

THE EFFECT OF POPULATION PRESSURE ON THE EROSION HAZARD LEVEL OF SUB-WATERSHEDS

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Abstract

The accuracy of land use and management affects the watershed's or sub-watershed's health, especially upstream. The Lesti sub-watershed in Malang Regency is the upstream part of the Brantas watershed; their land use pattern is always associated with erosion rates, which impact sedimentation in the middle and downstream. When discussing erosion, the rate increase is generally influenced by erodibility, erosivity, length/gradient of the slope, and plant factors/conservation measures. Population pressure has not been discussed much, although the erosion rate affecting sedimentation in the Sengguruh Reservoir as an outlet for the Lesti Sub-watershed has much to do with the Population's activities. People's activity and choice of land use put pressure on the land, affecting the watershed's carrying capacity. Measuring the land's carrying capacity is usually known from the value of existing population pressure and its effect on vulnerability or Erosion Hazard Level (EHL). This study attempted to assess the relationship between erosion hazard levels and population pressure and determine conservation priority areas in the Lesti sub-watershed. This research method was carried out quantitatively, which involved calculating the analysis of population pressure and the EHL obtained spatially from the erosion rate of the Modified Universal Soil Loss Equation (MUSLE) and soil solum. The results showed a similar wedge between high population pressure and severe EHL. This Area is recommended as the most priority location for conservation policies in the Lesti sub-watershed.

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INTRODUCTION

Watershed problems are ecological balance problems related to environmental carrying capacity and its components (Asdak 2010; Chaidar 2017). Meanwhile, the environment referred to here is related to the Area as the boundary of economic activities that affect the development of life in it (Pambudi, 2021; Bellfield et al., 2016; Common & Stagl, 2005). All activities of living things in the hydrological container of the Watershed Area (DAS) drive changes in land carrying capacity so that it often becomes the basis for policy-making for development planners in the modern era (Yusuf et al., 2022; Pambudi, 2022; Miller & Spoolman, 2015).



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Conversion of areas in a watershed is a result of population pressure on land, indicating that there is a role for society, both on a specific scale and in general, which affects the sustainability of natural resources (Watson et al. 2014; Cumming 2016; Mtibaa et al., 2018). Population pressure on land is driven by the imbalance between population growth rates and land availability, resulting in increased activity and intensity on existing land or opening up new land (Soemarwoto, 1999). Conversion without considering topographical, geological, and ecosystem carrying capacity conditions causes natural disasters such as landslides, floods, and droughts (Sinukaban, 2007). Land conversion is always related to erosion (Pa, Budi, 2020; Arsyad, 2006). In this regard, Bappenas has stated that the Brantas Watershed is one of the watersheds facing erosion problems, making it a high priority to address (Pambudi, 2019a; Bappenas, 2015). The upstream part of the Brantas Watershed, such as the Lesti Sub-DAS, needs attention regarding erosion issues, considering its strategic position regarding the continuity of Sengguruh Reservoir sedimentation. Sengguruh Reservoir affects the provision of irrigation water for flood control and generates most of the electricity (hydropower) in East Java Province (Ma'wa et al., 2015; Djajasinga et al., 2012). The study by Ma'wa et al. (2015) stated that erosion from the upstream of the Lesti sub-watershed impacts the reservoir's storage capacity, accelerating the reduction in the reservoir's useful life from the original plan. Previous studies on erosion in the Lesti sub-watershed have shown a significant trend of increasing erosion rates. In 2006, the average erosion rate per hectare of land in the Lesti sub-watershed was 30.57 tons/ha/year (Yupi, 2006). Meanwhile, in the following 6 years, the average erosion rate per hectare of land in the Lesti sub-watershed reached 105,763 tons/ha/year (Setyono & Prasetyo, 2012). 2015 the average erosion rate/hectare was 131,098 tons/ha/year (Ma'wa et al., 2015). This study further shows a significant fluctuation in the erosion rate, so the determination of conservation policies by development planners for the Lesti Sub-DAS area should be based on the latest erosion analysis.

Population pressure has not been widely discussed, even though the erosion rate that affects sedimentation in the Sengguruh Reservoir, which is the outlet of the Lesti Sub-DAS, is closely related to the activities of its residents. Population activities and land use choices actually put pressure on the land, thus affecting the carrying capacity of the watershed. Measuring land carrying capacity is usually known from the value of population pressure and its influence on erosion vulnerability or hazard level.

