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RESEARCH ARTICLE

The Influence of Land Cover and Socio-Economic Aspects on Umbulan Spring Discharge in Pasuruan Regency

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ABSTRACT

This research aims to analyze the influence of land cover and socio-economic aspects on the discharge of Umbulan Spring in Pasuruan Regency, East Java, which has experienced significant discharge decline in recent decades. The research was conducted in Winongan District and surrounding areas, using primary data from surveys and field observations, as well as secondary data from government documents. The land cover change model uses Land Change Modeler (LCM) and hydrological analysis uses Soil and Water Assessment Tool (SWAT) to assess water discharge changes. Geographically Weighted Regression (GWR) model was used to identify the influence of socio-economic aspects on water discharge. The results show that land cover changes from vegetation to settlements, population density, and water use for household, agriculture, and industry contribute negatively to water discharge decline. An optimal spatial pattern plan is recommended to suppress water discharge decline by up to 88.32% in the recharge area by regulating land use conservatively. This research concludes that sustainable land cover management and policies limiting socio-economic activities need to be implemented to preserve the Umbulan Spring.

INTRODUCTION

Land use or land cover change has long been considered a factor affecting the environment globally (Lambin & Geist, 2008). Several studies over the past decade have examined the role of land cover change on various aspects of the environment such as: hydrological response (Ghaffari et al., 2010), climate change (Xu et al., 2016), biodiversity (de Castro Solar et al., 2016), food security (Rutten et al., 2014), energy conservation (Preston & Kim, 2016), and water quality (Giri & Qiu, 2016). Land cover change is one of the human influences on the landscape manifested in various processes such as agricultural expansion, deforestation and urbanization. In recent decades, rapid land cover change worldwide has been caused by population growth leading to environmental degradation.

Several studies on the impact of land cover change on hydrological responses and related factors such as water quality have been the focus of water resources research. However, there is still a need for further exploration of the linkages between land cover change and water resources due to the poorly understood complexity of land cover change processes and associated hydrological processes. This is due to the diverse land cover changes and drivers in ecological, socio-economic and historicalpolitical contexts (Lambin & Geist, 2008). These drivers influence each other, making it difficult to assess the relative importance of each driver. Previous studies have shown that there are variations in drivers and land cover in each study area (Birol et al., 2009; Davies et al., 2014; Prishchepov et al., 2012). Land use change in watersheds has hydrological impacts and several negative impacts such as increased runoff and erosion, and exacerbated vulnerability to drought and flooding (David et al., 1997; DeFries & Eshleman, 2004; Paul & Meyer, 2001). This indicates that land use or land cover change is an intervention of the growing population in meeting their needs.

In addition to the influence of land cover, socio-economic aspects are also considered to have an indirect hydrological impact. The socio-economic conditions of the people who use water resources will also influence the pattern of water use and land activities around the source (Aprillia & Satya, 2023). The size of the population using the water source is also important to review based on the intensity and activity of its use. Human activities such as industrial activities with waste by-products have a major influence on water quality in the long term (Luo & Zuo, 2019). Human activities such as sand mining also have an impact on the physical and non-physical quality of water sources (Dwityaningsih et al., 2018).

Indonesia, the fourth most populous country in the world, has a pattern of rapid and sporadic land cover change on a large scale, especially during the period of significant economic growth from 1975 to 1996 (Firman, 2009). Java is the most populous region with approximately 60% of Indonesia's 250 million inhabitants and a population density of more than 900 people/km2. Over the decades, Java has witnessed constant pressure on land resources and is rapidly undergoing a transition from largely rural to urbanized areas (Handayani, 2013; Verburg & Bouma, 1999). In recent years, dependence on water resources has become heavier due to increased water use and deteriorating watershed conditions (Pawitan & Haryani, 2011). About 458 watersheds in Indonesia have been declared in critical condition, calling for improvements in watershed management (Fulazzaky, 2014).

Umbulan Spring, as one of the largest water sources in East Java Province, has also experienced a decline, one of which is in terms of quantity. It was noted that there was a decrease in the discharge of Umbulan Spring measured from February 2007 to October 2008 where the shrinkage ranged to 3,278 liters/second from the initial 4,051 liters/second. It is projected that the potential of Umbulan Spring can reach 4000-5000 liters/second. In previous research, Ginting (2010); Rengganis (2011); Rengganis and Seizarwati (2015) regarding the hydrological conditions of Umbulan Spring, mentioned the influence of land use changes on the output discharge at the spring. In addition, uncontrolled groundwater withdrawal carried out in the modeling shows changes in the groundwater level and the occurrence of subsidence in CAT Umbulan. Therefore, with some influence of land use change and not yet maximizing the level of drinking water service coverage, which is around 51.7% of the population in urban areas and 46.5% of the population in rural areas in the East Java region, it is the background for the need to further study the influence of land cover and socio-economic aspects on the decline in Umbulan Spring discharge in order to maintain sustainability between the benefits and existence of Umbulan Spring at large.

Umbulan Spring as one of the largest water sources in East Java Province has an important role in supporting various activities of the surrounding community. The existence of Umbulan Spring is considered very crucial as the majority of the East Java community uses this water source. However, time-series factual data shows a decrease in the discharge output of Umbulan Spring, which is accompanied by changes in land cover and land use as well as the socioeconomic conditions of the population around Umbulan Spring. Therefore, the problem formulated in this study is how changes in land cover and use and economic aspects affect the discharge of Umbulan Spring.

