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ANALYSIS OF THE KINEROS MODEL FOR PREDICTING THE EFFECT OF LAND USE ON THE SURFACE RUN-OFF

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ABSTRACT

Topics protection of catchment area relating to land use to support sustainability and environmental capacity is an interesting topic to be discussed scientifically. The Kineros Model for predicting the effect of land use on the surface run-off need to be improve in application. It has shown that the protection of natural ecosystems has a better impact than infrastructure development, especially about preventing inundation due to high surface runoff. The advantage or positive side of this journal is that it has brought up the concept of unlimited space for administrative areas where there is a link between buffer zones outside the Klojen District which also determines the run-off rate within the Brantas sub-watershed coverage, although it not discussed in detail. This journal will strengthen the need for watershed-scale erosion prediction analysis because of its ability to define strategic areas of policy intervention to enable policymakers and the community to carry out recovery programs/activities more effectively and focused. The accuracy of determining the location of the policy has an impact on cost, time, and energy efficiency. Spatial calculation/analysis models combined with social and economic approaches will create a balanced and integrated sustainable development. The reviewer suggests a realistic combination of approaches, which combines the spatial aspects and technocratic calculations aspects of economic instruments that become balanced in a multidisciplinary concept.

1. INTRODUCTION

Topics protection of catchment area relating to land use to support sustainability and environmental capacity is an interesting topic to be discussed scientifically. The increasing frequency of floods, droughts, landslides, and water crises are recently showed that the management of watersheds has not been optimal (Pambudi, 2019; Reddy et al., 2017; Kindu et al., 2018; Indonesia, 1999). It is characterized by the tendency of increasing the number of critical lands and reduced potential catchment areas. The effectiveness of risk mitigation is part of the evaluation of integrated watershed management (Pourghasemi et al., 2020).

Indonesia is a country that has a rainy season of more than six months with quite high rainfall (Pambudi, 2021; Kodoatie, 2002). Natural conditions like this become the basis for managing an area. Changes in land use will cause the precipitation does not seep back into the ground during the rainy season, so there is a high surface causing inundation (Nabi et al., 2017; Chow et al., 1988). This problem affects conservation efforts if the prediction efforts are inadequate, both in terms of erosion, sedimentation, and run-off. Erosion is likely to be more affected by changes in rainfall and cover than runoff, though both are likely impacted in similar ways (Nearing et al., 2005).

For urban areas, the issues of the water crises will be happened, if the water resource management is carried out this effort in programmatically, fully integrated, continuously, and seriously. The coronavirus (COVID-19) spread-prevention actions had a remarkable impact on urban water consumption, leading to a decrease in commercial, industrial and public usage, and a slight increase on residential consumption (Kalbusch et al., 2020).The water sector has an important role to play in immediate response to COVID-19, as well as in the recovery and rebuilding phases, as the world readjusts to a range of legacy impacts from the pandemic. This role spans and incorporates the breadth and depth of the various domains and disciplines of water resources management (Neal, 2020).The changes in land use from areas that used to be potential water catchment areas to become impermeable areas and the loss of water sources cause a reduction in the water supply (Kagoya et al., 2018). The impacts are increased surface run-off, inundation or flooding during the rainy season, and reduced water availability in the dry season.

There needs to be an understanding for the communities, that there is a very strategic relationship between regional development and strategic area planning for the protection of buffer zone (A. S. Pambudi et al., 2020). The conservation principles about upstream water sources and regional development are should be thoroughly informed. The information about the condition of strategic areas must be include in a comprehensive development strategy within a certain time. Integrated watershed management) offers a promising land resources management and development solutions (Teka et al., 2020).

Journal of "Application of the Kineros Model for Predicting the Effect Of Land Use on the Surface Run-Off, Case Study in Brantas Sub-Watershed, Klojen District, Malang City, East Java Province of Indonesia", written by Bisri et al., (2017). The aim of this study is to discuss the relationship between the protection of catchment areas that affect the sustainability of life and the economy of an area through prediction and identification of the distribution of surface run-off. The Kineros Model for Predicting the Effect of Land Use on the Surface Run-Off need to be improved in application.

