THE APPLICATION OF LANDSAT IMAGERY PROCESSING FOR EROSION STUDY

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ABSTRACT

Landsat imagery has a relatively smaller resolution than topographic maps, within certain limits it can support the morphometric analysis of a watershed. The results of the average difference test between the drainage density population from Landsat imageries and topographic maps, at a significant level of 0.20, are proven to be significant. In certain cases, its value can reflect the effectiveness of erosion in an area. For relatively supportive bedrock types, it is can reflect the erodibility of soil from weathering the bedrock. Combination of fit some bands of Landsat Images can appear unique tones and features. They can lead for erosion zones delineation. Thus phenomena reflected by various scatter gram patterns. The range of digital number can reflect erosion grade by ratio analysis of band 1- band 4 and band 1- band 7. The phenomenon shows that Landsat imagery can be used for delineation of erosion zones based on the characteristics of the earth's surface constituent materials through digital number range analysis.

Keywords: Landsat imagery, digital number, band ratio, erosion, Bandung Basin

1. INTRODUCTION

The rapidly developing remote sensing technology has changed the concept of thinking of scientists in studying natural phenomena (Aber, 2005). The method of direct survey on the earth's surface has been equipped with a method of interpretation of remote sensing data. This completeness is even more evident when the data analysis is done digitally. The use of remote sensing methods in the field of mineral exploration and geological mapping allows obtaining data from a large area that is fast, efficient and relatively inexpensive compared to direct mapping in the field (Balia, 1993). The crack patterns, topographic expression, and drainage density can assist in the interpretation of rock characteristics and their response to erosion (Sudradjat, 1978).

Remote sensing technology has now developed rapidly, both with regard to vehicles, power, sensors, and data processing techniques. Now a variety of remote sensing data is available. Landsat imagery is a type of image that has many users. Landsat missions have been ongoing since 1972. Based on the range of electromagnetic wavelengths used, Landsat consists of several wave channels or bands. Landsat 7 has advantages over the previous generation, including the addition of a panchromatic channel with a wavelength of 0.5 to 0.9 μm and a resolution of 15 m.

Landsat imagery is ideal as a source of information for medium-scale landscape mapping, namely 1: 100,000 or smaller scale (Aber, 2005). In a conventional image processing system, steps must be carried out separately, so it requires a lot of time and storage space. Whereas the current generation software allows image processing operations to be made in only one step, which consists of an operation package and the results are directly displayed on the monitor. The arrangement of the remote sensing image data processing steps is called an algorithm (van Genderen & Uiterwijk, 1987; Balia, 1993; Earth Resource Mapping Ltd., 2003).

Algorithms are used to display simple data, very complex processing and modeling operations that involve multiple images, data transformations, and data overlays. Examples of image processing operations using algorithms include image classification, image merging, image mosaics, and mathematical transforma-tions such as the band ratio and principal components analysis.

In the field of geology, algorithms can be applied to recognize complex structural patterns and estimate rock distribution (Balia, 1993). Algorithm application in the field of mineral exploration allows users to perform quantitative color analysis of minerals (Susilowati, 1994).

In line with advances in data acquisition techniques through remote sensing technology, techniques for processing data into attractive and powerful information are also developing rapidly. Advances in information technology enable data retrieval procedures through location coordinates or vice versa, looking for numerical data by indicating the location of a graphic object on the monitor (Aronoff, 1989). This system is known as GIS (Geographic Information System). GIS is also equipped with the ability to create thematic maps, map overlays, modeling spatial data, etc.

GIS consists of several main components, namely data (graphic, numeric, and image), computer hardware, computer software, human resources for managing computers, and systems. (Aronoff, 1989). Based on the type and method of handling, data can be grouped into two groups, namely spatial and non-spatial data. The GIS software package basically consists of five technical modules, namely data entry and checking, data storage, data output and presentation, data manipulation, and interaction with various users. The system is a procedure, which is used to handle and manage data as information material to be displayed.