METHODOLOGY

The area or location of the Study of the Influence of Land Cover and Socio-Economic Aspects on Umbulan Water Discharge in Pasuruan Regency is in Winongan District (location of Umbulan Spring) and surrounding sub-districts bordering Winongan District.

The data used are secondary data and primary data. Primary data was obtained through surveys and field observations related to the existing conditions of the study area. Secondary data included demographic and socio-economic data, time-series and planned land use data, Regional Spatial Plan documents, and Umbulan Spring condition data. These data were sourced from government agencies in Pasuruan Regency and East Java.

Analysis and Modeling of Land Cover or Use Using Land Change Modeler (LCM)

Land Change Modeler (LCM) is a software integrated with IDRISI Selva that can be used to explore Land Use Cover Change (LUCC) by combining CA-Markov and Artificial Neural Network approaches (Adhikari et al., 2019). LCM can provide a platform to assess land use change spatio-temporally and dynamically. Such utilization can also be used to better allocate land in the planning and policy-making process. The utilization of LCM can also be used to anticipate changes and predict land use under various scenarios (Mishra et al., 2014).

Hydrological Modeling Using Soil and Water Assessment Tools (SWAT)

Identification of hydrological conditions is done through a hydrological modeling approach using SWAT (Soil and Water Assessment Tool). SWAT is an extension of ArcGIS software. SWAT is useful for balance sheet modeling of river basins or water boundaries to predict the effect of land management on water conditions, sedimentation, and agricultural chemistry in large and complex watersheds with diverse soil types, land use, and management conditions over a long period of time. The stages that must be passed to determine the hydrological conditions of Umbulan Spring are through the process of delineating the watershed, forming and defining hydrological response units (HRU), establishing climate data, building input data, and SWAT simulation.

Analysis of the Effect of Land Cover/Utilization and Socio-Economic Activities on Umbulan Water Discharge Using Geographically Weighted Regression (GWR)

Geographically Weighted Regression (GWR) is a statistical method to analyze spatial heterogeneity where the same independent variable gives an unequal response at different locations in a research area. GWR model analysis provides the results of estimating model parameters that are local at each point or location where the data is studied. In the GWR model, the response variable Y is estimated with predictor variables whose respective regression coefficients depend on the location where the data is observed. The role of weights in the GWR model is very important because the weight values represent the location of observations with each other.

Spatial variables of longitude and latitude are variables used in weighting in the formation of GWR models. Longitude is a longitudinal line that connects between the north side and the south side of the earth (poles) which is used to measure the west-east side of the coordinates of a point in the hemisphere. While latitude is a transverse line between the north pole and the south pole that connects between the east and west sides of the earth which is used as a measure in measuring the north-south side of the coordinates of a point in the hemisphere. The GWR model can be formulated as follows:

$$Y_i = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i) X_{ik} + \mathcal{E}_i$$

Description:

Y_i : Observation value of the responded variable

X_{ik} : Observation value of the kth predictor variable at the i-th observation location

$\beta_0 (u_i, v_i)$: Constant/intercept at the i-th observation

(u_i, v_i) : State the geographical coordinates (longitude, latitude) of the i-th observation location

$\beta_k (u_i, v_i)$: Observation value of the k-th predictor variable at the i-th observation location

ε_i : The i-th observation error which is assumed to be identical, independent and normally distributed with zero mean and constant variance σ2

RESULT AND DISCUSSION

SWAT Simulation Results

SWAT simulations were conducted in two years, namely in 2012 and 2019 with several differences in input data such as weather data and land use. The simulation is intended to assess the decrease / increase in discharge and see the involvement of some input data that affects. The SWAT simulation process is carried out after the stages in the previous step have been completed, namely the subbasin delineation process, HRU and climate data input. The results of the simulation produced annual or average monthly discharge data for a period of one year starting from January 1, 2012 to December 31, 2012. The following is the runoff discharge generated during the span of one year:

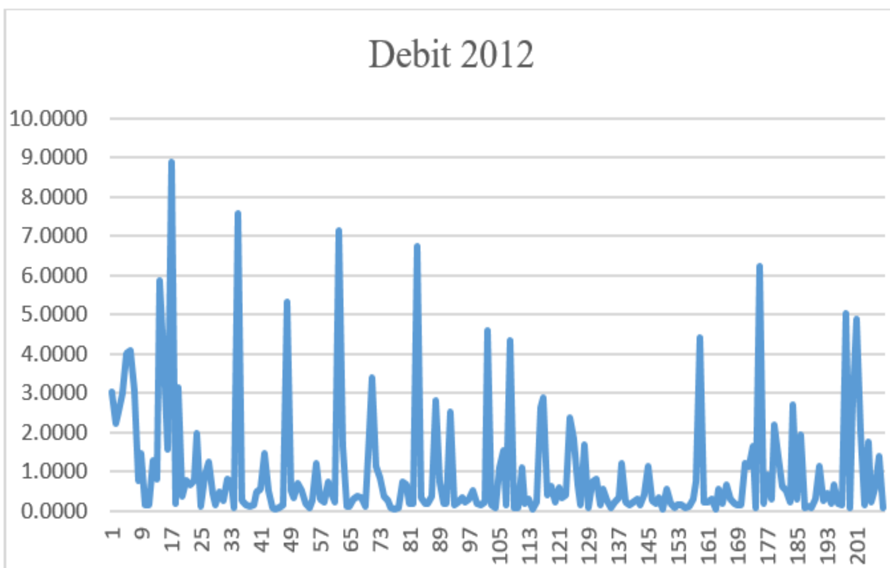

Figure 1. 2012 SWAT Simulation Discharge Chart

It can be seen from the simulation results that in 2012, the run-off discharge generated by Umbulan Spring was 4030 liters/second. Several other rivers such as Kali Sembayu, Kali Welang and one of the rivers in Winongan sub-district have annual discharges of 213.2 liters/second, 6363 liters/second and 200 liters/second respectively.