Research related to erosion in the Lesti Sub-DAS has been influenced only by physical factors of the watershed, such as slope gradient, vegetation factors, and soil erodibility (Kagoya et al., 2017). The relationship between population pressure and the extent of the erosion hazard area in determining the most priority areas for conservation is something that is rarely done (Utomo 1994, Hardjowigeno 1995, Notoadmodjo 2007, Tambunan 2008, Koentjaraningrat 2009). The relationship and determination of the most priority areas for environmentally conscious conservation are interesting things to be studied further based on environmental science.

METHODS

Time and Location. The research completion time was 12 months from the concept, data collection, data analysis and report writing. The research location was limited to the Lesti sub-watershed as one of the upstream areas of the Brantas watershed. Administratively, the Lesti sub-watershed is located in Malang Regency with a total area of 64,740.84 ha. The research location covers 12 sub-districts, namely Poncokusumo, Tirtoyudo, Ampelgading, Turen, Wajak, Dampit, Bululawang, Sumbermanjing Wetan, Pagak, Gondanglegi, Gedangan, and Bantur. The boundaries



of the research area start from the upstream of the Lesti River in Poncokusumo District to the outlet of the Sengguruh Reservoir.

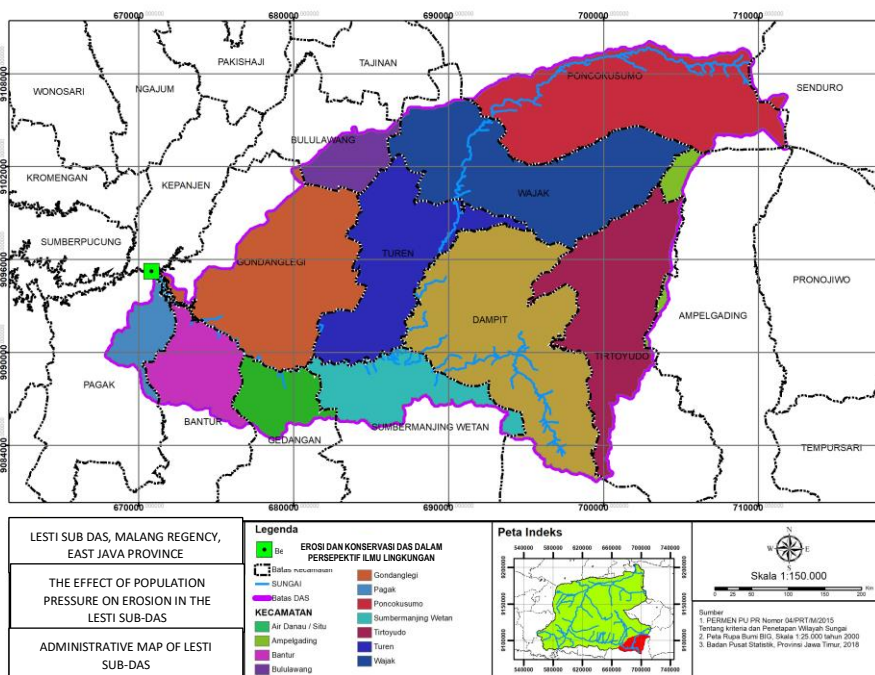


Figure 1. Study Location

Materials and Tools. This study uses several secondary data from related agencies, such as 1) rainfall data for the last 10 years; 2) the latest land use data for 2018 issued by the Watershed Management and Protected Forest Center (BPDAS-HL); 3) spatial data on contour, soil type, slope and plant management factors and conservation measures. In addition, there are also several tables agreed upon by experts from previous researchers. Secondary data related to the agricultural and Population sectors from agencies such as the Central Statistics Agency (BPS) and the Ministry of Agriculture are also needed, especially to analyze population pressure in the Lesti Sub-DAS.

Research Methods. This research method is carried out quantitatively, calculating population pressure analysis and Erosion Hazard Level (EBH) obtained spatially from the MUSLE erosion rate and soil solum. The calculation of the erosion rate was analyzed using the MUSLE method supported by Geographic Information System tools (Tajbakhsh et al., 2018). A modified rational formula was used to calculate the erosivity of surface runoff as part of the MUSLE method. The software used was Arc GIS 10.3 and Microsoft Excel 2019. The erosion hazard level (EBH) was obtained by overlaying the erosion rate map from the analysis results with the soil solum map in the Lesti Sub-DAS. The selection of priority areas for environmentally conscious conservation is based on the population pressure analysis > 1 results, which intersects with the severe/very severe erosion hazard level at the sub-district scale.