The application of remote sensing technology and GIS in research related to erosion and tectonics has been carried out by several researchers, including Van Genderen & Uiterwijk (1987), Sukiyah (1993), Haryanto (1994), Ogawa et al (1997), Mitasova (1999), Kandrika & Dwivedi (2003), Sukiyah et al (2004), Okubo & Rokugawa (2005), Jordan et al (2005), Sukiyah et al (2006), Sukiyah et al (2007), Sukiyah (2007), Sukiyah et al (2015), Sukiyah et al (2016), Makkawaru et al (2016), Sukiyah et al (2017), Sukiyah et al (2018), and Riswandi et al (2020). All of them utilize remote sensing technology and GIS for erosion studies and partly for other geomorphological aspects including morphotectonics with various study areas.

Based on the results of this literature study, the authors argue that the use of remote sensing technology and GIS is still needed and relevant to support research related to erosion. Erosion traces recorded in landscape forms can be recognized through analysis of remote sensing data. Referring to the advantages of using remotely sensed data, especially satellite imagery, synoptic view, repetitive coverage, multispectral data, and low-cost data, then remote sensing technology has the potential to support erosion model analysis.

However, there are limitations to human capabilities, especially when the analysis is done manually. One of the limitations is the human sense of sight, which is only able to sort out the reflection wavelengths from 0.4 to 0.7 μm. Another limitation is that the image scale is generally very small, making it difficult to distinguish relatively subtle traces of erosion (splash, sheet and rill erosion). The limitation can actually be overcome by processing digital remote sensing data. This processing method makes it possible to perform a combination of several satellite image channels. In addition, it is best if combined with the interpretation of aerial photographs on a larger scale to overcome this limitation.

The results of previous research conducted by Sukiyah et al. (2006) showed a correlation between tectonics, volcanic rock types, soil characteristics, land use, and erosion. However, relationship patterns and levels of interaction have not been studied in an integrated manner. Optimization of digital image processing, combined with interpretation of aerial photographs, results of field surveys, and laboratory analysis, is expected to be able to identify the patterns of interaction among these various variables in an integrated manner.

2. METHODOLOGY

Some of the variables that are not possible to measure in the field are measured using satellite imagery, aerial photographs and topographic maps. The method of interpretation and information acquisition from remote sensing images used in this study are (i) visual interpretation based on the appearance of hues, patterns, shapes, textures, etc .; (ii) identification of objects based on spectral signatures or digital numbers; (iii) integration of remote sensing data with other data types, for example DEM (Digital Elevation Models) and DTM (Digital Terrain Models); and (iv) interpretation of remote sensing images quantitatively, namely measurement of horizontal dimensions, slope, DN ratio, rivers, valleys, etc.

Digital Landsat image processing is carried out with the support of ER Mapper software version 6.4, while the analysis of data management is supported by MapInfo software version 8.0. The results of image analysis which is equipped with the results of the interpretation of aerial photographs provide a variable response to the characteristics of rocks, soil and landscape to electromagnetic waves through several channels (band 1, band 2, band 3, etc.). Variables of rock and soil characteristics obtained from Landsat image processing include DN which can be formulated into albedo. DN shows the level of darkness or hue measured numerically with a range between 0 to 255 for bands 1, 2, 3, 4, 5, 6, 7, and 8 in Landsat 7 imagery (*Earth Resource Mapping Ltd*, 2003). The combination of various wave channels in the RGB display is also carried out, in order to produce a distinctive hue for erosion model analysis. Quantitative analysis can be applied to a DN population, either on a single band or a combination of three bands (Figure 2).

Figure 1. The map shows the research locations in the South Bandung area, West Java

Measurement of landscape and tectonic response variables that can be carried out on remote sensing data media are slopes, river segment azimuth, landscape straightness azimuth, river density, river branch ratio, and river branch segment length ratio. The three-dimensional appearance using a stereoscope or software (Surfer, MapInfo, and ERMapper) is very helpful in measuring the slope, as well as the azimuth of river segment and landscape alignment.

