Agrotech Journal ATJ
Url: http://usnsj.com/index.php/ATJ
Email: editor.atj@usnsj.com

Land Use Potential on Water Balance Based on SWAT Method in Saddang Watershed in Bendung Benteng Irrigation System

AUTHORS INFO

Muh. Ikbal Putera
University of Muhammadiyah Parepare
iqbalputera1@gmail.com

Syahirun Alam
University of Muhammadiyah Parepare
safa@yahoo.com

Suryansyah Surahman
University of Muslim Maros
suryansyahsurahman@yahoo.com

Irmayani
University of Muhammadiyah Parepare
irmaumpar@yahoo.co.id

Masnur
University of Muhammadiyah Parepare
masnur2010@gmail.com

ARTICLE INFO

e-ISSN: 2548-5148
p-ISSN: 2548-5121
Vol. 3, No. 2, December 2018
URL : http://dx.doi.org/10.31327/atj.v3i2.857

Abstract

The purpose of this study is how the Saddang watershed has the ability to store large amounts of water throughout the year. Saddang Watershed (DAS) as a large watershed in Sulawesi, rich in natural resource potential in the form of land, topography, slope, geology, soil, vegetation, climatology; rainfall, temperature, humidity, and sunshine. In maintaining and utilizing (watershed management) availability and water requirements for; humans, plants and animals. The availability and demand of water in watershed management requires the role of land in regulating agroclimatology and hydrology conditions. The water balance approach method used is SWAT (Soil and Water Assessment Tool) method of soil and water assessment tools, to determine the condition of availability and demand of water in an effort to maintain water flow conditions at all times (number and distribution) of Bendung Benteng irrigation system, which is capable of supply water for paddy field irrigation in two regencies of South Sulawesi's paddy granaries namely Pinrang Regency and Sidrap Regency. According to the Schmidth-Fergusson climate classification, the type of climate in Saddang watershed area belongs to type C climate = slightly wet area with tropical rainforest vegetation, the average amount of rainfall ranges from 2.155 mm/year. This indicates that there islarge level of rainfall every year and land use with a forest area of 676,39 or 26,41% of the watershed area, thus Saddang watershed is able to save tremendous amount of water supply. Based on the results of the water balance analysis using SWAT method, the amount of water available in the average watershed ; 3.133 mm year^{-1}, the amount of water being flowed ; 1.040,9 mm, and stored as ground water; 29,60 mm, as well as direct runoff ; 366,9 mmand flow coefficient of 0,45. Hence, there is 45% of the flow loss as surface stream and there is 55% of the flow stored in the watershed, and the model application is categorized as good both in conducting simulations and validating the flow discharge on Saddang River. Watershed processing classified as having good watershed conditions, because one indicator of a watershed's water performance can be seen from the river dischargefluctuation. River discharge fluctuations can be seen from the river regression coefficient, which is a number that shows ratio between maximum discharge (Q_{max}) and minimum discharge (Q_{min}). The highest discharge (Q_{max}) was 30.805 m^3/sec while the lowest discharge (Qmin) was 994 m^3/sec. The regression coefficient value of Saddang River watershed was 26.650 m^3/sec.Based on the results of the 2017 data analysis, the condition of Saddang watershed provides surplus value of 1.911.986 (m^3 $year^{-1}$), out of the total water availability of 2.155.273 (m^3 $year^{-1}$) minus the total irrigation water requirement of 243.286,50 m^3 $year^{-1}$, with the pattern of planting paddy-paddy-secondary crops (palawija). Therefore, Saddang watershed has the ability to store large amounts of water throughout the year

Keywords: agricultural irrigation, SWAT, watershed management, water balance, water availability

A. Introduction

The potential that must be preserved and maintained in Saddang watershed management is how to maintain and manage the availability and water needs (number and distribution) can be available throughout the year by improving the management of land, forests and vegetation. Improving the land condition so that it does not cause a lot of surface flow, but increasing the potential of rainwater into the watershed as infiltration water, which is then stored as shallow ground water and ground water store.