RESULT AND DISCUSSION



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The definition of population pressure on land is the comparison of the number of people with the minimum land area for a decent life (Soemarwoto, 1985). Ideal population pressure is that which can still adjust the carrying capacity of the land. The land's carrying capacity is the environment's ability to support life. The higher the percentage of land that can be utilized/used for agricultural land, the greater the land's carrying capacity (Soemarwoto, 1985).

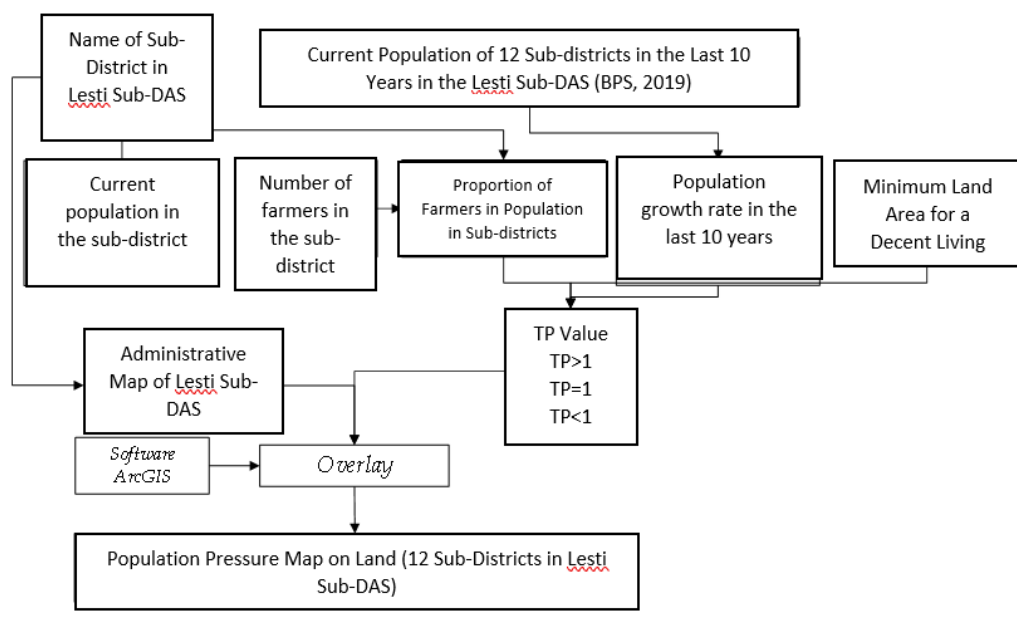


Figure 2. Flow of Population Pressure Analysis on Land in the Lesti Sub-DAS

TP value < 1 indicates that there has been no population pressure or that the Area can still meet the Population's needs in more than sufficient numbers (Ariani & Harini, 2012). TP value equal to 1 means that the Area is still able/capable of adequately meeting its Population's needs. TP value greater than 1 means that there has been population pressure on land in an area so that it is no longer able/capable of adequately meeting its Population's needs.

Population pressure on land is calculated using the Otto Soemarwoto formula (1985) as follows:

$$TP = Z \times \frac{f P_0 (1 + r)^t}{L} \tag{Rumus 1}$$

- Where:
- TP = Population pressure
 - L = Total Area of agricultural land
 - Z = Minimum land area per farmer to be able to live decently.
 - Po = Population in the initial year
 - f = Proportion of farmers in the Population (%)
 - t = Period in years
 - r = Average population growth rate per year

The minimum/minimal land area for each farmer to be able to live decently (Z value) is calculated based on the following formula:

$$Z = \frac{(0.25 LSI_2) + (0.5 LSI_1) + (0.5 LST) + (0.76 LLK)}{(LSI_2 + LSI_1 + LST + LLK)} \quad (\text{Formula 2})$$

Where:

Z = Minimum land area for each farmer to be able to live decently (ha)

LST = Area of rain-fed rice fields (ha)

LLK = Area of dry land (ha)

LSI1 = Area of irrigated rice fields with 1 harvest per year (ha)

LSI2 = Area of irrigated rice fields with 2 harvests per year (ha)

The value of the Proportion of farmers in the Population (f) is obtained from the formula presented by Soemarwoto (1985), namely:

$$f = (\text{Number of farmers} / \text{Number of Population}) \times 100\% \quad (\text{Formula 3})$$

The population growth rate is calculated using the following geometric formula:

$$P_t = P_o (1+r)^t \quad (\text{Formula 4})$$

Where:

r = Population growth rate

t = Period, expressed in years.