The sampling method for DN as a response variable for land, landscape, and tectonic characteristics on the Landsat image media is by means of cluster sampling. The research area is divided into several regions (clusters), then samples are taken randomly in each region. The sample DN obtained is used for land classification, as the basis for delineating area units that have a certain level of erosion vulnerability.

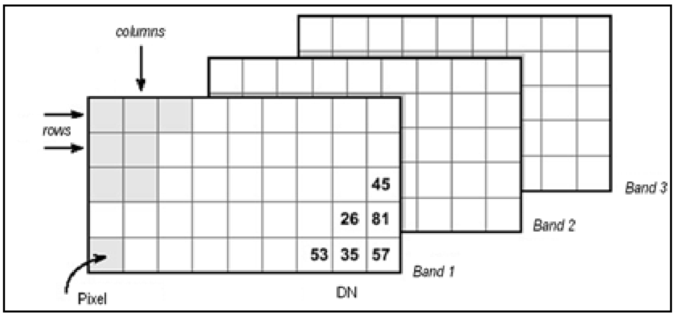

Figure 2. The elements in a digital format imagery (Drury, 2001)

The results of digitally processed Landsat imagery allow data in raster format to be displayed in several ways, namely (i) spatially; (ii) data wave frequency format; and (iii) spectrally as a scattergram. Display data in spatial format in the form of images

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or maps that have geographic references (georeferenced). The appearance of the data wave frequency makes it possible to remove noise. Data displays of this type are usually combined with geophysical data. While the spectral display of data can provide two-dimensional information on the frequency of data. This type of view is usually used as the basis for land classification.

The scattering diagram shows the correlation between DN data on two different bands (band 1 vs band 2, band 1 vs band 3, band 4 vs band 5, etc.) in the same image. The value of each point on the scattering diagram is the result of calculating the combined number of values for the two types of input bands. The area of the scatter diagram is displayed on the image using the scatter region classification layer. Scattering diagrams can be used to validate sample areas, create new areas, and create vector areas (polygons) for the purposes of displaying spatial data in map form.

Matched pixels in the scattering diagram are shown in the same color as the selected area in the image. Regions or polygons can use existing data, draw new regions, or call sample regions (training regions) from other places. Two images from the same area but with different shooting dates, can use the sample area that has been assigned to one of the images. The scattering diagram can also be used to refine the sample area before the image classification process.

3. RESULT AND DISCUSSION

The Landsat imagery used for analysis in this study has a very large size, ranging from 16,186 kb to 258,547 kb (Table 1). Therefore, in order for data processing to be more optimal and fast, the image needs to be cut (image subset) according to the scope of the research area.

Table 1. Specifications of the 2001 Landsat ETM + imagery used in the study

Band	Size (kb)	Resolution (dpi)	Size (pixel)	
			Horizontal	Vertical
Band 1	64,667	72	8665	7635
Band 2	64,667	72	8665	7635
Band 3	64,667	72	8665	7635
Band 4	64,667	72	8665	7635
Band 5	64,667	72	8665	7635
Band 6	16,186	72	4333	3818
Band 7	64,667	72	8665	7635
Band 8	258,547	72	17330	15270

The algorithm is a series of digital image analysis steps that can be saved in a file format. Algorithm files have the extension "alg" for example, Bandung.alg. Algorithm files that have been saved can be reused, by opening or displaying them using image processing software, for example ER Mapper.

In the case of erosion, the algorithm can be used to improve the capability of satellite image data in delineation of areas prone to erosion. Improving the capabilities of satellite imagery includes several ways, including clarifying hues and patterns using a variety of filters available in image processing software, display of scattergrams, combinations of various bands, and supervised image classification.