2. METHOD

Mapping ecosystem protection areas of water resources is expected to be helpful to support the water supply in urban destinations at the same time in the downstream flood prevention policy determination (Pambudi et al., 2021; Indonesia, 2007). The reviewer's purpose is to understand how the approach concept shown in the journal is related to the reviewer's journal entitled “Analysis of Recent Erosion Hazard Levels and Conservation Policy Recommendations for Lesti Subwatershed, Upper Brantas Watershed” (Pambudi et al., 2021). The reviewers chose this journal because of two things: 1) The similarity of location and regional characteristics, that is the Brantas Watershed; and 2) Using the analysis model of erosion estimation and spatial analysis of Geographical Information System (GIS).

The methodology used by Bisri et al., (2017) in the journal is Kineros model (kinetic run-off and erosion model). This model is part of the AGWA program which is the development of the ESRI ArcView Geographical Information System (GIS) software, which is a tool to analyze hydrological phenomena in watershed research that simulates the process of infiltration, run-off depth, and erosion in watersheds. In reviewing this model, the author uses a literature study and analysis of development planning based on expert judgment. Review of journals written by Bisri et al., (2017) used the method of giving a review/review on an article in order to know the advantages, disadvantages, and quality. In general, this journal review aims to provide information, descriptions, ideas / ideas about journal articles that have been made. A logical evaluation of the main themes, supporting arguments and their implications for the original document is the content of a review. Articles resulting from review activities do not provide new research because article reviews are a summary of the original document. Comparison with journals written by Pambudi et al., (2021) is in order to complement and become the basis for recommendations for improvement of the journal written by Bisri et al., (2017) to be even more optimal when implemented.

3. RESULTS AND DISCUSSION

Results section is provided prior to the discussion section. Each section stands alone as a subtitle. The findings and discussion should be written in not less than 60% of the entire body of the manuscript.

3.1. Results

According to Halim, (2014), the function of the watershed is as a catchment area, water storage and distribution water. The main challenge in managing water resources in Indonesia is the increasing demand for water but with a relatively constant supply, and even in some cases, it tends to decrease (A. S. Pambudi, 2021). Watersheds are natural ecosystems that hydrologically involve water-giving areas (upstream areas) and water receiving areas (downstream areas) which are interconnected and affect each other. The increase in surface run-off, as well as the reduced availability of water in big cities, show how the upstream and downstream linkages in the water cycle are little overlooked by policymakers. Water supply is a key factor in how cities can grow both economically and support other livelihoods. The low level of formal protection of strategic water source areas is very concerning, even though this is very important for water supply. Pressures on protected areas of water resources and their impacts show great value to the community, both in the surrounding environment and in general (Cumming, 2016; Watson et al., 2014).

This study found that the development of the Malang City area requires changing the use of open land into built-up land so the run-off often occurs in this area. Rain run-off is a problem caused by changes in land use that are not well regulated (Arsyad, 2009; Asdak, 2018). The soil in built-up land has less water absorption than open land. The journal showed that the Klojen sub-district in the Brantas watershed is an area where run-off occurs more often, but the process of measuring run-off directly requires high costs, takes time, and more energy. Therefore, it is often difficult to obtain run-off data due to the very heavy measurement process. It is necessary to simulate run-off caused by land-use change by establishing a run-off spatial model to assist decision-makers in making efforts to control the run-off that occur. The aim of this study to analyze surface run-off and distribution at the same study site in 2000, 2005, and 2010; then evaluate the suitability of the Kineros model to analyze surface run-off at the study site.

The growth and development of Malang City created several spatial changes. Land use, especially from agriculture, becomes a non-agricultural function, water catchment areas become residential areas, river border problems become settlements. In the end, the increase in the covered area causes the water absorption to decrease. Malang City consists of several districts. The selected study location is Klojen district and has a rapid population growth which is directly proportional to the rare finding of good water catchment areas so that every time it rains there is always a high surface run-off. In general, the problems in Klojen district are as follows: 1) There is a change in land use from a water catchment area to a residential area; 2) More residential areas causing high run-off; and 3) Analytical tools are needed to simulate the depth and area of inundation due to rainfall intensity and land use changes.