Saddang watershed is a watershed that has a very wide catchment area, covering Mamuju Regency (West Sulawesi), Tanah Toraja Regency, and Enrekang Regency (South Sulawesi). Hence,Saddang watershed has very great contribution in utilizing the hydrological cycle/watershed cycle, and is able to maintain the availability and needs of water in land management, irrigation for agricultural irrigation which outlets are located in Bendung Bendeng, Pinrang Regency, and Sidrap Regency.

One method to determine the availability and needs of water of a watershed is to utilize SWAT model application, which allows a number of different physical processes to be simulated in a watershed. The utilization of SWAT model can identify, assess, evaluate the level of a watershed problem and as a tool to select management actions in controlling the problem. Thus, it is expected that SWAT model utilization can develop several scenarios to determine the conditions of the best watershed management planning.

The basis for selecting the research location in Saddang watershed is that the watershed is a catchment area of Bendung Benteng and its outlet includes center district of paddy granary in South Sulawesi, namely Pinrang Regency and Sidrap Regency.

This study aims to analyze the carrying capacity of Saddang catchment area for the water availability or water supply capacity, and the demand of water for agricultural irrigation (water demand capacity).

B. Literature Review

Land Use

Water and soil are very closely related, when rainwater reaches the surface of the earth, some will enter the soil (infiltration) to become part of groundwater (groundwater), while rainwater that is not absorbed by the soil will become a surface flow/run -off (Nugroho, 2015). The land needs to be well managed for development purposes, because of four things. First, land varies, both horizontally and vertically, and even between times. Second, the function of land in the context of space (and spatial distribution) is very large and touches almost all development activities in human life. Third, the body of the land and all the elements contained inside and above its surface constitute a single complex system, which is resource component (to be utilized), and an ecological/environmental component (to be conserved). Fourth, overall, the land area is fixed while the need for space/land increases in line with the increasing number of human populations. Hence, good land use management is very necessary for the benefit of the current generation by not ignoring the interests of future generations (Baja, 2012).

Water Availability

The amount of water on earth is fixed, the changes experienced by water on earth only occur in the characteristic, shape and distribution. Water will always experience rotation and changes in shape during the hydrological cycle. The watershape changingprocess occurs with the heat of the sun during the day causing water on the earth's surface to experience evaporation and transpiration into water vapor. Water vapor will rise until it experiences condensation to form clouds. As a result of continuous cooling, the water droplets in the clouds become larger and eventually fall into precipitation. Furthermore, this rainwater will seep into the ground (become ground water) or flow into surface water which eventually forms rivers, lakes, or swamps (Pamungkas, 2012).

Water demand

The demand of water is the amount of water used for various purposes or community activities in the area. In this case the water demand that are taken into account are the water needs for paddy and secondary crops (palawija) irrigation.

Demand of irrigation water is calculated based on the area of irrigated paddy fields and analyzed by calculating 15 days Planting Pattern with the water balance method. Demand of irrigation water that are taken into account are surface irrigation water because on average farmers irrigate their paddy fields by using river water.

Water demand for river maintenance is estimated based on the multiplication of the population with the standard of water requirements for flushing (river maintenance).

According to Triatmodjo (2010), the demand of irrigation water is determined by the agricultural land area, the type of crop, the type of soil, agroclimatology and the planting pattern established, thus the water demand for irrigation can be calculated by the following equation;

$$Qi = ((Etc + IR + RW + P - Re) / Ie) \times A \quad \text{.................. (1)}$$

Description :

Qi = Demand of irrigation water (m^3),
Etc = Demand of plant consumption (mm/day) = Eto x K,
K = Plant coefficient,
Eto = Evapotranspiration (mm/day),
IR = Water demand for land preparation (mm/day),
RW = Demandof land processing (mm/day),
P = Loss due to percolation (5 mm/day),
Re = Effective rain (mm/day),
Ie = Irrigation efficiency,
A = Area of irrigation (m^2).

C. Methodology

This research analysis is based on GIS (Geographic Information System), analyzing spatial data using ArcView GIS 10.3 Software, while for non-spatial data is analyzed using Microsoft Excel. Spatial and non-spatial data processing were carried out to determine the availability and demand of water, project the data determining the availability and demand of water, and to determine the status of the carrying capacity of the land within Saddang watershed. SWAT methode is a model developed to predict the impact of agricultural land management on water, sedimentation and the amount of chemicals, in a complex area of the watershed taking into account variations in soil type, land use, and management conditions of a watershed after a long period.

