Aplication RS and GIS

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Submission date: 01-Jan-2023 11:02PM (UTC+0700)
Submission ID: 1987760659
File name: Application_RS_and_GIS_to_Identifi_Ground_water.pdf (1.33M)
Word count: 4239
Character count: 22161

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To cite this article: K Prasetyo and Yulinar 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1089** 012026

IOP Conf. Series: Earth and Environmental Science 1089 (2022) 012026 doi:10.1088/1755-1315/1089/1/012026

Application of remote sensing and gis to identify the vulnerability of ground-water pollution in topograhic karst

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Abstract. Karst or limestone is a landscape in the form of unique. Karst or limestone has sensitive properties and is easily dissolved in water so that the karst topography has a subsurface water system in the form of holes that are susceptible to degradation due to the very fast flow of water so that it is easy to pass water underground. The purpose of this study was to determine the level of vulnerability of karst underground water pollution based on remote sensing data and GIS in the Rengel-Tuban Indonesia karst region. This type of research is quantitative research. Data analysis techniques in this study used image interpretation and logistic regression tests. The researched result is known that Remote sensing imagery and GIS as a tool to identify the level of vulnerability of underground water pollution in the karst region. Utilization of remote sensing imagery and GIS is presented as information of vulnerability of underground water pollution, and the study showed that the average area of karst Rengel was classified as vulnerableto pollution. In conclusion that the average area study was classified as vulnerable to pollution, and the Rengel karst hills are in line with local levels of vulnerability and pollution

1. Introduction

Karst regions such as the Rengel area in Tuban Regency have abundant water resource potential because karst is an area with unique and rolling hills. The formation of karst is caused due to rock dissolution or karstification so that pounders appear in the karst area which easily pass water into the underground. Karst as comprising terrain with distinctive hydrology and landforms that arise from a combination of high rock solubility and well developed secondary (fracture) porosity. Such areas are characterized by sinking streams, caves, enclosed depressions, fluted rock outcrops, and large springs [1].

All life on Earth depends on water, a vital natural resource [2]. Karst is a potential natural resource because most of the time it can store large amounts of water. Water is a major requirement in the karst region, karstic aquifers that have different hydrogeological characteristics from other aquifers make the karst region poor on surface streams. Karst area has abundant water potential because of the drainage system where most surface water enters underground rivers through a pit which makes underground water in the karst area vulnerable to pollution. Karst landscape generally has a high vulnerability to pollution [3]. An increase in population and development will have an impact on increasing the amount of water needed. An increase in various human activities will produce both solid and liquid waste that can easily enter underground waterways. Population activities such as waste disposal in the form of pollutants into rivers, limestone development, agriculture and urbanization have triggered an increase in the number and types of pollution in karst underground rivers. Vulnerability of ground water as diffusion and percolation of pollutants from the ground surface into groundwater in the naturalconditions [4].

Remote sensing has an important role as a source of data in assessment and mapping efforts. Remote sensing relies heavily on high quality and spatial resolution of data to produce accurate information about the location, distribution, boundaries, size and type of land use so that it is easy to map the distribution of groundwater pollution sources. Remote sensing is a science and technology for obtaining, obtaining, processing and interpreting images so that they can be utilized in various desired applications. Remote sensing is an activity recording, observing, recognizing objects or events remotely. Geographical Information System (GIS) is a system for entering, collecting, manipulating, collaborating and producing geographically referenced data. Several researchers have utilized remote sensing technology combined with geographic information systems to detect, map and analyze the presence of groundwater pollution in the Karst topographic environment. Their research locations for example at India, China, and the Nile Valley in Qena region [5]–[7].

