Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.16, 2015

Utilization Surface Water for Raw Water and Irrigation in Maros Watershed, South Sulawesi, Indonesia

Muhammad Yunus Ali[1], Naik Sinukaban[2], Suria Darma Tarigan dan[2] Nora H Pandjaitan[3]

1, Doctoral Student on Watershed Management Major,Postgraduate Program, Bogor Agricultural University Indonesia and Faculty of Engineering, Muhammadiyah of University Makassar, Indonesia.

2, Department of soil and Land resources, Bogor Agricultural University Indonesia.

3, Department of Civil Engineering and Environment, Bogor Agricultural University Indonesia

Abstract

This research is intended to analyze the existing water for the needs of raw water and irrigation.The methodology applied in this research is surface water availability analysis conducted on rainfall analysis result basis and monthly hydrograph flow analysis for one year period. The needs of crude water are determined by the total population and consumption level in a region with and under mathematics method. Raw water requirement is determined by the total population and consumption level in a region. Average irrigation water requirement in the research area are calculated based on the average use of water for irrigation for one year period. The use of water for irrigation is approximately determined by variable of rice field area width, height of average water surface during the planting, plant age and planting frequency within a year, and efficiency factor (loss). The rainfall analysis result applying polygon theissen at Maros watershed is 2810 mm/year and average rainfall is 141 mm/year. The calculation of monthly debit of Maros River in 1993 through 2012 using the opportunity approach with the reliable discharge is 65.49 m^3/sec and the average is 287.56 m^3/sec, meanwhile the minimum discharge is 0.14 m^3/sec. The projected raw water requirement are 7.42 million m^3 for period of 2013-2017 to become 9.02 million m3 for 2028-2032. Further the needs of domestic water for period of 2038-2042 is 10.27 million m3, rises to be 11.69 million m3 in 2048-2052.The projected need of water for irrigation of Maros watershed for period 2013-2017 is 393.91 million m^3, increases to be 459.96 million m^3 for period of 2018-2022 and rises to be 1165.7696 million m^3 for period of 2048-2052.

Keywords: Watershed, polygoh theissen, discharge, raw water and irrigation.

Introduction

Contribution water to the economy and social development is considerably vital. Along with the increase of population and promoting of economy and social development, the demand of water will go up and water crisis will start coming out. The crisis is due to the water resources, though geophysical waters are abundance, but only some part can directly be beneficial (Fauzi 2004). This condition causes water resource is then not treated as pure public goods to be freely usable, as water is not only needed for human life need, but also for keeping water-based ecosystem that forms globally life supporting system.

The existence of interest of water (availability and water requirement) along with the wider discrepancy requires water resource management reform and policy. Water resource management must be sustainable in order to any divergence between the need and availability of water is still within the acceptable and tolerable level in line with the natural resource condition, and thus, the water resource development and conservation shall be based on the accurate and precise planning and directed to the sustainable utilization of water resources.

In Maros watershed region comprises 2 irrigation areas, namely: Bantimurung Irrigation Area (6.513 ha) and Batubessi weir and Lekopancing Irrigation Area (3.626 ha) with Lekopancing weir. Farming plant season is during April to September and rainy season planting is from October to March (PSDA Sul-Sel, 2010).

The maximum discharge (Q_{max}) of Maros watershed within the last 2 years reaches 283 m^3/sec with average monthly discharge (Q_a) for more than 10 years is 102 m^3/sec and reliable discharge(Q_r) is 25,422 m^3/sec. Maros watershed has flow regime coefficient value (KRA) of 11,116 and annual flow coefficient (KAT) is 1,83 and water utilization index (IPA) is 2,44. The sediment concentration value is 0,05 gr/lt and the sediment delivery ratio (SDR) is 85 so the sediment load (MS) at Maros watershed reaches 0,36 ton/ha/year. This condition causes the overflow of Maros River and floods occur with frequency once a year. This indicates the damage of catchment area in the upstream region of watershed and constriction of water diameter section and the decrease of river carrying power mainly in the middle and downstream areas of watershed. (BPDAS Jen-Wal,2009).