This study found that the surface runoff depth was still permitted. The analysis can be used to evaluate land use references at the study site. The location including as part of the Brantas Sub-watershed has been functionally changed significantly from its ideal condition and has caused an increase in run-off depth from year to year. The simulation results of the Kineros model showed that the surface run-off depth is directly proportional to land-use changes. Therefore, an alternative control is needed to reduce run-off in the city center of Malang. The alternative run-off control suggested by Bisri et al., (2017) in this journal as follows: 1) Rehabilitating canals by building widening channels, especially areas around high runoff depths; 2) Areas that do not have drainage channels will be made new channels; 3) Required the design of the channels so that rainfall easily flows into drainage channels; 4) Periodic operation and maintenance of the drainage system are required.

There is no significant difference between the Kineros Model result and the maximum surface run-off in the field, so it can be concluded that they are relatively the same, especially for the return period of two years and five years with a relative error of 9.09%. This model can be applied in Indonesia so that relevant if used as the basis for watershed conservation policy in the medium term for five years. In the scheme of environmental conservation in UU No 26/2007 about Spatial Planning, the forest area with a minimum of 30% of the watershed must be considered. The Kineros model can map out priority areas for implementation of the land rehabilitation policies that are more appropriate based on run-off depth so that the policy results can be more effective to be implemented.

The growing older of the city indicates that it is much more complex and more needs to be provided. The most fundamental thing is the fulfillment of the availability of natural resources such as water, energy, and clean air. The phenomenon of the downward trend in environmental quality is the background of the concept of the "green urban water security model" which is a city concept that is very concerned about environmental sustainability. Urban spatial planning is better if firstly identify areas that must naturally be saved (protected areas) to ensure the sustainability of the environment and the areas that are prone to natural hazards on the upstream such as earthquakes, landslides, floods, and other natural disasters. We must develop these areas as open spaces, both green and non-green. Thus, spatial planning must begin with the question: "where can we not build?"

The advantage or positive side of this journal is that it has brought up the concept of unlimited space for administrative areas where there is a link between buffer zones outside the Klojen District which also determines the run-off rate within the Brantas sub-watershed coverage, although it not discussed in detail. Another positive side of this journal is that the model used, namely Kineros, already calibrated with the results of field calculations marked for the return period of 2 years and 5 years with a relative error of 9.09%. This model can be used in Indonesia so that it is quite relevant as a basis for formulating watershed conservation policies in the medium term of 5 years. This paper has shown that the protection of natural ecosystems has a better impact than infrastructure development, especially about preventing inundation due to high surface runoff. This journal will strengthen the need for watershed-scale erosion prediction analysis because of its ability to define strategic areas of policy intervention to enable policymakers and the community to carry out recovery programs/activities more effectively and focused. The accuracy of determining the location of the policy has an impact on cost, time, and energy efficiency.

One of the weaknesses or negative side of this journal is that it only takes into account hydrological technical calculations and does not take into account other aspects such as population pressure factors on land, analysis of community behavior and the level of erosion hazard. This journal is also still not comprehensive because it still focuses on one aspect, and has not touched the social and economic aspects. The scope of the journal area is also still narrow and has not been overlaid with the results of the erosion hazard level so that the results are more optimal.

The research in this journal still focuses on providing map data for areas prone to run-off, but the strategy after obtaining the data has not been reviewed in detail. The reviewers view that to ensure the balance of nature and the economy of the community, a combination of approaches that can bridge the two interests must be a concern.

The concept of urban planning concept is inseparable from the management watershed which considers the balance of upstream and downstream ecosystems within the same hydrological boundaries (Asdak, 2010; Arsyad, 2006; Suripin, 2002; Indonesia, 1999). Watershed management is closely related to the ecosystem approach and hydrological regulation (A. Pambudi, 2021). Hydrological regulation is an important ecosystem service and is easily affected by human disturbances. Many studies have been conducting on the impact of human activities on regimes and capacity regulation with one environmental factor (Li et al., 2018). Water security with a combination of spatial approaches, watershed concepts, economics, and social will realize a green urban water security model concept as the hope of the result of the research by Bisri et al., (2017).