Geographic Information System (GIS) combines spatial analysis with descriptive translation so that in its development geographic information systems are widely used as tools or ways of looking at solving problems in various fields. GIS information provides a comprehensive, overall and easy picture of the approach to various phenomena [8]. According to Rhind that is a computer system intended for the collection, inspection, analysis and analysis of information relating to the surface of the earth. Geographic information systems are computer-based systems that are used to compile, store, manipulate, process, display and analyze geographical information and various accompanying attributes. Lund University GIS Center. Remote sensing and Geographic Information System (GIS) are technologies that cannot be separated from surveying, mapping and management activities [9].

The ability of GIS in providing and presenting information spatially from geographic data and attribute data (non-spatial) makes GIS a very helpful tool in various geographical studies. Remote sensing and geographic information systems also have advantages and disadvantages of each, therefore it is not easy to present it to the real world in the form of maps, for this reason a groundwater vulnerability assessment method based on karst surface condition parameters can be analyzed through data remote sensing and GIS. The remote sensing capability and geographic information system are veryuseful for assessing the vulnerability of Rengel karst groundwater pollution. Therefore, the role of remote sensing and geographic information systems in this study is expected to play a role as a tool to identify vulnerabilities in karst groundwater pollution

Based on the description above, it is interesting to conduct research by making the title "Utilization of Remote Sensing Imagery and GIS to Identify the Vulnerability of Rengel Karst Underground Water Pollution in Tuban Regency, East Java Province-Indonesia". The purpose of this study was to determine the level of vulnerability of karst underground water pollution based on remote sensing data and GIS in the Rengel karst region at District Tuban, East Java.

2. Method

This research is a quantitative research type, the location of the study was conducted in the Rengel karst region in Tuban Regency, East Java Province, Indonesia. Sampling uses a systematic random sampling method based on the spectral index from the population of Landsat 8 OLI and GDEM ASTER remote sensing image data in the form of pixels. Sources of data obtained from this study are primary and secondary data. Primary data were obtained from direct field data observations in the study area, while secondary data were obtained from the Environmental Services (DLH) data, satellite imagery from the USGS (United States Geological Survey). Data analysis techniques in this study used image interpretation and logistic regression tests. The results of the logistic regression model calculations are compared with conditions obtained from observational measurements in the field.

3. Results and Discussion

3.1. Rengel Karst Area Conditions.

Geographically, Tuban Regency is located at coordinates $111^0 30'$-$112^0 35'$BT and $6^0 40' 7^0 18'$LS. The length of the area is approximately 65 km which stretches from east to west with an area of the ocean around 22,608 km². The height of the mainland area is around 0-500 meters above sea level and therefore it is not surprising that there are karst hills in the Tuban Regency area because it was once former seawater.

The Rengel karst region was formed due to the process of dissolving rocks to form karst hills. Karst hills in the Rengel karst region are different forms because indeed not all karst hills are formed by the process simultaneously. Different rock outcrops also affect the shape of the karst. Soil conditions in the Rengel karst region play an important role in karst groundwater quality. Soil conditions in the Rengel karst region play an important role in karst groundwater quality. The nature of the soil will affect the interaction of water and more or less sediment in the underground river system which in turn affects water pollution. In the karst area of Rengel, a thin layer of soil is found on the peaks and hillsides. The thickness of the soil in the Rengel karst region is less than 4 cm. The Rengel karst area is difficult to plant because of the thin layer of soil. The karstification or rock peeling process that occurs in the Rengel karst region results in this region having secondary porosity. Water on the surface of the karst is very rarely encountered. The water on the karst surface that collects in the basin between karst hills partly forms karst springs. Most karst springs experience drought when the dry season arrives because water from the surface that enters the pit will collect in the karst underground river. The Ngerong spring is an example of an underground river system in the Rengel karst area. The Ngerong spring is dominated by subsurface drainage. The main water in the Ngerong aquifer is rainwater. Land use in the Rengel karst region is in the form of drylands, forests, settlements, and open land. The Rengel karst area is closely related to the location and position of the land. The top peaks and hillsides are widely used as uplands, shrubs, and forests. Land that is at the bottom of a valley or hills is used as agricultural land and settlement. Land productivity in the Rengel karst region is relatively low due to limited water and thin soils that undergo a process of karstification or rock peeling which is difficult to plant or plant. Vegetation cover in the Rengel karst region is affected by seasons. Land cover in the rainy season is very dominant on karst land while in the dry season land cover becomes very minimal due to drought so that a lot of vegetation is dead, especially grass and shrubs. Rock outcrops are becoming wider due to loss of vegetation cover. Rocky empty land is mostly found on steep slopes. Steep land is not much covered by vegetation because of the thin layer of soil [10].