The decrease of the forest area width encourages hard fluctuation between the minimum and maximum discharge during rainy season and dry season that is between 1 : 80, and also hard to obtain fresh water. This is caused by lowering water discharge of Lekopancing up to 80% or from 1000 lt/sec (normal condition) to be 200 lt/sec. Maros watershed has high annual rainfall of 2500 – 3500 mm. The annual rainfall spread pattern in this region is not always correlated with total rain days taken place in one year. The high average total rain days (> 150 hh/year) occurs in the Southern and Western part namely at Maros watershed. In 2003 to date during rainy season flood frequently overwhelms in Maros Baru sub-district and some of Turikale sub-district areas and in 15th February 2009 flood occurred that damage 5 ha rice field. In 2010 flood also occurred for 2 days with flooded area of 12.694 ha at Sub-districts of Maros Baru, Mandai, Tanralili and Maros. On the other side, during dry season, many streams were dried.(PSDA Sul-Sel,2010).

Material and Method

Materials needed in this research area land use map, soil type map, topography map, rainfall map and geology map. The chemical substances are used for soil analysis on laboratory.

The equipment used in this research consists of: set of survey devices such as *Geographical Position System* (GPS), *clinometers,* stationery and camera. Other devices are laboratory instruments, stationery (ATK), and set of computer and the printer machine.

Analysis Model

Water Availability Potential. Surface water availability analysis was conducted based upon the rainfall analysis results and monthly current hydrograph analysis for one year by using Maros River discharge data of 1990-2012. Water availability was stated in unit of m^3/second and volume unit (m^3).

Rainfall. Rainfall data is secondary data, which such data were collected from number of rainfall stations existing around Maros watershed and constitute serial data for 22 years (1990- 2012).

Rainfall water availability indicates the magnitude of average rainfall of a region. The regional rain water availability postulation uses Polygon Thiessen method with the equation (Thiessen, 1911; Singh, 1992) :

$$Pa = \sum_{i=1}^{n} \frac{AiPi}{An} \qquad \text{..} \qquad 1$$

where P_a = regional average rainfall; A_i = polygon wide of station i; P_i = station average rainfall -i; A_n = area width (total polygon area width).

Anticipating loss and incomplete data in rain station, a better calculation method of loss and incomplete data is *reciprocal method,* using the inter-station distance as the *weighting factor*. The analysis results are used to produce regional rainfall availability inclination for the future (Singh, 1992).

Maros watershed discharge. The collected data of water debit are serial data of Maros River discharge for the last 22 years (1990-2012), these data are used to analysis the potential availability.

River discharge analysis is conducted to identify river flow hydrograph distribution tendency along the year starting from January through December.

Flow hydrograph analysis of Maros River was conducted through two approaches namely arithmetic average approach and average occurrence opportunity approach. In this research, the occurrence opportunity was 80%, this means that the discharge opportunity with magnitude of more than one or equal to a certain magnitude was 80 %.

The River flow hydrograph analysis with average arithmetic approach uses the measured average monthly discharge data of Maros River at AWLR Station, Bantimurung and AWLR Station, Lekopancing from 1990-2012.

The River flow hydrograph analysis results either using average arithmetic approach or occurrence opportunity approach are used to determine Maros watershed water availability distribution.

Raw Water Requirement. The need of raw waters is based on the total population and consumption rate in a region. Water consumption level is determined by the community social stratum, which getting higher a community social stratum is, getting higher the water consumption will be. The social stratum is differentiated into three categories, namely, low social stratum, middle social stratum and high social stratum, which are established based on the community average income, that is: < Rp. 1 million per month = low social stratum, Rp 1 million– Rp.3 million per month = middle social stratum, > Rp. 3 million per month = high social stratum.

Raw water requirement throughout Maros watershed is computed by using the equation (Purwanto, 1995) :

$$Ycommunity = \sum_{i=1}^{m} PP_i xPxKAPxCP_i \qquad \text{..................................} \qquad 2$$

Water requirement per capita uses *World Health Organization* (WHO) standard, namely 110 liter/capita/day.

Raw water requirement projection is highly determined by total population and the population growth. The population growth is projected by using the equation:

$P_{t.} = P_o.e^r$ 3

where $P_{t.}$ = total population in year -t (life); Po = total initial population (life), r = population growth rate per annum (%), and t = total projected year, and e = natural logarithm number (2,7182818).

Based on the equation (5) and (6), so that the need of raw water is projected by combining the two equations :

$$Y_t = \sum_{i=1}^{m} PP_i x P_o e^r xKAPxCP_i \qquad \text{...} \quad 4$$

where Y_t = is water requirement by population in year -t.

The population water consumption rate is established by a survey of daily average water consumption in the research area.

