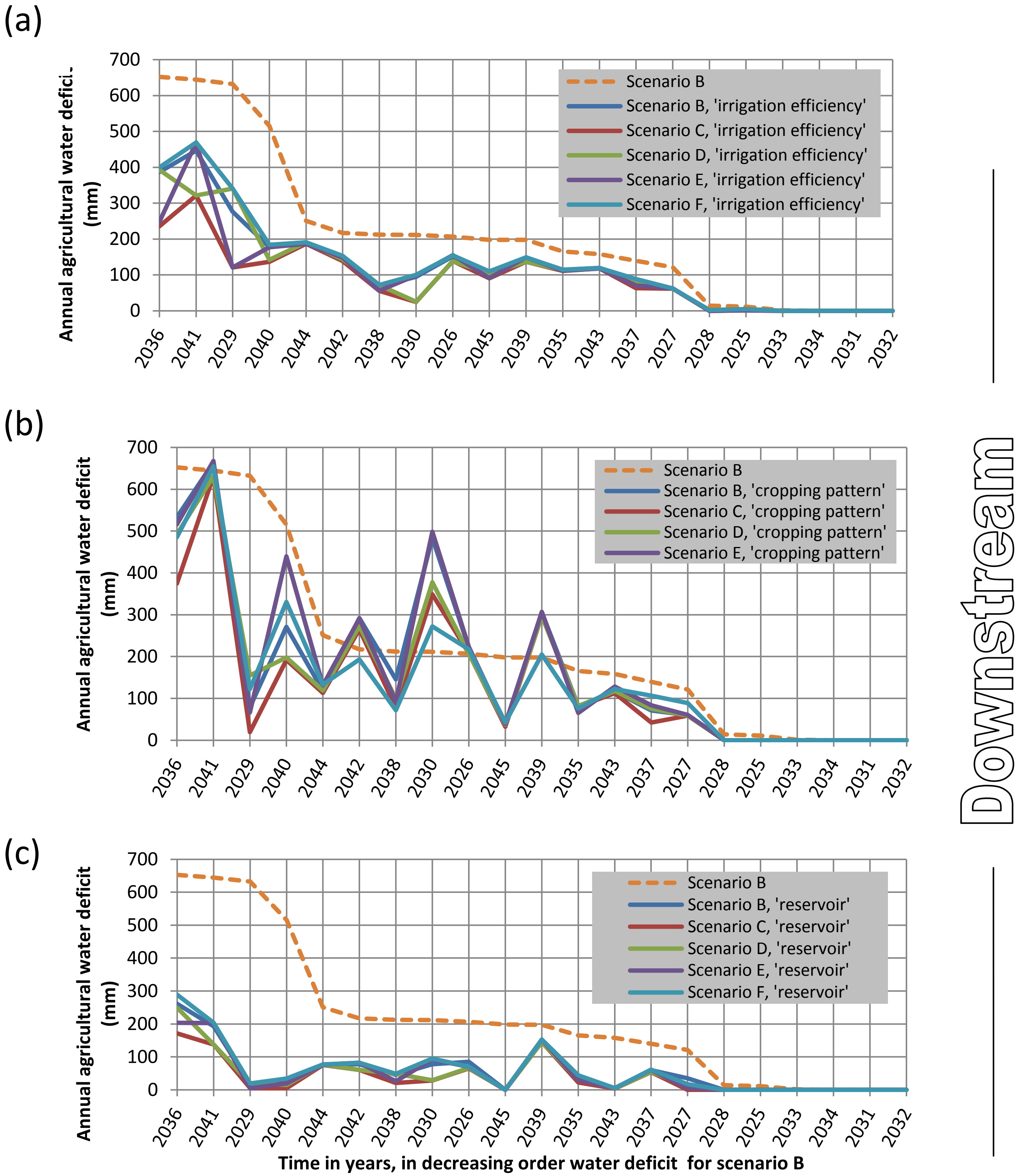


Figure 5.3. Annual agricultural water deficit in downstream Bogowonto catchment including climate scenarios for climate variability for period 2025-2045 measure 'irrigation efficiency' (a), measure 'change cropping pattern' (b) and measure reservoir(c).

5.4 Preferred solution package

In this section the responses of the stakeholders for the three measures are presented (5.4.1). Subsequently the criteria for the comparison of the measures by a multi-criteria analysis are presented (5.4.2) and applied for the comparison of the measures in a multi-criteria analysis (5.4.3). Finally the proposed measure(s) are presented, including the final prognoses for the simulated monthly and annual water deficits for 2025-2045 (5.4.4).

5.4.1 Response measures

This paragraph addresses the responses of the stakeholders to the prognoses for the water deficit for the three simulated measures. The responses have been sorted for the upstream (5.4.1.1), midstream (5.4.1.2) and downstream stakeholders (5.4.1.3) for each irrigation weir. The response of the government is covered in a separate paragraph (5.4.1.4).

5.4.1.1 Upstream farmers + UPT

As previously shown, the water deficit at the irrigation node Guntur reached 400 mm in 1994. The most recent year with a significant water deficit took place in 2001. The interviews showed that most farmers could not remember these dry periods, partly because for most years no cumulative annual water deficits above 50 mm have taken place. In essence the farmers and weir operators agreed with the simulated frequency of the water deficits.

During a participatory session at the upstream irrigation weir Guntur, the three simulated measures were ranked in the following order: Irrigation efficiency (1), cropping pattern (2) and reservoir (3). Rehabilitation of the irrigation channels (measure irrigation efficiency) was without doubt chosen as the best measure by all participants to deal with water deficits (Muhon, 2014). The measure should include a no-crop-buffer-zone close to the irrigation channel to prevent the collapse of the channel banks, which would result in blocking the irrigation water flow. This measure should also include the removal of the current sediment from the irrigation channels and providing a sustainable solution to keep the irrigation channel free from sediment. Furthermore the farmers disagreed with the option to change their cultivated rice type, due to insufficient knowledge and long traditions of cultivating this specific crop (Muhon, 2014). The farmers did not know any examples in their environment were the production of another cropping type resulted in higher revenue compared to their own revenue. Also the cultivation of paddy rice encompasses a long tradition of growing this crop, and it is not easy to break this tradition. Finally the farmers were strongly against the construction of the upstream reservoir, because they were anxious to negative effects like the involuntary move of a lot of households due to the construction of the reservoir (Muhon, 2014). According to the upstream farmers only the mid- and downstream farmers usually would take advantage of the reservoir. The uncertainty of this yet undefined location of the reservoir resulted in anxious responses causing that all the farmers voted negatively for this option.

5.4.1.2 Midstream farmers + UPT

The largest annual cumulative water deficit measured at the irrigation node Kedung Putri was 750 mm in the year 1997, which is confirmed by the farmers and irrigation workers. Because the UPT did not have any data on the intensity of the water deficit, the exact values of the simulated water deficits could not be validated by this UPT.

During the participatory session in Purworejo, where the midstream weir Kedung Putri is located, the measures were ranked as follows by the farmers and employees of the water board: Reservoir (1), irrigation efficiency (2) and cropping pattern (3) (Triyanto, 2014). Everyone was in favor of the construction of the reservoir, because the reservoir increases the water availability in times of droughts. The measure irrigation efficiency was also favored by all participants, if the measure included the following conditions: a program to remove sediment and keep the irrigation channel free from silting again (i), remove garbage from the irrigation channels (ii) and finally organize a better enforcement against the illegal intake of irrigation water by other farmers (iii). Finally the farmers did not agree to cultivate another rice type, for the same reasons as mentioned in paragraph 5.4.1.1

5.4.1.3 Downstream farmers + UPT

In 2003 the water deficit in the downstream located irrigation weir Boro reached the maximum simulated annual value of 650 mm. Due to lack of data and knowledge the frequency as simulated by the RIBASIM model could not be validated by the farmers or employees of the water board.

During the participatory sessions exactly the same ranking for the measures reservoir and irrigation efficiency as the midstream location was retrieved for the same reasons (Nosikia, 2014). In addition the measure cropping pattern was also seen as a possible option, because some farmers were willing to change their rice type into a rice type with a shorter growing period if the same production could be guaranteed.

5.4.1.4 Balai PSDA Probolo

Balai PSDA Probolo is responsible for the general water management of the weirs Kedung Putri and Boro in the catchment of Bogowonto. The director of PSDA Probolo agreed with the shared findings of the up-, mid- and downstream participants, in other words the rehabilitation of the irrigation network is the best option to deal with the future simulated water deficits (Balai PSDA Probolo, 2014). Furthermore an additional measure was proposed, which consisted of a combination of rehabilitation of the irrigation system and building the reservoir, since both measures are appropriate measures to deal with the water deficit. By combining these measures the water deficit can be reduced to the smallest amount possible, in order to have a higher availability and productivity for the cultivated crops. This option is included in the multi-criteria analysis in paragraph 5.4.3 as measure four, ‘increasing the irrigation efficiency + construction of reservoir’.

5.4.2 Multi criteria analysis

In this section the simulated measures are assessed in a multi criteria analysis.

Table 5.3: Multi-criteria analysis of proposed measures. A=excellent, B=good, C=moderate, D=insufficient and E=poor score. For the measures IV – V only one of the following grades can be given (A, C or E).

Measure	I. Decrease of annual agricultural water deficit	II. Economic perspective farmers	III. Robustness measure	IV. Cost efficiency measure	V. Level of agreement up-, mid- and downstream farmers	VI. Level of agreement between different type stakeholders
1. Irrigation efficiency	B	B	D	C	A	A
2. Cropping pattern	D	C	B	A	E	C
3. Reservoir	A	B	E	E	C	A
4. Irrigation efficiency + reservoir	A	A	D	E	C	A

Table 5.3 shows the outcomes of the multi-criteria assessment. How each criterion is assessed has been presented in the previous paragraph. For most combinations of measures and criteria the assessment is straightforward. However, some less straightforward cases will be explained in the following paragraphs.

The first criterion assesses the 'decrease of annual agricultural water deficit' to reveal to what extend the water deficit is reduced for the driest years of each up-, mid- and downstream irrigation weirs. The measure 'irrigation efficiency' reduces the water deficit to 65%, resulting in a 'B' (table 5.3). The measure 'cropping pattern' does not result in an in- or decrease for the driest year, resulting in a 'D'. It has to be noted for some years the water deficit even increases, which is an adverse effect of this measure. Finally, al measures which include the reservoir (measure III + IV) reduce the water deficit to 33% or less for the driest year, resulting in an 'A'.

The second criterion assesses the 'economic perspective of the farmers'. The measure 'irrigation efficiency' increases the quality of the irrigation channels by repairing leakages, getting out the sediment and if necessary the replacement of old irrigation channels from dirt into concrete. This results in a more reliable flow in the irrigation channels, resulting in less risk to the farmers the crop will die to the lack of water. Some farmers may optimize their water consumption by cultivation of extra crops. As a consequence this measure results in a good perspectives (score B). The measure 'cropping pattern' recommends a paddy rice type with a shorter growing period. However, this does not result in a better economic perspective for the farmers since they cannot expand their production due to the low reliability of available water. Therefore the measure 'cropping pattern' has moderate cropping conditions (score C). The measure 'reservoir' result in good perspective (score B) for economic perspective of the farmers, since the reservoir regulates the water availability and reduces the water deficits. The measure ‘irrigation efficiency + reservoir’ results in an excellent economic perspective for the farmers, since the water availability for irrigation can be controlled and the poorly functioning irrigation infrastructure is replaced, resulting the water reaches its destination.

The third criterion is ‘robustness measure’. This criterion will be assessed quantitatively, since no study has been done to the performance of these measures for the Bogowonto catchment for 2025-2045. Thus, to quantify robustness, the number of years the measure will perform for at least 80% of its originally designed value, equals the score for this criterion. For the measure ‘irrigation efficiency’ it is expected rehabilitated irrigation channels will be filled up with sediment (Marhaento, 2014) within 10 years to such an extend it will reduce the irrigation efficiency by more than 20%, resulting in the score ‘D’. The measure ‘cropping pattern’ is considered very robust with a steady efficiency, since the gained efficiency of the new crop type with a shorted growing period it still valid for the next 25 years. Although this does not solve the water deficit, for this measure this criterion results in an ‘A’. The measure ‘reservoir’ is considered to have a low robustness (E) as a result of the high rates of sediment transport in the river. A dam will accumulate this sediment, reducing the capacity of the reservoir.

The fourth criterion is ‘cost efficiency’. Cost efficiency is minimizing efforts and maximizing the desired effect. Cost efficiency in this criterion is addressed by analyzing the cost for a reduction of the annual water deficit by for example 50 mm. The measure ‘irrigation efficiency’ results in medium cost efficiency, since a lot of irrigation channels should be rehabilitated for the measure to reduce the water deficit by 50mm or more. On the other hand, renewing the irrigation channels is not very expensive. The measure ‘cropping pattern’ has a high cost efficiency due to the low investment cost of changing the seed for the farmers. However, it is recommended to build example farms were this new cropping type is successfully applied. These pilot farms should be build a strategic places and the farmland should be cultivated by a governmental farmer. The interviews showed (Muhon, 2014) the process to convince the farmers about applying a new cropping type can be very labor intensive and time consuming. The cost efficiency of the measure reservoir is low, if the water deficit should only be reduced by 50mm. The high initial cost of the construction of the reservoir and the process of compulsory resettlements at the destined location of the reservoir result in enormous costs. On the other hand, this measure has a much larger effect in reducing the water deficit, resulting on the long term this measure is the best choice.

The fifth criterion is level of agreement up-, mid- and downstream farmers. The measure ‘irrigation efficiency’ is supported by all interviewed farmers in the Bogowonto catchment, resulting in a full consensus (score A). The measure ‘cropping pattern’ resulted in no consensus at all (score E), since it is really hard to change a decennia of cropping habits. Some farmers were willing give a try, were others refused every change to the current cropping pattern. For the measure reservoir the down- and midstream farmers on the irrigation weirs were in favor of the reservoir, whereas the upstream farmers were furiously against the construction of this reservoir. The measure ‘irrigation efficiency + reservoir’ also scores an ‘C’, since the upstream farmers still voted against the construction of the reservoir.

