Validation of land management information system model (SILAHAN) on plot scale, case study in Citaman, Nagreg, West Java

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Abstract. Upland has potential uses for agriculture practices in Indonesia. However, there are some problems to manage, one of them is many existing upland in sloping areas and high risk to erosion and runoff. Indonesian Soil Research Institute developed a recommendation model for the land management information system (SILAHAN) based on the study of criteria for soil conservation indicators with calculation of erosion hazard index and surface runoff. The aim of this study was to validate SILAHAN prediction models from surface runoff aspects on a plot scale as the basis for formulating recommendations for the most complex land management technology. Validation of the prediction results of surface runoff in SILAHAN model is done by comparing surface runoff results of real measurements in field with the results predicted by SILAHAN with three simulation. The results of statistical tests with r Pearson correlation coefficient is 0.31, 0.31, and 0.32, PBias is -90.6, -86.6 and -83.5, and NSE is -0.76, -0.68, and -0.63. The results of the prediction of plot scale surface runoff in the SILAHAN model were not same as the measurements result on the field observations. It is suggested to determine the correction factors and development capabilities of the SILAHAN model to assess the effectiveness of a land management system in reducing the amount of surface runoff.

1. Introduction
Upland has potential uses for agriculture practices in Indonesia. The upland area has about 144.47 million ha and only 99.65 million ha (68.98%) are suitable for agricultural cultivation. The land potential analysis result revealed about 29.39 million ha (29.50%) potential for food crops, 1.12 million ha (1.13%) potential for highland vegetable crops, 66.72 million ha (66.95%) potential for annual crops including fruits, and 2.42 million ha (2.43%) potential for livestock grazing [2].

The Problems of upland management varies from one region to the other in technical as well as socio-economic aspects. In general, the problems located on sloped areas, so it’s tend to cause erosion. Erosion can occur due to several factors and one of which is surface runoff. Surface runoff is part of rainfall that flows on land surface. Surface runoff occurs when the amount of rain exceeds the rate of infiltration of water into the ground [1]. The amount of surface runoff is basically determined by two factors: (1)
climate (the type of rain, rainfall intensity, rainfall distribution, temperature, wind, and humidity); (2) watershed conditions (initial groundwater content, watershed size and shape, elevation and topography, growing vegetation, geology and soil) [13].

Indarto (2010) state that surface runoff occurred on land surface when the soil has become saturated, then passed on ditches, canals, or rivers. This statement relevant to the results of Erfandi et al. (1989) that on bare land, precautionary measures surface runoff was less effective.

For estimating and studying surface runoff, Dehotin et al. (2015) revealed that there are two very important approaches such as: 1) an approach based on modeling and 2) an approach based on the observation method [4]. Hydrological modeling approach had started a long time ago. The estimation of maximum discharges based on watershed area, watershed characteristics, and also based on rainfall was introduced in 1850 by Mulvaney [11]. Furthermore, modeling continues to be developed, in 1940 using the parameters of the slope and length of the land which was then corrected in 1941 by adding crop parameters and soil conservation techniques [14]. With the diversity and dynamic development of the hydrological model, there are still many opportunities for the study of hydrological models that can be developed in accordance with soil and climate conditions in Indonesia.

Land Management Information System (SILAHAH) is an application component derived from the development of Land Based Management System (SPLaSH). SPLaSH is a decision support system (DSS) software for erosion value simulations developed by Indonesian Soil Research Institute (ISRI). SILAHAN was developed from SPLaSH by adding spatial and web-based surface runoff calculations.

This application can be used as a tool to choose alternative land management technologies so that the level of degradation can be minimized. The SILAHAN recommendation model was developed based on the study of conservation indicator criteria, that was the calculation of the Erosion Hazard Index (IBE) and surface runoff which are useful for land management planning. In conditions where rainfall exceeds the ability of soil infiltration, surface flow can occur and predictions can be calculated using a certain formula [17].

The results of research conducted by Yustika et al. (2007) revealed the SPLaSH model is accurate enough to predict erosion at the plot scale, and can be used to assess the effectiveness of a conservation action. However, in estimating the surface runoff it is still necessary to validate the value generated by the SILAHAN model, so that the accuracy of this model can be determined in predicting surface runoff. The purpose of this study is to validate the results of surface runoff predictions using the SILAHAN model on a plot scale as a basis for making appropriate recommendations for land management technology.