In the 2019 hydrological simulation, the discharge simulation was generated through the same stages as those carried out in 2012. Where the results of the simulation produce discharge data for a period of one year starting from January 1, 2019 to December 31, 2019. From the simulation results, the following is the runoff discharge generated during the span of one year in 2019:

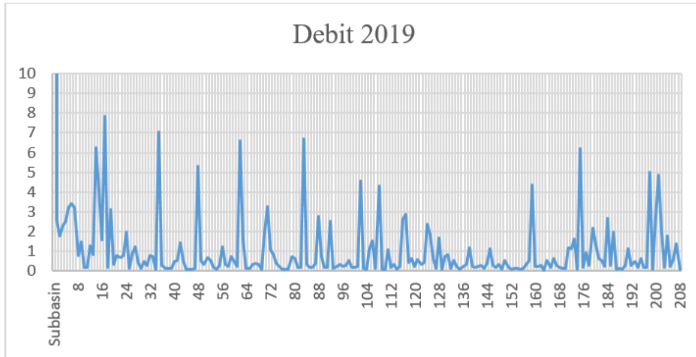

Figure 2. 2019 SWAT Simulation Discharge Chart

The results of the simulated discharge year in 2019 show a run-off discharge flow of approximately 3382 liters/second located in subbasin 4. These results indicate that there is a significant decrease in discharge between 2012 and 2019, especially at the outlet of Umbulan Spring, where this area is included in the core use area. The decrease in discharge is projected to be approximately 600 liters/second. This is due to a number of factors that may be influenced by land use change and residential use, which can affect the infiltration of rainwater into the ground.

Model Validation Test with Field Data

The validation test was carried out by comparing the simulated discharge and the observed discharge obtained from various secondary sources. Of the many data obtained, there are several points that can be used as validation tests where the points are located in the research study area as follows:

Table 1. Umbulan Area Observation Discharge Data Point

Watershed/Source	Year	Discharge lt/sec	Source
Umbulan	1980	6000	Alix Toulier, peneliti dari Universite de Monpellier, Perancis https://www.ekuatorial.com/id/2020/03/krisis-air-umbulan-sumber-air-terbesar-di-jawa-timur-menyusut/
Umbulan	2007	4028	(Jurnal Teknik Hidraulik, Vol. 6 No. 1 Juni 2015: 63 – 76)
Umbulan	2008	3900	(Jurnal Teknik Hidraulik, Vol. 6 No. 1 Juni 2015: 63 – 76)
Umbulan	2009	3350	(Jurnal Teknik Hidraulik, Vol. 6 No. 1 Juni 2015: 63 – 76)
Umbulan	2010	3600	Heni Rengganis, Wulan Seizarwati, 2015
Umbulan	2011	3900	Heni Rengganis, Wulan Seizarwati, 2015
Umbulan	2012	4002	(Jurnal Teknik Hidraulik, Vol. 6 No. 1 Juni 2015: 63 – 76)
Umbulan	2013	3509	(Jurnal Teknik Hidraulik, Vol. 6 No. 1 Juni 2015: 63 – 76)
Umbulan	2018	3278	Jurnal Aplikasi Teknik Sipil, Vol. 20 No. 1 Februari 2022
Umbulan	2020	3302	Pengukuran Debit Umbulan, PUSDA
Winongan	2012	0.115	Jurnal Teknologi dan Rekayasa Sumber Daya Air Vol. 3 No. 2 (2023)

K. Rejoso Hulu	2012/2018	0.162	Jurnal Teknologi dan Rekayasa Sumber Daya Air Vol. 3 No. 2 (2023)
K. Rejoso Hilir	2012/2018	0.983	Jurnal Teknologi dan Rekayasa Sumber Daya Air Vol. 3 No. 2 (2023)
Kali Sembayut	2012	217.5	Heni Rengganis, Wulan Seizarwati, 2015
Banyubiru	2012	386	Heni Rengganis, Wulan Seizarwati, 2015
Watugajah	2012	6.5	Heni Rengganis, Wulan Seizarwati, 2015
Mego	2012	26	Heni Rengganis, Wulan Seizarwati, 2015
Torbayan	2012	22.5	Heni Rengganis, Wulan Seizarwati, 2015
Kali Petung	2012	4960	Rispam Pasuruan, 2016
Kali Gembong	2012	4420	Rispam Pasuruan, 2016
Kali Welang	2012	6550	Rispam Pasuruan, 2016
Kali Kadaipang	2012	7090	Rispam Pasuruan, 2016

The validation test is to look at the R2 of the calculated results between simulated and observed discharge. The results obtained from the calculation show that the resulting R2 is 0.9 which means that the closer to 1, the model is in a good category.

