Soil Water Analysis Tools (SWAT) hydrology modelling as a basis for spatial planning: a case study in Cimandiri Watershed, West Java Province

To cite this article: I Ridwansyah et al 2019 IOP Conf. Ser.: Earth Environ. Sci. 380 012017

View the article online for updates and enhancements.
Soil Water Analysis Tools (SWAT) hydrology modelling as a basis for spatial planning: a case study in Cimandiri Watershed, West Java Province

I Ridwansyah1*, M Yulianti1 and H Wibowo1

1Research Center for Limnology, Indonesian Institute of Sciences (LIPI), Cibinong Science Center-Botanical Garden, Cibinong 16911, Indonesia

*Corresponding author: iwanr@limnologi.lipi.go.id

Abstract. Appropriate spatial planning can be analysed by looking at its impact on water resources on a watershed scale through a hydrological modelling approach. The objective of this study was to examine the effect of land-use change and the spatial plan of the region in the Cimandiri watershed using Soil Water Analysis Tools (SWAT) hydrological modelling. The Cimandiri watershed (1,830 km²) is situated in West Java Province, Indonesia. This watershed has a strategic position because of its proximity to the Capital City of Jakarta. This study highlights the importance of hydrological response considerations in spatial planning. From 1994 to 2016, there has been a reduction of forest land cover (157.8 ha), paddy fields (688.5 ha) and plantations (216.4 ha). This land-use change affects the hydrological conditions of the Cimandiri Watershed. The results indicated that there was an increase in the surface flow of 8.7 mm/year (186.6 to 195.3 mm/year), from 1994 to 2016 while baseflow decreased from 781.64 to 777.7 mm/year. The verification models were in satisfactory categories (R² 0.62 and NSE 0.51). Therefore, this indicated hydrological conditions in 1994 were relatively better than in 2016. The simulation result on the spatial plan shows the surface runoff, and the base rate was 284.9 mm/year and 684.7 mm/year, respectively. Interestingly, land use proportion based on urban spatial planning generated relatively higher surface runoff and sediment yield compared to existing land use. Hence there should be a review of the existing urban spatial planning of Sukabumi Regency that was resulting in the worst hydrological response based on SWAT model.

1. Introduction
Spatial planning is a method and approach used by a government in regulating the spatial distribution of human activities that aims to improve the welfare of society [1,2,3]. Spatial planning provides essential information for a policymaker to determine the proper strategies in the management of natural resources [4,5]. The latest regulation on spatial planning in Indonesia is set in the Spatial Planning Law No. 26/2007. This regulation is then followed by several rules at the lower level. The law stated that spatial use refers to the spatial function specified in the spatial plan implemented by developing land, water, and air, as well as other natural resources.

Spatial planning cannot be separated from hydrological response within watershed scale. The water system must be adapted to the planning system in the region. Continued pressure on watersheds due to economic growth and population should also be considered in the development and preparation of the spatial plan in the region. One of the main factors affecting the hydrological cycle in the watershed is...
the anthropogenic factor, such as land-use change and land management [6,7]. It is clearly stated in the law that spatial planning needs to consider sustainability of water resources. However, the creation process of the spatial plan often does not take into account land use change issue and its relationship to hydrology response [4] that has the potential to cause an imbalance of water resources. This process has implications for the development of a complicated and complex water resource system. The influence of land-use change on water balance in the watershed scale is a priority in the hydrological study because such change influences land-cover type that alters surface runoff generation and then affects the catchment hydrological process [7]. Therefore, the decision planning purpose of the region requires the fulfilment of water resources services.

One of the watersheds that need attention is Cimandiri Watershed, West Java, Indonesia. Based on reports from the West Java natural resource management centre, Cimandiri Watershed is one of the watersheds experiencing enormous land degradation. Cimandiri watershed is characterised by high sedimentation, extreme river fluctuation and increased pollution of river water. This information can be proven from the results of simulated data around the Cimandiri estuary, which showed that degradation has occurred from 1972 – 2015 (figure 1). Unwise land conversion is the main issue in Cimandiri Watershed that has an impact on severe erosion and high discharge. Moreover, mining activities such as gold, iron, and quartz cause sedimentation, abrasion, and coastal damage that adversely affect watershed ecosystems. Cimandiri Watershed is located in the Sukabumi region, which has the potential to experience rapid regional development. The construction of toll roads access to Sukabumi will accelerate land-use changes, thus increased the pressure on the watershed. Therefore, appropriate spatial planning based on land-use changes approach is needed to minimize the impact of regional development on the watershed ecosystem.