2. Materials & Methods

Validation of surface runoff in land management information systems (SILAHAH) is done on a plot scale, by taking a case study in Citaman, Nagreg, Bandung regency, West Java. This location was chosen because a complete soil conservation technique simulation has been applied. In the initial stage, rainfall data from the measurement results of the Citaman research plot were collected in one rainy season for a period of 6 months (Soil Research Institute, 1980). The plot used to validate the model is an erosion plot used to test the effectiveness of several soil conservation techniques.

Simulations or calculations of surface runoff in the SILAHAN model are performed using rainfall, permeability, texture, soil depth, and land use data [7]. Land use used is control plot (without treatment techniques of soil conservation and in open/no plant conditions). In addition, the calculation of surface runoff is based on map information on soil types of scale 1: 250,000 [3]. The results of the calculation of surface runoff in the model are compared with observations of surface runoff data.

The surface runoff produced from the plot scale is compared with the 3 surface flow values from the simulation model, that was:
1) surface runoff of medium clay texture class with AMC I (APLS1) soil moisture,
2) surface runoff flow of medium clay texture class with AMC II (APLS2) soil moisture,
3) moderate clay surface runoff with AMC III (APLS3) soil moisture.
AMC (Antecedent soil Moisture Condition) is an initial soil moisture condition which is calculated by adding up the rainfall during the previous 5 days, which is divided into three conditions [12], namely:

1. AMC I represents dry soil with dry season rainfall (5 days) < 10 mm and wet season rainfall (5 days) < 28 mm.
2. AMC II represents normal soil with dry season rainfall of 10-22 mm and wet season rainfall of 28-42 mm.
3. AMC III represents wetlands with dry season rainfall > 22 mm and wet season rainfall > 42 mm.

Surface flow is determined based on the Curve Number model developed by USDA-NRCS (2004) with the following equation:

$$Q = \frac{(P-Ia)^2}{(P-Ia)+S},$$

Information:
- $Q$ = surface runoff,
- $P$ = Average amount of rain (mm),
- $Ia$ = Initial abstract (mm),
- $S$ = maximum potential retention (mm),

The value of $s$ is related to the characteristics of the land and land use which is also a variable determining the curve number ($CN$). The equation used to determine $S$ is as follows [11]:

$$S = \frac{25400}{CN} - 254$$

In the curve number the hydrological group is first determined based on texture, permeability, and soil depth, then the initial soil moisture classification is determined (AMC I, II, II).

To know the description of the uncertainty of a model in a hydrological process that occurs, it is necessary to validate the model [10]. Validation is performed using Pearson, PBIAS, and Nash-Sutcliffe Efficiency (NSE) statistical analyzes with R statistical software to process the results of the comparison of observations and simulations, with soil moisture and rainfall factors so that the validity of the model as a step in validation can be known and conclusions can be drawn.

The selection of statistical models was done to represent the analysis criteria based on 1) dimension less Nash-Sutcliffe Efficiency model (NSE), 2) Error Index (PBIAS), 3) standard regression (r Pearson) for validation of the hydrological model. NSE method is used to see the normal distribution that determines how much between measurement and simulation. NSE values provide an overview of the proximity of each data per time event. in this study provides a picture of the comparison of observational and simulation data per rainy time event where the NSE value ranges between $-\infty$ - 1, where the value 1 is the optimal value that can state the data is good or not.

PBIAS values provide an overview of errors or residues between observational data and simulations where PBIAS values range from $-\infty$ which states the underestimate data, to $\infty$ which states the overestimate bias model, where the value 0 is the optimal value. While Pearson's r value is a regression standard that has an interval of values 1 to -1, where if the data approaches 1 or -1 indicates that the data is positive or negative linear relationship between observation data and simulation data [10].

3. Results And Discussion

The results of surface simulation calculations and observations presented in figure 1.
The results obtained in the calculations showed very high surface runoff variations depending on the amount of rainfall that occurs. The surface runoff simulation results showed the simulated soil conditions with soil moisture in dry conditions with medium clay texture class AMC I (APLS1) surface runoff is far below the observed surface runoff (APobs) (figure 2). However the surface runoff trends are the same in the same rainfall conditions, where high surface runoff occurs during high rainfall. These results showed the same things with the research conducted by Wei et al. (2007) which states that surface runoff measurements are strongly influenced by initial soil moisture, and will be higher during the rainy season.
The same thing happened in the simulation of both surface runoff with AMC II (APLS2) soil moisture conditions, this condition simulates soil moisture under normal conditions in the medium clay texture class (figure 3).