Calculation of Estimated Groundwater Reserves

Recharge calculations are carried out using several variables such as Annual Recharge Amount, Area of recharge area, and Discharge Type. Recharge amount is obtained from the SWAT simulation results in the form of recharge potential or the coefficient of water entering the ground for a year. The area of the recharge area is obtained from the Subbasin area formed from the delineation process in the first stage of SWAT modeling, which is 53333.93 Ha. While the type of discharge variable is a coefficient of how much proportion of run-off water can enter the soil based on each soil forming material. Soil conditions in the 80% and 20% recharge areas are dominated by Mollic Andosols, Ochric Andosols and a small portion of Vitric Andosols and Vertic Andosols in the north. These soil types are located in volcanic areas or formed by volcanic activity. Based on the type of material, this soil has constituent materials in the form of passive loam and clay pebbles with a coefficient of release of 30%. The following is a detail of the type of release based on the type of material forming the soil.

Table 2. Data of Release Type

No	Material	Release Type (%)
1	Gravel	30
2	Coarse sand and sandy gravel	25
3	Medium sand	20
4	Fine sand and slightly cohesive sandstone	10
5	Clay soil and clay gravel	5
6	Fine-grained sedimentary rocks	3-5
7	Limestone, chalk	2-3

After obtaining the three variables, it was found that in 2012, the total groundwater recharge potential for a year in the Umbulan area was 71,97,7936.69 m3. While in 2019, the total groundwater recharge potential was 70,338,622.36 m3. These results indicate a decrease in groundwater recharge potential of 2.27%. The decrease is due to several reasons, including a decrease in the amount of Recharge in 2012 to 209 where in 2012, the recharge coefficient was 260-590 mm / year. While in 2019 the amount of recharge was 250-580 mm / year.

Sensitivity Analysis

Sensitivity analysis is an analysis used to see the amount of increase or reduction in discharge caused by the conversion of one type of land use to another. This analysis produces an output that will be used to provide direction for optimal land use in order to maintain the sustainability of Umbulan Spring in terms of land use. The following are the results of the sensitivity analysis:

Table 3. Sensitivity Analysis Results

Initial LU	Final LU	Average Increase (Ha)	Average Decrease in Discharge	Impact/Ha (M^3)	Typology
Perennial Plants	Settlements	5.95	0.12645	0.02124	1
Perennial Plants	Mining	4.28	0.05350	0.01250	2
Agriculture	Mining	0.86	0.00510	0.00593	3
Perennial Plants	Community Forest	2.36	0.00400	0.00169	4
Perennial Plants	Agriculture	6.09	0.00517	0.00085	5
Nature Sanctuary	Settlements	8.79	0.00310	0.00035	6
Nature Sanctuary	Perennial Plants	38.20	0.01082	0.00028	7
Nature Sanctuary	Agriculture	43.31	0.01023	0.00024	8
Protected Forest	Perennial Plants	9.20	0.00138	0.00015	9
Nature Sanctuary	Production Forest	87.26	0.00947	0.00011	10
Protected Forest	Agriculture	42.48	0.00319	0.00008	11
Protected Forest	Production Forest	54.80	0.00240	0.00004	12
Perennial Plants	Production Forest	2.06	0.00002	0.00001	13

Based on the results of the analysis, the change from perennial plants to settlements is the largest contributor to the decrease in discharge in the Umbulan Spring Area. The resulting decrease is 21 liters/second from a change of 1 ha of land. Meanwhile, the change of perennial plants to mining ranks second with a decrease of 12 liters/second per 1 ha of land change. The above results are then used in the process of preparing optimal land use in the form of each typology in order to maintain the sustainability of Umbulan Spring.

Modeling the Influence of Land Use Change and Socioeconomic Activities Using GWR

GWR analysis was used to examine the relationship between Umbulan spring discharge (Y) and physical variables and socio-economic activities. The explanatory/independent variables in this model include: land use change (X1), population density (X2), water use for household purposes including industry and micro-small-scale businesses (X3), water use for agricultural activities (X4), and water use for plantation activities (X5) with detailed values of each variable spatially shown in Figure 45. This analysis was conducted to see GWR modeling at the sub-basin level as information on the influence of each independent variable on the discharge variable (dependent). Then, for each independent variable in each sub-basin, a significance test was conducted with a t-test at the real level of 0.05 to determine whether each sub-basin has variations in influential independent variables.