The sixth criterion is level of agreement between different types of stakeholders. This is the agreement between farmers, employees of the irrigation weir and the local government for the support to implement a measure. For the measure “irrigation efficiency” all stakeholders unanimously voted for this solution and therefore an ‘A’ score is given. Since the local government did not believe changing a crop would result in the desired reduction of the water deficit, no agreement on this solution could be establish. The majority of the farmers, all employees of the irrigation weir and the local government were in favor of the measure ‘reservoir’ and ‘irrigation efficiency + reservoir”. Although the upstream farmers did not like this solution, the remaining stakeholders were in favor of this solution, resulting in the score ‘A’. In addition, due to the small size of the upstream irrigation weir, they mid- and downstream famers have in general more power in the decision process on potential measures.

In general measure ‘irrigation efficiency + reservoir” which simulates the increase or the irrigation efficiency at each irrigation weir and the construction of an upstream reservoir, results in the lowest possible simulations of these four options for the period 2025-2045. After all interview sessions and participatory meetings, the final preference of the farmers, employees of the waterboard and local government agreed with this measure, with the constraint a considerable amount of money if involuntary movements and movement of their present irrigation fields were necessary should be given to the upstream farmers. The effect of this measure for 2025-2045 for an annual and monthly scale is presented in the next paragraph.

5.4.3 Future agricultural water deficits with preferred solution package

This section summarizes the hydrological results measure “irrigation efficiency + reservoir” .

Figure 5.5 present the monthly water deficits for the mid-stream irrigation weir. Starting at the left, figure 5.5a shows the monthly water deficit for scenario B0 for the years 2025-2045 depicted in a box plot. The 75th percentile during May is 380 mm, in June 170 mm and in October 360mm. The remaining three figures from left to right present the effect of measure IV for scenario B (no climate variability) (figure 5.5b) , C (wettest scenario) (figure 5.5c) and F (driest scenario) (figure 5.5d). The monthly water deficits are completely solved for this midstream irrigation weir. The same yields for the up- and downstream irrigation weirs. Furthermore it can be seen that the effect of the wettest and driest scenario is minimal, because the water deficit in all months remains zero for the 75th percentile. Only some extreme water deficits are simulated as outliers in figure 5.5d.

Figures 5.6a-5.6c present the annual agricultural water deficits for measure ‘irrigation efficiency + reservoir’ for all climate scenarios. For the upstream irrigation weir (figure 5.6a) no water deficits are simulated for the period 2025-204. For the midstream irrigation weir (figure 5.6b) only two years (2035 and 2039) have a minor water deficit up. This can be up to an annual 250 mm caused by extreme dry periods. For the downstream irrigation weir (5.6c) the largest water deficit takes places in 2039 with an annual value of 100mm. For the remaining years the water deficit varies between 0-70mm per year.

The two extreme climate scenarios, respectively C and F, do not result in different in different extreme values for the monthly water deficits during 2025-2045. The measure ‘irrigation efficiency + reservoir’ is therefore not sensitive to climate variability in rainfall and evaporation.

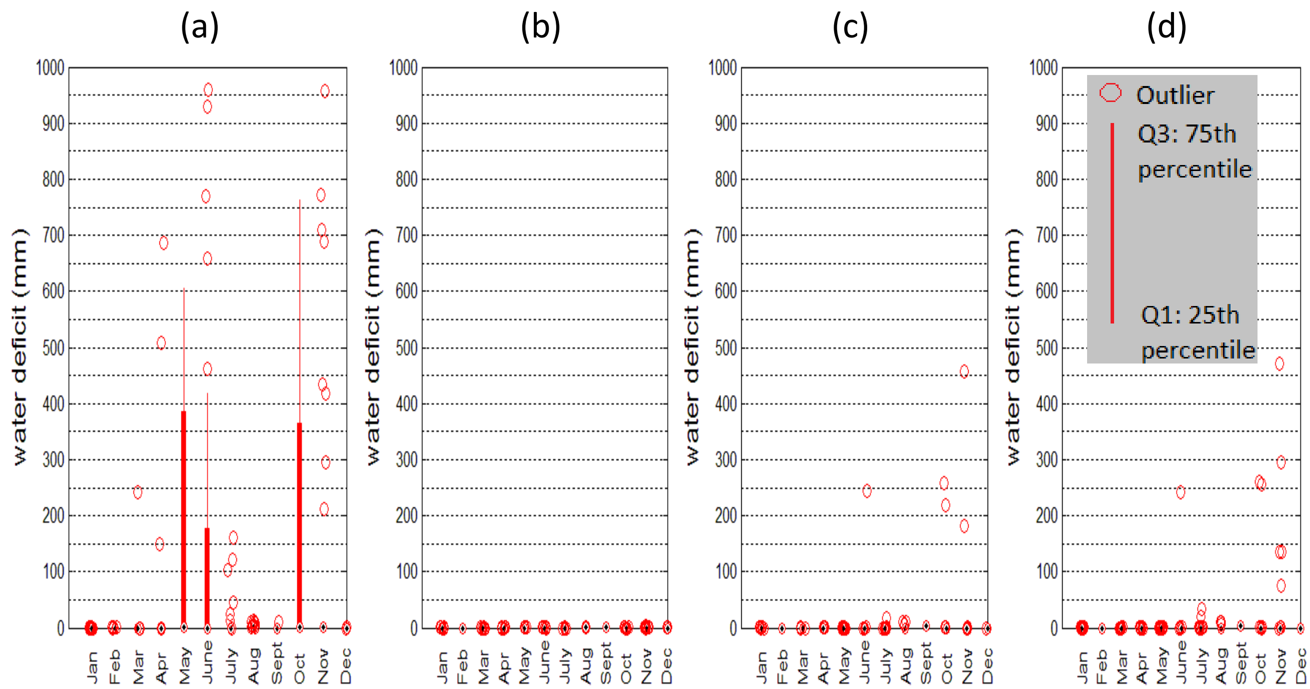


Figure 5.5: Distribution monthly water deficits irrigation weir Kedung Putri (midstream) (2025-2045) scenario B, reference scenario (a), scenario B, measure "increasing irrigation efficiency + construction of reservoir" (b), scenario C measure "increasing irrigation efficiency + construction of reservoir" (c) scenario F measure "increasing irrigation efficiency + construction of reservoir" (d)

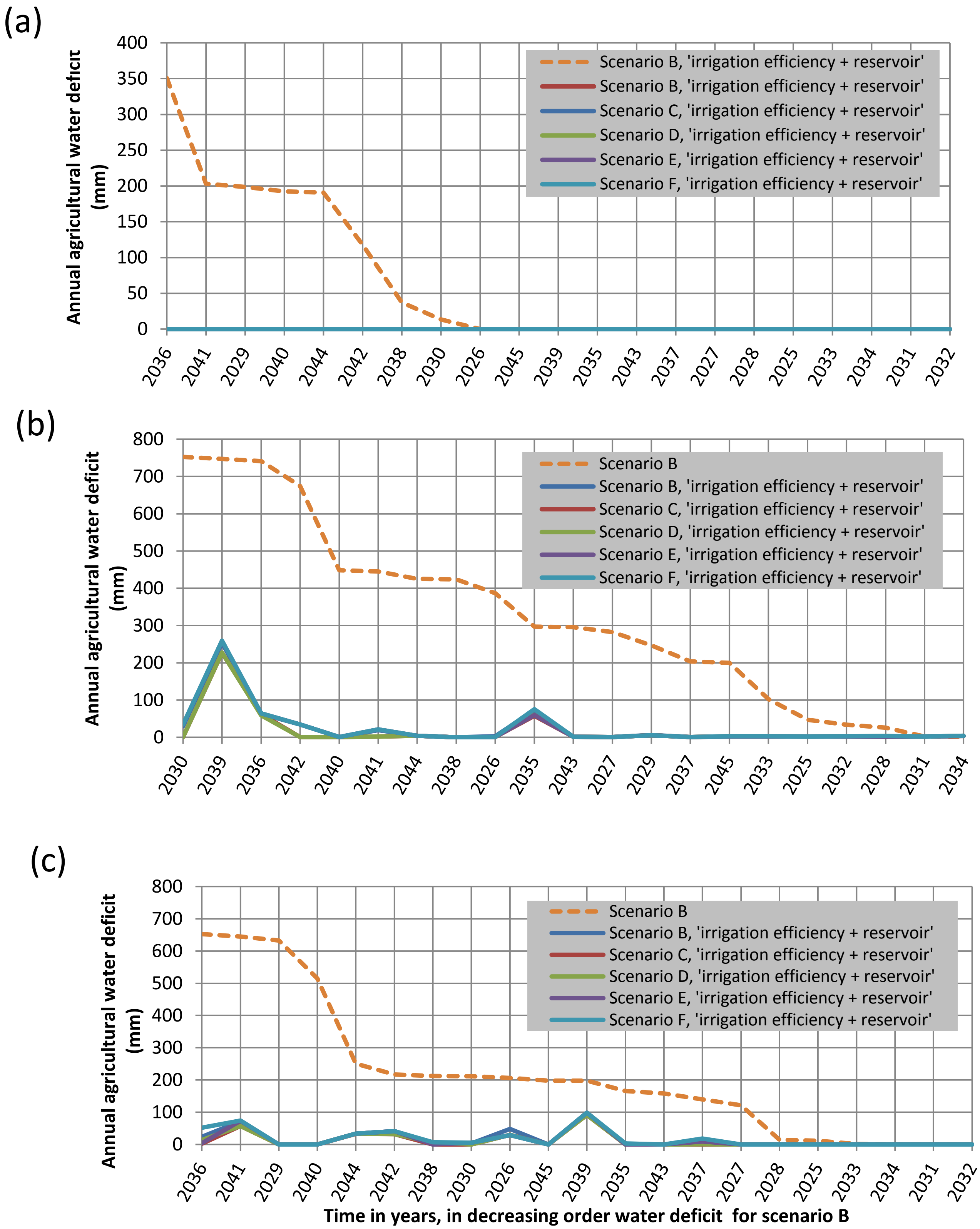


Fig 5.6: Yearly water deficit Bogowonto for 2025-2045 up- (a), mid- (b) and downstream (c) part.

6 Discussion

This chapter discusses the applied method and obtained results and highlights parts of the research which can be improved. First the available data are discussed, thereafter the applied model, subsequently the participatory sessions, methodology and finally the discussion of the results is presented.

Available data

- The selected locations for the up-mid-and downstream irrigation weirs for this research are spatially not well distributed. The discharge stations and corresponding irrigation weirs Boro, Pungangan and Kedung Putri are all quite close to each other. On the contrary, no irrigation weir is present downstream of Boro. However, a better interpretation of the differences in water deficits between the mid- and upstream section can be obtained by including the upstream located irrigation weir Pingit. In this study this weir is not included because the data is not available for this research.
- The applied time series for runoff and precipitation have not been validated because no data was available for this study about the design of the water districts, which rainfall stations were used and which formulas and assumptions have been applied to convert the precipitation into runoff. Experts in the region could not provide additional information (BBWS Serayu-Opak, 2014; Muchamad, 2014; Sutarto, 2014). However, statistical analysis of the rainfall and runoff data revealed that the time series behavior follows the expected annual dry-wet pattern and no unusual outliers have been marked (figure 2.2 and 2.3), except for the drop of the average rainfall in the 2^{nd} part of December and 1^{th} part of January over the period 1992-2012. This deviation did not result in any water deficits. In general it is chosen to apply this runoff and precipitation data, because no other data was available for this research.
- The exact measurement location for the applied evaporation series is unknown. If only temperature is considered, the effect of possible variations in the reference evaporation is considered to be small. A difference of 1 C˚ causes the ET to increase with a factor 1.03 according to strongly simplified Thornwaite formula. However, the effect of the fluctuating altitude for the three irrigation weirs cannot be neglected. Factor like solar radiation, air temperature, wind speed and relative humidity change over height. In general the ET decrease if the height increases (Gavilán, 2009). A 100m increase in altitude results in a decrease of 10% of ET (Shaw, 2013). Guntur is located at +215.5m, Kedung Putri +86.0m and Boro +22.0m a.m.s.l. This results in an elevation range of roughly 200m, wherefore the ET in Guntur (upstream) is a factor 1.2 smaller compared to Boro (downstream). This shows a significant bias can be present in these data for ET. For example if this evaporation series is measured in the downstream flat area, the ET in Guntur (upstream) is overestimated resulting in an underestimation of the water availability. The water deficits will therefore be overestimated in the upstream part. And vice versa if the evaporation series is measured in the downstream part.

RIBASIM model

- Due to incomplete data not all irrigation fields have been implemented as irrigation node in the model schematization implying an underestimation of the water demand. However, the effect of this underestimation is considered to be small because most of the not incorporated irrigation areas are smaller than 100ha. In addition the irrigation areas at the Boro and Kedung Putri weir together cover 9477 ha, which is more than 90% of all irrigation areas in Bogowonto.
- The data showed no groundwater measurement devices for Bogowonto have been installed yet, resulting no quantitative data is available on groundwater flows and the amount of extraction. Due to time constraints no other assumptions have been done for simulating the groundwater flow. Because some famers extract groundwater during dry periods, the simulated surface water deficit does not always result in a water deficit for the farmer. Also special water saving distribution methods are applied at the irrigation weirs during periods of water deficit, because the paddy rice is able to deal with the short periods of water deficit. However, since this data is not available for this research and considering the time constraints of this research, the groundwater and special distribution methods during dry periods are not incorporated for this research.
- The RIBASIM model is able to simulate the water deficits for different future scenarios. This helps in determining the minimum and maximum ranges for the water deficit during the year and for the up-mid-and downstream sections of Bogowonto. However, these scenarios are based on IPCC (2013) scenarios with prognoses at a very large scale (South-East Asia). It is preferred to apply climate scenarios which are designed for Java only. Secondly some farmers stated that the start of the wet season during previous years sometimes was delayed, creating uncertainty whether the farmers should start planting rice or wait. However, RIBASIM does not automatically delay the start of the cropping season if the precipitation is not sufficient to start preparing the land. For the midstream irrigation weir with the largest water deficit, the 75th percentile of the water deficit for the period 2025-2045 for October is 360mm, with extreme water deficits up to 760mm. For November the 75th percentile of the water deficit is 0mm, with some extreme water deficits up to 950mm. Based on the 75th percentile, the error can be up to 360mm for the month October. On the other hand, the farmers will experience extra water deficits at the end of the second cropping seasons, due to the delayed start. It is assumed these water deficits average each other out, resulting in a representative simulation of the annual water deficits.
- The reducing effect of the measures ‘reservoir’ and ‘irrigation efficiency’ on the water deficit may be overestimated on the long term. The Bogowonto river transports high loads of sediment, resulting the reservoir and the irrigation channels will be slowly filled by the sediment, decreasing the reservoir capacity and transport capacity of the channels. It is assumed proper maintenance will be executed to ensure the quality of these measures. In addition, research to the negative effects of the sediment flow to the performance of these measures in this river is recommended to help in designing an effective maintenance program.