![Figure 1](image_url)

**Figure 1.** Change of Cimandiri Watershed based on simulated data in year (a) 1972 (b) 1991, and (c) 2015.

Hydrological modelling is one of the tools that can be used to examine the suitability of spatial planning that has been applied. Among the most commonly used simulation models in spatial planning analysis is the Soil Water Analysis Tools (SWAT) model. SWAT is a GIS-based hydrologic simulation model developed by USDA Agricultural Research Service [8]. In recent years, the SWAT Hydrology Model has been widely used in watershed management as a hydrological model [9,10].

The objectives of this study was to: (1) analyse land-use changes in Cimandiri Watershed, (2) calculate the water balance of watershed under different land-use scenarios using the SWAT hydrology model. This information is significant to assist policymakers for spatial planning in Cimandiri Watershed as part of Sukabumi Regency.
2. Materials and methods

2.1. Study area
The study area was Cimandiri Watershed, situated in Sukabumi, which constituted a small part of Cianjur Regency, the southern part of West Java, Indonesia (figure 2). The catchment has an area of 4,128 km² and lies between latitude -6.701 to -7.175 and longitude 106.476 to 107.093. The average annual precipitation was 2,524 mm, and the average maximum and minimum temperature were 28°C and 20°C, respectively. The topography of the Sukabumi Regency, in general, includes a curved surface in the south and mountainous in the northern and central regions; and the height ranges from 0 - 2,960 m above sea level (asl).

![Figure 2. Change of Cimandiri Watershed based on simulated data in year (a) 1972 (b) 1991, and (c) 2015.](image)

2.2. Data collection
The data used in this study consisted of primary data collected from field sampling and secondary data in spatial and tabular forms derived from various sources (table 1). The collected data were used for two main stages of the study, which were land use analysis and hydrological modelling using SWAT.

| No | Margin | Data format | Source |
|----|--------|-------------|--------|
| 1  | Digital elevation model | Grid (cell size 30 x 30 m) | SRTM, USGS |
| 2  | Soil types scale 1:100.000 | Vector (shapefile) | Land and agro-climate research centre, Ministry of agriculture |
| 3  | Meteorological data (daily) from two weather stations | Table (.dbf and text) | Meteorology and climatology agencies |
| 4  | Landsat image 1994 |  | USGS |
| 5  | Landsat image 2016 |  | USGS |
| 6  | Soil properties for SWAT database | Numeric | Field sampling and laboratory analysis |
| 7  | Daily discharge | Table (.dbf and text) | Ministry of public works |
2.3. Land use classification

Land use classification in the Cimandiri Watershed was mapped by the use of Landsat imagery data from 1994 and 2016. Land use analysis was conducted with remote sensing methods and GIS. Land use analysis was initiated with the processing of satellite imagery as the primary data, followed by image processing that consists of two parts: pre-processing and image classification. Pre-processing of image includes a process of preparing image data for subsequent analysis which tries to correct or compensate for systematic errors, such as atmospheric, radiometric and spatial error, this process was for Landsat image 5 (the year 1994). The image classification method is used supervised classification, and the training sample area is derived from ground check data was collected by Camera GPS.

Accuracy of assessment is defined as a comparison of a map produced from remotely sensed data with ground check data. How closely the new map produced from the remotely sensed data matches to the source map is an important analysis \[11\]. Kappa coefficients were used to estimate the similarity between the two maps. Values > 80% are categorized as the same, 60% -80% of high similarity, almost the same 40% -60% and < 40% do not have a common \[12\].

Detection of land-use changes in two periods was carried out using the cross-tabulation method. Comparisons will involve observing changes in each pixel \[13,14, 15\]. Detection produces a matrix of transformation. This matrix provides information on land-use changes in the region, spatially and quantitatively, including gains and losses between 1994 and 2016.

2.4. Model description

The SWAT model was utilised to examine the impact of land use on water balance components and sediment yield in Cimandiri Watershed. SWAT is a physically-based, distributed hydrological model regarded as a versatile model that is used to integrate environmental processes to support more effective watershed management \[16\]. A more detailed explanation of SWAT is available in several publications \[17, 8, 18\].