$CAP_i = CP_i$ x KAP, so that $CP_i = (CAP_i/KAP)$ 5

where CAP_i is average water consumption of social stratum -i capital per day, CP_i is coefficient of water consumption of social stratum -i and KAP is average water consumption of the population per capita per day (WHO standard).

Irrigation Water Requirement. Irrigation water requirement projection is based on the computation result of total irrigation water requirement and increase of rice field area width around Maros watershed. The growth (increase or decrease) of rice field areas uses secondary data issued by Agricultural Service of Food Crops and PSDA Service of South Sulawesi Province, Maros Regency and Gowa Regency.

In relation thereto, then, the computation of average irrigation water requirement in the study area is as follows:

$$\mathbf{C_{onsumption} = A \times H \times F_g \times F_t} \qquad \text{..} \quad 6$$

$$\mathbf{H = (h_{ot} + h_b + h_v + h_g)/4} \qquad \text{..} \quad 7$$

$$\mathbf{Y_{irrigation} = Y_{consumption} + lY_{consumption}} \qquad \text{..} \quad 8$$

where $Y_{consumption}$ is the average consumption of water for irrigation (m^3/hectare/year), A is rice field area width (hectare), H is average high flooded area (cm), F_g is replacement frequency of flooded area lining along the planting period of each season, F_t is planting frequency in a year, h_{ot} is high flooded area when land cultivation (cm), h_b is high flooded area when seedling (cm), h_v and hg is high flooded area respectively during vegetative and generative growth (cm), $Y_{irrigation}$ is average need of water for irrigation in the study area, and l is loss factor or frequency valued of 15 % (PSDA Service of South Sulawesi Province, 2010).

The calculation of coefficient of irrigation water requirement in the study area uses the equation of:

$$\mathbf{C_{irrigation} = (Y_{irrigation}/Y_{irrigation}\ Standard)} \qquad \text{....................................} \quad 9$$

where $Y_{irrigation}$ standard is average standard of irrigation water requirement is 1.2 liter/second/hectare (Puslitbang Pengairan PU, 1999).

Results and Discussion

Water availability is based upon existing rainfall and discharge in Maros watershed. Rainfall data is secondary data, which such data are collected from number of rainfall station existing in Maros watershed. They are serial data for 22 years (1993- 2012). Rain water availability indicates the magnitude of average rainfall of a region. The regional rain water availability postulation uses Polygon Thiessen method with the equation 1. For details, see figure 2.

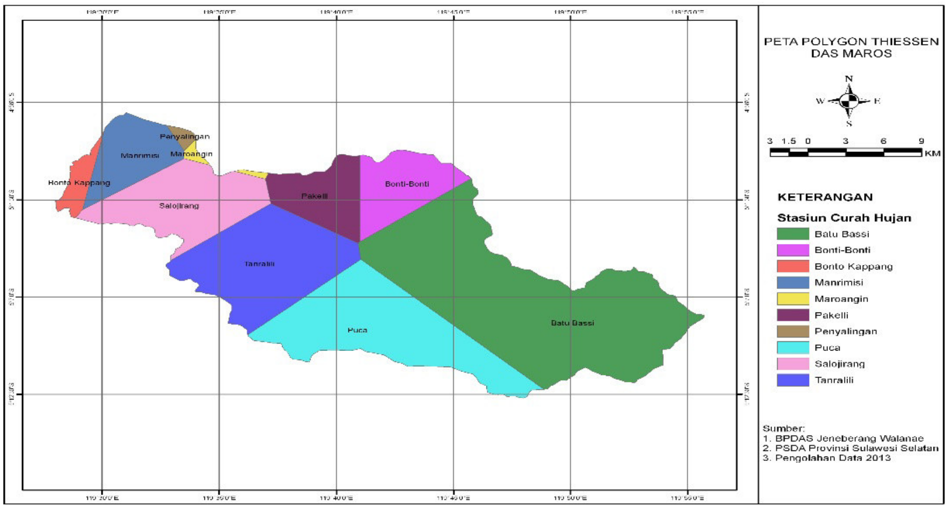

Figure 1 Rainfall in Maros watershed with Polygon Thiessen Method.
(Source; Data Processing Result, 2014)

Figure 1 shows analysis results with landsite image for determination of the rainfall station coordinate points existing in Maros watershed with polygon thiessen and the calculation results are total rainfall is 1880 mm and the average rainfall is 157 mm. Monthly rainfall estimation in Maros watershed by arithmetic is total rainfall is 1975 mm and the average rainfall is 165 mm. The rainfall analysis results in Maros watershed are the total maximum monthly rainfall is 1151 mm in 2001 and minimum monthly rainfall is 449 mm by 1994.