Participatory sessions/interviews

- Because only group interviews were carried out, it was not fully possible to retrieve the opinion of an individual stakeholder. To deal with this issue, individual questions were asked. However, conducting interviews in the setting of a group discussion is highly sensitive to bias. By interviewing twice at the same location, with an interval of two months with the same persons, the consistency of the opinions was checked.

- The interviews have been conducted with a translator, which results in a loss of information. This problem was tackled by recording these interviews, which have been transcribed and translated by employees of the Gadjah Mada University. This helped in obtaining a more complete understanding of the opinion of the stakeholders.
- The representativeness of the selected farmers for this research is sub-divided in homogeneous and non-homogeneous characteristics. Homogeneous aspects are the cropping schedule and type, the technical irrigation infrastructure, the land of the interviewed farmer did not exceed 10 ha, the same questions and translator have been used and the management of these areas is done by the same institution. The non-homogeneous aspects are the decreasing water availability from up- to downstream due to the decrease in precipitation and increase in evaporation as a result of the decreasing height. Moreover the downstream farmers also have to deal with annual floods and salt water intrusion from the sea, whether the upstream famers only have minor water deficits since they cannot store the water due to the high reforestation rates. As a result, the downstream farmers also proposed solutions to solve these problems, but these arguments have not been incorporated since they are outside the scope of this research. Finally, the location of the farmers land at the irrigation weir is unknown, causing a bias in the validation of the water deficits for the farmers, since the water deficits far from the irrigation weir are higher compared to the water deficits close to the irrigation intake. Therefore this validation by the farmers should be interpreted with care. It is recommended for further research to gather information on the positions of these or let them be selected by the researcher.

Methodology

- To simulate the agricultural water deficit in Bogowonto the RIBASIM model has been chosen. An old schematization of Bogowonto for this model was already available. RIBASIM has relevant limitations too, for example it is not able to simulate land use changes or sediment transport in the river. For example SWIM (Krysanova, 2005) has been developed to simulate sediment flows to assess the robustness of the applied measures. SWIM is based on two previous developed tools, SWAT and MATSALU. The SWIM model is developed for regional impact assessment and helps to address climate and land use changes. Also the model is able to deal with crop yields, which can be a more direct output variable compared to water deficit (mm) for assessing which measures regarding water availability and demand are necessary. Another model which also could have been applied for this research is WEAP, developed by the Stockholm Environment Institute. The model operates on a monthly time step and applies the basic principles of water balance accounting. Similar to RIBASIM the user specifies various sources of supply, withdrawals, water demands and ecosystem requirements (Yates, 2005). In essence the model should be as simple as possible. Correspondingly the RIBASIM model has widely spread and extensively used in Indonesia and the model is able to simulate the agricultural water deficits for 1992-2012 and for 2025-2045 and it is able to simulate measures regarding water availability or water demand. Given these points, the RIBASIM model is an appropriate model for this study.

- This study applied interviews and interactive discussion sessions to exchange information about possible measures to decrease the agricultural water deficit in collaboration with the stakeholders. Although this method was really successful in discussing potential measures and listening to the stakeholders, it is still subjected to bias due to group interviews, language and cultural barriers. Moreover time was needed to model the proposed solutions. If a model can be developed which can operate onsite and is very fast, direct feedback on stakeholder proposed measure can be given and the decision process on potential measures can be accelerated. Also the application of farms were governmental farmers demonstrate new solutions, is a possible way of convincing the community of the added value of the considered measure. This method tackles the culture and language barrier, since the example farm is exploited by locals, financed by the government. On the contrary this method is very time consuming, resulting the application of interviews and interactive sessions is considered a sufficient tool for this research.

Results

- This study analyses the agricultural water deficit at an annual and two-weekly interval, since no daily data for the model is available. Simulation at a daily scale would more accurately simulate the water deficits. However, a two-weekly scale is sufficient to simulate the agricultural water deficit, since only water deficits larger than two weeks result in irreversible damage to the crops (Nosikia, 2014). The monthly timing of the water deficits in this study is confirmed by Marhaento (2014), who executed a data review and constructed a simple water balance for the Bogowonto catchment.
- The participants especially proposed measures which increase the water availability. However, measures that decrease the water demand by the farmers have been hardly proposed by the stakeholders. It is possible the stakeholders are very dependent on the government, but have not been trained to look for water decreasing solutions at their own farms, as they are anxious for receiving less water. Research to options for decreasing the water demand shows numerous options: increasing the yield per unit ET (i), reducing the unproductive water outflows and depletion (ii) and making more effective use of rainfall or irrigation water (iii) (Kijne, 2003). Currently 20% of all irrigation water is simulated as return flow. For example by reducing this water outflow less water is lost.
- The added value of incorporating the opinions of the local farmers and irrigation workers is confirmed by a similar study where technical interventions at a farm level have been executed, performed in the Mekong Delta in Vietnam (Hoanh, 2003). It shows the added value of the local stakeholders to help understanding how farmers evaluate the interventions of the government and increases the chances of a successful implementation.
- Given the uncertainties and limitations in this study, the simulation and interview results should be interpreted with care. However the simulation results give an indication of the future water deficit with variations due to climate variability and potential measures to decrease this water deficit. Being aware of the uncertainties mentioned in the previous paragraphs and performing the recommendations will results in a better answer of the research objective. The incorporation of the community feedback with these more detailed simulations will help in properly dimensioning the four simulated measures.

7 Conclusions and recommendations

The overall objective of this study is to select potential measures for the Bogowonto catchment to decrease the agricultural water deficit by following a participatory approach to obtain preferred measures and by applying a water allocation model which addresses the spatial and temporal variations in the agricultural water deficit. Paragraph 7.1 present the conclusions resulting in an answer for this research objective and paragraph 7.2 presents recommendations for further research and the operational management.

7.1 Conclusions

Paragraph 7.1.1 presents the conclusions on the present and future agricultural water deficit in Bogowonto, as simulated by the RIBASIM model for different scenarios. Paragraph 7.1.2 describes the conclusions on the preferred measures by the up-, mid- and downstream stakeholders in Bogowonto in the challenge to reduce the water deficit for the period 2025-2045.

7.1.1 Present (1992-2012) and future (2025-2045) water deficit Bogowonto

Since the historical (1992-2012) and future (2025-2045) period are simulated with the same time series for water availability and only a minor decrease of the water demand is expected and simulated, the water deficits for the period 1992-2012 and 2025-2045 are almost the same for the reference scenarios (A and B). The following conclusions only apply for the 2025-2045 period: For the upstream irrigation weir the agricultural water deficit varies around 350 [330-370] mm for the driest year. The brackets show the minimum and maximum value as modeled by the climate scenarios for the driest year. The months May-June and October-November are the largest contributors to the cumulative annual water deficit, as a direct result of the low rainfall in these periods and the high agricultural water demand. For five out of the twenty simulated years the agricultural water deficit exceeds 50 mm/year. In other words, every four years the annual water deficit exceeds 50 mm. This value is significantly lower compared to the mid- and downstream irrigation areas, mainly because the upstream area receives more precipitation.

For the midstream irrigation weir the future agricultural water deficit is 750 [620-810] mm for the driest historical year. The peaks of this cumulative annual water deficit take place during May, June and October. Sixteen out of twenty years have a water deficit which exceeds 50mm per year. To put it differently, almost every year the annual water deficit exceeds 50 mm.

For the downstream irrigation weir the future agricultural water deficit is 650 [750-520] mm per year for the driest year. The peak of the cumulative annual water deficit takes place during October. Thirteen out of the twenty years have a water deficit which exceeds 50mm per year. In other words, every one and a half year the annual water deficit exceeds 50 mm.

7.1.2 Preferred measures by stakeholders to decrease agricultural water deficit

The participatory sessions illustrated the rehabilitation of the irrigation infrastructure was preferred out of all simulated measures by all stakeholders, which can be explained by the current degraded status of the irrigation infrastructure in Bogowonto. Secondly the stakeholders from the mid- and downstream irrigation weirs preferred the construction of an upstream reservoir that would satisfy the larger irrigation demand during periods of insufficient rain like May, June and October. Enrolling a new cropping pattern was not preferred by the stakeholders, due to the lack of successful examples at neighboring farms and alternatives like the reservoir and irrigation efficiency were much more popular. The stakeholders in this study are the farmers at the irrigation weir, the employees of the irrigation weir and the local government. Other measures which were proposed by the stakeholders like small rain fed reservoirs, heightening of river banks to stop the annual floods or stopping illegal extraction by farmers from surface- or groundwater have not been selected for simulation. These measures are outside the scope of this research, or RIBASIM was not able to simulate such a measure or the level of scale was inappropriate. During the final participatory session the local government proposed the combination of the measures 'irrigation efficiency + reservoir', since none of the measure was able to reduce the annual water deficit to such an extend it satisfied the stakeholders.

The following water deficits are expected if the measures 'irrigation efficiency + reservoir' is executed as stated in this report:

For the upstream irrigation weir the maximum water deficit decreases from 350 [330-370] to 0 mm for the driest year. During none of the 20 simulated years a water deficit is present. This means no water deficits are expected for the future.

For the midstream irrigation weir the maximum water deficit decreases from 750 [620-810] to 250 [220-260] mm considering the driest year. In addition, three out of the twenty annual simulated years still exceed 50 mm per year. To put it in another way, roughly every seven years a water deficit takes place which exceeds the annual water deficit of 50 mm.

For the downstream irrigation weir the maximum water deficit decreases from 650 [750-520] to 90 [80-100] mm for the driest year. It is expected every seven years the annual water deficit still exceeds the 50 mm.

7.2 Recommendations

This paragraph shows the recommendations for further research and findings for the operational irrigation management of Bogowonto. The recommendations are listed from high to low priority.

Recommendations for further research

- The first priority is to compare the current half monthly data on precipitation and runoff (in mm) for the six water districts for the period 1992-2012 for Bogowonto with other datasets to address the quality of these data for this research.
- The second priority is to perform a study to the groundwater extractions by farmers for the up-, mid- and downstream irrigation weir in Bogowonto. This helps to better simulate the water availability, hopefully resulting in a better simulation of the current and future water deficits.
- The third priority is to analyze additional methodologies to retrieve the individual and group opinion on a specific measure or situation. It is recommended the researcher speaks the local language fluently and additional information on the background of the stakeholders is done to gain knowledge how these stakeholders can optimally be involved in the decision making process.

- The fourth priority is to analyze to what extend the farmers vary the start of the cropping season in respect to the start of the wet season. These results can be processed in the water allocation model by more accurately schematizing the cropping period, resulting in a better simulation of the current and future water deficits.

Recommendations for operational management Bogowonto

The following recommendations are meant for the local and higher authorities who are responsible for managing the water resources in Bogowonto:

- Firstly the measures “irrigation efficiency” and “construction of the reservoir” are able to positively contribute in the reduction of the agricultural water deficit for 2025-2045 and are supported by the majority of the stakeholders which effectuates a positive implementation of these measures.
- Secondly is it recommended to perform research on the current quality of the irrigation channels and decide which parts should be replaced to achieve an irrigation efficiency of at least 65% in 2035.
- Thirdly if one is considering the construction of the reservoir, it is recommended to perform research to the exact location and dimensions of the reservoir, which should be communicated to the local community in an early stage. In this way added value for the local community can be developed and a win-win scenario is established for the farmers, civilians and government.
- Fourthly it is recommended to investigate how farmers can be convinced of a proper solution. For example the construction of multiple governmental farms at the up-, mid- and downstream weir who cultivate new low water use crop types, can be helpful in convincing the local farmers of the effect of new cropping types. Also creating opportunities to share knowledge on new irrigation techniques and crop types between up-, mid- and downstream farmers, will help in decreasing the agricultural water deficits and increases the economic perspectives of the farmers.

References

Balai PSDA Probolo. (2014). Data Debit Banjir, Hidrolgi Neraca Air Kab. Purworejo. Purworejo, Central-Java, Indonesia: Center for Water Resource Management Progo Bogowonto Luk Ulo.

BBWS Serayu-Opak. (2014). Purwadi, H. chief of planning devision BBWS Serayu-Opak (personal interview). Yogyakarta, Indonesia: Interview conducted at BBWS Serayu-Opak at 15-02-2014.

Bulsink, F., Hoekstra, a. Y., & Booij, M. J. (2010). The water footprint of Indonesian provinces related to the consumption of crop products. *Hydrology and Earth System Sciences*, *14*(1), 119–128. doi:10.5194/hess-14-119-2010

Cheng, C., Cheng, S., Wen, J., & Lee, J. (2011). Effects of Raingauge Distribution on Estimation Accuracy of Areal Rainfall. *Water Resources Management*, *26*(1), 1–20. doi:10.1007/s11269-011-9898-7

Daru, R. D., & Tips, W. E. J. (1985). Farmers participation and socio-economic effects of a watershed management programme in Central Java (Solo river basin, Wiroko watershed). *Agroforestry Systems*, *3*(2), 159–180. doi:10.1007/BF00122641

Dessai, S., & Hulme, M. (2007). Assessing the robustness of adaptation decisions to climate change uncertainties: A case study on water resources management in the East of England. *Global Environmental Change*, *17(1)*, 59–72.

Gavilán, P., & Castillo-Llanque, F. (2009). Estimating reference evapotranspiration with atmometers in a semiarid environment. *Agricultural Water Management*, *96*(3), 465–472. doi:10.1016/j.agwat.2008.09.011

Gracia, A. E. (2014). Private consultant in water resource management (personal interview). Yogyakarta, Central-Java, Indonesia: Interview conducted at BBWS Serayu-Opak at 30-03-2014.

Hasi Analisis. (2010). *Pengelolaan Sumer Daya Air Wilaya Sungai: Water Resources Management Wilaya river*. Yogyakarta, Indonesia.