The equipments used are; GPS, Softwere Arc Gis 10.3, GPS, Computers and Cameras. The material used is; land use map results of spot satellite interpretation 7.

Data analysis

Rainfall

Rainwater availability is calculated using Thiessen method. Thiessen Polygon Formation is done with the help of ArcView GIS 10.3 Software. Thiessen's coefficient is the percentage of each polygon area, which according to Soemarto (1999), the average area rainfall can be determined from the multiplication of the area of each polygon with the depth of rain on the station in the polygon (Equation 1).

$$P = \frac{P1A1 + P1A2 + P3A3 + ... + PnAn}{A1 + A2 + A3 + ... + An} \quad 1)$$

description;

P1, P2, P3, ... Pn = rainfall recorded in the rain detector post 1, 2, ..., n.

A, A, ... A = area of polygon 1, 2, ..., n, and

n = the number of rainfall checkpoints, to determine rainwater volume in each area in the Sub-watershed by multiplying the value of the average rainfall in the area with watershed area.

River Flow Discharge

The availability of river water for water utilization is determined based on the availability of the mainstay river flow discharge. The procedure for calculating mainstay discharge availability is conducted with Basic Month Planning Method. River water availability is determined based on discharge with 80% reliability (Sosrodarsono & Takeda, 2006).

Land Carrying Capacity

Determination of land carrying capacity status based on the ratio can be determined after the amount of water availability and water demand at the research location is known.

Criteria for the status of land carrying capacity based on the water balance are not enough to be stated with a surplus or deficit. But to show the relative magnitude, it is also necessary to state the value of supply / demand (Admadhani, *et al.* 2014).

Supply shows the amount of water availability in the region, namely the amount of water availability from the area's average rainfall volume and river flow discharge with 80% reliability, while demand shows the amount of water demand based on the determinants of water demand at the research site. Rustiadi, *et al.* (2010), stated that for Supply Demand Ratio> 2, the status of environmental carrying capacity is included in the safe category, while for the ratio between 1-2 is included in the conditional safe category, and for the ratio <1 is included in the unsafe category (land carrying capacity has been exceeded).

Irrigation water needs

The need for irrigation water is determined by the size of the agricultural land, the type of plant, the type of soil, agroclimatology and the planting pattern determined, so that the water needs for irrigation are calculated by the following equation:

$$Qi = ((Etc + IR + RW + P - Re) / Ie) \times A \quad ....2)$$

Description :

Qi = Demand of irrigation water (m^3),

Etc = Demand of plant consumption (mm/day) = Eto x K,

K = Plant coefficient,

Eto = Evapotranspiration (mm/day),

IR = Water demand for land preparation (mm/day),

RW = Demand of land processing (mm/day),

P = Loss due to percolation (5 mm/day),

Re = Effective rain (mm/day),

Ie = Irrigation efficiency,

A = Area of irrigation (m^2).

D. Result and Disscussion

The Schmidth-Fergusson climate classification system is based on rainfall events, namely monthly rainfall. Wet month rainfall (BB = CH> 100 mm/month, and dry month rainfall (BK = CH <60 mm/month), and rainfall with humid months is the month with rainfall between 60 mm to 100 mm/month. The results of the analysis show that the type of climate in Saddang watershed area belongs to type C climate = slightly wet area with tropical rainforest vegetation, where the average number of dry months rainfall is divided by the average number of wet months ranging from 0,85%, with the average rainfall is 2.155 mm/year.The data shows that with a large level of rainfall each year and land use with a forest area of 676,39 or 26,41% of the watershed area, Saddang watershed is able to save sufficient water availability The highest monthly average rainfall occurs in April while the lowest rainfall in August with the total rainfall of each are 578 mm and 181 mm. Annual rainfall in Saddang watershed varies greatly during the period 2007-2010, the highest amount of rainfall occurred in 2010 amounting to 3.213 mm, while the lowest amount in 2014 was 1,381 mm.