Based on the data of Maros River discharge is monthly of 1993 to 2012 using river flow hydrograph analysis either with average arithmetic approach or occurrence opportunity approach applied to determine monthly water availability distribution of Maros watershed by means of decisive indicator of water availability. The results indicate the computation of monthly discharge of Maros River in 1993 to 2012 with occurrence opportunity so that the reliable discharge is 78.52 m^3/sec and the average is 328.63 m^3/sec, while the minimum discharge is 0.17 m^3/sec.

Raw Water Requirement

Raw water requirement is based on the total population and water consumption rate of a region. The water consumption rate is determined by the community social stratum, where, getting higher the community social stratum is, getting higher the water consumption rate will be.

Raw water requirement is affected by total population and the population growth in every community social stratum, the community social stratum (income rate), and the average water requirement by the community. The total population projection of the community around Maros watershed uses the population data by the social stratum from 2005 to 2011. Data of the total population around Maros watershed by the social stratum of 2005-2011. The regression analysis of total population from 2005-2011 around Maros watershed indicates that the total population increases exponentially from time to time. The analysis result of population growth model around Maros watershed in 2005-2011 is presented in Figure 2.

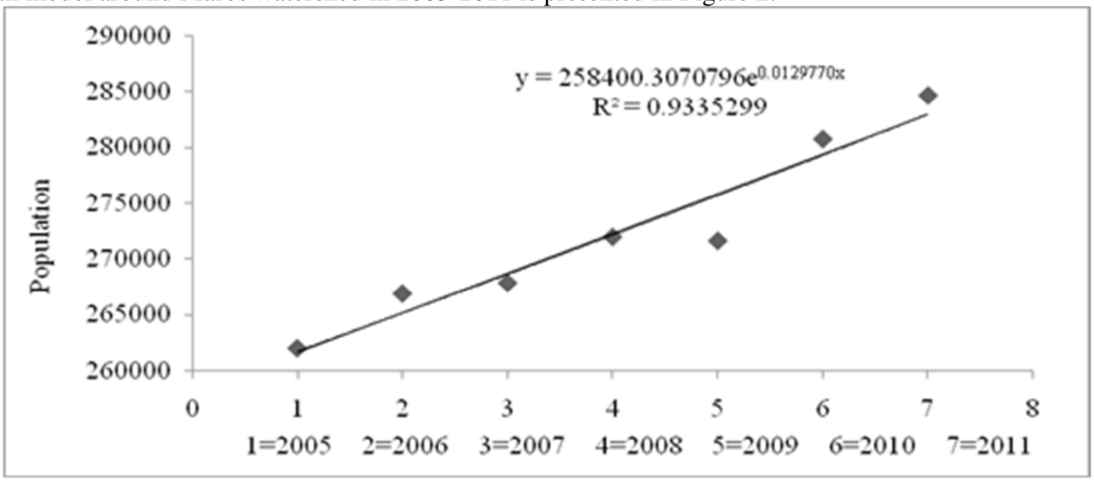

Figure 2 Population Growth Model around Maros watershed in 2005-2011
(Data Processing Result, 2014)

Figure 2 is the population growth model around Maros watershed from 2005-2011. The figure shows that the population growth around Maros watershed is exponential following the equation of:

$$y = 258400.3070796e^{0.0129770x}$$

where y is total population at the t time (life), x is the year of data where x=1 for the year 2005, x = 2 for the year 2006, and so forth, and e is natural logarithm number valued of 2,7182818. The equation mentioned above is used to estimate the total population around Maros watershed from 2012-2052.

The research results indicate that the coefficient average raw water requirement is 0,56 for respondent having income level of less than 1 million rupiah per month and 0,67 for respondents having income level of 1 – 3 million rupiah per month, in the meantime the coefficient requirement of respondents having income level of over 3 million per month is 0,80. The calculation of coefficient raw water requirement is determined based on the survey result of water requirement in the study area around Maros watershed.

The projected domestic water requirement for period of 2013-2052 is projected in figure 3.