Hoanh, C. T., Tuong, T. P., Gallop, K. M., Gowing, J. W., Kam, S. P., Khiem, N. T., & Phong, N. D. (2003). Livelihood impacts of water policy changes: Evidence from a coastal area of the Mekong river delta. *Water Policy*, *5*(5-6), 475–488. Retrieved from http://www.scopus.com/inward/record.url?eid=2-s2.0-0347270352&partnerID=40&md5=bfad5d3af610b85ff5f60397548181e2

IPCC (2013): Annex I: Atlas of Global and Regional Climate Projections Supplementary Material RCP4.5 [van Oldenborgh, G.J., M. Collins, J. Arblaster, J.H. Christensen, J. Marotzke, S.B. Power, M. Rummukainen and T. Zhou (eds.)]. *In: Climate Change 2013: The Physical Science Basis.* Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Available from www.climatechange2013.org and www.ipcc.ch.

Kijne, J. W., Barker, R., & Molden, D. (2003). *Water productivity in Agriculture: Limits and Opportunities for improvement* (first edit., p. 120). Colombo, Sri Lanka: CABI Publishing.

Krogt van der, W. N. M. (2008). *Technical Reference Manual RIBASIM* (No. Version 7.00) (p. 193). Delft, the Netherlands: Deltares.

Krysanova, V., Hattermann, F., & Wechsung, F. (2005). Development of the ecohydrological model SWIM for regional impact studies and vulnerability assessment. *Hydrological Processes*, *19*(3), 763–783. doi:10.1002/hyp.5619

Liu, C.P., Tesi, W.H, Hsien, K.C., Tao, F. T. (2010). Investigation, assessment and operation management of the reuse of agriculture return water in Taiwan. *Paper Presented at the 61th International Executive Council Meeting & 6th Asian Regional Conference*, (Yogyakarta, Indonesia).

Marhaento, H. (2014). *Research Proposal: Effects of Land Use Changes on Spatial and Temporal Water Availability in Two Tropical Catchments in Java, Indonesia* (pp. 1–19). Enschede, the Netherlands.

Mediero, L., Garrote, L., & Martín-Carrasco, F. J. (2011). Probabilistic calibration of a distributed hydrological model for flood forecasting. *Hydrological Sciences Journal*, *56*(7), 1129–1149. doi:10.1080/02626667.2011.610322

Ministry of infrastructure. (2003). *Development south Java flood control sector* (1th ed., p. 230). Jakarta, Indonesia: Ministry of Infrastructure.

Muchamad, A. B. (2014). Private consultant in water resource management (personal interview). Yogyakarta: Interview conducted at BBWS Serayu-Opak at 20-03-2014.

Muhon, A., Muhajir, C., Alamat, K., Facture, H., & Kusfiyanto, E. (2014). Participatory session about community supported measures (group interview). Sapuran, central Java, Indonesia: Interview conducted at BPSDA Probolo at 20-03-2014.

Nosikia, N., Riadho, M., Rahamanto, D., Petari, H., Budiyanto, P., Karyono, A., … Wahidin, E. (2014). Participatory session about community supported measures (group interview). Purwodadi, Central-Java, Indonesia: Interview conducted at Balai Purwodadi at 21-03-2014.

Peraturan Menteri Pertanian. (2011). *Rencana strategis kementerian pertanian: Ministry of Agriculture strategic plan* (p. 247). Jakarta, west-Java, Indonesia.

Shaw, E. M., Beven, K. J., Chappel, N. A., & Lamb, R. (2013). *Hydrology in practise* (4th editio., p. 530). Oxon, Great Britain: Spon Press.

Sutarto, A. (2014). Private consultant in water resource management (personal interview). Yogyakarta, Central-Java, Indonesia: Interview conducted at BBWS Serayu-Opak at 05-03-2014.

The World Bank. (2014). *Country and Lending Groups wordwide*. *The World Bank Group*. Retrieved March 13, 2014, from http://data.worldbank.org/about/country-classifications/country-and-lending-groups

Triyanto, Y., Sugito, P. H., Amd, L., & Ngodeti, A. (2014). Participatory session about community supported measures (group interview). Purworejo, Central-Java, Indonesia: Interview conducted at Balai Purworejo at 22-03-2014.

Verburg, P. H., Veldkamp, T., & Bouma, J. (1999). Land use change under conditions of high population pressure: the case of Java. *Global Environmental Change*, *9*(4), 303–312. doi:10.1016/S0959-3780(99)00175-2

Yates, D., Sieber, J., Purkey, D., & Huber-Lee, A. (2005). WEAP21—A Demand-, Priority-, and Preference-Driven Water Planning Model. *Water International*, *30*(4), 487–500. doi:10.1080/02508060508691893

Yu, P.-S., & Yang, T.-C. (2000). Fuzzy multi-objective function for rainfall-runoff model calibration. *Journal of Hydrology*, *238*(1-2), 1–14. doi:10.1016/S0022-1694(00)00317-6

Contents Appendices

Appendix A: Hydrological data

This appendix presents a general rainfall map for the complete Serayu-Opak watershed, the location of the water districts and a box plot of the half monthly rainfall and runoff for each of these water districts.

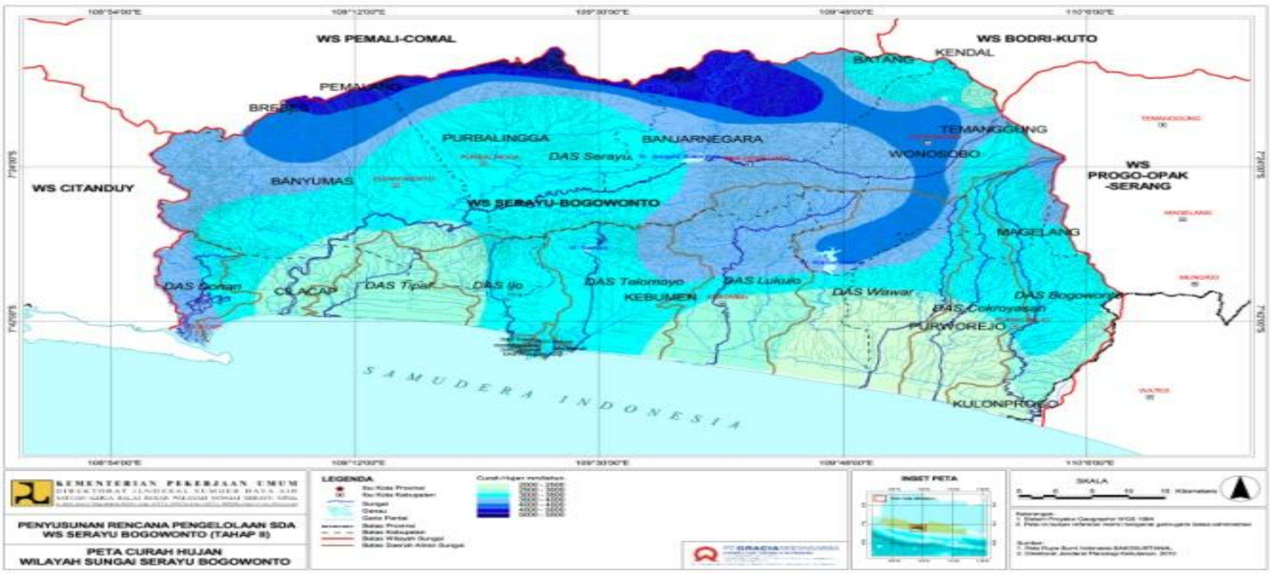


Figure A-1: Rainfall distributions over region Serayu-Opak. The Bogowonto catchment is located in the east (BBWS Serayu-Opak, 2014)

Figure A-1 shows a rainfall map is constructed by the BBWS Serayu-Opak to give general information on the rainfall intensity for different regions in the Serayu-Opak watershed (BBWS Serayu-Opak, 2014). The Bogowonto catchment shows a gradual increase of rainfall from downstream to upstream. In addition the elevation map is a useful tool to analyze why water deficits take place a certain locations. In general an increase in height means results in a higher precipitation.

Figure A-2 shows the distribution of the water districts in Bogowonto, based on previous schematizations in RIBASIM (Muchamad, 2014).

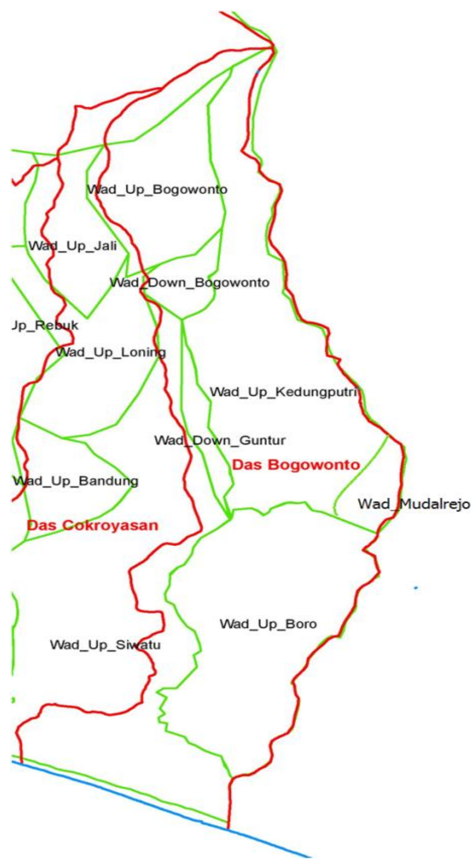


Figure A-2: Water Districts (WD) in Bogowonto

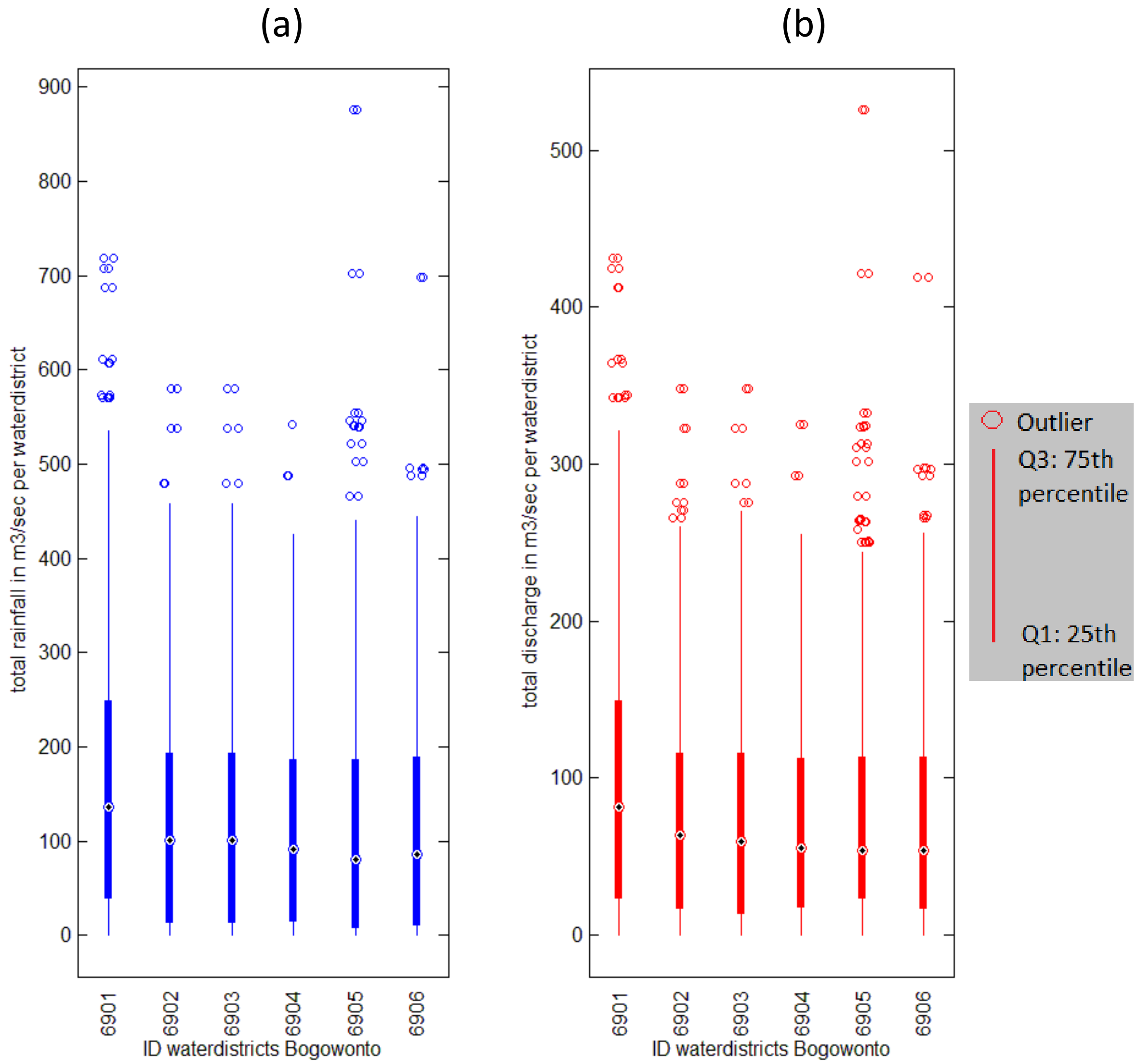


Figure A-3: Box plot of annual rainfall (a) and runoff (b) distribution Bogowonto 1992-2012.

Figure A-3 presents a box plot for half-monthly precipitation and runoff for the period 1992-2012. It can be seen WD 6901 receives a higher rainfall and runoff. This can be explained by the more intensive rainfall in the upstream part (figure A-1), where WD 6901 is located.

Appendix B: Thematic maps

This appendix presents the land use distribution in Bogowonto and the Digital Elevation Map (DEM) of the Serayu Opak region.