SWAT analysis was generated by ArcSWAT tools in ArcGIS 10.1. SWAT model requires a series of stages including watershed delineation, Hydrology Response Units (HRUs) definition, database input, calibration and validation. The first step was to delineate Cimandiri Watershed using Digital Elevation Model (DEM) into 57 sub-catchments. A further step was a division into the smallest spatial unit of the model, which is HRUs based on land uses, soil types and slope characteristics. After input of meteorological data, SWAT model was executed and continued for calibration and validation stages. Daily discharge data from several gauging stations in the study area was used in the calibration and validation process. The calibration process of the SWAT model used a manual method where the parameters that determine the discharge output were changed and adjusted to the natural conditions of the Cimandiri Watershed. Some parameters that are sensitive to discharge variation were also changed by trial and error. Model calibration was performed using data from 2009, while validation was used in 2010.

The performance of SWAT model in simulating streamflow was evaluated using Nash-Sutcliffe efficiency \[19\] and the coefficient of determination \[20\]. The NSE statistical model is widely used to show the performance of a model because it can provide more accurate information about the value given. Moriasi et al. \[21\] divided the statistical value criteria for NSE as: 0.75 <NSE <1.00 (very good), 0.65 <NSE <0.75 (good), 0.5 <NSE <0.65 (satisfying) and NSE≤ 0.50 (unsatisfactory).

After calibration and validation, SWAT was applied to predict the water balance, and sediment yield for five land uses scenarios (table 2). These scenarios changed the HRU distribution in the model; however, delineation of sub-catchments remained the same. Therefore, the results can reflect the impact of land use on the hydrological response as a basis for spatial planning.
Table 2. Five land use scenarios for SWAT model simulation.

| No | Land use | Explanation                                      |
|----|----------|--------------------------------------------------|
| 1  | Land uses 1994 (LU 1994) | Land use resulting from image data processing       |
| 2  | Land uses 2016 (LU 2016) | Land use resulting from image data processing       |
| 3  | Urban spatial planning (RTRW) of Sukabumi Regency (USP) | Spatial planning of Sukabumi Regency (2012-2032) |
| 4  | USP and Best Management Practices (USP + BMPs) | Combination of spatial planning and Best Management Practices |
| 5  | Optimum land use (OLU) | Land use based on Law No. 41, 1999 and Law No. 37, 2014 |

3. Results and discussion

3.1. Land use changes in Cimandiri Watershed

The nine categories of land use composition produced from Landsat images for 1994 and 2016 are displayed in Table 3. The results of image interpretation and classification show that there has been a considerable change during the twelve years, even though the major land use did not change significantly. The major land-use types in Cimandiri Watershed were plantation and agriculture, accounting for 26 % and 24 % respectively. Nonetheless, these land uses were decreased. The decline also occurred in almost all natural land uses such as mixed forest, paddy fields and bushes. On the other hand, there is an increase in the built-up area, such as commercial area and settlement. Settlement increased by 1,044 ha (0.6 %) while commercial area improved by 137.4 ha (0.2 %). This result indicates that population growth and development program had been triggered by the expansion of settlement and commercial area. Based on data from West Java in Figure (Statistics Indonesia), the population in Sukabumi Regency rose from 1,832,966 to 2,434,221, or 32.80% between 1994 and 2016.

Table 3. Land use proportion of Cimandiri Watershed in 1994 and 2016.

| No | Land uses class | Land uses 1994 | Land uses 2016 | Changes |
|----|-----------------|----------------|----------------|---------|
|    | Area (ha)       | Percentage (%) | Area (ha)       | Percentage (%) | ha       |
| 1  | Water bodies    | 980.5          | 0.5            | 999.7    | 0.5     | 19.2    |
| 2  | Bushes          | 28,031.2       | 15.4           | 27,535.6 | 15.1    | -495.6  |
| 3  | Commercial area | 280.9          | 0.2            | 418.3    | 0.2     | 137.4   |
| 4  | Mixed forest    | 26,705.3       | 14.6           | 26,552.6 | 14.5    | -152.7  |
| 5  | Plantation      | 48,269.9       | 26.4           | 48,053.5 | 26.3    | -216.4  |
| 6  | Settlement      | 17,209.8       | 9.4            | 18,254.2 | 10.0    | 1,044.4 |
| 7  | Open area       | 1,150.9        | 0.6            | 1,257.4  | 0.7     | 55.4    |
| 8  | Paddy field     | 45,251.5       | 24.78          | 45,342.2 | 24.8    | -90.7   |
| 9  | Dry agriculture |                |                |          |         |         |
|    | Total           | 182,656.4      | 100.0          | 182,565.4| 100.0   |         |

3.2. Calibration and validation model

Figure 3 shows a comparison of daily hydrograph between observed and simulated streamflow in a one-year period. There was some period that simulated streamflow (blue line) that was outperformed compared to observed data (black dashed line). Simulated data was underestimated at the end of January and the beginning of August, and overestimated in May. However, SWAT model produced a relatively...
similar pattern of peak and low flows from observed daily hydrograph. The average streamflow simulated by SWAT (22.0) was close to the average of the observations (22.3).