Figure 2. Rainfall and surface runoff simulation and observation on AMC I humidity

Figure 3. Rainfall and surface runoff simulation and observation on AMC II humidity
The third simulation was carried out under soil conditions in the AMC III wet humidity condition with the same soil texture that is medium clay (APLS3) and the results obtained were the same as the two previous simulations (figure 4). In simulations with wet soil moisture conditions the simulation results are still far below the results of observations.

![Figure 4. Rainfall and surface runoff simulation and observation on AMC III humidity](image)

Based on the three simulation results stated that all results of surface runoff validation are not satisfactory because the simulation results are far below the observation results. So to see the closeness and validity of surface flow data needs to be validated with a statistical approach. The statistical test results are presented in table 1.

| Uji Statistik | APLS1 | APLS2 | APLS3 |
|---------------|-------|-------|-------|
| r Pearson     | 0,31  | 0,31  | 0,32  |
| NSE           | -0,76 | -0,68 | -0,63 |
| PBias         | -90,6 | -86,6 | -83,5 |

R Pearson value of the relationship between rainfall and surface runoff on AMC I, II, and III soil moisture were 0.31, 0.31, and 0.32, respectively. These results indicate that there is a positive relationship between rainfall and surface flow by 31% in AMC I and AMC II, and 32% in AMC III. While 68-69% are influenced by other factors.

NSE statistical test values to see the proximity of observational and simulated surface flow data per rainy time event on soil moisture AMC I, II, and II, showing negative values, ie each NSE value is -0.76, -0.68, and -0.63. NSE values have criteria as shown in table 2.

| Nilai Nash-sutcliffe efficiency(NSE) Interpolation |
|--------------------------------------------------|
| 0.75 < NSE ≤ 0.75                     | Very Good |
| 0.65 < NSE ≤ 0.75                     | Good       |
Based on these criteria, the SILAHAN model does not meet the requirements to predict surface runoff simulations based on NSE testing. This is because the value of NSE <0.50 indicates unsatisfactory value. Thus the simulation data is not close to the observation data so the model does not meet the requirements to be said to be good enough in calculating surface flow. PBias value shows a negative value on all simulations, this illustrates that the simulation data underestimate the observation data with test values are -90.6, -86.6 and -83.5.

Referring to all statistical test results, it is seen that the simulation value generated by the SILAHAN model to predict surface runoff shows values that are not close to the observation value at the plot scale, where the model shows the simulation value that is underestimated from the observational data.

To improve the results of plot scale predictions in the SILAHAN application, additional correction factors are needed in predicting and calculating surface flow estimates. The SILAHAN application that uses 10 land cover factors [7] may not be sufficient to predict surface runoff. Need for more detailed land cover factors such as: 1) plant cover (plant canopy), 2) diversity of vegetation types, 3) age of plants from cover vegetation [9]. Based on this statement, the application of SILAHAN requires additional land cover factors that are more detailed as determinants of the amount of surface runoff on a plot scale.

In addition to the above, SILAHAN application also applies the calculation method by using a curve number, one of the factors being the initial abstraction value (Ia) of 20%. According to research conducted by Woodward et al. (2003) that the Ia value is 20% further to approaching the observed measurement value compared to using the Ia value of 5% which will be closer to the observation value. This is also supported by research conducted by the results of research conducted by Lim et al. (2006) which also shows that an initial abstraction to storage (Ia / S) of 5% can produce a more representative surface flow value approaching the observation value. Based on the above, it is better that in application SILAHAN need to apply a 5% abstraction value.

4. Conclusion

With the difference in the observed surface flow values with the simulation values and proved by validating three statistical tests, it was concluded that the SILAHAN prediction model was not accurate enough for estimating surface flow at the scale of the plot. The correction factor needs to be determined by adding more detailed land cover variables and also a 5% abstraction value approach in calculating surface runoff. Furthermore, it is also necessary to develop the ability of the model to assess the effectiveness of a land management system in suppressing the amount of surface runoff.

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