Water allocation for agriculture complex terrain under changing climate

2017 IOP Conf. Ser.: Earth Environ. Sci. 54 012030

(http://iopscience.iop.org/1755-1315/54/1/012030)

Water allocation for agriculture complex terrain under changing climate

I Putu Santikayasa*, Perdinan and Rizki Abdul Basit
Department Geophysics and Meteorology, Bogor Agricultural University, Indonesia

E-mail: psantika@gmail.com

Abstract. The current water resources management in Indonesia requires the government to pay more attention on sustainable water management. Agriculture as the highest water demand in the country need better water management as the impact of future changing climate. Furthermore, the water managers as well as policy makers may require integrating the climate change assessment into water resources allocation policy and management. Agropolitan in Malang district, East java – Indonesia is an agriculture which is characterized by complex agricultural system and was assigned as a case study. The supply-demand water allocation approach was applied on allocating water to different water users under current and future climatic condition. Both climate and the changing nature of water demand have affected the development and evolution of water allocation. The result shows that the water supply is expected to decrease under future climate comparing with the current condition. Furthermore, it is required to incorporate the future climate information on design the future water policy and management to reduce the adverse impact of changing climate. This study also suggested policy actions as recommendation to better manage current climate variability as well as future uncertainty from climate change impacts on water allocation and resources management.

1. Introduction

Water resources sustainability means using the natural resource wisely and protecting the complex ecosystems with future generations in mind. But sustainability will not be achieved with current patterns of resource consumption and use [1]. It is therefore of paramount importance to rational planning and decision making in equitable water management. This must be undertaken within the widely accepted integrated approach at all levels of the society.

Population growth and the intensification of irrigation on agricultural lands have increased water demand over the past decade. As a result, water abstraction for irrigation, livestock and domestic use have severely stressed the water resources, particularly during dry seasons causing conflicts between upstream and downstream water users. There is therefore a need to understand the spatial and temporal water availability and to formulate a tool for planning and decision making in prioritisation of water allocation in the area or basin. However, given the complexity of the system and the interactions between water supply and demand, a large-scale water supply management tool would be useful for decision makers when formulating water management strategies for coping with future changes in water demands [2].

Poncokusumo is the area which developed from the agriculture area to be the agropolitan area. The development status of the area has increasing the water demand especially for the domestic and industry. The development of the infrastructure, to support the agropolitan area has increasing the water demand. Furthermore, the changing climate in which is expected to decrease the precipitation increases the water stress mostly during the dry season. Therefore, it is required to assess the impact of infrastructure development and water demand on the water allocation in the current and future period.

To contribute towards this goal, the current study adopted and applied Water Evaluation and Planning (WEAP) model as a decision support system (DSS) to assess water availability and investigating the impacts of different water allocation scenarios (water demand management strategies) aimed on assessing the impact of infrastructure development and future climatic change on water allocation in study area.

2. Data and Methodology

2.1. Study area

Poncokusumo is located about 112.42º - 122.54º E and 8.68º - 7.58º S, eastern part of Malang District, Java island (figure 1). The area is dominated by lowland with the altitude less than 1,000 meter above the sea level (masl). The area is hilly area which is mountainous around the area. The precipitation is dominated by the monsoonal pattern which is peak precipitation occurs during December to February. The dry season occurs during the period of June to August. The climate is identified based on the temperature and precipitation and is classified as the wet tropic based on Koppen climate classification.

The precipitation is about 2300 mm in average with the temperature is about 21.7^{o} C in average annually. The 68 mm on monthly average of precipitation was observed during dry month in August and the maximum precipitation was observed about 423 mm during December. The area was also classified as humid area which is the relative humidity (RH) about 82%.

The Poncokusumo was selected as the study area of the impact assessment of the water resources under changing climate. The area is about 103 km^2 (3.46% from the Malang district area). The area is grouped into three area based on the topography. The flat area covers the area of nine sub districts namely Desa Karanganyar, Jambesari, Pajaran, Argosuko, Ngebruk, Karangnongko, Wonomulyo dan Belung. The hillside area which are dominated by agriculture covers about eight district namely, Desa Dawuhan, Sumberejo, Pandansari, Ngadireso, Poncokusumo, Wringinanom, Gubugklakah, dan Ngadas. The rest area is hilly area which is elevation more than 1200 masl.

2.2. WEAP for Water Allocation

WEAP, which is an object-oriented computer modelling package is an Integrated Water Resources Management (IWRM) tool designed for simulation of water resources systems and trade-off analysis. The tool considering that water supply is defined by the amount of precipitation that falls on a watershed or a series of watersheds, with the supply progressively becoming depleted through natural watershed processes, human demands and interventions, or enhanced through watershed accretions. These processes are governed by a water balance model concept that defines watershed scale evaporative demands, rainfall–runoff processes, groundwater recharge, and irrigation demands [3][4].