Remote sensing (RS) is the process of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance (typically from satellite or aircraft) [10]. Geographical Information System (GIS) is a series of activities to record, observe, enter, collect, manipulate and produce data that are geographically protected and recognize objects or events from a long distance. Groundwater pollution obtained from remote sensing data has an important role as a source of data in the assessment and mapping of vulnerability to groundwater pollution. The use of high-resolution imagery can produce accurate information about the location, distribution, boundaries, size and type of each land use so that it can be easily mapped out the distribution of groundwater pollutant sources.

The ability of GIS in providing and presenting information spatially from geographic data and atibut data (non-spatial) makes GIS a very useful tool in various geographical studies. GIS has the advantage of integrating and analyzing data from various sources such as remote sensing, thematic maps, field measurements (soil surveys, rocks and sample test results) and census data. Data obtained from various sources can be processed, mapped, analyzed and presented as spatial information in accordance with the desired scale through GIS.

3.2. Remote Sensing in the Vulnerability Assessment Model

1) Evaluation Z_1.

The model for assessing the vulnerability of karst groundwater pollution through remote sensing in this study is the parameter data derived from remote sensing, namely Landsat 8 OLI imagery and spectral index values. The parameters chosen are parameters that meet the requirements in the model. The model was formulated through logistic regression analysis by including selected parameters as independent variables. This analysis produces two logistic regression equations to formulate a vulnerability assessment model, namely:

$$Z_1 = -2{,}735 + 104{,}670\ B_2 + 6{,}797\ B_5 - 0{,}672\ IB - 0{,}177\ IK \quad (1)$$

Information:
Z_1 : logistic regression model score
B_2, B_5 : spectral band 2 and band 5 score
IB: spectral rock index score
IK: spectral surface roughness score

2) Evaluation Z_2

The model for assessing the vulnerability of karst groundwater pollution through remote sensing in this study is the parameter data derived from remote sensing, namely Landsat 8 OLI imagery and spectral index values. The parameters chosen are parameters that meet the requirements in the model. The model was formulated through logistic regression analysis by including selected parameters as independent variables. This analysis produces two logistic regression equations to formulate a vulnerability assessment model, namely:

$$Z_2 = -3{,}078 + 86{,}004\ B_2 + 17{,}366\ B_5 - 4{,}268\ IB - 0{,}337\ IK \quad (2)$$

Information:
Z_2 : logistic regression model score
B_2, B_5 : spectral band 2 and band 5 score
IB : spectral rock index score
IK : spectral surface roughness score

Values of Z_1 and Z_2 derived from the logistic regression model function are used to calculate logit values as a basis for determining vulnerability categories. The determination of categories is calculated by the Grid-Calculator module in the SAGA GIS (System for Automated Geoscientific Analyzes). Karst vulnerability assessment is carried out using a vulnerability assessment model. The main data used in vulnerability assessment are spectral data of band 2, band 5, rock index, and surface roughness index. The calculation process is done using the Raster-Calculator module in QGIS and Arcgis software. Image with Z_1 and Z_2 values from band 2, band 5, rock index, and surface magnitude data.