Table 4. Parameter coefficient value of GWR estimation result

Zone	Parameter (X1-X6)	GWR Parameter Coefficient (BAU Scenario)	GWR Parameter Coefficient (CON Scenario)
Core Utilization Zone	Intercept	3.787224	3.582614
	Land use change	-1.749403	-2.226581
	Population density	-1.482514	-1.502342
	Water use for domestic purposes	-2.824421	-2.732721
	Water use for agricultural activities	-0.243842	-0.164871
	Water use for plantation activities	-0.743603	-0.851844
	Water Use for Industrial Activities	-1.845612	-2.145612
80% Recharge Zone	Intercept	0.893404	0.881675
	Land use change	-0.050834	-0.113842
	Population density	-0.818515	-0.828225
	Water use for domestic purposes	-0.132774	-0.126764
	Water use for agricultural activities	-0.009851	-0.010225
	Water use for plantation activities	-0.003269	-0.004196
	Water Use for Mining Activities	-0.002256	-0.003451
20% Recharge Zone	Intercept	1.48106	1.523912
	Land use change	-0.106684	-0.137141
	Population density	0.005154	0.0267649
	Water use for domestic purposes	-0.04689	-0.036471
	Water use for agricultural activities	-0.003567	-0.003532
	Water use for plantation activities	-0.018233	-0.028343
	Water Use for Mining Activities	-0.008371	-0.010622

In the significance test with a real level of 0.05, each GWR parameter coefficient is significant. The results of the GWR model on independent variables all have conformity with the research hypothesis and have variations in each sub-basin in the Umbulan Spring Conservation Area. All variables have a negative coefficient value, so it can be interpreted that the explanatory variables X1-X6 have an indication of a negative influence on Umbulan spring discharge and to formulate a spatial pattern that supports the conservation function to suppress the decline in Umbulan spring discharge, it will be necessary to suppress all explanatory variables from getting bigger.

The coefficient of determination (R2) is a description of the suitability of a model. The higher the coefficient of determination (R2), the better the model. The GWR model produced 208 regression equations according to the number of sub-basins in the Umbulan spring conservation area. GWR modeling produced regression equations locally in each sub-basin with an average R2 value of 0.5442 or 54.42 percent. The R2 value explains that the decrease in Umbulan spring discharge can be explained by the variables X1-X6 by 54.42%. When viewed based on the spatial distribution and based on the zones, the GWR modeling results can conclude several results and characteristics as follows:

a) Umbulan Spring as one of the largest water sources in East Java Province has decreased in terms of quantity.
b) The decline in Umbulan Spring discharge based on GWR modeling shows that all observed variables (Population density, Water use for households, use for agriculture and plantations, land use change, and utilization for industry/mining) have an indication of a negative contribution to the discharge of Umbulan Spring.

c) The variables of land use change, household use, use for industrial activities, and population density are the variables with the most significant influence on the decline in Umbulan Spring discharge - The core utilization zone has significantly higher sensitivity than the other two zones to changes in the determining variables.

Formulation of Optimal Spatial Pattern Plan for Umbulan Spring Conservation Area Formulation of Optimal Scenario for Umbulan Spring Conservation

The vulnerability characteristics of each sub-basin to changes in land use and physical activity are quite diverse with varying spatial distribution. Sub-basins in the core utilization zone that are alleged to have higher sensitivity occur due to changes with typology 1 which is a change from annual crops to settlements that ultimately increases the level of water use for household purposes (including micro-small level businesses). Changes with typology 5 also have a significant influence, namely for intensive agricultural activities. In the sensitivity test conducted, mining areas that have a fairly small area are also seen to have a significant impact when viewed from the impact of changes in discharge per hectare of land use change (Typology 2 and 3). The 80% and 20% recharge zones have a larger vulnerable area to a decrease in discharge due to land use change and socio-economic activities of the community, with overall the highest influence that causes a decrease in discharge is due to the conversion of protected areas (natural reserves and protected forests) into cultivated areas (settlements, agriculture, production forests).

The results of hydrological modeling show the typologies of land cover change and the level of decrease in discharge caused, where changes towards land with more intensive utilization have a more significant impact on decreasing discharge. The same thing is also detailed through GWR analysis where overall in all zones it is found that utilization activities for households, industry, mining, agriculture, and plantations have a significant negative influence on Umbulan Spring discharge. The formulation of the optimal spatial pattern is basically to minimize changes in land use to intensive cultivation functions by considering the level of land growth and priority changes based on the level of typology and GWR models obtained. Therefore, based on the results of hydrological modeling and the influence and interaction between variables in GWR modeling, it is necessary to formulate the basics of determining the optimal spatial pattern for the conservation function of Umbulan Spring as follows:

Core Utilization Zone Recommendation

a) The core utilization zone is dominated by changes from annual crops to settlements and agriculture (Typologies 1 and 5). Therefore, it is necessary to reduce the growth rate of settlements and intensive agriculture.
b) Restriction of residential land growth must also be accompanied by restrictions on household use with interests beyond consumption (industrial purposes and micro and small class businesses).
c) Application of conservation scenarios by allocating the direction of growth to other zones outside the Umbulan utilization and recharge areas.
d) Application of a 200m buffer area for direct groundwater utilization around the core utilization zone area and towards the recharge zone.

Recommended Infiltration Zone

a) The 80% and 20% recharge zones are dominated by changes from protected areas (protected forests and nature reserves) to semi-intensive cultivation (perennial plants, wetland agriculture, and mining); Typology 6-13).
b) Limitation of residential land growth in the core utilization zone also needs to be applied to the recharge zone.

c) Protected areas (protected forests and natural reserves) must be maintained and cannot be converted as in the provisions of the Regional Spatial Plan.
d) Application of conservation scenarios by allocating the direction of growth to other zones outside the utilization and recharge areas of the Umbulan.
e) Existing agricultural areas are maintained through Protected Rice Fields policies and perennial plants according to the potential of the local area.