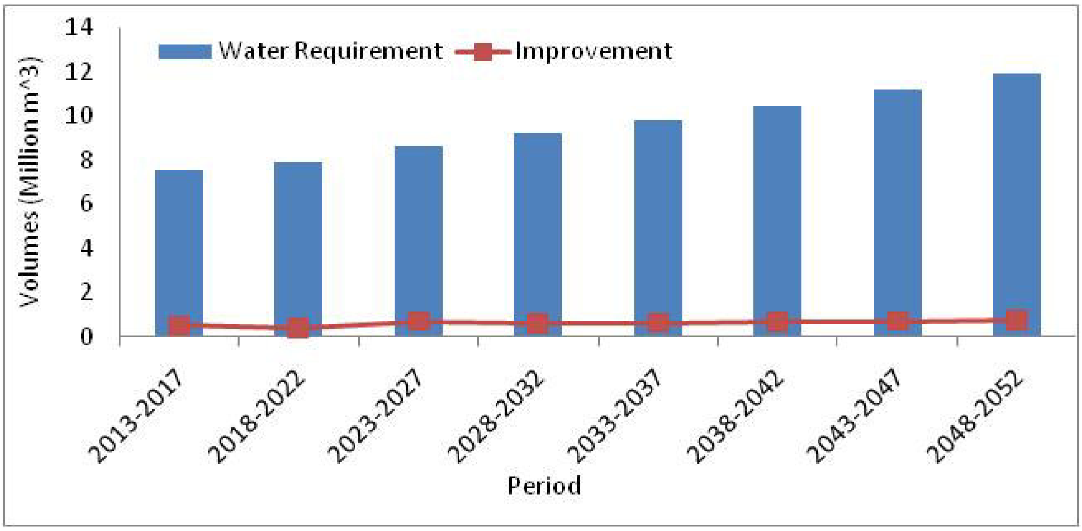

Figure 3 Projected Raw Water Requirement for Period of 2013-2052 around Maros Watershed.

Figure 3 shows that the average raw water requirement sector in Maros watershed increases from time to time, namely 7.42 million m^3 for period of 2013-2017 to be 9.02 million m3 in the period of 2028-2032. Further, the raw water requirement for period of 2038-2042 is 10.27 million m3, rises to be 11.69 million m3 for period of 2048-2052. The inclination of raw water requirement increase is caused by the increase of total population from year to year with the population growth rate is about 1,50 % per annum.

Irrigation Water Requirement.

The research results area around Maros watershed to calculate the coefficient irrigation water requirement indicate that the coefficient irrigation water requirement is 0,68. The regression analysis of rice field area width around Maros watershed in 2005 to 2011 produces the following equation;

$y = 26445e^{0.031x}$, $R^2 = 0.771$

where y is the rice field area width of t (hectare), x is the year of data where x=1 for the year 2005, x = 2 for the year 2006 and so forth, and e is natural logarithm number valued of 2,7182818. Irrigation water requirement projection in 2012-2052 and the average standard irrigation water requirement (Puslitbang Pengairan PU, 1999) is 1,2 liter/second/hectare. Irrigation water requirement projection for the period of five years is presented in Figure 4.

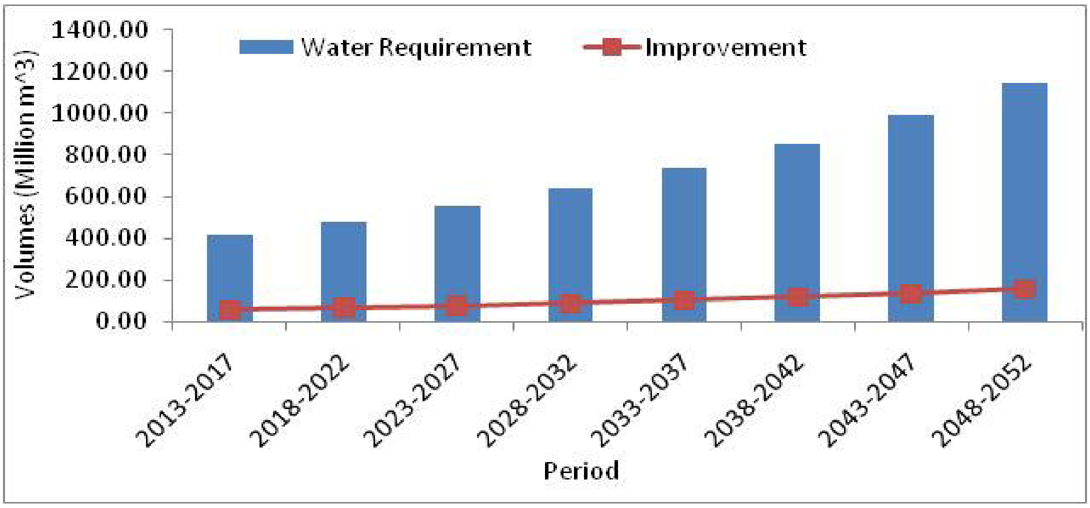

Figure 4 Irrigation Water Requirement Projection for Period of 2013-2052 in Maros Watershed