3.1 The Characteristics of Hue and Pattern

The hue in conventional images (in the form of printed or hardcopy) is influenced by five factors, namely the characteristics of the object, the materials used, the emulsion processing, the weather, and the location of the object. In the digital format, there are only three possibilities that play a role in influencing the hue, namely the characteristics of the object, the weather, and the location of the object (Sutanto, 1992). Therefore, the use of images in digital format is recommended for a certain level of accuracy.

The distinctive hues and patterns can be obtained by combining the Landsat ETM + imagery in 2001 bands 1, 4, and 7. The combination of these bands can produce the appearance of the Bandung Basin area as shown in Figure 3. In the northern part, the Lembang fault is visible, indicated by a relatively west-east direction. The Ciwidey - Patrol- Wangisagara Fault is visible in the

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center. The existence of this fault is indicated by its relatively alignment with the Lembang fault. The two faults are clearly visible in the Landsat image due to their regional nature, and their traces are partly recorded in volcanic rocks which are relatively hardy compared to the surrounding rock formations.

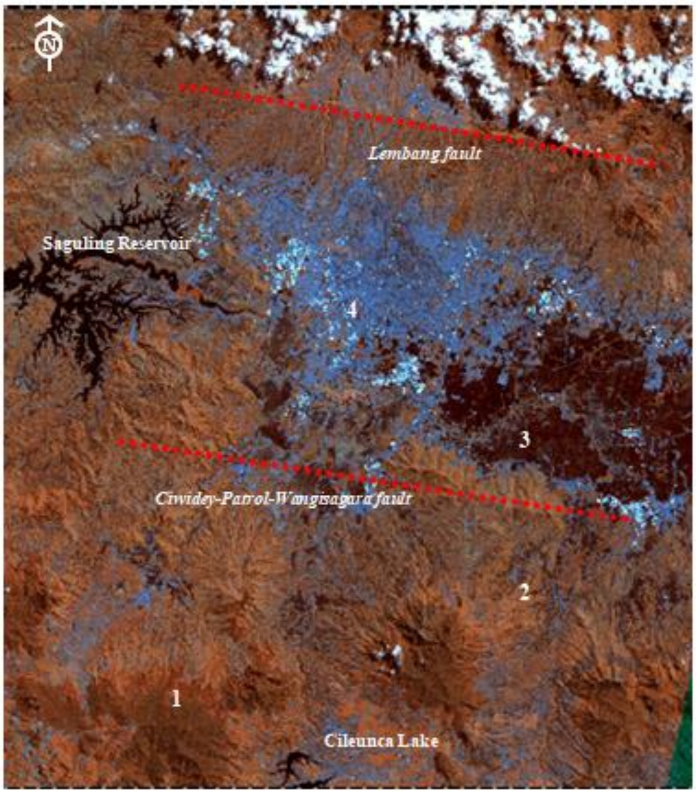

Figure 3. The appearance of the Bandung Basin area in the 2001 Landsat ETM + imagery. (1) forest areas, (2) cultivation areas (fields, plantations, etc.), (3) rice fields and wetlands, (4) settlements, offices, and industries

Figure 4 shows the scattergram diagram obtained from the image analysis in Figure 3. The diagram shows the correlation between a number of DN from two bands. Each pixel is displayed in two dimensions, represented by a number on the x and y axes. The colors displayed represent the accumulated frequency (density) of DN data values in both bands. The areas of high density scattering diagrams are shown by the color at the top of the yellow to red band, while the areas with low density are in light blue - dark blue. Specifically, areas of high density are features with a large number of digital numbers in both bands, for example large areas of water or moisture. The wide scattering of data points indicates that the data in bands 1 and 4 are weakly correlated. This condition describes the different types of information between the two bands. Band 4 records reflectance in near infrared wavelengths while band 1 records reflectance at visible wavelengths.

