Projected conservation of agricultural land to prevent detrimental effects of land-use changes upstream Brantas Watershed in Indonesia

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Abstract. This research aims to project the conservation of agricultural land due to land-use changes in 2029 in the upstream Brantas watershed, in avoiding agricultural land degradation to realize sustainable agriculture. This study applies the Cellular Automata (CA)-Markov combined model to quantitatively predict and spatially simulate the trend of land-use change in 2029. Analysis of total sediment and flow out uses Soil Water Assessment Tools (SWAT) analysis applied to land use in 2019, and land use in 2029 the CA-Markov prediction result. After that, a technical vegetative and civilian conservation projection model was carried out using SWAT. The results of the observation-model sediment validation resulted in a Nash-Sutcliffe Efficiency (NSE) value of 0.87. The projection results of agricultural land conservation in land-use in 2029 resulted in a total sediment value of 1500,483 tons/ha/year, indicating a decrease in total sediment of 55% compared to the total sediment in 2029 without conservation, and and 8% compared to the total sediment in 2019.

1. Introduction
The upstream Brantas watershed has a crucial role in the agricultural, economic, and social sectors of the surrounding communities. This area is located in Batu City, Malang Regency, and Malang City, East Java Province, Indonesia. In this area, erosion and sedimentation are problems that threaten the function of the watershed [1]. The calculation results of the sedimentation level due to erosion in the upstream Brantas watershed using the USLE method accounted for 98.99 (tonnes/ha/yr), which was the highest sediment yield compared to the Central Brantas watershed and downstream with their respective values are 88.83 and 50.73 (tonnes/ha/yr) [2].

On the other hand, unsustainable ecological land changes will result in the process of land degradation [3]. In the case of deforestation, land degradation, including the loss of soil biodiversity, reduced soil infiltration capacity [4]. The main driving factor in the process of increasing the erosion run-off of a land is land-use change. As the impact of this case, the loss of topsoil is a severe problem for land productivity in the agricultural sector [5]. Besides, most soil nutrients such as nitrogen and phosphorus are very susceptible to being carried away by sediment and can even cause more than 90% of the total loss of soil nutrients [6].

Changes in land use that are not ecologically sustainable require soil and water conservation, using vegetative or civil engineering [3]. Agricultural land conservation projections have a vital role in avoiding the negative impacts of land-use change, especially in the topsoil, to stabilize land.
productivity for food, ecological, and to realize sustainable agriculture. This study aims to project soil and water conservation on land-use in 2029 in the Upper Brantas watershed.

2. Methodology
This research was conducted from August to December 2020. The research location is in the upstream part of the Brantas watershed. The Brantas watershed is located in Batu City, Malang Regency, and Malang City, and consists of 3 sub-watersheds. The materials used are Landsat 7 OLI / TIRS imagery in 2009, Landsat 8 imagery in 2014 and 2019, Boundary Map of the Brantas Sub-watershed, a map of land use and land cover Scale of 1: 50,000 in 2019 and a projection map for 2029 using the CA-Markov method. Digital Elevation Model (DEM) 8 m x 8 m, Boundary Map of the Brantas Sub-watershed, Climate Data 2009-2019. (Rainfall, Air Temperature, Wind Speed, Solar Radiation, and Air Humidity, 2009-2019 River Discharge Data, and Land Map at a scale of 1: 50,000.

2.1. Projected land-use change in the Brantas watershed in 2029
The projection of this research applies a combined CA-Markov model that quantitatively predicts and spatially simulates the trend of land change in 2029. Based on time series theory and spatial prediction using the CA-Markov method, this model can predict land-use changes in spatial size and extent. The CA-Markov results were then validated using the overall accuracy and kappa accuracy [7].

2.2. Impact of Land Change in the Brantas Watershed on Land Degradation
Analysis of land-use changes using ArcGIS 10.3 software was carried out by overlaying land use maps of the upstream Brantas watershed in 2009 and 2019, and a projected land-use change in 2029 produce spatial information on land-use changes. The overlay results are then compared to changes in land use each year and become the data reference in the hydrological model. Soil sedimentation analysis of the Brantas watershed were carried out using the SWAT model of sediment estimation. The stages of the analysis activities carried out are as follows [8]:
1. Sub-watershed delineation.
2. Analysis of Hydrological Response Units (HRU), Basin Input File (BSN), Main Input Channel (RTE), Watershed Water Quality (WWQ), Stream Water Quality (SWQ), Management Input File (MGT)
3. Weather Generalization
4. Running
5. Calibration and Validation