3) Calculation of Y_1

The next class vulnerability assessment is carried out by substituting the logistic regression equation in equations 1) and 2) into binary logit as in equations 3), 4) and 5) as follows:

$$Y_1 = \frac{2{,}718^{Z_1}}{(1+(2{,}718^{Z_1})+(2{,}718^{Z_2}))} \quad (3)$$

Information:
y: logit value in category 1
z: regression value in the 2nd category
e: natural log number = 2,718 Pixel vulnerability category tested

Values of Z_1 and Z_2 derived from the logistic regression model function are used to calculate logit values as a basis for determining vulnerability categories. The determination of categories is calculated by the Grid-Calculator module in the SAGA GIS (System for Automated Geoscientific Analyzes). Karst vulnerability assessment is carried out using a vulnerability assessment model. The main data used in vulnerability assessment are spectral data of band 2, band 5, rock index, and surface roughness index.

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4) Calculation of Y_1

The next class vulnerability assessment is carried out by substituting the logistic regression equation in equations 1) and 2) into binary logit as in equations 3), 4) and 5) as follows:

$$Y_1 = \frac{2{,}718^{Z_1}}{(1 + ((2{,}718^{Z_1}) + (2{,}718^{Z_2})))} \tag{4}$$

Information:
y: logit value in category 1
z: regression value in the 2nd category
e: natural log number = 2,718

The category of pixel vulnerability tested is known from the proximity of the logit regression value to the value of y. The value of the logit regression will be in the range of the value of y which becomes the identity of a category [11]. The result of the calculation of Y1 is included in the 1st category.

5) Calculation of Y_2

The next class vulnerability assessment is done by substituting the logistic regression equation in equations 1) and 2) into binary logit as in equations 3), 4) and 5) as follows:

$$Y_2 = \frac{2{,}718^{Z_2}}{(1 + ((2{,}718^{Z_1}) + (2{,}718^{Z_2})))} \tag{5}$$

Information:
y: logit value in category 1
z: regression value in the 2nd category
e: natural log number = 2,718

The result of the calculation of Y_2 which is included in the 2nd category

6) Calculation of Y_3

The next class vulnerability assessment is done by substituting the logistic regression equation in equations 1) and 2) into binary logit as in equations 3), 4) and 5) as follows:

$$Y_3 = \frac{1}{(1 + ((2{,}718^{Z_1}) + (2{,}718^{Z_2})))} \tag{6}$$

Information:
y: logit value in category 1
z: regression value in the 2nd category
e: natural log number = 2,718

Logit values that are close to $yi = 1$ will be in category 1, if the logit value is close to $yi = 2$ will be in category 2, while the rest will be in category 3. Pixel values that are in category 1 are declared as high vulnerability category pixels. Values in category 2 are stated as pixels with moderate vulnerability. The value in category 3 is expressed as a pixel with low vulnerability.

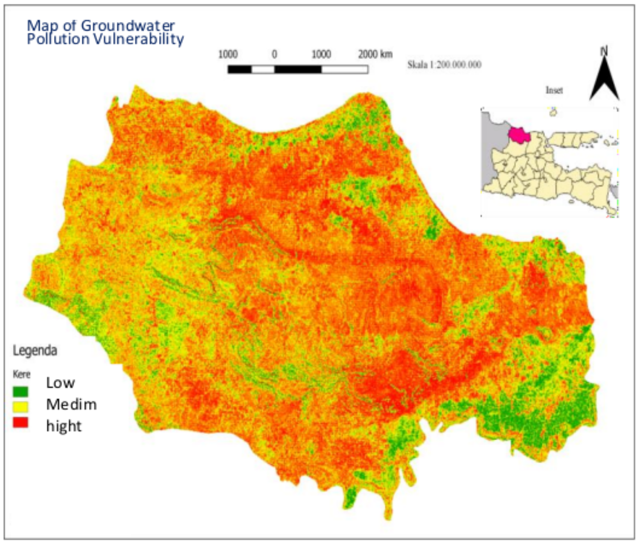

Figure 1: Map of Rengel Karst groundwater pollution vulnerability level

3.3. Vulnerability Map Assessment

The category classification process is performed by logical grid operations on SAGA using the Grid-Calculator module. A basic grid is a grid containing image data with logit values $yi = 1$, $yi = 2$, and $yi = 3$ with the following formula:

$$\text{If else (and (g1> g2, g1> g3), 1, if else (and (g2> g1, g2> g3), g2, g3))} \quad (7)$$