The steps taken in implementing SWAT model using ArcSWAT 10.3 software are watersheddelineation. The model automatically delines watersheds based on the DEM data entered. The method used in the delineation process is the threshold method. The size of the threshold entered will determine the number of river networks and sub-watersheds that will be generated. The topography and the area shape in Saddang watershed obtained from the slope class spatial data are automatically generated by SWAT in the DEM (Digital Elevation Model) process and analysis according to specified interval classes with 5 classes, namely 0-8% (flat), 8-15% (ramps), 15-25% (slightly steep), 25-40% (steep), and> 40% (very steep).

Table 1. Slope class of Saddang watershed

Slope Class (%)	Size of area	
	Ha	Percentage (%)
Flat (0-8)	78.964	11.87
Ramps (8-15)	60.148	9.04
Slightly steep (15-25)	114.420	17.21
Steep (25-40)	195.665	29.42
Very steep (>40)	215.837	32.45
Total	665.035	100.00

Source : Digital Elevation Models (DEM) SRTM, USGS year 2010.

This indicates that the presence of forests in Saddang watershed is very important in the arrangement and control of the water system which includes the amount, distribution and time of water supply to support the irrigation system of Benteng Bendung. The higher the rainfall, the higher the erosion produced, as well as the greater sedimentation produced (Nugroho, 2015)

Model Validation

The use of particular model in a watershed must consider the validity factor, it is due to each watershed has different characteristics. Validation aims to make the model output used has similar results close to the output of the actual watershed. This is very necessary to asssess the model suitability in watershed hydrology analysis. Validation for Saddang watershed was carried out at one outlet in accordance with the available secondary data, namely Saddang River flow dischargedata obtained from Bendung Benteng River Area Central Office. The statistical criteria used in model validation include the coefficient of determination (R^2), and the Nash-Sutcliffe (NS) coefficient.

Validation for Saddang watershed uses flow discharge data in 2010. The outlet used for calibration in the model is adjusted to the SPAS location of Bendung Benteng which is an outlet located in the downstream of Saddang River. Validation results of the daily flow discharge on

Saddang River showed the coefficient of determination (R^2) of 0.58, while the calculation for the coefficient between model discharge and observation was 0.55.

From the simulation results show there is a positive relationship between the model flow and observation flow where the percentage difference in value is very small, which means that the model discharge is almost very close to the amount of observation discharge, and the model application is categorized as good in simulating the daily flow of Saddang River. The validation results of the daily flow of Saddang River can be seen in Figure 1 and Figure 2.

Land use in Saddang watershed area will affect watershed hydrology conditions such as increased peak discharge, surface flow coefficient, and surface flow volume (Hartanto, 2009; Lipu, 2010; Emilda, 2010). Changes in the land use of Saddang watershed in 2007 and 2010 affected the Dirrect Runoff values of 268.82 mm and 465.07 mm, respectively (Table 2).