Hydrologic cycle is simulated with SWAT model based on the following water balance equation

\[ SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{perc} - Q_{gw}) \]

where \( SW_t \) = final soil water content (millimeters); \( SW_0 \) = initial soil water content (millimeters); \( t \) = simulation period (days); \( R_{day} \) = amount of precipitation on the ith day (millimeters); \( Q_{surf} \) = amount of surface runoff on the ith day (millimeters); \( E_a \) = amount of evapotranspiration on the ith day (millimeters); \( W_{perc} \) = amount of water entering the vadose zone from the soil profile on the ith day (millimeters); and \( Q_{gw} \) = amount of base flow on the ith day (millimeters).

\[ Sed = 11.8 \times (Q_{surf} \times qpeak \times Area_{hr}) \times 0.56 \times K \times C \times P \times LS \times CFRG \]

where \( Sed \) = sediment yield on a given day (metric tons); \( Q_{surf} \) = surface runoff volume (millimeters per hectare); \( qpeak \) = peak runoff rate (cubic meters per second); \( Area_{hr} \) = area of the hydrological response unit (HRU; hectare); \( KUSLE= \) universal soil loss equation (USLE) soil erodibility factor; \( CUSLE= \) USLE cover and management factor; \( PUSLE= \) USLE support practice factor; \( LSUSLE= \) USLE topographic factor; and \( CFRG= \) coarse fragment factor.
2.3. Soil and air conservation recommendations

The application of conservation techniques is carried out on the projected land use that has been analyzed by SWAT, namely the vegetative method and the civil engineering method as shown in Table 1. The vegetative methods applied include strip cropping, cropping patterns, and alley cropping in agricultural areas and dry land mixed with shrubs with a slope of 0-25%, while agroforestry is applied at a slope of 25-40% [9]. Strip cropping is a vegetative soil and water conservation system by planting several plant types in alternating strips on a plot of land over the same period. All land uses with a slope of > 40% are subject to reforestation. The cropping pattern method is carried out on the use of paddy fields on slopes of 0-8% and 8-15%. The land-based technical civil activities used include contouring on dryland agricultural land use, dry land mixed with shrubs and plantations on slopes of 0-8 and 8-15% [10].

Table 1. Soil and Water Conservation (SWC) parameters that are applied.

| No | SWC types                  | Application of SWC Technique | SWAT Parameters               | Sub Basin Location |
|----|-----------------------------|------------------------------|--------------------------------|--------------------|
| 1  | Vegetative SWC              | Agroforestry                 | CN2, SOL_K, SOL_C, SOL_BD, dan SOL_AWC | 17, 19, 27, 29, 32, 33,34 |
|    |                              | Strip cropping               | STRIP_CN, STRIP_P, STRIP_C, dan STRIP_N | 2, 5, 6, 7, 9, 10, 12, 13, 17, 18, 19, 22, 23,29 |
|    |                              | Cropping pattern             | CN2, SOL_K, SOL_C, SOL_BD, dan SOL_AWC | 2, 6, 7, 9, 11, 13, 32, 34 |
|    |                              | Alley cropping               | CN2, SOL_K, SOL_C, SOL_BD, dan SOL_AWC | 6, 7, 8, 10, 12, 13, 16, 17, 21, 22, 23, 27, 30, 33, 34 |
| 2  | Civil Technical SWC         | Contouring                   | CONT_P dan CONT_CN             | 2, 5, 7, 8, 9, 10, 13, 16, 18, 19, 30, 34 |

3. Results and Discussion

Figure 1 shows the NSE value of the SWAT flow out model in the sub-watershed of tolongrejo with a range for 2013-2017 of 0.78 good category, in Figure 2 shows the NSE value of 0.82 the category is satisfactory in the sediment validation test in the 2014-2016 period so that the model can be run on land use projections in 2029.
R² values of flow out and sediment yield of 0.79 and 0.89, respectively, indicate a sensitivity between the observed results and the model results. The SWAT model has been widely used in the watersheds of various countries, such as applying the SWAT model to model water catchment areas with mountainous topographical conditions focusing on the catchment area of Espiro Santo, Brazil. The results show that the SWAT model can be used as a potential monitoring tool, especially for tropical watersheds [11].