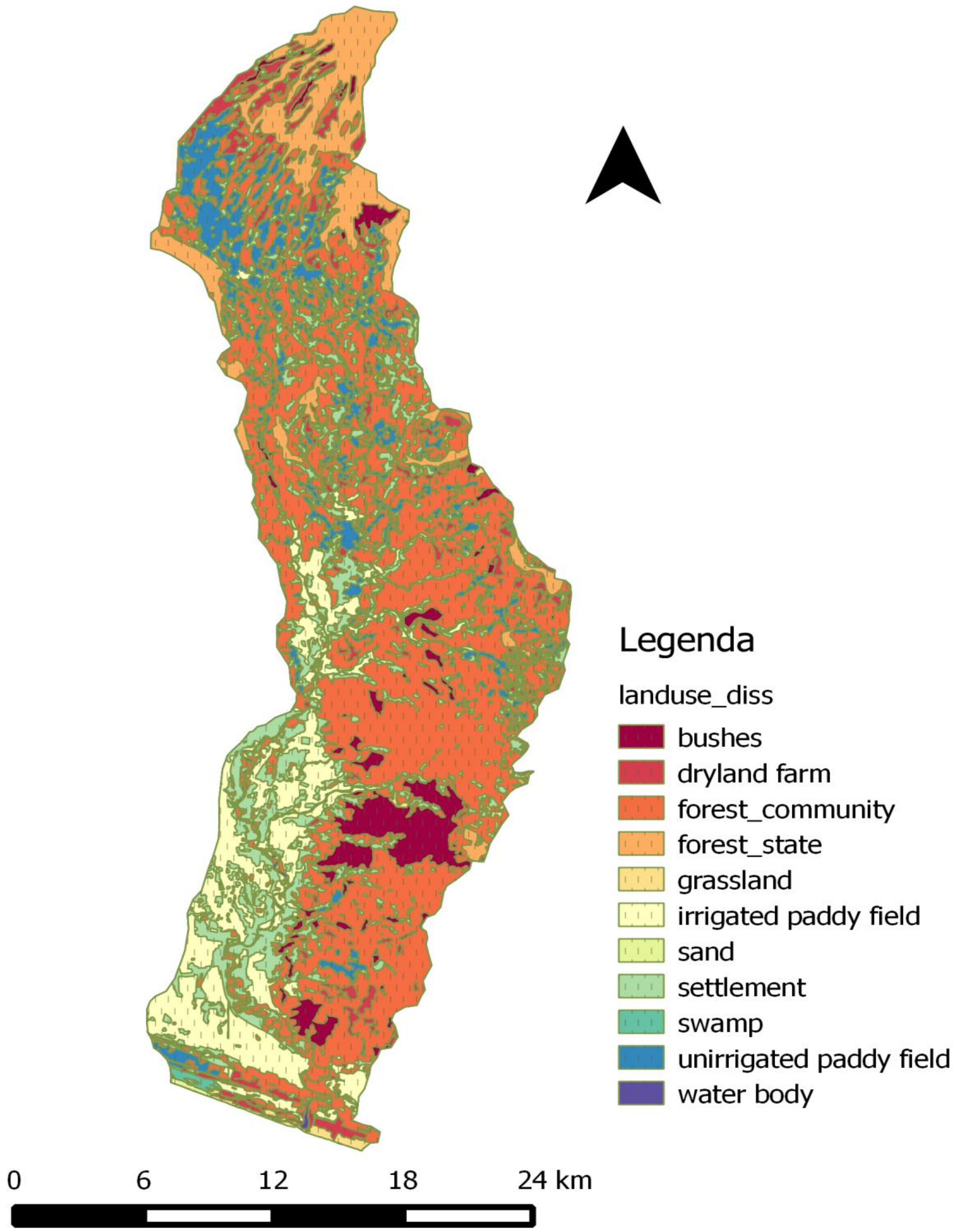


Figure B-1: Land use map Bogowonto 2014 (Marhaento, 2014)

Figure B-1 shows the land use distribution based on satellite images from 2010. It can be seen a lot of forest and irrigated paddy fields are present. The proper conservation of these forests is crucial for the retaining capacity of the soil.

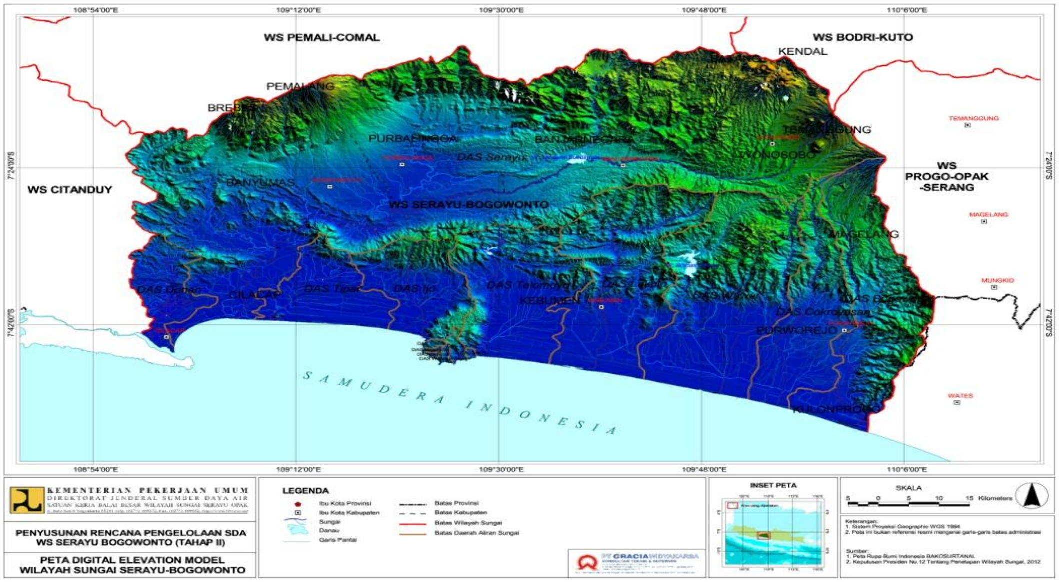


Figure B-2: Digital Elevation Map profile Serayu-Opak region (BBWS Serayu-Opak, 2014)**.**

Figure B-2 shows the Digital Elevation Model (DEM) of the Serayu-Opak region. In can be seen the upstream part of Bogowonto is situated in the hilly part, but the mid- and downstream part are both relative flat.

Appendix C: RIBASIM model

This appendix illustrated the water applied water model and lists the applied changes to the advanced irrigation nodes for the reference scenario.

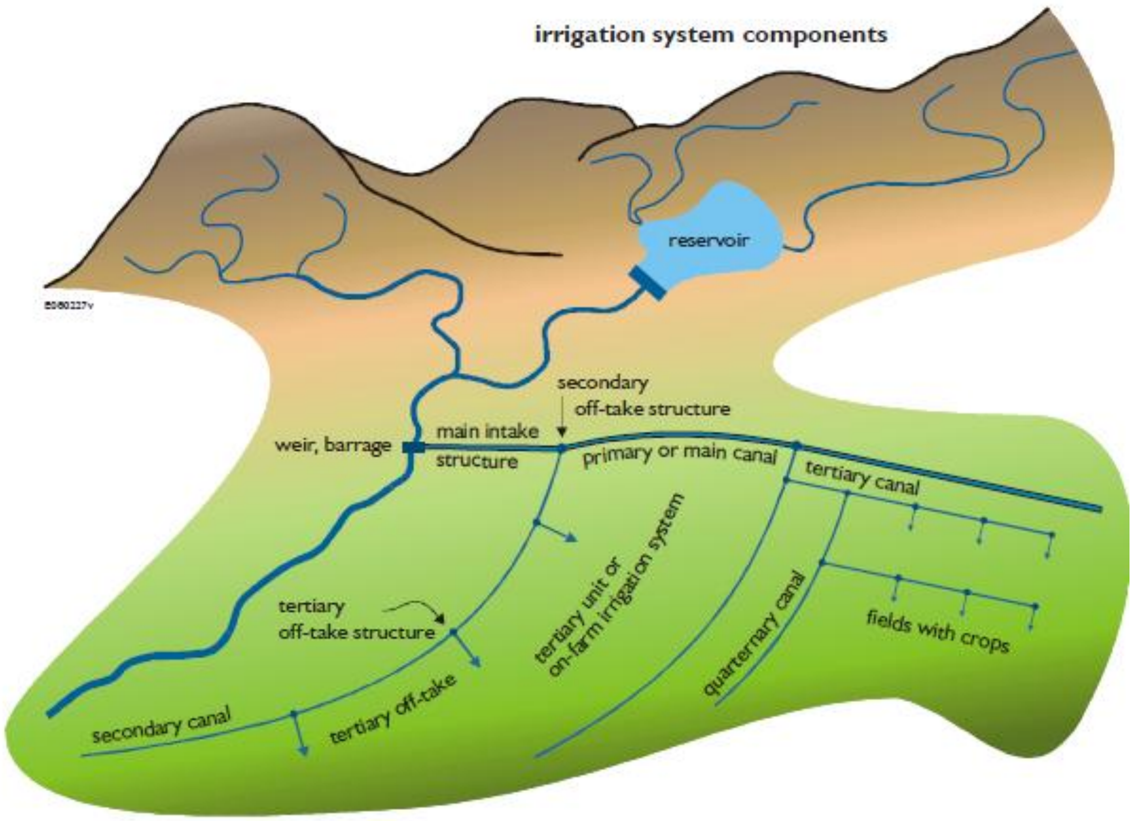


Figure C-1: Example of river basin and irrigation system components (Krogt van der, 2008)**/**

Figure C-1 shows an example of a possible river basin and the schematization of its irrigation system components. The channel downstream of the main intake represents the primary irrigation channel. By the secondary and tertiary irrigation channels the water reaches the irrigation area. Rice fields can have a layered structure and the stream often flows from field to field. The flow in the channel is controlled, whether the flow in the secondary and tertiary channels are often uncontrolled.

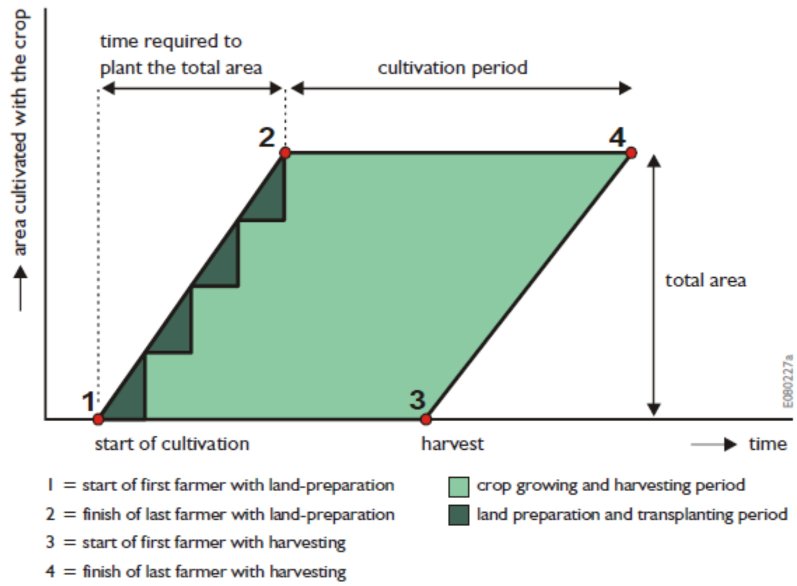


Figure C-2: Format for presentation of planned cultivation for a particular area

Figure C-2 represents the crop plan, which is characterized by:

- Cultivated crop
- Cultivated area (ha)
- Starting date of the land preparation and transplanting period
- Percolation (mm/day)
- Pre-saturation (mm)

The cropping plan is the same for each year. Various constraints are taken into account for the determination of the cropping pattern: Crop characteristics, maintenance period(s) and overall water availability. Figure C-2 shows illustrates main two characteristics.

- Length of the land preparation period. At the start of the planning period the first farmers starts and the end of the planting period the last farmer is finished.
- Length of the growing period of the crop, which also includes harvesting.

For each irrigation node and sub-parts of these irrigation nodes, a cropping plan has been designed. Each cropping plan has been validated at the irrigation nodes. In general the farmers cultivate Paddy rice – paddy rice – Palawijo.

During the simulation of a cropping plan, the irrigation performance is determined as follows:

1. RIBASIM computes the water demand from the network for the present time step. This takes into account the initial soil water content, the crop plan, the survival faction of the present cultivations, dependable rainfall, the target level of the water layer or soil moisture, percolation, rainfall effectiveness, the irrigation practice and the irrigation efficiency within the irrigation area.
2. RIBASIM computes the actual irrigation supplies for each irrigation node for the present time step, take into account water demand, the available water at various sources, operation of the infrastructure (dams, weirs), return flow of other upstream users and the water allocation priority for each demand node.
3. RIBASIM updates the actual soil water balance for each time step based on the actual irrigation supplies, actual rainfall, actual crop evaporation, deep percolation, field buffer storage, seepage and drainage losses. The soil water content at the end of the time step becomes the new initial content for the next step.
4. Finally RIBASIM computes the crop survival fraction of each field, sub-unit, and cultivation based on the actual crop evapotranspiration. Crop yield and production can also be calculated.