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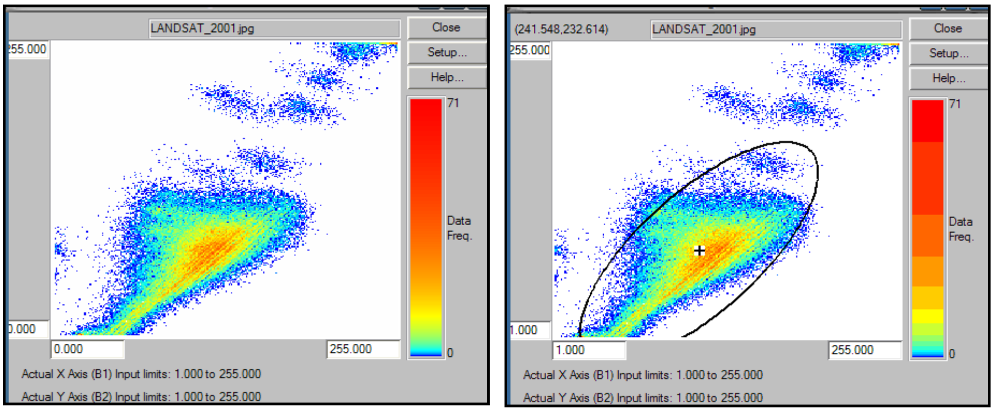

Figure 4. The scattering diagram analyzed from the Landsat imagery display in Figure 3

Based on the interpretation of remote sensing data, it can be estimated that areas experiencing deformation due to active tectonics and areas prone to erosion, sedimentation, and flooding. Land appearance as in Figure 3, namely (1) forest areas, (2) cultivation areas (fields, plantations, etc.), (3) rice fields and wetlands, (4) settlements, offices, and industries, can guide to carry out further erosion analysis.

The appearance of distinctive hues and patterns in Landsat images can also be used for morphotectonic analysis. Certain hues and patterns can guide the identification of morphological lineaments and trends, as a representation of the existence of geological structures. This analytical ability has been utilized for morphometric analysis.

Even though Landsat imagery has a relatively smaller resolution than topographic maps, within certain limits it can support the morphometric analysis of a watershed, such as drainage density (Dd). The results of the average difference test between the Dd population from the Landsat image and topographic maps, at the real level (α) of 0.20, are proven to be significant. In certain cases, the value of Dd can reflect the effectiveness of erosion in an area. For relatively supportive bedrock types, the Dd price in the watershed can reflect the erodibility of the soil from weathering the bedrock.

3.2 Erosion Responce on Digital Number

The digital number is the response of several electromagnetic wave channels to the characteristics of objects on the earth's surface. This fact is also revealed in the response to erosion, especially for land without cover. A certain range of digital numbers can provide information on the quality or level of erosion, namely very low erosion (level I), low erosion (level II), moderate erosion (level III), high erosion (level IV), or very high erosion (level V) .

The results of the analysis of the erosion data sample and DN on each grid show that the higher the annual average erosion intensity, it will be reflected by the relatively decreasing response of the digital numbers. Table 2 below shows the difference in average erosion DN within each class, which is obtained from the analysis of 158 samples. In the ratio of DN band 1 to band 4 and the ratio of DN band 1 to band 7, it appears that the response tends to decrease in line with the increase in the rate of erosion. Meanwhile, the ratio of DN band 4 to band 7 is fluctuating. This phenomenon is in line with deduction, that the higher the level of erosion, the land in the area is relatively more damaged and seems moist compared to land with a low level of erosion.