Information:
g1: Grid 1
g2: Grid 2
g3: Grid 3

The process of logical statistical operations produces a raster grid with grid values 1, 2, and 3 on each pixel of the image according to the distance of the logit value to one of the values yi. Figure 1 shows that areas with high vulnerability are symbolized in red, medium vulnerability in yellow and low vulnerability in green. The vulnerability map of the Rengel karst region shows the distribution pattern of each level of vulnerability in the karst region

3.4. Validation of the vulnerability assessment model

1) Vulnerability Validation Calculation

The calculation of the z value is carried out using equations z1 and z2 to get the logistic regression values in categories 1 and 2. Category 3 is the reference category. The next category of vulnerability is based on the results of calculating the logit value of each z-i.

Table 1. Calculation of Vulnerability Validation

Clarification of Observations In The Field					
	Classes	1	2	3	Total
Clasification	1	16	4	2	22

The Result	2	1	1	0	2
Calculation	3	2	0	4	6
Total		19	5	6	30

(Source: Primary data processed in 2018)

Table 1 shows that the comparison value above shows the accuracy of the model calculation against the conditions in the field, the higher the accuracy value generated by the model means the chance of estimating error using the model is smaller. Pixels that can be accurately predicted by the model are shown in bold diagonal cells. The total accuracy value is calculated from a comparison of the number of pixels that can be predicted exactly compared to the pixels that were wrongly predicted. The results of the analysis calculations which in which the number of samples taken is 30, show that the accuracy of the logistic regression model produced in this study is 70%. This means that the vulnerability value of class 1 in the field must be the same as class 1 in the image, so the accuracy of the data can be seen. According to Skidmore [11] states that the accuracy of the assessment can be accepted if the calculation results are greater than 60% as a model that can be accepted and applied, then the logistic regression equation produced in this study can be derived as a mathematical model.

2) Calculation of Accuracy of Research Areas

The calculation of the z value is carried out using equations z1 and z2 to get the logistic regression values in categories 1 and 2. Category 3 is the reference category. The next category of vulnerability is based on the results of calculating the logit value of each z-i.

They are 30 sampling points in the field resulting in an overall average accuracy of interpretation is 94,95 %. The mean is higher interpretation than interpretation result when using Landsat ETM+ 89,30%; ASTER VNIR 91,49%; and ALOS AVNIR-2 93,62% at Wonosobo [12].

Base on the resulting study, the calculation of 30 samples in the field shows that land suitability in the study area is 94,95 % of the calculation results. According to of Aronoff's approach is the following: given a required accuracy of B0 percent and a consumer's risk of 0.05. At the same time, it can be found that the minimum accuracy is 74.0 percent and that the producer's risk is 0.04 for a classificati6n with an actual accuracy of 90 percent [13]. Based on this research, the suitability of the land produced in this study can be accepted for the suitability assessment of the study area.

4. Conclusions

The vulnerability assessment of groundwater pollution is one alternative to protect groundwater quality. Groundwater vulnerability assessment will provide information about which 15 locations naturally have a high level of sensitivity to changes and human activities on the surface of the earth. By interpretation of remote sensing data is very useful in identifying the distribution of pollutant sources which is done through the interpretation of land uses that are in certain locations. Furthermore, by carrying out the process of weighting, assessment, and mapping using the GIS application, information will be obtained about which locations have the highest possibility of pollution. The study showed that the average researched area was classified as vulnerable to pollution.

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