P_t = Population in year t

P_o = Population in the initial year

Table 1. Level of Population Pressure on Land

Sub-district in Sub-DAS Lesti	Populati on Number	Numb er of Farmer s	Propotio n of Farmers	Populati on Growth Rate	Minimu m Land Area for Decent Living	Agricultur al Land Area (Ha)	Populati on Pressure Value	Criteri a
Poncokusum o	26.221	24.460	0,93	1,53	0,17	4.226,381	0,97542	<1
Wajak	74.121	66.292	0,89	1,20	0,19	4.621,481	0,87528	<1
Dampit	108.914	89.087	0,82	1,50	0,19	8.361,963	3,61627	>1
Tirtoyudo	44.121	28.991	0,66	1,44	0,17	3.029,741	0,86021	<1
Sumbermanji ng Wetan	24.739	15.099	0,61	1,47	0,19	1.548,180	0,55234	<1
Turen	107.607	61.445	0,57	1,68	0,16	3.713,927	3,68583	>1
Bululawang	12.282	4.927	0,40	0,72	0,16	209,196	0,00427	<1
Gondanglegi	82.052	57.984	0,70	1,50	0,16	5.444,617	1,95847	>1
Ampelgading	14.823	9.084	0,69	1,24	0,16	307,824	0,13464	<1
Gedangan	12.032	5.043	0,42	0,19	0,26	1.329,656	0,00001	<1

Bantur	20.384	13.051	0,64	0,66	0,26	1.757,160	0,01192	<1
Pagak	7.683	7.123	0,93	1,49	0,26	1.082,391	0,38289	<1

Source: Analysis Results, 2023

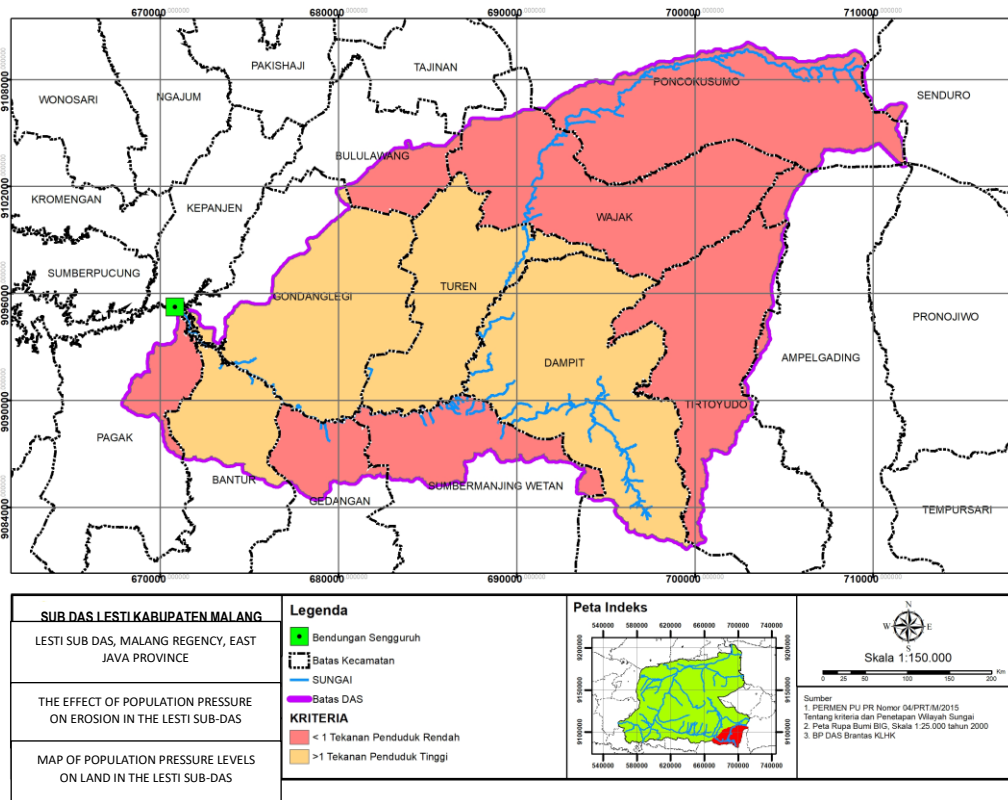


Figure 3. Map of Population Pressure Conditions in 12 Sub-DAS Lesti Sub-Districts

The conditions shown in Table 1 show that there are 3 sub-districts with high levels of population pressure on land: Dampit Sub-district, Turen Sub-district and Gondanglegi Sub-district. Regarding current land use, several sub-districts identified as having a Population Pressure (TP) value > 1 are located on open land.