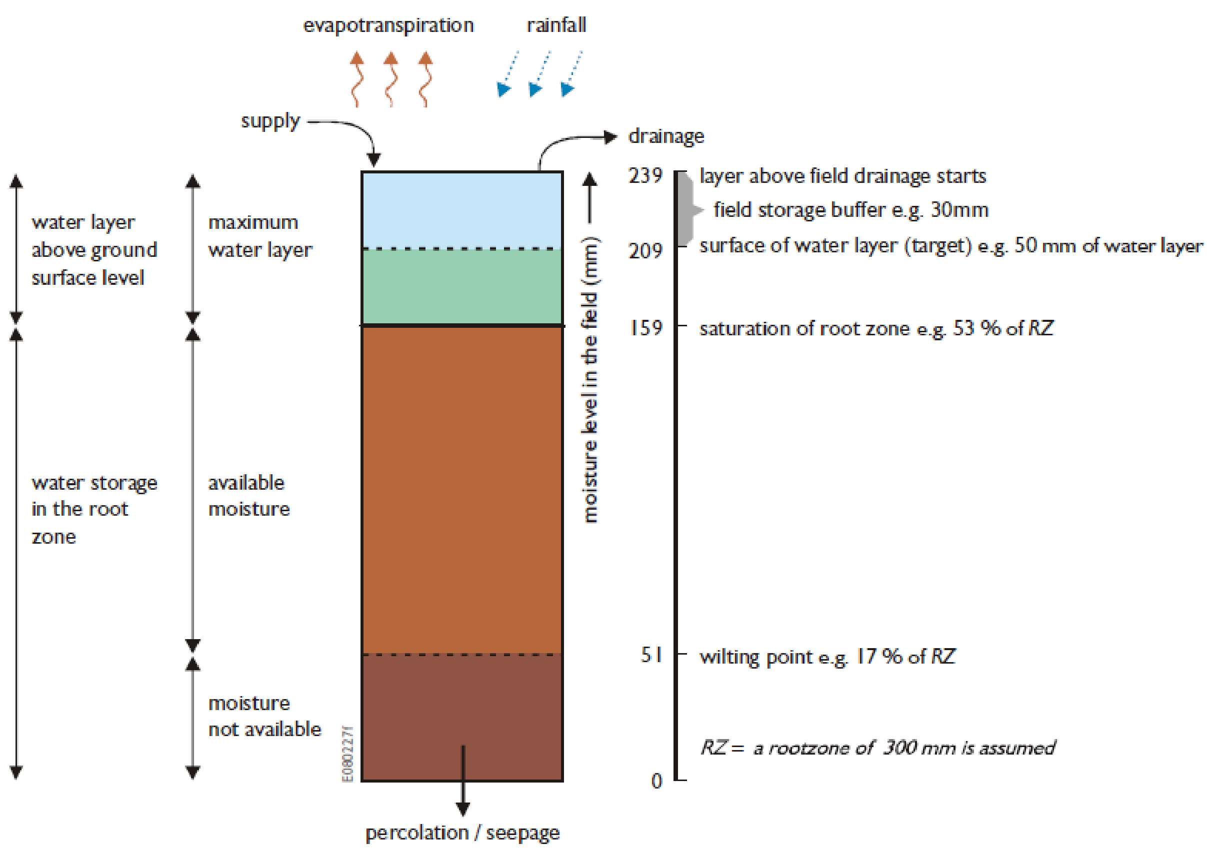


Figure C-3: Standard schematization of field moisture for rice in RIBASIM

Figure C-3 shows soil moisture and its availability to the crops are characterized by soil wilting point, soil field- and soil saturation capacity. Soil wilting point (% of root zone) is the depth of soil water below which the plant cannot effectively obtain water from the soil; soil water content at 15 atmospheres soil water tension. Soil field capacity (% of root zone) is the depth of water held in the soil after ample irrigation or heavy rain when the rate of downward movement has substantially decreased, usually 1 to 3 days after irrigation or rain; soil water content at soil water tension of 0.2 to 0.3 atmosphere. The field capacity is used as the target soil moisture for dry land crop types. Soil saturation capacity (% of root zone) is the soil moisture at which the soil is completely saturated and the field water layer begins. This is used for flood basin crops. The target field layer is a crop characteristics which is specified per time step in the growing period (mm above soil saturation capacity) (Krogt van der, 2008).

Changes to advanced irrigation nodes

- Drought per distribution efficiency: Lowered from 95% to 85%, according the PROGO BASIN file for all advanced irrigation nodes.
- GW conveyance efficiency: Lowered from 95% to 80%, according the PROGO BASIN file for all advanced irrigation nodes
- Drainage: 100% to SW, 0% to GW, because this study only looks at the surface water streams, due the lack of ground water data. This will result in a small overestimation of the water availability, because in reality not all water will flow back to the surface water.
- Production, minimal cost at no survival: raised from 50% to 75%, according the PROGO BASIN file for all advanced irrigation nodes.
- Tab: Supply, field application efficiency: Lowered from 90 to 70%, because Indonesia is an developing country (The World Bank, 2014)
- Tab: Supply, drainage: Lowered drainage to SW and GW from 70% to 14%, because no data is available for Indonesia. For Taiwan recent research has been done on the drainage to SW and GW. These reports recommend 14% as a realistic value (Liu, C.P., Tesi, W.H, Hsien, K.C., Tao, 2010).

Appendix D: interview I

This appendix covers the applied research questions during the first round of interviews.

1. **Introduction**
- How long have you been a farmer?
- How much ha is your field?
- What is your regular cropping pattern?
- What kind of water do you use? (irrigation water // spring water // groundwater)

2. **History**
- How many times have you experienced a water deficit during the past 20 years?
- What are the effects of drought?
- How many times have you experienced a flood during the past 20 years?
- What are the effects of this floods?
-

3. **Irrigation management**
- What is your current cropping pattern?
- What are alternative cropping patterns, if you expect a dry year?
- How do you decide on what cropping pattern you will use?
- What crops need irrigation?
- What time of the season do you use irrigation?
- How do you manage the maintenance of the irrigation channels?
- Do you want to contribute in maintaining the irrigation channels?

4. **Challenges water resource management DAS Bogowonto**
- What local problems are you encountering regarding irrigation practices?
- Do you think the current structures for allocation the water to your field are sufficient? If not, what should be improved?
- Are you experiencing problems in the delivery of your irrigation water?
- What happens if there is not irrigation water? How long can your crops survive before they will die?
- Do you have other sources of water (beside rainfall and irrigation water)?

5. **Potential measures DAS Bogowonto**
- What are in your perspective possible measures to decrease the agricultural drought?
- What should the government do?
- What can you do?

Cropping pattern

Jan	Feb	Mr.	April	May	June	July	Aug	Sep	Oct	Nov.	Dec

Appendix E: Climate variability

To address climate variability, four Representative Concentration Pathways (RCPs) are provided by the IPCC (2013) to address possible pathways for the future greenhouse gas concentration. These trajectories are explained in detail in the fifth Assessment Report of the IPCC.

The four RCPs, RCP2.6, RCP4.5, RCP6, and RCP8.5, are named after a possible range of radiation forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W/m^2, respectively). This study looks at the extremes of climate variability, wherefore the RCP 4.5 is chosen to address climate variability. Within this climate model, three sub-scenario's are distinguished: a scenario with a increased rainfall of 1 in the wet season and dry season (I), with a higher rainfall in the wet season and less rainfall in the dry season (II) and with a wet and dry season (III).

Table E-1: IPCC prognoses for precipitation and temperature for 2035 for Southeast Asia

	Delta precipitation 2035(%)		Delta temperature 2035(C)	
	DFJ (wet)	JJA (dry)	DFJ (wet)	JJA (dry)
min. value	-2	-3	0.3	0.3
25% boxplot	1	0	0.5	0.6
50% boxplot	2	1	0.7	0.7
75% boxplot	4	3	0.8	0.8
max. value	12	7	1.1	1.2

Table E-1 shows the prognoses for the precipitation and temperature for Southeast Asia.

Table E-2: Changes in precipitation and temperature for 2035 according to RCP 4.5 scenario (IPCC, 2013) for Southeast Asia. Wet season = October-March. Dry season= April- September.

Constructed scenarios vs. change in P and T (%)	Scenario C "overall wetter"	Scenario D " wetter wet seasons, dryer dry season"	Scenario E "dryer wet season, wetter dry season"	Scenario F "overall dryer"
Precipitation change wet season (%)	+12	+ 12	-2	-2
Temperature change wet season (%)	+1.1	+1.1	+0.3	+0.3
Precipitation change dry season (%)	+7	-3	+7	-2
Temperature change dry season (%)	+1.2	+1.2	+1.2	+0.3

For the scenario's C-F the extreme upper and lower limits for the temperature and precipitation have been applied, since these scenarios are applied to check the robustness of these proposed measures regarding variations in the simulated water deficit for 2025-2045.

Estimation of EP

Based on the given time series of runoff and precipitation (BBWS Serayu-Opak, 2014), the evapotranspiration can be calculated if storage is neglected. In the next step four new precipitation scenarios are generated for 2025-2045 by multiplying the given precipitation series of 1992-2012 with the given factors (table 3.2e). Subsequently the corresponding new evaporation series for each of these four new scenarios is calculated, assuming the prognoses of the IPCC for temperature and precipitation are linked. This is done as follows:

The relation between evaporation and temperature is given by Crowe (1971):

$$\frac{P}{E} = \frac{9P}{T - 10} \qquad (1)$$

This formula can be derived to:

$$E = \frac{T - 10}{9} \qquad (2)$$

Where:

P and E are in inches

T in Fahrenheit

This Thornwaite-Crowe formula is useful because only precipitation and rainfall data are available. The common used empirical formula of Turc (1955) is not applicable due the precipitation data is a 14-days average and not a yearly average. Thornwaite-Crowe will be used to determine the effects, which is a very simple but effective formula for estimating the relation between evaporation and temperature. For getting the correct units we use (4):

In this way the spatial correlation between the water districts keeps intact and the effect of the temperature increase resulting in a higher evaporation is also taken into account in calculating the new runoff for one of the future scenarios. Now the new evaporation series are known, we can calculate the new runoff series for each scenario by:

$$\mathrm{Q}_{\mathrm{C,D,E,F}} = P_B * c_x - E_{C,D,E,F} \qquad (3)$$

Five scenarios for the future water availability and demand have been generated (table 3.2e). All these

$$Fahrenheit = Celcius * \frac{9}{5} + 32 \qquad and \qquad 1\ [inch] = 0.0254\ [m \qquad (4)$$

These scenarios will be implemented and modeled in RIBASIM. The results can be found in table 3.4.

Appendix F: Proposed measures

This appendix presents an overview of the proposed measures to decrease the agricultural water deficit for the up-, mid- and downstream irrigation weirs. The measures have been sorted on problem type. Secondly, each measure is assessed at three criteria:

1. **Compatibility RIBASIM:** It should be possible to simulate the measure in the simulation program applied in this study. This means for the water availability no changes in runoff caused by changing land use can be simulated. For the water demand only manipulations can be done for the irrigation nodes, no external factors are applied. Furthermore because the model only simulates surface water, no measures regarding groundwater can be simulated.
2. **Level of scale:** The measures should in general have the potential to have an impact on the complete catchment, not only on a small spatial scale. This criteria limits the risk of modeling hundreds of small measures, which only have a very local impact but do not solve the problem as a whole.
3. **Appropriate to answer research objective:** This criteria assesses the proposed measure is within the scope of this research. This research focuses on measures that decrease the agricultural water deficit. This can be measures that lower the water demand, or increase the water availability.

Table F1: Problems and proposed solutions by stakeholders in the Bogowonto catchment

Problem	**Proposed solution by actors:**	**Supported by:**	**Location** U= upstream, M=midstream, D=downstream	**1: Compatible RIBASIM**	**2: Level of scale**	**3 : Appropriate to answer research objective**
Sedimented irrigation channels	1. Build a dam to stop sediment flow	Farmers	U, M,D	NO	YES	YES
	2. Put sediment out of the rivers and irrigation channels.	Farmers, water auth.	M,D	NO	YES	YES
Leakage in infrastructure	<u>3. Repair leakage in secondary and tertiary infrastructure</u>	<u>Farmers,</u>	<u>U,M,D</u>	<u>YES</u>	<u>YES</u>	<u>YES</u>
	4. Increase maintenance period for irrigation to each month, not only Feb-Nov.	Farmers,	U,M,D	NO	YES	YES
	<u>5. Upgrade irrigation channels from soil to concrete</u>	<u>Farmers,</u>	<u>M</u>	<u>YES</u>	<u>YES</u>	<u>YES</u>
	6. Get budget from the government to repair bad irrigation and make sustainable improvements	Farmers	M	NO	YES	YES
	7. Get a chief who is in charge of the maintenance for 5	Water auth.	D	NO	YES	YES

	years, not only 1 year.					
Water deficits	8. Build local small reservoirs to store precipitation for irrigation	Farmers, water auth.	M,D	YES	NO	NO
	9. Better enforcement for taking action against illegal tertiary irrigation channels	Farmers	U,	NO	YES	YES
Floods	10. Improve the walls of the tertiary irrigation network to better deal with floods and droughts	Farmers	M	NO	YES	NO
	11. Get a gathering with the chief of farmers, UPT and local DINAS on how to deal with these floods.	Farmers	M	NO	YES	YES
	12. Build higher dikes to prevent the crop area of being flooded + ecological approach	Farmers, water auth.	D	NO	YES	NO
	13. Build dam at estuary to prevent salt water intrusion from the sea	Farmers	D	NO	NO	NO
Deforestation	14. Re-forest the upstream area to increase the water availability during the dry season	Farmers, water auth., governme nt	M,D	NO	YES	NO
Decreasing spring water availability	15. Stop illegal extraction of groundwater by farmers by better law enforcement	Water auth.	M,D.	NO	YES	NO
Uncertainty in timing dry-wet season	16. Better information from the meteorological institute when they predict the rainy season starts to decide on the optimal cropping pattern	Water auth.	D	NO	YES	YES

Measure 3 and 5, i.e. repairing leakages and rehabilitation of the irrigation channels, both serve the same cause: Increase of the transport irrigation efficiency (1). Because these are the only measures that passed the three criteria, other additional measures are proposed and are debated with the community. This resulted in two additional measures for simulation: Apply changes in cropping type and timing (2) and build an upstream reservoir (3) (Muhon, 2014; Nosikia, 2014; Triyanto, 2014).