Recommended Release Zone

The release zone has an insignificant influence on the decline of Umbulan spring water discharge. Therefore, the spatial pattern arrangement in this zone can be carried out by prioritizing the allocation of the growth of built-up land needs in this zone, so that the Umbulan spring conservation area as a whole can still meet the needs of settlements due to population growth. These recommendations are also accompanied by the application of rules of transition in scenario CON (conservation) so that the best formulation can be obtained to optimize efforts to conserve Umbulan spring water.

Spatial Pattern Plan for Umbulan Spring Conservation

The regional spatial pattern plan is a plan for the distribution of regional spatial designations that includes spatial designations for protected functions and regional cultivation functions, formulated with criteria:

a) Based on the regional spatial planning strategy;
b) Considering the allocation of regional space in order to support socio-economic activities and environmental preservation;
c) Considering the carrying capacity and environmental capacity of the region;
d) Referring to the national spatial pattern plan (national Neighborhood Association (RT)/Community Association (RW) and its detailed plan), the provincial spatial pattern plan (provincial Neighborhood Association (RT)/Community Association (RW) and its detailed plan), and paying attention to the spatial pattern plan of the bordering district / city;
e) Can be transformed into the preparation of indications of the main five-year medium-term program for 20 (twenty) years; and
f) Referring to laws and regulations.

In general, the spatial pattern plan consists of:

Protected Area Plan

Protected area is an area that is determined with the main function of protecting the preservation of the environment which includes natural resources, artificial resources and historical and cultural values of the nation for the benefit of sustainable development. Based on this understanding, in general, the purpose of strengthening protected areas in the Umbulan Spring Conservation Area is to prevent the emergence of various damage to environmental functions and secure from the possibility of use intervention into non-protected areas. The targets to be achieved are:

- Increase the protected function of land, water, climate, plants and animals as well as historical and cultural values.
- Maintain the diversity of plants, animals, ecosystem types, and the uniqueness of nature.

The protected areas in the Umbulan Spring Conservation Area consist of:

Nature Reserve Area

The nature reserve area in the Umbulan spring conservation area is the Bromo Tengger Semeru National Park (TN-BTS). The Bromo Tengger Semeru National Park area in the Umbulan spring conservation area has an area of 9102.07 Ha which is spread over Tutur, Puspo, Tosari and Lumbang sub-districts. Protection of the National Park is carried out for the development of education about certain animals and fauna, improving environmental quality for the surrounding area and protecting the environment from pollution. Efforts to manage the Bromo-Tengger-Semeru National Park area are in the hands of the Government, synchronizing and coordinating with the District Government, by way of:

- Restore protected functions in eliminated areas by developing productive plants that can infiltrate water into the soil;
- Development of thematic tourism packages of Tengger ethnic culture and historical artifacts and volcanic tourism;
- Building research facilities for flora and fauna in addition to developing rare animal breeding;
- If there is a change in protected functions, it must be returned to its original function;
- Management program for the Bromo-Tengger Semeru National Park area together with the community with the aim of providing an understanding of the importance of forests in addition to having an ecological function also indirectly has economic value.

Protected Forest Area

Protected forest areas are included in areas that provide protection to subordinate areas. Efforts to handle/manage protected forest areas are carried out through:

- Supervision and monitoring for the preservation of conservation areas and protected forests;
- Establishment of prohibitions to conduct various businesses and/or activities except for various businesses and/or activities supporting protected areas that do not interfere with natural functions and do not change landscapes and natural ecosystems;
- Restoring the area of protected areas, due to conversion;
- Preservation of biodiversity and its ecosystems;
- Regulation of various businesses and/or activities that can still maintain protected functions;
- Prevention of various businesses and/or activities that interfere with protected functions;
- Application of applicable provisions on Environmental Impact Analysis (AMDAL) for businesses and/or activities that will be located in protected areas, having a major and important impact on the environment;
- Development of inter-regional cooperation in the management of protected areas;
- Acceleration of rehabilitation of community-owned land that includes protected area criteria by planting protected trees that can be used as protection of subordinate areas that can be taken for non-timber forest products;
- Acceleration of forest rehabilitation / reforestation of protected forests with plants that are in accordance with the protected function with a strip cropping system;
- Implementation of provisions to restore the protected function of areas that have been disturbed by their protected function gradually and sustainably so as to maintain the existence of protected forests for hydrological purposes. As for activities that can be allowed to make fire observation posts, guard posts, signboards or lighting, triangulation stakes, monuments, electricity poles and television station towers as well as footpaths of tourism destination areas whose buildings are not permanent; - Restoring the function of areas along the coast, river borders, reservoirs and springs as a protected function by replanting (reforestation);
- Conducting guidance programs, counseling to the community in efforts to preserve protected areas and disaster-prone areas.