Simulated and observed daily discharge matched well in calibration process with ENS = 0.62 and R2 = 0.786 and for validation ENS = 0.58 and R2 = 0.618 (figure 3). Even though the values were relatively low, they were still acceptable for the validation process [21]. The results of this calibration were almost similar to other work conducted using SWAT in the Cisadane watershed [22]. It is indicated that the SWAT model can be used in Cimandiri Watershed.

![Figure 3. Comparison of observation and simulation streamflow.](image)

3.3. Water balance hydrology model

Table 4 provides the respective results of simulation and comparative impact from different land-use scenarios in Cimandiri Watershed. The simulation results of SWAT model displayed a notable effect of varying land-use types of land use on hydrology response (table 4). It was found that the most significant consequence of land use was on the amount of surface runoff. The simulated of the annual hydrological response indicates that compared to land use in 1994, the annual surface runoff is 9 mm higher in 2016, increases of 4.82%. The effects of land-use change was also directly linked to changes in other hydrological components such as interflow, baseflow and sediment load from the watershed. The impact of this change resulted from a decline in forest cover and a growth of the built-up area similar to results from previous studies in several parts over the world such as [23, 24, 25, 26, and 27].

| Parameter              | Land uses 1994 | Land uses 2016 | Urban Spatial Planning (USP) | USP + BMPs | Optimum land uses (OLU) |
|------------------------|----------------|----------------|----------------------------|------------|-------------------------|
| Surface runoff (mm/year) | 186.58         | 195.27         | 284.9                      | 220.2      | 170.4                   |
| Interflow (mm/year)    | 830.1          | 821.69         | 800.66                     | 838.2      | 803.5                   |
| Baseflow (mm/year)     | 777.72         | 781.64         | 684.7                      | 708        | 759.9                   |
| Sediment yield (x10^3 Ton/year) | 1,227.7      | 1,233.6        | 2,505.7                    | 2,119.6    | 1,061.7                 |

Surprisingly, the simulation results indicate significant increase in annual surface runoff and sediment yield under land-use scenario using urban spatial planning of Sukabumi Regency for 2012 – 2032 (USP). Compared with the baseline land use (1994), there was 52.70% change for surface runoff and 104.10% for sediment yield. By adding conservation approach through Best Management Practices of agricultural land on USP (USP+BMPs), surface runoff and sediment yield were decreased, even though the values remain higher relative to other scenarios. The result of this simulation confirms previous studies that best management practices using terracing, contouring and ponds successfully
reduce surface flow and sediment yield [28, 29, and 30]. However, BMPs application in the existing urban regional planning did not provide significant improvement of hydrological conditions proportionate to current land use. The best hydrological results were performed by simulation using the optimum land use (OLU). The OLU was based on government regulations which determine the proportion of protected forest areas in upstream and irrigated land in the region.

These findings further support the idea of taking into considerations of water resource management [31] and land-use change [32] in spatial planning. [33] argued that spatial planning based on land use approach is mitigation to prevent future risks on water balance caused by land-use change. Therefore, policymakers need to ensure that the impact of proposed land-use changes on water balance is considered during an early stage of spatial plan [34]. Furthermore, the planner should be aware that any possible adverse effects on the ecosystems will impact social and economic welfares, as well as other ecosystem services [2]. Ideally, spatial planning should be used to overcome problems regarding water availability through the utilization of soil and water conservation technology. Hence, the government, especially at the local government level as a spatial planner, must be able to balance the framework of land use planning with integrated water resources management.

The use of hydrological model potentially become one of the useful tools in spatial planning in a region. Integrating the effects of water resources into decision planning involves a robust model [35] to provide a better prediction of land-use impacts on a hydrologic response [36]. This study proved the potential of SWAT as one of the widely used hydrology models to support decision making in spatial planning. A physically-based SWAT model can be used to analyze the impact of land changes on hydrological responses in a watershed region. Furthermore, this model can assess the regional spatial plan, whether it has a good effect on sustainable water resources management. The findings of this study revealed the potential use of a hydrological model for a review of the regional spatial plan so that it can be implemented per the mandate of the law.