The MUSLE (Modify Universal Soil Loss Equation) method formula is used to calculate the erosion rate.

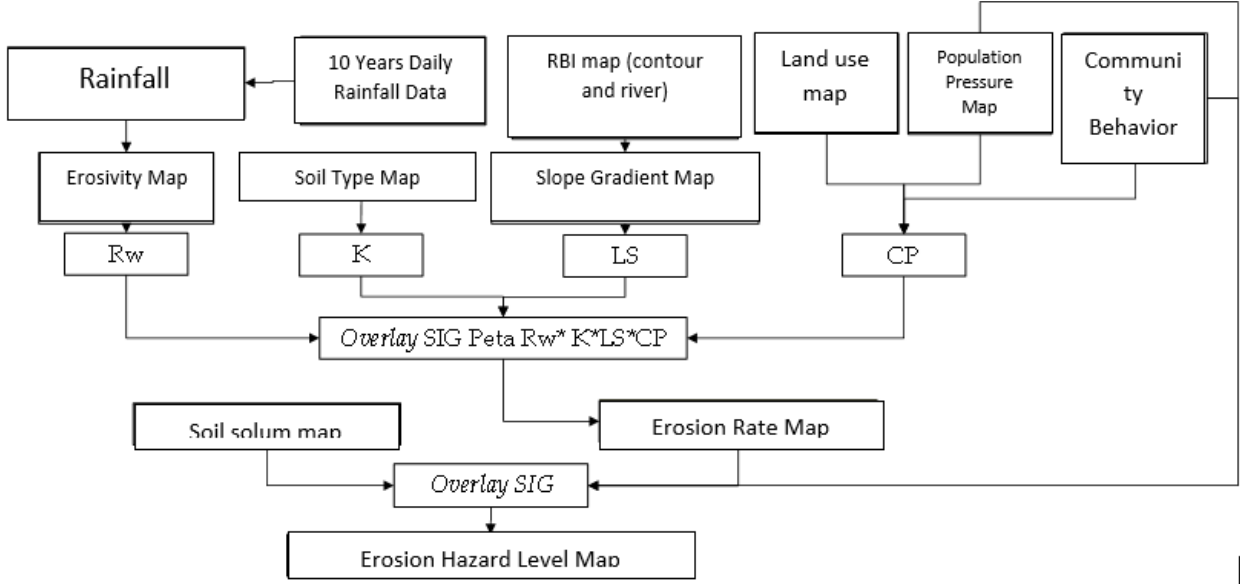
$$A = R_w \times K \times LS \times CP$$

Where : $R_w = 9,05 (V_o \times Q_p)^{0,56}$

Description :

- ✓ A = Erosian Rate (ton/ha/year)
- ✓ R_w = Surface runoff erosivity index
- ✓ K = Soil erodible factor
- ✓ LS = Slopr gradient factor
- ✓ CP = F Land use and soil cultivation factor
- ✓ V_o = Surface runoff volume (m3)

Figure 4. Flowchart of Erosion Rate Analysis and Erosion Hazard Level in Lesti Sub-DAS



Based on the author's calculations, which state that the current erosion rate is 153,868 tons/ha/year, it can be said that the erosion rate of the Lesti Sub-DAS has always increased since the last 14 years, so better conservation management is needed. In addition, the analysis results show that this value exceeds the tolerable erosion rate of 30 tons/ha/year.

The calculation of the erosion rate in the Lesti Sub-DAS is used as a basis for obtaining the Area and information on the Erosion Hazard Level Category (TBE). The TBE value estimates the maximum soil loss that will occur on land. Spatially, the TBE map makes it easier to see the conditions of a particular area as a priority conservation area. The TBE map is obtained by overlaying the current erosion rate, behavior, and population pressure maps with the soil solum map in the Lesti Sub-DAS.