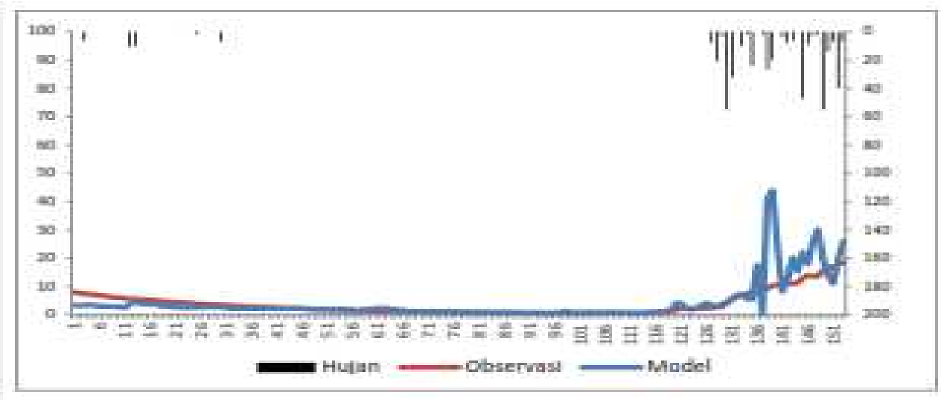

Figure 1. Validation Results of Debit Flow and Debit Model

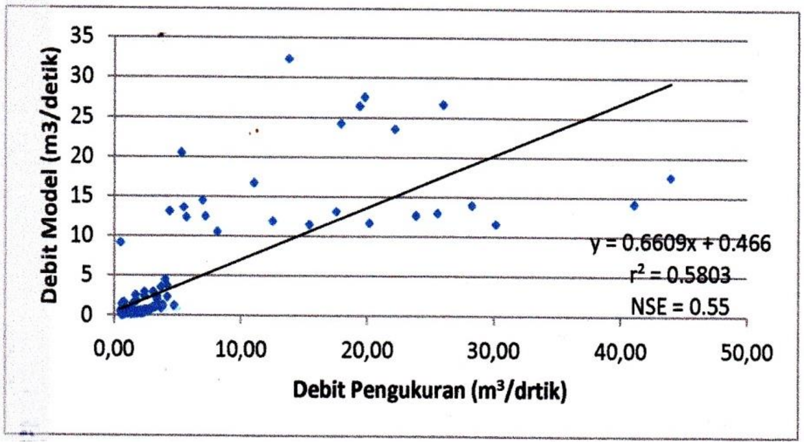

Figure 2. Regression Analysis and Validation with NS values: 0,55 and R^2: 0,58

Table 2. Effect of land use changes on water conditions of Saddang watershed

Land Use Year	Rainfall Rate (mm)	Number of streams (mm)	*Base Flow* (mm)	*Direct Runoff* (mm)	*Coefisien Runoff*
2007	3.053	596.42	18.48	268.82	0.28
2010	3.213	1.485.3	40.71	465.07	0.61

Source : SWAT Analysis 2017.

One indicator of performance, particularly the water system of a watershed, can be seen from the fluctuation of river discharge. River discharge fluctuations can be seen from the river regression coefficient, which is a number that shows a comparison between maximum discharge (Q_{max}) and minimum discharge (Q_{min}). The highest debit (Q_{max}) was 30.805 m^3/sec while the lowest debit (Q_{min}) was 994 m^3 / sec. The regression coefficient value of Saddang watershed (KRS) 2010 value of 28,824 m^3/sec is classified as moderate or Saddang watershed condition is still good.

Table 3. Effect of land use changes on discharge fluctuations of Saddang watershed

Tahun	Q Max (m^3/detik)	QMin (m^3/detik)	KRS (Q Max/Q Min)
2007	30.805	3.708	8.308
2010	28.824	5.860	4.991

Source : SWAT Analysis 2017.

Water availability (water supply capacity)

According to the Schmidth-Fergusson classification of climate types, Saddang watershed area belongs to type C climate = the area is slightly wet with tropical rainforest vegetation, with an average rainfall of 2.155 mm/year. This indicates that there is large level of rainfall every year and land use with a forest area of 676,39 or 26,41% of the watershed area, thus Saddang watershed is able to save large amount of water supply capability.

Table 4. Calculation of Water Balance

Component	Number of units
Total Water Availability	2.155.273(m^3 $tahun^{-1}$)
Total Water Demand	243.286,50 m^3 $tahun^{-1}$
TotalSurplus	1.911.986 (m^3 $tahun^{-1}$)

Table 5. Land use of Saddang watershed

No.	Land use	Size of area	
		Ha	Percentage (%)
1.	Secondary Forest	465.372	69.97
2.	Forest	39.296	5.91
3.	Mix Garden	61.107	9.19
4.	Open Land	110.52	1.66
5.	Habitation	48.28	0.73
6.	Rice Field	272.74	4.10
7.	Shrubs	289.92	4.36
8.	Fishpond	48.69	0.73
9.	Field	19.39	2.89
10.	Water body	30.45	0.46
	Total of DAS Size	665.035	100.00

Source: Results of the 2013-2016 SPOT67 Satellite Imagery Data Interpretation.

Irrigation water demand include meeting the demand of water for agricultural purposes in general. In addition to fulfill the water demand in fields, it is also needed to meet the water demand oflivestock and fisheries. The demand of water for irrigation is estimated from the multiplication of the land size area that is flowed by irrigation needs.