The model simulates water system operations within a river system with basic principles of water accounting on a user-defined time step, usually a month. Simulation allows the prediction and evaluation of "what if" scenarios and water policies such as water conservation programs, demand projections, hydrologic changes, new infrastructure and changes in allocations or operations [3][4][5][7]. Thus WEAP is considered as an integrated water management tool for evaluating water use and allocation with a greater focus on balancing supply and demand in a swift and transparent way.

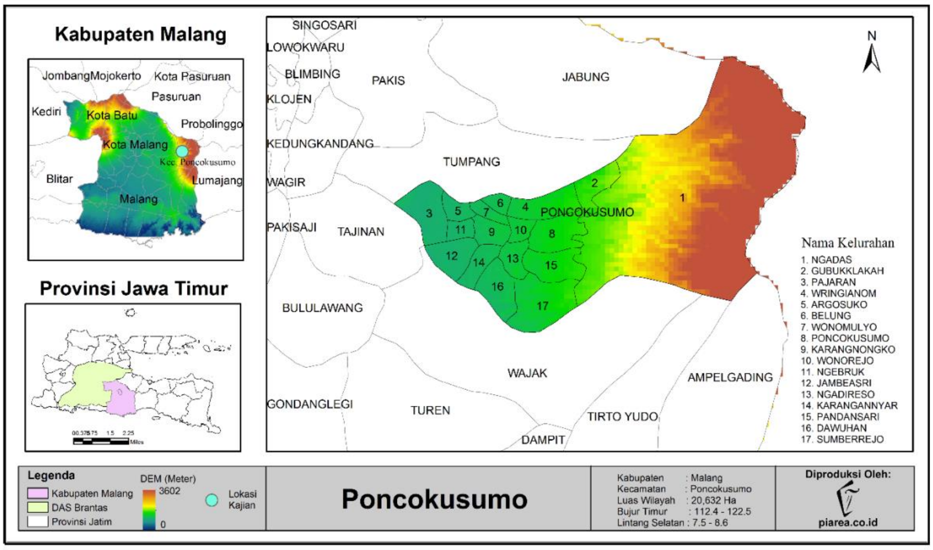


Figure 1. Map of the study area

WEAP model was applied by simulating recent base year or *'business as usual'* account, for which water availability and demand was determined. This information was obtained from different water users/stakeholders in the basin on year 2015 as the baseline. The application was defined by time frame, spatial boundaries, system components and configuration of the problem. The current account, which is the calibration step of the model, provided the actual water demand, resources and supplies for the system. Scenarios built on the current account enabled the exploration of the impact of alternative policies on future water availability and use. Construction of different scenarios was based on alternative sets of policies, which were evaluated with regard to water sufficiency, costs and benefits [6]. During this study, WEAP model was developed on the monthly time step.

2.3. Water Supply and Demand Assessment

The water availability was assessed based on the water discharge to the area. The discharge was modelled using hydrological rainfall – runoff model HEC HMS model. HEC HMS model is a lumped model which is simulates the hydrological processes in the area based on physical characteristic of the catchment. The water demand consists of three group namely domestic, industry and agriculture. The use of the water requirements of three user is based on field data indicating that the third is the dominant users of water in the study area. Water usage of those three group based on Indonesian National Standard (SNI) water use (SNI 19-6728.1-2002). In general SNI describe the amount of water use is approached by the population. Estimated water use for the domestic sector is done by using the approach of the number of people multiplied by water use national standard (SNI for domestic water demand). Uses of water for industry use a similar approach to the calculation of water demand for the domestic sector. The use of water for agriculture in this study is limited of water uses for irrigation. The water requirement for agriculture in units of cubic meters per hectare, therefore, the amount mentioned previously is multiplied by the area.

2.4. Scenario development

The scenario was developed to assess the impact of increasing water demand to the allocation as well as the decreasing of water supply. To assess those impacts, in this study, the water demand were simulated to increase by 10, 20, 30, 40 and 50% based on the baseline scenario. On the supply side, the water supply were simulated to decrease by 10, 20, 30, 40 and 50% based on the baseline scenario.

3. Result and Discussion

Estimated water demand for three water users were applied on the reference scenario. The water demand for the period of year 2010 – 2015 was used to estimate the water demand for three water users. In this study, the only water supply is from the surface water. The estimated water demand is based on the population and industrial group multiplied by the SNI of each water demand for domestic and industrial. The SNI of water demand per hectare was also applied to estimate irrigation water demand for agriculture. The total water demand was estimated by multiplying the water demand per hectare by total irrigation area on each district.

3.1. Water Allocation: Reference Scenario

Water allocation models must able to represent the model component of water resources in the model. The ideal water allocation model should simulate the water demand and supply. Priorities for different water demand and supply in this study was set as similar for each water users and supply. This priorities were able to describe the water condition in the field which is all of the water user has similar priorities to be fulfilled.