Tabel 2. Soil Solum Depth Data of Lesti Sub-DAS

No	ID Solum	Depth	Solum Class of Soil	Area (m²)	Area (Ha)	Percentage (%)
1	A	>90cm	Deep	561419204,2	56141,92042	86,72
2	B	60-90 cm	Medium	68067150,77	6806,715077	10,51
3	C	30-60 cm	Shallow	9920131,548	993,0132548	1,53
4	D	<30 cm	Very shallow	7991912,474	799,1912474	1,23
Amount				647408400,00	64740,84	100,00

Source: Analysis Results, 2023

Tabel 3. Percentage of Current erosion Hazard Level of Lesti Sub-DAS



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No	Erosion Hazard Level	Area (m2)	Area (Ha)	Percentage (%)
1	Very Light	115142109	11514,21	17,79
2	Light	113345070	11334,51	17,51
3	Medium	97183967	9718,40	15,01
4	Heavy	69542700	6954,27	10,74
5	Very Heavy	252194553	25219,46	38,95
Amount		647408400	64740,84	100,00

Source: Analysis Results, 2023

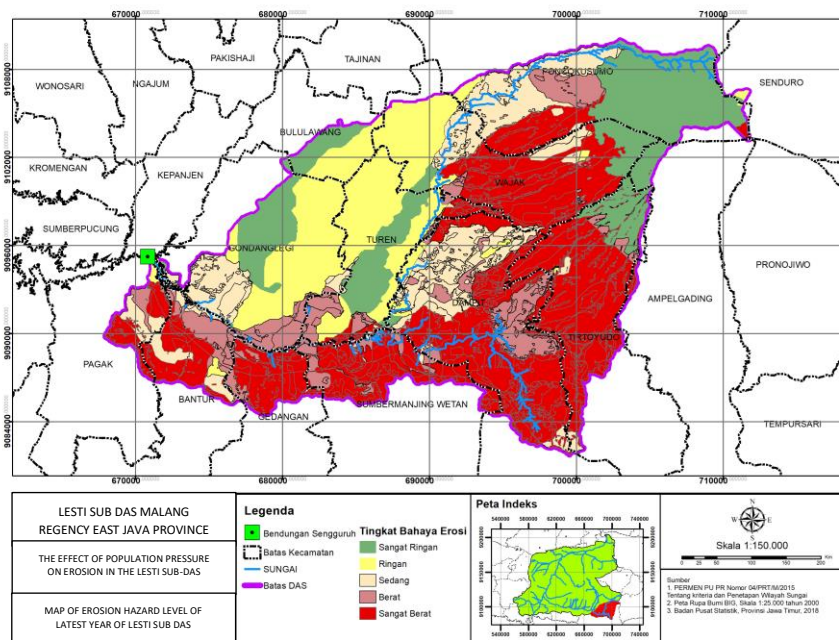


Figure 5. Current Erision Hazard Level Map of Lesti Sub-DAS

Several sub-districts identified as having the highest Erosion Hazard Level (EBH) area marked in red on the map are in Wajak Sub-district, Tirtoyudo Sub-district, Dampit Sub-district, Sumbermanjing Wetan Sub-district, Gedangan Sub-district and Bantur Sub-district. As is known, Dampit Sub-district, Turen Sub-district and Gondanglegi Sub-district have TP values > 1, which means that there has been population pressure on the land in an area so that it is no longer able to meet the needs of its residents properly.

From an environmental science perspective, erosion, which is usually seen as an aspect of environmental carrying capacity, also has a strong relationship with social and economic aspects in the form of pressure. Based on the analysis of EHH and TP, one sub-district was found to have an intersection, namely Dampit Sub-district. Environmentally aware conservation directions are suggested to be focused on this sub-district by implementing civil, technical, vegetative, agronomic or combined soil and water conservation by involving the community and by local conditions.

CONCLUSION



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Based on the data analysis and discussion results, it was concluded that in the Lesti Sub-DAS, there is a correlation between population pressure and the current choice of land use, which impacts erosion vulnerability. At high population pressure (> 1), it is generally directly proportional to the condition of land use that is prone to erosion, such as settlements, dry land rice fields and open land. Based on environmental science, the government needs to balance economic, social and environmental needs in several areas. Conservation priorities are prioritized in Dampit District because it is an area with high TP and heavy TBE. The recommendation that can be given to this district is the government's provision of subsidies or incentives for people who want to carry out agricultural efforts with conservation principles. This is to reduce the income gap because, in some cases, agricultural yields will decrease when applying environmentally conscious conservation principles. In the social aspect, efforts are needed to involve the community with their local wisdom to carry out civil technical, agronomic and vegetative conservation efforts so that there is a sense of ownership of government programs carried out to prevent erosion in the upstream DAS.

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