Cultivation Area Plan

Cultivation areas are areas that can be utilized partly/wholly for the benefit of the community and develop the regional economy, while still considering sustainability. The cultivation area in the Umbulan spring area consists of:

Production Forest and Community Forest

Production Forest areas in the Umbulan spring conservation area are spread in almost all zones with an area of 9878.01 Ha, while Community Forests amount to 898.79 Ha. Utilization of areas in production forests and community forests is carried out to utilize growing space so as to obtain optimal environmental benefits, social benefits, and economic benefits, such as cultivation of plants under forest stands. Efforts to manage production forest areas can be carried out by:

- Determination of technical criteria and patterns of land arrangement as well as management of Production Forest Areas whose land is owned by the State will be determined and coordinated by the Government, in this case the Minister whose duties and responsibilities are related to the Forestry Sector;
- Some existing permanent production forests have shown a low density of plant stands so that reforestation must be accelerated;
- Processing of forest products so that they have a higher economic value and provide more employment opportunities;
- Management of production forest areas with the development of overlapping activities or similar cultivation by not disturbing the main plants.
- Increasing the participation of forest communities through the development of community forestry;
- Monitoring and controlling forest exploitation activities and other forest security disturbances;
- Developing and diversifying the planting of forest species so that it is possible to extract non-timber products, such as fruit and sap;
- Improving ecological functions through the development of selective logging, rotational logging and crop rotation systems that support natural balance.

Agriculture

The agricultural area referred to in this spatial pattern plan includes: wetland agriculture (paddy fields), dryland agriculture namely rainfed rice fields and moor/fields, and horticulture. The area of agricultural designation in this spatial pattern plan is 13892.96. Agricultural area management efforts are carried out by means of:

- Encourage the establishment of special agricultural centers with a spatial approach, including Wetland Agricultural Center Areas (paddy fields) or Agricultural Center Areas for perennial food crops; Agricultural Center Areas for Plantation Crops / Annual and Seasonal Crops; Agricultural Center Areas for Horticultural Crops; Livestock Center Areas (per type); and Fishery Center Areas (Freshwater Aquaculture, Brackish Water Aquaculture, and Marine Aquaculture), which may not be converted and guaranteed by the Government. All of which must be included in an area that synergizes and harmonizes to support agriculture, namely the Agropolitan Area.
- Determination of technical criteria and patterns of land arrangement and area management in each Agricultural Area;
- Determination of Protected Rice Fields (LSD) as a scheme to increase regional food security.

Plantation/ Perennial Plants

The plantation/ perennial plants area includes all commodities cultivated in the Umbulan spring conservation area. The plantation area in the entire Umbulan spring conservation area has a total area of 15582.82 Ha and is spread throughout the planning area. Efforts to manage the plantation/ perennial plants are carried out by:

- The determination of perennial plants commodities in addition to considering land suitability, soil and water conservation, also needs to consider socio-economic aspects and beauty/aesthetics.
- Plantation area development plans can in principle be developed in each sub-district that is adjusted to the availability and carrying capacity of the land in the sub-district concerned;
- Increased utilization of plantation areas is carried out through increased participation of the community around the respective area and landowner farmers;
- Determination of perennial plants commodities in addition to considering land suitability, soil and water conservation, also needs to consider socio-economic aspects and beauty/aesthetics.

Settlements

Settlement areas in the Umbulan spring conservation area are rural settlements with an area of 975.37 ha and are spread throughout the planning area. Overall, the direction of residential area development is planned on lands that have the potential to be developed as residential areas, and is not planned in protected areas. Efforts to manage residential areas are carried out by means of:

- In general, urban and rural residential areas must be a safe, comfortable and productive place to live, and supported by settlement facilities and infrastructure;
- Each residential area is equipped with settlement facilities and infrastructure according to the hierarchy and level of service of each;
- Facilities and infrastructure in the residential environment are developed proportionally according to the needs, hierarchy and level of service of each, which are technically recommended based on applicable rules / regulations;
- The development of activities that can cause danger to humans and the settlement environment is not permitted in settlement designation areas;
- Rural settlements as agrarian-based housing, developed by utilizing agricultural land, home yards, and less productive land as the basis for business activities;
- Rural settlements located in the mountains are developed based on plantations and agro-tourism, accompanied by processing of products. Rural settlements located in the lowlands, the basis of development is food crop agriculture and inland fisheries, as well as processing of agricultural products.

Table 5. Umbulan Spring Conservation Area Spatial Pattern Plan

No	Zone	Space Pattern	Width (Ha)	Percentage %
1	Core Utilization Zone	Protected Forest	0	0
2		Production Forest	430.80	30.09
3		Community Forest	8.37	0.58
4		Nature Reserve Area	0	0
5		Settlements	202.94	14.17
6		Agriculture	189.05	13.21
7		Perennial Plants	587.63	41.04
8		Mining	12.39	0.86
Total			**1431.20**	
1		Protected Forest	6679.48	17.26

2	80% Recharge Zone	Production Forest	8016.67	10.71
3		Community Forest	828.55	2.14
4		Nature Reserve Area	106.23	0.27
5		Settlements	3969.96	10.26
6		Agriculture	7855.88	20.30
7		Perennial Plants	11132.13	28.77
8		Mining	106.51	0.27
Total			**38691.28**	
1	20% Recharge Zone	Protected Forest	4103.56	20.11
2		Production Forest	1464.38	7.18
3		Community Forest	12.10	0.06
4		Nature Reserve Area	8300.44	40.67
5		Settlements	480.79	2.35
6		Agriculture	4402.94	21.57
7		Perennial Plants	1643.34	8.05
8		Mining	0	0
Total			**20407.43**	

Impact Analysis of Spatial Planning on Changes in Umbulan Spring Discharge

The optimal spatial pattern plan for the Umbulan spring conservation area was formulated to determine how much impact it would have on changes in Umbulan spring discharge. This can be known through a comparison between the optimal spatial pattern in 2045 and the predicted land cover without intervention (trend or Business as Usual scenario). Table 6 shows that there is a significant difference between the two land cover patterns (optimal spatial pattern and trend-based prediction), where overall the prediction results without the intervention of spatial control will be dominated by land cover changes with a considerable impact/ha value on changes in Umbulan spring water discharge (especially on changes in protected areas - intensive cultivation).