3.2. Discussion

Integrated watershed management puts the “human–land–water” resources interactions in a central position, making the need to characterize the related land resources rights (Katusiime & Schütt, 2020). Watershed behavior and hydrologic cycle are to be wholly examined so as to discover the variability in environmental and economic conditions. The reliable prediction of the various hydrological parameters becomes tedious and time consuming by conventional methods. Currently, many hydrological models have been developed over the world to determine and analyze the effect of land use, climatic conditions and soil characteristics on hydrology. Each watershed model has got its own attributes to carry out the different processes and capability to analyze the parameters (Gull & Shah, 2020). This research is a quantitative descriptive study using an ecological approach. This study describes, analyzes, and provides information about the existing conditions in the field related to erosion that occurs on land in the Lesti sub-watershed up to the sedimentation that enters the outlet in the Sengguruh Reservoir, Malang Regency. This study describes the relationship between human activities and erosion that occurred in the Lesti sub-watershed as one of the upper reaches of the Brantas watershed (Pambudi et al., 2021).

Based on the previous discussion, the research method uses mixed methods. This research direction is to simulate the erosion rate in the Lesti sub-watershed that considers the aspects of the social and economy (population pressure) and the environment (land capacity). The quantitative method of erosion rate was adapted by calculation method from the Modify Universal Soil Loss Equation (MUSLE) calculation method that supported by Geographic

Information System (GIS) tools. The qualitative methods are performed using questionnaires and interviews in the Lesti sub-watershed area to know the knowledge, attitudes, and behaviors of the community to erosion and the impacts.

In this study, the authors limit the research location to the Lesti sub-watershed as one of the upper reaches of the Brantas watershed. Administratively, the Lesti sub-watershed is located in Malang Regency with a total area of 64,741 ha. The research location covers 12 sub-districts, namely Poncokusumo, Ampelgading, Wajak, Tirtoyudo, Turen, Dampit, Sumbermanjing, Bululawang, Gondanglegi, Gedangan, Bantur and Pagak sub-districts. The boundaries of the research area start from the upstream of the Lesti River in Poncokusumo District to the outlet of the Sengguruh Reservoir.

In general, many erosion prediction methods have been developed by scientists, such as USLE, MUSLE, RUSLE, WEPP, GUEST, ANSWER, AGNPS, and others (Pambudi, 2021). In Indonesia, the most frequently used erosion prediction model is the USLE method and its derivatives such as MUSLE and RUSLE. For example, the MUSLE method meets the requirements of universal modeling and requires fewer inputs or parameters than other complex methods. Prediction of the average erosion rate of land on a slope with a certain rain pattern for each type of soil and the application of land management must at least pay attention to the factors of rain erosivity, soil erodibility, slope, slope length, ground cover, and conservation measures.

Soil erosion is a gradual process of movement and transport of the upper layer of soil by different agents such as water, wind, and mass movement (Fortuño Ibáñez et al., 2021). The rate of land erosion is calculated for each land unit where to get the land unit a Geographic Information System (GIS) tool is used, that is by overlaying the slope map (LS value), a soil type map (K value), and land use map/ land use (CP value). Population pressure factors on land (TP) and community behavior factors (positive or negative) affect the determination of the CP value as part of the erosion calculation.

Analysis of the erosion rate is using land-use maps in 2012 and 2017 so that can be known the effect of land-use change on the magnitude of the erosion rate. After analyzing the erosion rate, it is followed by analyzing the Erosion Hazard Level (TBE) by overlaying the erosion map with the soil solum depth map. In simple terms, the flow in finding the TBE Map with the help of GIS tools is as shown in Figure 1.