4. Conclusion
This study has shown that SWAT model is capable of simulating daily flow in Cimandiri Watershed within the range acceptable accuracy of model performance based on NSE value. It was also revealed that SWAT is an appropriate tool to be used as a basis for spatial planning. The findings of this study highlight the importance of taking into account the hydrological response to spatial planning. An implication of this is the possibility to re-examine the existing urban spatial planning of Sukabumi Regency that is resulting in the worst hydrological response compared to other scenarios.

5. References
[1] Leppert G, Hohfeld L, Lech M and Wencker T 2018 Impact, diffusion and scaling-up of a comprehensive land use planning approach in the Philippines: from development cooperation to national policies Bonn:Deutsches Evaluierungsinstitut der Entwicklungszusammenarbeit (DEval)
[2] Granit J, Lymer B L, Olsen S, Lundqvist, J and Lindström A, 2014 Water governance and management challenges from land to the coastal sea–spatial planning as a management tool
[3] Wiering M and Immink I 2006 When water management meets spatial planning: a policy-arrangements perspective Environment and planning C: Government and policy 24(3)423-38
[4] van der Kwast J, Yalow S, Dickens C, Quayle L, Reinhardt J, Liersch S, Mul M, Hamdard M and Douven W 2013 A framework for coupling land use and hydrological modelling for management of ecosystem services Int J. Env. Mon. and Anal. 1(5)230-6
[5] Arciniegas G and Janssen R 2012 Spatial decision support for collaborative land use planning workshops Lands. Urban Plan. 107(3)332-42
[6] Schilling K E, Jha M K, Zhang Y K, Gassman P W and Wolter C F  2008 Impact of land use and land cover change on the water balance of a large agricultural watershed: Historical effects and future directions Water Resour. Res. 44(7)
[7] Ghaffari G, Keesstra S, Ghodousi J and Ahmadi H 2010 SWAT-simulated hydrological impact of land use change in the Zanjanrood basin, Northwest Iran *Hydro. Proc.: An Int. J.* 24(7)892-903

[8] Neitsch S L, Arnold J G, Kiniry J E A, Srinivasan R and Williams J R 2002 Soil and water assessment tool user’s manual version 2000 *GSWRL report 202(02-06)*

[9] Karvonen T, Koivusalo H, Jauhiainen M, Palko J and Weppling K, 1999 A hydrological model for predicting runoff from different land use areas *J Hydrol.* 217(3-4)253-65

[10] Naef F, Scherrer S and Weiler M 2002 A process based assessment of the potential to reduce flood runoff by land use change *J Hydrol.* 267(1-2)74-9

[11] Senseman GM, Bagley C F and Tweddale S A 1995 *Accuracy Assessment of the Discrete Classification of Remotely-Sensed Digital Data for Landcover Mapping* (No. CERL-TR-EN-95/04) CONSTRUCTION ENGINEERING RESEARCH LAB (ARMY) CHAMPAIGN IL

[12] Landis J R and Koch G G 1977 The measurement of observer agreement for categorical data. *Biometrics* 159-174

[13] Koeln G and Bissonnetton J 2000 Cross-correlation analysis: mapping landcover change with a historic landcover database and a recent, single-date multispectral image In *Proc. 2000 ASPRS Annual Convention Washington DC*

[14] Lunetta R S and Elvidge C D 1999 *Remote sensing change detection (Vol. 310)* Taylor & Francis

[15] Lillesand T M, Kiefer R W, Dulbahri, Suharsono P, Hartono, Suharyadi and Sutanto 1993 *Penginderaan Jauh dan Interpretasi Citra Gadjah Mada University*

[16] Gassman P W, Williams J R, Benson V R, Izaaurralde R C, Hauck L M, Jones C A, Atwood J D, Kiniry J R and Flowers J D 2005 Historical development and applications of the EPIC and APEX models *2004 ASAE Annual Meeting* American Society of Agricultural and Biological Engineers

[17] Neitsch S L, Arnold J G, Kiniry J R and Williams J R 2011 *Soil and water assessment tool theoretical documentation version 2009* Texas Water Resources Institute