In this study, the water supply in the region comes from two main rivers. The water sources are Lesti and Amprong River. Lesti River located in the southern region of the area while Amprong River located on the northern region. The study on water availability approximated by calculating the value of the discharge of the two major river is. Based on the water supply analysis output, the availability of water in the area Poncokusumo is shown in figure 2.

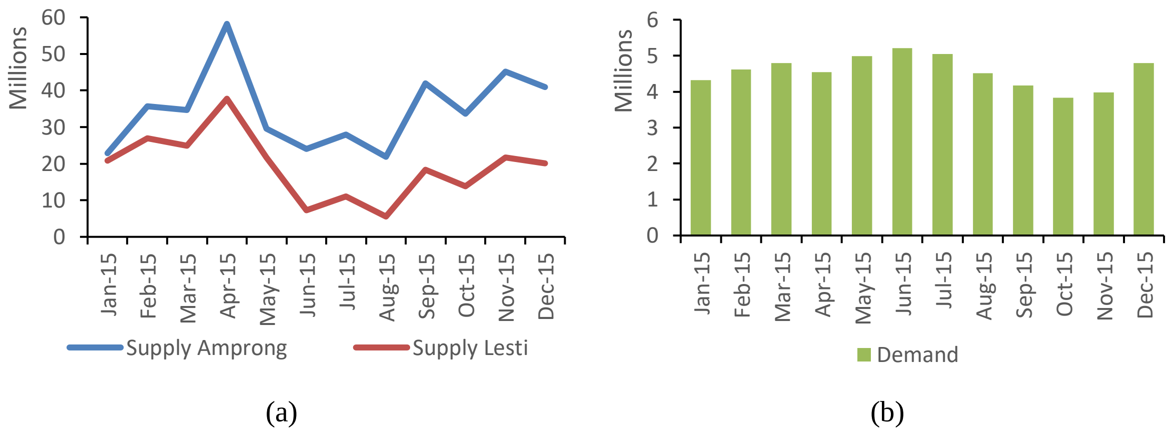


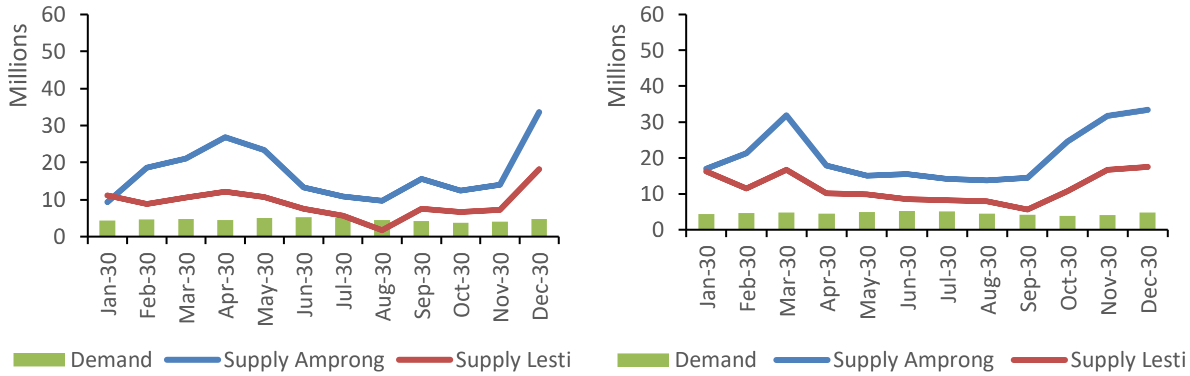
Figure 2. Graph Poncokusumo water availability in the region, based on the flow of rivers and streams Amprong Lesti (a) and total water demand (industrial, domestic and agricultural) in the region Poncokusumo (b).

Based on figure 2(a), the highest and lowest water availability in the area is occurred in April and August, respectively. While compared with the precipitation, it is high confidence that the water availability pattern follows the precipitation pattern. It shows that as the region is influenced by monsoon, the precipitation in the area also follows monsoonal pattern. Furthermore, the changing of precipitation pattern on each month is directly affected the pattern of the water availability.

The water demand as shown in figure 2 (b) is the amount of water is required to meet the water requirements of domestic, industrial and agricultural. Water demands vary on each months, it is influenced by the number of days each month. It mainly affects the amount of water demands for domestic and industrial. Unlike the water needs for domestic and industrial, the water demands for agriculture are influenced by cropping patterns in respective fields. As shown in figure 2 (b), the high water demand in the dry season, it is because the water requirements of agriculture through irrigation during the dry season is increasing, as additional water for agricultural needs of decreasing precipitation. Based on the supply and demand (figure 2), it shows that for all water demands can be met by the availability of water in the area.