Appendix G: Effect of measures

This appendix shows the effect of the measures including climate scenarios for the upstream irrigation weir. De results of the mid- and downstream irrigation weir can be found in paragraph 5.3

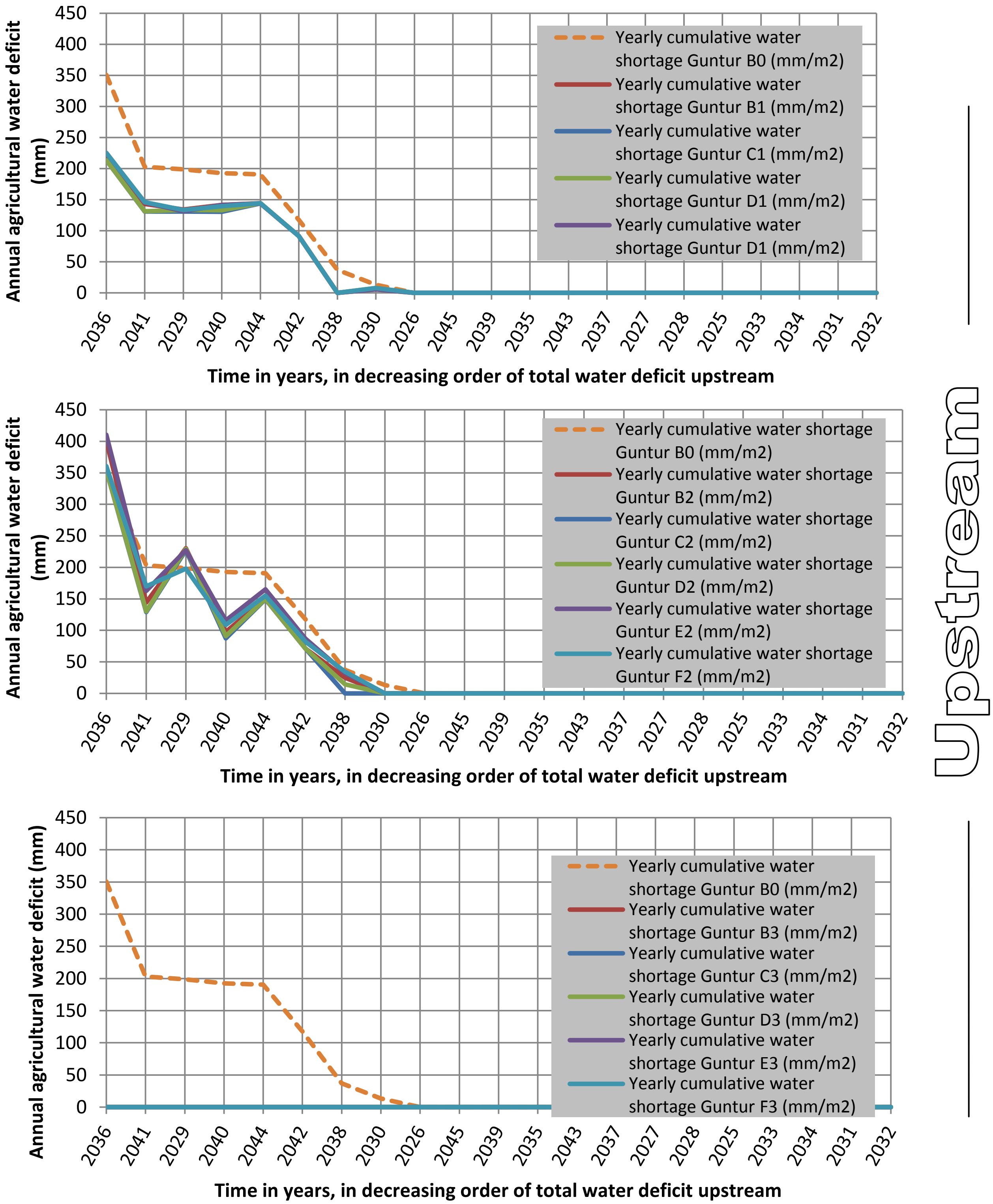


Figure G-1: Annual water deficit upstream in Bogowonto catchment including climate scenarios for climate variability for period 2025-2045.

Appendix H: Proceedings interviews I

The following proceedings are the translations in English. The original transcribing are available on request.

Upstream irrigation weir

Participants	Interviewer	Translator	Transcriber	Date	Location
5	Gerrit van Zwol		m. Karyanto		Nareh Gasandi

Table H1: Interview data upstream irrigation weir

Name: Ahmad Saitur

I am a farmer, a P3A at Kelurahan Kempil Kecamatan Kempil Kabupaten Wonosobo. I have around 0,5 Ha of land. In rainy season we plant rice, in dry season we plant non-rice-crop (peanut, corn, cassava) because Bogowonto River's debit is decreasing. At Kelurahan Kempil, there are 4 irrigation channel that originated from Bogowonto river :

1. Sitenggol channel, length 1 km, in rainy season can irrigate 5 ha field
2. Cigandul channel, length 1 km, in rainy season can irrigate 15 ha field
3. Mojosingi channel, length 2 km, in rainy season can irrigate 10 ha field
4. Wiyu channel, length 1,5 km, in rainy season can irrigate 15 ha field
5. Cibakung channel at dukuh Sumpet, length 600 m, in rainy season can irrigate 15 ha

The sad thing is, Mojosingi and Wiyu channel are in damaged condition

Name: Saiful Amin from dukuhSibuntang Kelurahan Kempil Kabupaten Wonosobo
I represent chief of dukuh Sibuntang

In our area, in rainy season all of us plants rice. In dry season, some of us plants non-rice-crops (chilly or corn), because the capacity of irrigation system is only 55 ha. It used to be 85 ha.

Name: Muh Hajir from kelurahan Kempil, I am P3A secretary. I have around 0,5 ha land, half of it is rice field and the rest is land around house. In rainy season I plant rice in my rice field but I don't plant anything in dry season because I don't have talent planting non-rice-crops.

Name: Musen, chief of Mugiraharjo Farmer Group. I have around 0,5 ha land. I plant rice, chilly and make catfish pond in that land. I only plant rice in rainy season.

Q : What is the source of your irrigation water?
A : Bogowonto, but to fill the pond I use water from spring in the forest. There used to be plenty of water from forest spring, but with deforestation practically now in dry season we depend on irrigation water. So in dry season the rate failure in plantation is high.

Name : Sukiranto, officer of kelurahan Kempil. I have around 0,5 ha land. In rainy season I plant peanut.

Q : Do you experience drought once, don't you?
A : Yes, irrigation channel was broken because of the flood.

Q : How many flood are there in 20 years?
A : Every year

Q : What is the effect of the flood?
A : Destroy the plant

Q : If the plant is destroyed, did you replant?
A : No, the damaged plant is only the one that close to Bogowonto River.

Q : What kind of plant do you grown up here? And how is the planting pattern?
A : Rice, rice non-rice-crops

Q : Does all the farmer do the same thing?
A : Yes, most of them

Q : Is there some kind of method in water distribution?
A : Yes

Q : In what base?
A : The term is "diwilah wilah", distribute equally for kelurahan area. One day and night (24 hours) here, tomorrow there etc.

Q : What about the maintenance? Who is in charge?
A : P3A is in charge of irrigation matter. It's volunteer work without payment.

Q : So only from the community?
A : The digging and management of primary channel is done by DPU, P3A do the terrier channel. Right now we are planning the budget for such kind of channel.

Q : Are there any problems about water distribution in irrigation channel area?
A : No

Q : Do you think this method is the best? Or perhaps this is SOP from the government? Is there improvements in practical level? Or is it applied according to the SOP exactly?
A : Yes, the same, no problems

There is no significant problem in our area, small problem only in dry season, and it has already managed by P3A and also has been discussed.

Q : In a meeting, how is the mechanism? Did farmers suggest something and then.....
A : Yes, in dry season there are usually suggestion from farmers. Then P3A initiate a meeting inviting all the water users. At this meeting the community decide this day and night for which area, and another day for another area, etc.

Q : Do you have any suggestion, better methods in water distribution that this establish method?
A : Just like my previous answer, the method is just like that. For example : if my 0,25 ha has been watered, we shut my channel, and move to other filed. My suggestion, the usage of irrigation water to wash cars must to be regulated. It's not good. Excuse me for this critics. The usage of water for car wash cause water shortage. Even in rainy season my rice field sometime get no water because of it. Actually I am not really sure the cause of water shortage, perhaps it is because of car wash or it is because of deforestation.

Q : It is an if and only if.... If you get a lot of fund for irrigation, what will you do?
A : To fix the irrigation channel and to built Sewiyu, Gemilang and Sebakung channel, those have not been built. So water can water more field.
I hope the farmers condition increase, be able to plant rice 3 times a year. Actually if we make a dam in the hill, there will be abundance water but the small channels aren't strong enough to handle a strong current, they will break. As a P3A chief, if money is available, I will fix channel wall. Now in kelurahan Kepilitu there is so many water that leaks in the edges of the channel. It's a waste.

Q : In the future, if there is too much water, what kind of plant that you will cultivate? Vice versa what if there is long dry season?
A : in Kepil, insya Allah it has never been too much water, even in rainy season, no water excess. Please, we hope there will be help/support from Netherland.

Q : Are there any Coordination with other locations?
A : Yes. Around bogowonto river there are Wonosobo, purworejo and Kulon Progo. Those three areas include in PSDA Purworejo. So if we gather in probolo that's in Bruno, from Purworejo include Wonosobo and Magelang.

Q : Between the three, which one is the wettest?
A : Wonosobo
Here there is term called "pingit", it is related with Bogowonto, only used in Kepil. In Wonosobo, the term's called "mungkung", "begundul mungkung" is bigger, it is hundrefs hectras, but it is stand in its feet.

Q : If drought arrives, what will farmers do? Stop planting rice or change the plant?
Athe plant?

A : We usually change the plant with dry resistant plant like corn, peanut and cassava. They only need small amount of water, 2 times or 3 times in harvest time.

Q : Pattern rice, rice, non-rice-crops can be applied if rice seed is available. How is there no rice seed? Will farmers change the pattern become non-rice-crop non-rice-crop non-rice crop? Or do you wait for SK Bupati?
A : Waiting for SK Bupati, during the waiting time we grow up any plant available. If there is corn seed, we plant corn, if there is peanut seed, we plant peanut.

Q : If there is no water at all?
A : We plant corn, but that's never happened. The longest drought in Wonosobo is 9 months. The land is wet enough to cultivate. The weather in Wonosobo is beautiful. Dry season in Wonosobo is different compare to Purworejo, Yogya, wonosari. Even in dry season, Wonosobo is never so dry. In Wonosobo if we want to we can plant non-rice-crop all year long.

Q : How is the meeting with UPT?
A : According to the needs, we have meeting in this office, make a plan and forward it to P3A, then P3A respond.

Q : What topics do you discuss mostly?
A : About the dry season

Q : About water distribution? What about that?
A : For example to maintain disciplinary, obedience and safety.

Q : The exact example?
A : UPT regulate and make it sure that all the regulation practice by farmers with disciplinary and obedience from the primary until lower level. In the lower level, P3A manages it.

Q : What do farmers do to preserve spring water?
A : Reposition/forestation perhaps. If there are big trees, insya Allah water availability increase.

Q : Is the condition better or worse now?
A : It's been already started the forestation for 2 – 3 years. We hope the availability of water will rise. We suggest the Faculty of Forestry UGM for not planting Sengon, because Sengon is quick growing, can be harvesting in 2-3 years. It is better to plant damar (resin producing tree), mahoni, please change the Sengon with these kind of trees.
Farmers refuse to plant non productive trees.

Q : Were those last seeds given to community or to Perhutani?
A : Not Perhutani. In Kepil, most of the spring water is in Perhutani. If it's possible, it's better if Perhutani replace the plant to such kind of Trembles. It's better if the mountain belongs to Perhutani. If the trees is

unproductive and is given to community, people will cut them every year. The condition of spring water will be worsening. Pleas forward this suggestion to Netherland, maybe....

Q : Are there any function change in land use?
A : No

Q : What I mean is... sometimes farms plant crop in the land that should be used by Perhutani (forest). Something like that happened in Lawu.
A : There is no such kind in Kepil.

Q : In the future, are there plans to change the planting method? Perhaps, change the pattern from rice rice non-rice-crop to another pattern or even change the commodity as palm oil?
A : We will maintain the farm. We hope there will be help from Netherland to increase the rice production. We hope that we can plant rice 3 times a year.
As a common farmer, I beg to Netherland government to supervise us so rice production can increase. I heard that in Netherland the rice productivity reach 10 tons/ha. We hope with your supervision, our rice productivty can reach 8 tons/ha.
The season in Indonesia is different compare to in Netherland. And it's easy to get water in Netherlands because it's 6 m below sea level.
Do Netherland farm use chemical fertilizer? Because Chemical fertilizer is the source of failure in Indonesia agriculture.
If we use chemical substance, the water absorption become difficult and the end product (food) is not good to eat.
It's very difficult to recover damaged soil, that's caused by chemical substance.

Q : What can we do to reduce the lack of water problem?
A : Nothing

Q : How about change the plant type that needs small amount of water?
A : Because this meeting is only attended by the representative, not all the community, the result of this meeting will be distributed to another group

Q : In your opinion, is the government decision right, make everything better? Or perhaps is there time that you wondering that perhaps the government make a wrong decision?
A : No, every time the government give us dissemination, we receive it and apply it.

Q : Did you speak to government about your problems? Did you ask fund from government to built irrigation channel? Did government approve it?
A : Yes, government gave us through Farmer Groups or Department of Agriculture
Thank you for your support. I think Indonesia system inherit Dutch system.

In Netherland most of the farm is potatoes and wheat. I will tell the next exchange student to focus on agriculture. I will return in 4 – 5 weeks to give you the result of my research. If it is good you can use it, if it is not suitable, just ignore it

Midstream irrigation weir

Participants	Interviewer	Translator	Transcriber	Date	Location
4	Gerrit van Zwol		m. Karyanto		Purworejo

Table H1: Interview data midstream irrigation weir

Q : What's your job?
A : I am a farmer

Q : How wide is your land?
A : At Kedung Putri or that belong to my village?

Q : Your own?
A : 1 ha

Q : How long have you been a farmer?
A : From adult age until now

Q : From what age?
A : Perhaps from 17 or 21 until now I am a farmer. Eventhough I have been a village chief (kepala desa) fot 10 years.

Q : So as a farmer, how many years?
A : Around 26 years.

Q : What's the meaning of P3A?
A : Group of Water Using Farmers (Perkumpulan Petani Pemakai Air). There is group of farmers called P3A in a village, the gathering of P3A from every village become P3A Kecamatan, and I am in Kedung Putri P3A.

Q : Are you the chief of your P3A?
A : Yes

Q : What are the responsibilities of the chief?
A : 1. In dry season, we and Dinas UPT Pengairan coordinate about water distribution.
2. Sometimes UPT asks us to discuss about planting pattern.

Q : How to determine planting pattern in this area?
A : Planting pattern is decided by res kabupati. Our duty is to socialite that decision to farmers.

Q : Is that option a choice or a compulsory? Res kabupati said rice rice non-rice-crops but farmers plant rice rice rice
Q : To watering the farm, what kind of water you used? Irrigation or spring water or wheel?

A : There are 3
At Kedung Putri we use water from Bogowonto river
Wheel, shallow ground water
Rain fed

Q : So there are 3 sources. How is the usage?

A : For the land that can be reached by irrigation channel, we use irrigation channel. For land that can't be reached by irrigation channel, we use pump. For land which depend on rain fed, first we plant rice, then non-rice crops. Here at Kedung Putri, the irrigation channel is very long and the area is very wide, so the water is very difficult to reach the end area (the name of the village in the end of irrigation channel is Petit). Even in rainy season, it is very difficult to reach the end area. In the last rainy season, water debit in MP1 was only 1500/second. That rainy season, farmers asked water supply (water dropping) because there was not enough water. So it's worse in dry season.