[18] Smarzyńska K and Miatkowski Z 2016 Calibration and validation of SWAT model for estimating water balance and nitrogen losses in a small agricultural watershed in central Poland *J Water Land Dev.* 29(1) 31-47

[19] Nash J E, Sutcliffe J 1970 River flow forecasting through conceptual models part I—A discussion of principles *J Hydrol.* 10 282–290

[20] Eisenhauer J G 2003 *Regression through the origin* Teaching Statistics (25)76–80

[21] Moriasi D N, Arnold J G, Van Liew M W, Bingner R L, Harmel R D and Veith T L 2007 Model evaluation guidelines for systematic quantification of accuracy in watershed simulations *Transactions of the ASABE* 50(3) 885-900

[22] Ridwansyah I, Pawitan H, Sinukaban N and Hidayat Y 2014 Watershed modeling with ArcSWAT and SUFI2 in Cisadane catchment area: Calibration and validation of river flow prediction *J Adv Sci Eng Inf Technol* 6(2)92-101

[23] Yini H, Jianzhi N, Zhongbao X, Wei Z, Tielin Z, Xilin W, and Yousong Z 2016 Optimization of land use pattern reduces surface runoff and sediment loss in a hilly-gully watershed at the Loess Plateau, China *Forest Syst.* 25(1)9

[24] Wang H, Sun F, Xia J, and Liu W 2017 Impact of LUCC on streamflow based on the SWAT model over the Wei River basin on the Loess Plateau in China *Hydrol. Earth Syst. Sci.* 21(4) 1929

[25] Baker T J and Miller S N 2013 Using the Soil and Water Assessment Tool (SWAT) to assess land use impact on water resources in an East African watershed *J Hydrol.* 486 100-111

[26] Marhaento H, Boojj M J, Rientjes T H M and Hoekstra A Y 2017 Attribution of changes in the water balance of a tropical catchment to land use change using the SWAT model *Hydrol. Process* 31(11) 2029-40

[27] Githui F, Mutua F and Bauwens W 2009 Estimating the impacts of land-cover change on
runoff using the soil and water assessment tool (SWAT): case study of Nzoia catchment, Kenya Hydrolog. Sci. J. 54(5)899-908

[29] Bracmort K S, Arabi M, Frankenberger J R, Engel B A and Arnold J G 2006 Modeling long-term water quality impact of structural BMPs Trans. ASABE 49(2) 367-74

[30] Betrie G D, Mohamed Y A, Griensven A V and Srinivasan R 2011 Sediment management modelling in the Blue Nile Basin using SWAT model Hydrol. Earth Syst. Sci. 15(3) 807-818

[31] Xie H, Chen L and Shen Z, 2015 Assessment of agricultural best management practices using models: Current issues and future perspectives Water 7(3)1088-1108

[32] Taylor N 2010 Commentary: What is this thing called spatial planning? an analysis of the British government's view Town Planning Review 81(2) 193-208

[33] Hersperger A M, Oliveira E, Pagliarin S, Palka G, Verburg P, Bolliger J and Grădinaru S 2018 Urban land-use change: The role of strategic spatial planning Global Environ. Chang. 51 32-42

[34] Memarian H, Balasundram S K, Abbaspour K C, Talib J B, Boon Sung C T and Sood A M 2014 SWAT-based hydrological modelling of tropical land-use scenarios Hydrolog. Sci. J. 59(10) 1808-29

[35] J G, 2007 Spatial planning, water and the Water Framework Directive: insights from theory and practice Geogr. J. 173(4) 330-42

[36] Guswa A J, Brauman K A, Brown C, Hamel P, Keeler B L and Sayre S S 2014 Ecosystem services: Challenges and opportunities for hydrologic modeling to support decision making Water Resour. Res. 50(5) 4535-44

[37] Maidment D R, Hooper R P, Tarboton D G and Zaslaksky I 2009 Accessing and sharing data using CUAHSI water data services In Hydroinformatics in hydrology, hydrogeology and water resources Proc.Symposium JS. 4 at the Joint Convention of the International Association of Hydrological Sciences (IAHS) and the International Association of Hydrogeologists (IAH) held in Hyderabad, India, 6-12 September 2009 213-223 IAHS Press

Acknowledgments

This study supported by Priority Research Program of Deputy of Earth Science, the Indonesian Institute of Sciences (LIPI), entitled "Response of water ecosystem to climate change and anthropogenic as the basis for the development of coastal region development strategies", funded by LIPI through the fiscal year of 2015-2017.