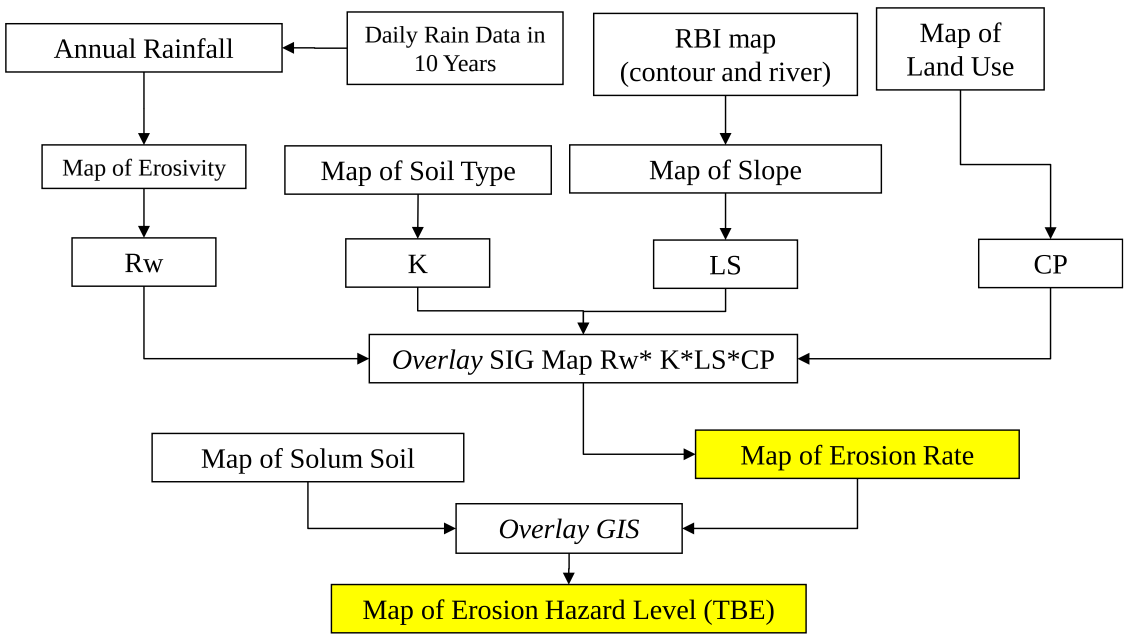

Figure 1 Flowchart of calculation from erosion hazard level area

After the TBE analysis, monitoring, and evaluation of watersheds associated with population pressure on land and then conducted the preparation of environmentally sound conservation directives by the conditions of the Lesti sub-watershed. The Kineros model in the journal written by Bisri et al., (2017) which also based on a Geographic Information System (GIS) and can be used to support the determination of conservation priority locations by overlaying the Erosion Hazard Level Map (TBE) by the author. Erosion and surface run-off are two things that are closely related to determining sustainable watershed management. Run-off occurs when the amount of rainfall exceeds the infiltration rate. After the infiltration rate fulfilled, the water begins to fill the hollows or depressions on the soil surface. After the filling is complete then the water will flow freely on the ground surface.

Kineros (Kinematic Run-off and Erosion Model) is an event-oriented model, which used to describe the processes of interception, infiltration, runoff, and erosion for watersheds. This model is designed to simulate the process of infiltration, the depth of surface runoff, and erosion that occurs in a watershed. The rationale of the Kineros model is if a land receives rain with a certain intensity, then the water that falls to the ground surface will partially infiltrate into the soil to a certain saturation limit, while some will run off above the ground surface or stagnate, this situation depending on the soil's ability to absorb water-based on various factors. The result of the KIneros model is a display in the form of a zoning map of the desired parameters, one of which is infiltration (mm) and runoff (mm).

With a more precise identification mapping, forest protection and rehabilitation policies are expected to be more effective and efficient. Therefore, the mapping model of strategic watershed conservation priority areas in the form of a spatial model to be used as a reference for determining the interrelated areas, between erosion-prone areas and areas with deep surface run-off. With the support of the Kineros model written by Bisri et al., (2017), a flow chart for determining conservation priority areas is obtained as described in Figure 2.