Q : How many time did you experience drought in the last 20 years?

A : Never

Q : I was told that there was drought in 2004 or 2007?

A : In 2004, the drought is long enough, but we still could harvest. In 2007, we still could harvest. Thank to the hard work of Dinas Pengairan (Irrigation Biro). At those times, the water distributed according to the age of the plant. The older plant got water earlier.

Q : Is there another effect of drought, instead of low harvest of rice? Another significant effect?

A : In 2004 – 2007, the drought was long enough, 9 months. At those times in Ndewi area, even for drinking was difficult. There was water dropping every week. That water was only for drinking, not for field irrigation.
Kedung Putri channel has multi function, for irrigation, town needs and wheels injection. In dry season, many villages ask water for watering the land so it can be absorbed to their wheels.

Q : What's the name of those areas? The ones that in difficulties of water?

A : Middle area, lower catchment area

Q : Instead of that, what is the special effect of drought for agriculture?

A : The harvest is lower. In normal time, the harvest is 7 – 8 tons/ha, in drought the harvest is 4 tons/ha.

Q : What about the flood, how many times is there flood in 20 years?

A : in my recollection, in 2001 and 2013, there were floods in my area and the southern of it.

Q : What's the flood effect for agriculture?

A : None, because the planting were done. If the floods were happened in the first week of planting, they would destroy the plants. If they were happened when rice was yellowing/ripening, there would be no harvest.

Q : At this time what do planting pattern you apply? Rice rice non-rice-crop or anything else?

A : Because now it is MP1 season, we plant rice

Q : What about in the drought time, what do you usually plant?

A : Here there are 3 kind : corn, soybean, mung bean and water melon. Some farmers plant peanut.

Q : What is the plant that need irrigation? Rice? Non-rice-crops?

A : Only rice, non-rice-crops don't need it. We use ground water for non-rice-crops.

Q : How to distribute water for agriculture? What is usually prioritized?

A : For water distribution we cooperate with UPT, water distribute to:
The field with older seedling
If there are more request, we consider the age of the plant, we prioritize the older plant.

Q : Do young rice plant need plenty of water?

A : Now we change the definition of rice. Rice is no longer a water plant, but rice is plant that needs water. Nowadays rice plant doesn't need to be immersed in water, only need enough water. We water the rice plant one day in a week, then let it dry for a week, then we water again for a day, then dry again, so on. It's better this way.

Q : What about the old rice plant? It needs plenty of water?

A : Water distribution was based on res kabupati, we have priorities. Seedling and land preparation stage need water the most (1,2 scale of need). 0,8 scale of need is after the stage one growth. After that the water need is less and less. Those are the scale priorities.
Special for Kedung Putri, we can't apply that kind of system. Kedung Putri is very wide, there is no enough water for all, must take turn, or we use kadi golongan system (?). Or even in critical condition we use dropping water. We ask water in tank. The demand is asked trough P3A to UPT, and UPT evaluate it.

Q : How is the management of irrigation channel maintenance?

A : There is KSU who take care of irrigation channel, KSU is daily payment job, it's duty is to check the channel every day.

Q : Are they farmers?

A : No, it doesn't involve farmers. KSU is not farmers, they take care of secondary channel, not tertiary channel. Tertiary channnel is farmers responsibility.

Q : So, is sedimentation digging a routine activity?

A : Yes, every day KSU digs sedimentation.

Q : If you have Rp. 10 million, what will you do with the money in relation with irrigation management?

A : Rp. 10 million is not enough.

Q : What can we do with Rp. 10 million?

A : Just for cleaning the grass, more or less. At Kedung Putri, every year we allocate Rp 100 million just for tertiary channel maintenance. Even it is still not enough to maintain every channel. At Kedung Putri at least we need Rp. 3 trillion, to make all the channel from upper catchment to lower catchment become permanent. There are two types of irrigation activities : operational and maintenance. Includes in maintenance are digging, cleaning thr garbage's, oiling etc. Operational will be good if maintenance is good. But maintenance is always very costly. And as I said before, we haven't be able to maintain 80 % of the channel. Many irrigation facilities left broken.

Q : What irrigation problem that can't be solved until now?

A : Fund problem

Q : Where do the fund come farm usually?

A : For the land wider than 3000 ha like Kedung Putri is from central government (pemerintah pusat). UPT or state government (pemerintah daerah) is only responsible in operational basis. So every maintenance fund is from central government, also rehabilitation.
There are 3 criteria's:
For 1000 ha land, the fund is from district government (kabupaten)
1000 – 2000 ha, the fund from province government
3000 ha and more, the fund come from central government
So if the channel is broken, if there is no fund from central government, we can't do anything.

Q : Is there any special training for farmers?

A : There are trainings from P3A that's given from village to village or given to gapoktan (gabungan kelompok tani/ the union of farmers group)

Q : How many group are there in one union?

A : Difference between union. There are 2 kinds of union : gapoktan which take care of agricultural matters; and P3A which take care of irrigation matters. The members of both union are farmers.

Q : Did you ever get problem in irrigation distribution?

A : Problems, there are problems always. For example : Because of there is no enough water to distribute; because of farmers don't follow the rule, they are late in planting or they don't obey the planting pattern.

Q : What are the consequences of those?

A : The first consequence are water deficiency. When the water had been already low, the farmers just started to plant. UPT wanted to drop/send water, but there was no water to drop. The second consequence is the planting pattern become unsynchronized. Those are the inhibitions here.

Q : Are there another sources of irrigation water despite of rained?

A : From shallow ground water

Q : Does every farmers have pumps?

A : No. According our observation, if we dig the southern ground of the railway, we only need to dig 10 – 15 cm, the water will not dry even until 24 hours. But if we dig the northern ground of the railway, we can dig 20 – 30 m or even 50 m without finding water.

Q : Is there any coordination about water management between upper, middle, and lower catchment areas?

A : We always coordinate. Before the planting season, there are always a meeting between farmers from upper, middle and lower catchment areas talking about water distribution.

Q : How to determine the water availability and to distribute it to the farmers?

A : To measure the water availability, we look at the water debit and then we make an agreement. The planting pattern starts from the south. There are 3 group, group 1, 2, 3. Starting from group 1 lower catchment.

Q : Why do it start from the lower catchment? What's the reason?

A : It's always like that, from the lower catchment, from the south.

Q : What about your own opinion? How is the best way to distribute water?

A : In my opinion, first there must be a dam, second there must be secondary channel from the upper until the lower catchment. The third, the existing channel must be clean regularly from grass, sedimentation. We hope the Biro (Dinas) do this because it is its responsibility. We hope that the central government add more worker (KSU) to clean the channel. Now KSU only works for 10 months, we hope they work for 12 months.

Because of environmental damage, in flooding time there is too much water, but if the rain sties just for 2 days, the water gone straight away. So we hope the central government improve the system, then improve the maintenance.

The fourth is the mind set (the way of thinking) of the farmers

Q : How is babied this mind set?

A : Their mind sent is still traditional

Q : What can we do without always depend on the government?

A : There used to be "go tong raying" (working together voluntarily), but now it is difficult to mobilize and to make community to participate. Now community only hope is from government.

Downstream irrigation weir

Participants	Interviewer	Translator	Transcriber	Date	Location
9	Gerrit van Zwol		m. Karyanto		Purwodadi

Table H1: Interview data downstream irrigation weir

Purwodadi 9 peserta

I have duty from UGM to work with Faculty of Forestry and Faculty of Forestry has several programs, one of them is student exchange. Gerrit is student from UNT Netherlands, he is in Yogya for 3 months for finishing his master assignment, ...

Mr. Suharyanto from Faculty of Forestry is one of his supervisor. His research is about water usage management and analysis, especially for agriculture from Bogowonto river. Why Bogowonto river? Because of the unique characteristic of this river, in rainy season its debit is very high even causing flood, in dry season its debit is low not enough for agriculture need. Gerick intend to make simulation to overcome that problem, hopefully this simulation can be used as recommendation what kind of water scale that can be applied in Bogowonto area. Around 4 – 5 weeks, after he gets data from Bogowonro community, he will present the result of his research, and the possibility to adopt it for different area. For this purpose he needs to survey agriculture irrigation channel and dam in Wonosobo and Purworejo, he also will interview the community especially farmers and village officer that regulate water distribution. This is as an introduction from me and also as a permission ask from us.

Thank you

Q : How wide is area 1?

A : Area 1 is 1445 ha, area 2 is 1803 ha and area 3 is 1778 ha

Q : What kind of the plants are?

A : Rice and non-rice-crops

Q : What are the water resources? Irrigation, river, wheel, or spring water

(Translator : So he wants to be explain how the distribution in 3 areas are, how the mechanisms of the distributions are, does the distribution method decide by farmers or there are regulations from government or something else? Is there different timing in planting in different area? He needs detail explanations. For example : you plant area 1 first, then area 2and area 3 the last?)

A : 2 or 3 months before planting time, P3A and pack Mantra would check in the field to gain condition info and what kind of plant that will be grown up. For this condition checking, pack mantra will ask support from P3A to do checking in their own location. Pak Mantra from every area would gather in a meeting called UPT (Pak Mantra is a coordinator in every area). The result of the meeting is a report of water requirement plan and there are several forms that must be filled by pack Mantra. All of them would be given to PSDA, and it would collect/sum all the report and PSDA report to Dinas. That report is one of the sources for commission meeting and to decide the water usage.

Q : Will the report be given to the government?

A : Indirectly, so first it will be discussed, and the result of the discussion is a recommendation that will be given back to the community.

Q : I think it will be easier for him if there are pictures that describes the water distributions. For example : in 2013, the first is area ..... the second is area .... etc (Detail of the date for every area).

For that kind of regulation, is it a fix regulation that applied every year?

A : No, it can change depend on the agreement.

Q : Can you explain for first session?

A : In Purwodadi, it start on 1 – 15 Dec, 15 – 31 Dec, 1 – 15 Jan for area 1 or per block. This condition can be changed according to the agreement.....

Q : As long as you know, how many times do you experience drought?

A : In this area in the last 20 years in Purwodadi as long as I know It's happened only once in 2009. In 2011 it's happened again but it is in Bugelen area in kecamatan Bugelen...

Q : Do all experience drought? Area 1, 2 and 3 ?

A : If we plant non-rice-crop, we water the field eith water from wheel, but it is not always like that. Sometimes when it is the time for certain area to get a turn to fill up their wheels, they don't get that turn, this is happened espescially for lower catchment area. That's mean, it's not all area depend on the wheel, some still depend on Bogowonto river. In a specific time (Mei – June) the water is decreasing, so as long as we can schedulling the water, we schedule it....

Q : In 2009, was the drought happened in all area or in one area only?

A : All area

Q : What did you do if the drought was happened? Did you still cultivate your farm?

A : Yes, if there is enough water, we schedule the water, but if there was not enough water, we optimized it to water paddy field that almost due to harvest time.

Q : Did you ever receive tank of water?

A : Never, it is clean water, not for farm.

Q : Or perhaps directly from Bogowonto river?... the wheel.... Is one wheel for each rice field? Or one wheel for several rice fields?

A : Depend Sir..

Q : Can you count how many flood you had?

A : The beginning of Jan 2011 and the end of 2012

Q : What did you do if there is flood? Especially in agriculture?

A : Make a fort or dam in the river bank

Q : Was there a preventive action? Can the flood be predicted, can't it? What about fix their damaged in the irrigation channel?

A : Automatically, before planting season, community clean up the plant area. In the secondary level, we dig the sedimentation, but we can't do all of it because the area was to wide. The floods were happened if there is long duration of rain and the flow aft water going on to the sea is too slow. In this condition with only 1 – 2 days rain, the flood was happened, even though the flood was not last long (not days).

Q : How many liters per hour?

A : Estimation .... he wants to know, what must we do like putting a valve to prevent flood, so a dam or water pool isn't needed. Like in Bugle, there is no dam , only direct water to flow to specific direction, so to minimalist the water flow like in Wonosobo.

Q : Is there a dam now?

A : No

Q : Please show us what the meaning of water that can be managed and water that can’t be managed?

Q : Is there a routine maintenance?

A : No

Q : Is all the water management according to the consensus/agreement? Are there fix regulations for example the water distribution is according to the altitude of the place?

A : I just answered is if it’s related with planting time but if from water debit point of view, it hasn’t been optimum.

Q : In drought condition, what is the meaning of the good management, how is the good management?

A : If there is not enough water debit, we prioritized the ones that’s really need water, for example the field that almost harvest time, then the field with the plant in growing state. The decision is in Borate’s hand, and it is depend on the plant that grows at the time of drought (rice or non-rice-crops).

Q : Why must there be prioritize a specific field?

A : Yes, it is a consequence of the consensus

Q : Is there another method?

A : From the Dinas Origami, we had data of water debit. So we can predict what will be our plan for next year. MP3 must decide what pattern of planting that must be done, for example rice non-rice crops. We can’t insist on rice and rice pattern.

Q : What can be done to solve irrigation problem in drought time?

A : In irrigation Biro System, the water source is only the river. We suggest to built water pool to catch rainwater and to plant trees that can absorb water, for example Focus Benyamin (Bering in)

Q : What about if there is too much water?

A : it’s difficult. Must to be closed. But the excess water still flood the field. Like the Dec flood, 250 m^3 water flow in Bogowonto river which the capacity is only 120 m^3. Perhaps the river must to be bigger?

Q : In your opinion, did government do something about those (in time of drought or flood)? For example : did government ask a lot of fund for dissemination and development?

A : In flooding time, there are special improvement in the deracination channel, in delta and the handling of the dam is improved. Those attempts are not enough because there is too much sedimentation. What about if we plant another plant for example water melon, chilly, etc.

Q : Is there data about water need? In area 1? Area 2? Area 3?

A : Yes, there is, for deciding what plant is suitable in the specific time?

Translator :

Gerrit thank to you for the data. He will process them. In 5 – 6 weeks, he will return. Hope we will meet again. He will present what he get, and if it can be implemented here, please do... If it can't, it can be used as in input in planting or water distribution consideration. He asked for your names and addresses, and please we will meet again here in 5 – 6 weeks. Also please write your title for example UPT, farmers etc. Now let's have photographs together. As I mention in the beginning, he is a student and not affiliate to any government, there will be recommendation from PSIA as we have informed to Mr. Haryono.