Table 6. Comparison of Spatial Plan with Predicted Land Cover Trends 2045

No	Zone	Space Pattern	Width (Optimal Scenario)	Width (BAU)
1	Core Utilization Zone	Protected Forest	0	0
2		Production Forest	430.80	327.45
3		Community Forest	8.37	14.62
4		Nature Reserve Area	0	0
5		Settlements	202.94	302.39
6		Agriculture	189.05	287.97
7		Perennial Plants	587.63	498.77
8		Mining	12.39	21.41
Total			**Total**	
1	80% Recharge Zone	Protected Forest	6679.48	3194.71
2		Production Forest	8016.67	9992.13
3		Community Forest	828.55	979.81
4		Nature Reserve Area	106.23	5.77
5		Settlements	3969.96	3461.58
6		Agriculture	7855.88	11218.16
7		Perennial Plants	11132.13	9660.90
8		Mining	106.51	178.22
Total			**Total**	
1	20% Recharge Zone	Protected Forest	4103.56	3038.71
2		Production Forest	1464.38	5447.16
3		Community Forest	12.10	12.30

4		Nature Reserve Area	8300.44	814.45
5		Settlements	480.79	909.22
6		Agriculture	4402.94	7254.97
7		Perennial Plants	1643.34	2930.62
8		Mining	0	0
Total			**Total**	

By considering the impact of land cover change and socio-economic activities (which are also represented in land cover and its weighting factors), it can be seen that the optimal spatial pattern plan formulated can reduce the decline in Umbulan spring water discharge by 75.27% in the core utilization zone; 66% in the 80% recharge zone; and 88.32% in the 20% recharge zone with details in Table 25 and spatially, Umbulan spring water discharge in 2045.

Table 7. Comparison of Discharge Reduction in Spatial Plan and BAU 2045 Prediction

Zone	2019 Discharge	2045 Discharge Space Pattern	Change in Space Pattern	% Change in Space Pattern	2045 Discharge Business as Usual	Change in BAU	% Change in BAU
Core Utilization Zone	2.704	2.666	-0.039	-1.431	2.548	-0.156	-5.784
80% Recharge Zone	1.034	1.024	-0.010	-0.968	1.005	-0.029	-2.848
20% Recharge Zone	0.689	0.683	-0.005	-0.797	0.642	-0.047	-6.828

Based on the results of the proposed scenario of optimal spatial patterns carried out, the resulting decrease in discharge discharge can be minimized even though it is still less than optimal. In accordance with the results of the SWAT analysis, the proposed existing spatial pattern has an annual recharge quantity of 67,093,762.4 m3. While the annual recharge in 2019 with the existing spatial pattern in that year, shows a decrease which previously was 70,338,622.3 m3. Therefore, the decrease in recharge quantity due to changes in spatial patterns needs to be adapted with some supporting infrastructure in order to maintain the sustainability of Umbulan Spring.

CONCLUSION

Umbulan Spring is one of the largest springs with a wide range of service functions. The spring is located in Umbulan Village, Winongan Subdistrict, Pasuruan Regency and is one of the largest water sources in East Java Province. Umbulan Spring has great potential with an output discharge of up to 5000 liters/second. However, this potential continues to decline from year to year. Therefore, it is necessary to conduct further research on the factors causing the decrease in discharge with the output according to the following discussion:

1. Umbulan Spring continues to experience a decline in output discharge from year to year. It was noted that the decline in observed discharge touched 3302 liters/second in 2020. Based on the SWAT simulation results, the simulated discharge of Umbulan Spring was 4030 liters/second in 2012. Whereas in 2019, it dropped to 600 liters/second or more precisely to 3382 liters/second with the results of the "Good" model significance test.
2. The decrease in the output discharge of Umbulan Spring has a negative correlation with changes in land use that have an impact on reducing the recharge capacity of rainwater to the ground.

3. Land use change from 2012 to 2019 had an impact on the effectiveness of the soil in absorbing water (recharge). There was a decrease in recharge power from 260-590 mm/year in 2012 to 250-580 mm/year in 2019.
4. Land use change from annual crops to settlements is the biggest factor in decreasing discharge with an estimate that each change of 1 ha of annual crops to settlements causes a decrease of 0.12645 m3/second. Furthermore, changes in natural reserves to other land uses also have a significant impact on reducing discharge.
5. Based on the results of the GWR analysis, the independent variables of land use change, population density, water use for domestic purposes, water use for agricultural activities and water use for plantation activities have a negative influence on spring discharge.
6. The core utilization zone has a higher sensitivity to determining variables such as land use change, population density, water use for domestic use, water use for agricultural activities and water use for plantation activities.
7. The optimal spatial pattern plan with consideration of land cover change and socio-economic activities is estimated to reduce the decline in Umbulan spring discharge by 75.27% in the core utilization zone; 66% in the 80% recharge zone; and 88.32% in the 20% recharge zone, which must also be followed by strict directions and policies in minimizing the occurrence of use interventions into non-protected areas.

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