3.2. Scenario Analysis

In this section, the scenario of the increasing water demand and decreasing water supply were assessed. As there are unavailable data for the future water demand, the water demand was assumed to increase about 10, 20, 30 40 or 50% based on the reference scenario. On the other hand, the supply scenario for the future are based on the projection of future precipitation in year 2030 and decreasing precipitation of 10, 20, 30, 40 and 50%. Future precipitation is based on two different Global Circulation Model (GCM) namely CSIRO and MIROC.



(a) (b)

Figure 3. Graph projections of water availability in 2030 using the CSIRO model (a) and projected water availability MIROC 2030 model (b) as well as the total water demand (industrial, domestic and agricultural) in the region Poncokusumo.

(a) (b)

Figure 4. Water resource allocation graph sensitivity to changes in water availability reduction by 50% from normal (a) and changes in water demand increase by 50% from normal (b).

Comparing with the reference scenario, the water availability is expected to decrease under CSIRO and MIROM model projection (figure 3). Under CSIRO model, the precipitation is expected to have a peak on April and December, with the lowest precipitation is expected to occur in August. However, the decreasing water availability in the future is able to fulfil the water demand if assumed that the future water demand are similar as the reference scenario. There are no water shortage in the area in the future.

Similarly, the MIROC model is also projecting the decreasing water availability in the future. The model projects that the precipitation is expected to be maximum in March and December, and achieved its minimum in September. The water availability under MIROC model is still able for fulfilling the water demand under reference scenario. The water availability in the area of Poncokusumo come from two sources as mentioned above, therefore, by this condition there are sufficient water for the future.

On this study, the sensitivity analysis were also assessed. The sensitivity of the decreasing water availability and also increasing water demand. The first scenario is decreasing water availability by 10, 20, 30, 40 and 50% comparing with the references scenario. The second scenario is increasing water demand about 10, 20, 30, 40 and 50% comparing with the water demand on references scenario. Based on those two scenario, the water availability in the Poncokusumo is still able to fulfil water demand of three water users; domestic, industry and agriculture. Moreover, the water is still available under dry season in which the water availability is expected to decrease up to 50% in this study (figure 4). On this research, all of the water availability is allocated only to those three water users. Furthermore, the efficiency of the water distribution is not considered and all of the water needs assumed fully utilized (100% consumed) with no backflow.

4. Conclusion and Recommendations

The water allocation is comparing the water demand and supply for certain area. Assessment of the water allocation in the future requires the future projection for the water demand and supply and also the allocation policy. The projection of the water supply can be expected using the precipitation projection based on the emission scenario under GCM model. On the other hand, the projection of the future water demand needs more parameters especially socio and economic parameters. On this research the future water demand projection using the assumption of increasing water demand of 10, 20, 30, 40 and 50%.

The result of this study shows that the Poncokusumo area is supplied by two sources water from Lesti and Amprong River. Those water sources is able to fulfil the water demand of domestic, industry and agriculture in the area. The increasing water demand is still able to be fulfilled in the future by up to 50% increasing water demand comparing to the reference period. Furthermore, it was expected that there will no water shortage in the future for the decreasing water availability up to 50% comparing the reference period. Furthermore, it is required to incorporate the future climate information on design the future water policy and management to reduce the adverse impact of changing climate. It was also suggested policy actions as recommendation to better manage current climate variability as well as future uncertainty from climate change impacts on water allocation and resources management.

References

[1] UN 2005 *The millennium development goals report 2005* (New York: USA)
[2] Chung G, Lansey K, Blowers P, Brooks P, Ela W, Stewart S, Wilson P 2008 A general water supply planning model: evaluation of decentralized treatment *Environ. Model Softw.* **23** 893–905
[3] Yates D, Sieber J, Purkey D, Huber-Lee A, Galbraith H 2005 WEAP21: A demand, priority, and preference driven water planning model: part 2, aiding freshwater ecosystem service evaluation *Water Int.* **30** 487–500
[4] Purkey D R, Hubber-Lee A, Yates D N, Henamann M, Herrod-Julius S 2007 Integrating a climate change assessment tool into stakeholder-driven water management decision-making processes in California *Water Resour. Manag.* **21** 315–329
[5] Raskin P, Hansen E, Zhu Z 1992 Simulation of water supply and demand in the Aral Sea *Region* **17** 55–67
[6] SEI 2008 *WEAP: Water Evaluation and Planning System, tutorial* (Stockholm Environment Institute: Boston Center)
[7] Santikayasa I P, Babel M S, Shrestha S, Jourdain D, Clemente R S 2014 Evaluation of water use sustainability under future climate and irrigation management scenarios in Citarum River basin, Indonesia *International Journal of Sustainable Development & World Ecology* **21** 181-194