Table 2. The characteristic of digital number (DN) in erosion class

No	Erosion (ton/ha/year)	Erosion Hazard Class	Ratio band 1 / band 4	Ratio band 1 / band 7	Ratio band 4 / band 7
1.	< 15	I	1.10	2.02	1.94
2.	16 – 60	II	0.82	1.62	2.00
3.	60 – 180	III	0.96	1.60	1.75

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4.	180 – 480	IV	0.94	1.68	1.89
5.	> 480	V	0.69	1.56	2.27

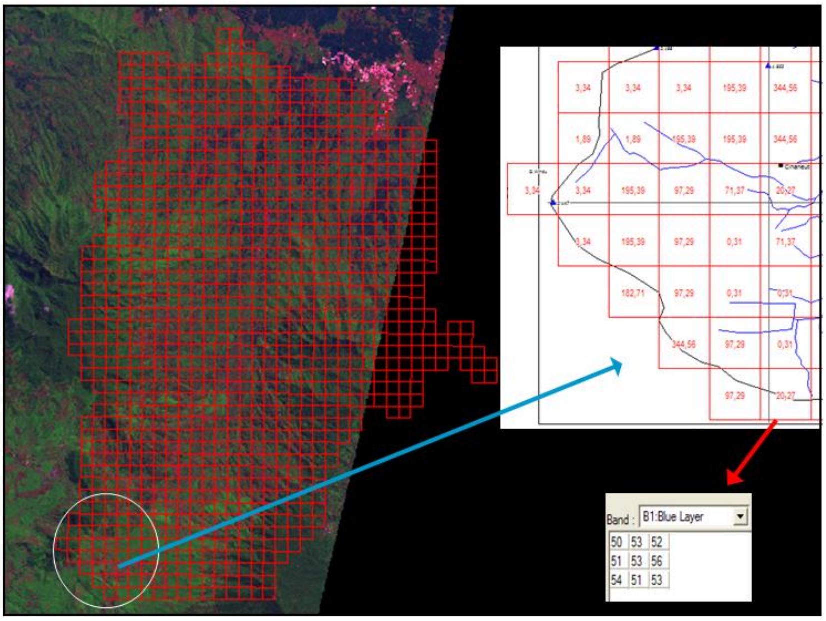

Figure 5. Extraction of digital number using image processing and GIS software

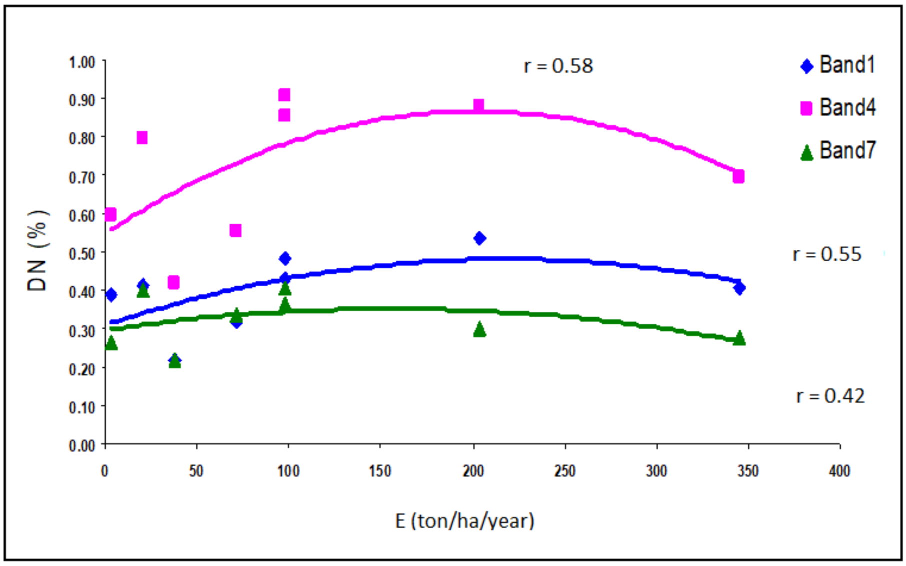

Figure 6. Graph pattern between variables of erosion and digital number proportion in Landsat imagery

Data of digital number can be obtained through image analysis using image processing software, such as ER Mapper. Menu of "*View* ☞ *Cel values profile*" can help the analysis process. Erosion intensity information on a suitable grid can be obtained by overlaying the grid layer containing the erosion information and the image layer (Figure 5).