According to Triatmodjo (2010), the demand of water for irrigation can be calculated by the following equation;

$Qi = ((Etc + IR + RW + P - Re) / Ie) \times A$ ……………………… .2)

Description :

Qi = Demand of irrigation water (m^3),
Etc = Demand of plant consumption (mm/day) = Eto x K,
K = Plant coefficient,
Eto = Evapotranspiration (mm/day),
IR = Water demand for land preparation (mm/day),
RW = Demand of land processing (mm/day),
P = Loss due to percolation (5 mm/day),

Re = Effective rain (mm/day),
Ie = Irrigation efficiency,
A = Area of irrigation (m^2).

Based on the results of the analysis obtained, the value of Etc was 6 mm/day, the value of the plant coefficient = 4.While evapotranspiration value was 10 mm/day. The water demand for land preparation (IR) = 4,17 mm/day, while the water demand for processing (RW) = 35,34 mm/day. Loss due to percolation (P) = 5 mm/day, effective rain (Re) = 13,93 mm/day), irrigation efficiency = 60%, area of irrigation (A) = 6.650,48 km^2. Hence, the total value of demand of irrigation water (Qi) of Saddang watershed was 2423.286,50 m^3 $year^{-1}$.

E. Conclusion

1. The large level of rainfall every year and land use with a forest area of 676,39 or 26,41% of the watershed area, thus Saddang watershed is able to save a large enough water supply.
2. There is 45% of the flow loss as a surface flow and there is 55% of the flow stored in the watershed, and the model application is categorized as good in conducting simulation and validation of the flow discharge on Saddang River.
3. The fluctuations in the flow discharge can be seen from the value of the river regression value, the number which shows the rasio between the maximum discharge (Q_{max}) and the minimum discharge (Q_{min}).
4. Based on the results of the 2017 data analysis, the condition of Saddang watershed provides a surplus value of 1.911.986 (m^3 $year^{-1}$), out of the total water availability of 2.155.273 (m^3 $years^{-1}$) minus the total demand of irrigation water of 243,286.50 m^3 $years^{-1}$, with the pattern of planting paddy-paddy-secondary crops.

F. References

Admadhani, N.A., A.T. Sutanhaji, & L.D. Susanawati. (2014). Analisis Ketersediaan dan Kebutuhan Air Untuk Daya Dukung Lingkungan. (Studi Kasus Kota Malang). *Jurnal Sumberdaya Alam dan Lingkungan,* 1(3): pp.13-20.

Baja, S. (2012). Perencanaan Tata Guna Tanah dalam Pengembangan Wilayah Pendekatan Spasial dan Aplikasinya, Yogyakarta:.Andi Offset.

Emilda, A. (2010). Dampak Perubahan Penggunaan Lahan terhadap Respon Hidrologi DAS Cisadane Hulu. Tesis Tidak Diterbitkan. Sekolah Pascasarjana Institut Pertanian Bogor.

Hartanto, N. (2009). Kajian Respon Hidrologi Akibat Perubahan Penggunaan Lahan pada DAS Separi Menggunakan Model HEC-HMS. Tesis Tidak Diterbitkan. Sekolah Pascasarjana Institut Pertanian Bogor.

Lipu, S. (2010). Analisis Pengaruh Konversi Hutan terhadap Larian Permukaan dan Debit Sungai Bulili, Kabupaten Sigi. Media Litbang Sulteng III No. (1): 44-50, Mei 2010.ISSN : 1979 - 5971.

Nugroho, P. (2015). Model Soil Water Assessment Tool (Swat) untuk Prediksi Laju Erosi dan Sedimentasi di Sub Das Keduang Kabupaten Wonogiri. [unpublished skripsi]. Universitas Muhammadiyah Surakarta.

Pamungkas, A. (2012). Pengertian Siklus Hidrologi dan Penyebab Terjadinya.Dilihat tanggal 17 Agustus 2014.

Rustiadi E., Saefulhakim, S., & Panuju, D.R. (2010). Perencanaan dan Pengembangan Wilayah. CrestPent Press. Bogor.

Soemarto, C.D. (1999). *Hidrologi Teknik*. Penerbit Erlangga : Jakarta.

Sosrodarsono, S. & Takeda. (2006). Hidrologi Untuk Pengairan. Jakarta : Pt.Pradnya Pramita.

Triatmodjo, B. (2010). Hidrologi Terapan. Gadjah Mada University Press. Yogyakarta.