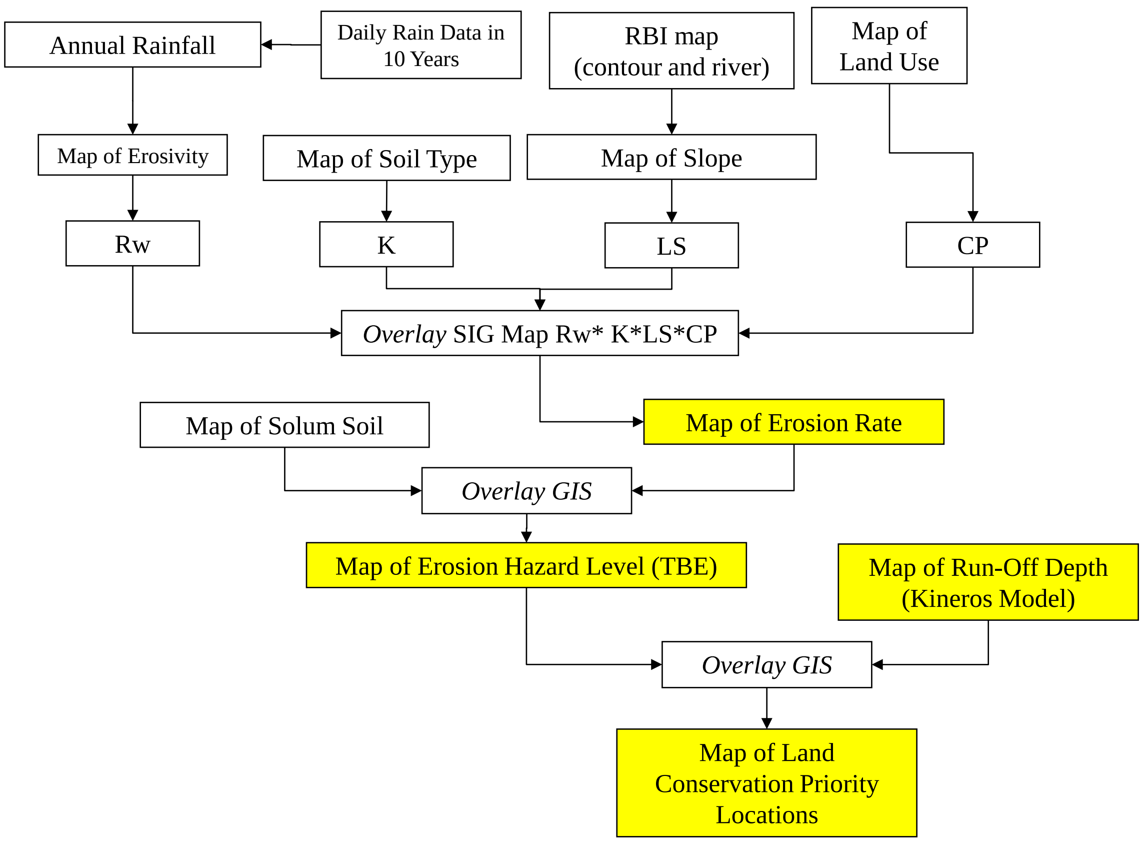

Figure 2 Flowchart of determining conservation priority locations
Source: Bisri et al., (2017) and Pambudi et al., 2021

4. CONCLUSION

Kineros is a semi-distributed model because it does not discretize the basin by cells but by sub-basins (composites by plane rectangular elements) that discharge into channels. If the user works with low resolution, average slopes will increase, enlarging flow velocity. In addition, sub-basins are represented by rectangular elements that shorten flow lengths, increasing runoff and flow times. In conclusion, without an optimal discretization, the calculated eroded sediment volume from the basin increases. The model presented in the identification of conservation priority locations includes things that have a significant influence on urban planning and watershed policymaking in a broad sense. In the end, its implementation depends on the ability and creativity of policymakers to use the data generated from this model to determine future policies. Articles in this journal are effective enough to look at from a wider technical scope when combined with other models and other fields of science.

Journal written by Bisri, et al. (2017) aims to be an alternative in helping to deal with land and water resource problems. Apart from the existing limitations, this model is possible to be developed/combined with another concept where the results of the model in this journal can determine strategic locations which are prioritized if the budget is limited development planning. In other words, this paper is sufficient to be a reference, especially for mapping water catchment areas, water sources, green open space, and areas that will apply the concept of sustainable development. The results of the reviewer analysis in the case that occurred in Indonesia is that the way or method used in Journal written by Bisri, et al. (2017) can use for mapping the strategic area of protection in Indonesia appropriately. The accuracy of this location mapping determines the effectiveness of the policy of protecting the strategic area of water resources to be protected. Spatial calculation/analysis models combined with social and economic approaches will create a balanced and integrated sustainable development. The reviewer suggests a realistic combination of approaches, which combines the spatial aspects and technocratic calculations aspects of economic instruments that become balanced in a multidisciplinary concept.

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