The response of the digital numbers to the intensity of erosion can be described in the form of a graphic pattern (Figure 6). This can provide information that the erosion intensity from 0 (zero) to about 160 tons/ha/year is responded to by an increase in the reflectance of the digital number, on the other hand there is a decrease in erosion

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intensity greater than 160 tons/ha/year. This phenomenon shows that further analysis with various correction factors is needed to optimize the resulting graphic pattern. The strong correlation between the two variables can form the basis for finding a reliable method for predicting erosion through satellite imagery.

3.3 Erosion in the Southern Bandung Basin

The southern part of the Bandung Basin is a Quaternary volcanic landscape. This landscape has characteristics that reflect the diversity of its constituent materials. Active tectonic traces also control landscape forms, including the lineaments of the ridge and the shape of the valley. These characteristics can be studied more deeply to determine the level of erosion intensity that develops in the area.

Based on the analysis of the level of erosion, it is known that areas that are very vulnerable to erosion are around Mount Halimun, Mount Sadatapa, Pasanggrahan, Cinanggela, upstream Citonjong River, upstream Rancakole River, Cidulang, northern slopes of Mount Bukitcula and Nini hills, and the Citarum River valley in the area of Dangdang. Whereas areas prone to erosion are around Cihaneut, Lembangsari, Cirawa, Cikembang, along the normal fault line of Mount Wayang, the Cihejo River valley, the upstream area of the Cirasea River, Ancol, and the Cirasea River valley in Pakutandang. Areas with relatively low to low levels of erosion are the peaks of Mount Gambung, Mount Malabar, Neglasari, the Cigalugah valley around Patrol, the Citarum River valley in Selaawi, Malimping, Ibun, the Cijoho River valley, Mount Sanggar, the Cibuniherang River valley, Datar, Mount Guha, and the peak area of Mount Bedil-Wayang-Gambung. Other areas, apart from those already mentioned, have relatively moderate levels of erosion. This area is usually a relatively flat area or a mature river valley area, for example around the Patrol.

Areas that are prone to erosion tend to be in the western part of the study area, while those with relatively low erosion intensity are in the eastern part. Geologically (Alzwar et al, 1992), areas prone to erosion are composed of coarse tuff (Qtr) volcanic products of Mount Malabar-Tilu and altered andesite which are products of Mount Waringin-Bedil or old Malabar, while low erosion intensity is composed of fine tuff. (Qts) a product of Mount Malabar-Tilu and tuff of lapilli (Qtl) a product of Mount Guntur-Pangkalan-Kendang. The western region is generally quite strongly deformed, while the eastern region is relatively stable. The combination of lithological variations and deformation intensity results in volcanic soil that is easily eroded when other erosion factors are met.

4. CONCLUSION

Even though Landsat imagery has a relatively smaller resolution than topographic maps, within certain limits it can support the morphometric analysis of a watershed, such as drainage density. The results of the average difference test between the drainage population from Landsat imageries and topographic maps, at a significant level (α) of 0.20, are proven to be significant. In certain cases, the value of drainage density can reflect the effectiveness of erosion in an area. For relatively supportive bedrock types, the drainage density value in the watershed can reflect the erodibility of soil from weathering the bedrock.

The characteristic of digital number range can reflect the level of erosion in an area without land cover. Reaching a certain erosion intensity (medium), digital number reflectance has increased but tends to decrease for areas with high erosion intensity. The phenomenon shows that Landsat imagery can be used for delineation of erosion zones based on the characteristics of the earth's surface constituent materials through digital number range analysis.

The characteristics of volcanic rock and their response to erosion are reflected in the hue and combination of various bands. The results of the analysis of the erosion data sample and digital numbers on each grid show that the higher the annual average erosion intensity, it will be reflected by the relatively decreasing response of the digital numbers.

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