The change in land-use in 2029 in Figure 3 shows decreased agricultural land and forests, and urban land use increases the highest compared to other land uses. Land-use change can lead to decreased ecosystem function, which can result in land degradation.
Table 2 shows a significant reduction in the total amount of watershed sediment, using soil and water conservation techniques in the upstream Brantas watershed, alley cropping, strip contour cropping patterns, and agroforestry can significantly reduce total sediment by 55% compared to the total sediment in 2029 without conservation, and 8% compared to the total sediment in 2019. These results indicate that the application of soil and water conservation can reduce land degradation caused by land-use changes in the future.
The application of vegetative conservation in agroforestry on agricultural land with a slope of 25-45% can increase the curve number value, soil permeability, soil organic matter, soil density, and soil water content, thereby reducing the rate of soil erosion [13]. Agricultural land with slopes of 0-25% is conserved by simulating the use of alley cropping, contouring, and strip cropping. This conservation implementation is carried out so that the soil's physical improvement will occur without decreasing the quantity of the land area for the agricultural commodity. Alley cropping simulations are carried out on agricultural land with a slope of 0-8% value. Besides reducing erosion and runoff, the alley cropping system can also control nutrient loss through erosion and runoff [14]. Alley cropping conservation technology using hedgerow plants can optimize dryland farming, because hedgerows, in addition to controlling surface runoff and erosion, also produce agricultural biomass useful for soil rehabilitation and fertilization [10]. The strip cropping simulation is used in the conservation of agricultural land on slopes of 15-25%, and this simulation will reduce the value of the processing factor (P-USLE) of the land, resulting in low sediment. Research in the Mississippi watershed shows that the alley cropping conservation simulation effectively reduces the total sediment yield by 36, 34% [15].

Figure 4. Sediment average (ton/ha) Upstream brantas 2019.

The results show that the upstream Brantas watershed has 34 sub-watersheds. Figure 4 shows that for the sediment yield from land use in 2019, there is one sub-watershed with a sediment value range of > 28 tons/ha/year and three sub-watershed with a sediment value range of 7 to 14 tons/ha/year and other watersheds are in the range of < 7 tons/ha/year.

Figure 5. Sediment average (ton/ha) Upstream brantas 2029.
Figure 5 shows the sediment yields for land use in 2029; there is an increase compared to land use in 2019. The sediment yields range from 7 to 14 tons/ha/year are in 5 sub-watershed areas. There are two sub-watershed areas with sediment values ranging from 21 to 28 tons/ha/year, two sub-watersheds have a sediment yield range value > 28 tons/ha/year, and other sub-watershed lines are in the range below 7 tons/ha/year.

Figure 6. Sediment average (ton/ha) Projectin Conservation Upstream brantas.

Figure 6 shows the application of conservation technology in land use in 2029. There is a decrease compared to land use sediment yields in 2019 and 2029. Sub-watershed with a sediment yield range of 7 to 14 tons/ha/year is one sub-watershed, two sub-watershed with sediment yields in the range from 14 to 21 tons/ha/year, 1 sub-watershed with a sediment yield range from 21 to 28 tons/ha/year, and the rest of the sub-watershed with sediment yields in the range < 7 tons/ha/year.

The technical conservation of contouring is carried out on mixed agricultural land. Agriculture along the contour can reduce soil erosion by 50% compared to agriculture with slopes on land with a slope of 14.8% [10]. The application of contour farming improves water quality by reducing sedimentation and water runoff and increasing water capacity for infiltration. In the upstream Brantas watershed, the application of contouring conservation can produce a Curve Number of 61-63 and a usle P processing factor of 0.7. The simulation of cropping patterns is used for lowland land use with slopes of 0-8% to maximize land productivity and prevent runoff erosion with a continuous amount. The use of cropping pattern simulations is carried out on lowland land uses, reducing the total sediment yield by 30%. In total, the sediment in the upstream Brantas watershed, with soil and water conservation technology, the total sediment in the upstream watershed has decreased to 1500,48 tons/ha/year.

4. Conclusion
The results indicated that transitions in the usage of watershed areas from forest and agricultural areas to urban areas resulted in a 104.42 % rise in total watershed sediment. The use of agricultural land management projections to mitigate soil erosion due to land-use changes in 2029 resulted in a 55% reduction in total sediment, which reduces the potential for agricultural land to lose its topsoil.

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