Figure 4 shows that irrigation water requirement in Maros watershed for period of 2013-2017 is 414.59 million m^3, rises to be 479.28 million m^3 for period of 2018-2022 and increases to become 1143.99 million m^3 for period of 2048-2052.

The results showed water requirements in the watershed Maros both monthly and annual water requirement is large enough so that a current supply can no longer meet the water needs in the region. This increase in water requirement due to increasing population and improving standards of living. Another factor affecting the high water requirement is low efficiency factor allocation of water resources.

Conclusion

Based on the analysis, it can be concluded that:

1. Raw water requirement projection is 7.42 million m^3 for period of 2013-2017 to be 9.02 million m3 for period of 2028-2032. Further the raw water requirement for period of 2038-2042 is 10.27 million m3, rises to be 11.69 million m3 for period of 2048-2052. Irrigation water requirement projection for period of 2013-2017 is 414.59 million m^3, rises to be 479.28 million m^3 for period of 2018-2022 and increases to become 1143.99 million m^3 for period of 2048-2052.
2. Increasing water requirements is caused by increasing population and improving standards of living, other factors affecting the high water requirement is a factor of low efficiency of water resource allocation.

BIBLIOGRAPHY

Abaje, I.B., O.F. Ati, and S. Ishaya. 2009. *Nature of Potable Water Supply and Demand in Jema'a Local Government Area of Kaduna State, Nigeria*. Research Journal of Environmental and Earth Sciences 1(1): 16-21, 2009. ISSN: 2041-0492 Maxwell Scientific Organization, 2009.

Bosscher, A. 1984. *Basic Hydrology and Water Resource Development*. Lecture Note. International Institute for Aerospace Survey and Earth Sciences.

BPDAS Jeneberang-Walanae. 2009. *Laporan Inventarisasi Potensi Kerusakan DAS Maros.* DIPA BPDAS Jeneberang-Walanae, Makassar.

Direktur Jenderal Sumberdaya Air. 2002. *Juni-September 2002 Persediaan Air Irigasi Tidak Mencukupi*. Departemen Kimpraswil Republik Indonesia. Jakarta. Internet : Www.Google.Com

Dziegielewski, B. 2003. *Strategy fo managing water demand*. Journal on Water Resources Update. Universities Council on Water Resources. University of Illinois, USA.

International Water Management Institute. 2006. *Gobal Water Outlok to 2025. Averting an Impending Crisis.* International Food Policy Research Institute. Washington, D.C, USA.

Linsley, R.K.Jr., M.A. Kohler and J. L. H. Paulhus. 1982. *Hydrology for Engineers*. McGraw-Hill, Inc. New York.

Montarcih L L. 2009. *Analisa Ketersediaan Air Untuk Pemenuhan Kebutuhan Air Baku Dalam Perencanaan Embung Tambak Pocok Bangkalan*. Jurnal Agritek Vol.17 No.5 September.2009.

Nugroho S, P. 2007. *Analisis Neraca Air Pulau Jawa.* Jurnal Alami Vol. 12 No.1.2007

PSDA Prov.Sul-Sel.2010. *Laporan Tahunan UPTD PSDA Wilayah Sungai Jeneberang*. Dinas PSDA Prov.Sul-Sel UPTD PSDA Wilayah Sungai Jeneberang.

Purnama S. 2009. *Neraca Air di Pulau Jawa.* Jurnal Forum Geografi Vol.21 No.1 Juli 2009.

Purwanto, M.Y.J. 1995. *Water Demand for Industry, Village and City*. Seminar on Water Demand in Developing Country, Tokyo, Japan.

Sinukaban N. 2007. *Soil and Water Conservation in Sustainable Deveploment.*. Direktorat Jenderal RLPS Departemen Kehutanan, Jakarta..

.