THE IMPACT OF EROSION-SEDIMENTATIONS TO SILTATION OF KENDARI BAY AND IMPLICATIONS IN TOURISM DEVELOPMENT OF SOUTHEAST SULAWESI, INDONESIA

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ABSTRACT

Kendari Bay is a strategic area, especially for Southeast Sulawesi Province. There lies Kendari city as the provincial capital. The government is intensively developing tourism to increase local revenue. Tourism potential that can be developed includes marine tourism, mangrove tracking, and Tahura forest as the lungs of Kendari City. Sedimentation in the bay is a major problem of silting. Sediment comes from the erosion in Kendari drainage basin. The rivers that carry material of erosion products, mostly boils down in Kendari Bay. This condition can threaten the development of tourism in the bay area. Monitoring of erosion and sedimentation should be done on an on-going basis. USLE formula be used calculate erosion rate. Several factors combined for reasons of easiness in the process of data acquisition. The data source obtained by various methods, one of them is satellite imagery processing. The study uses images of Landsat 8 OLI 2013 and SRTM 30 m. The whole data are processed using GIS software. The results showed that erosion rate in the area categorized moderate until very high level. The tree planting of upstream area and sediment dredging in the downstream area is done to slow down the rate of siltation in Kendari Bay.

Keywords: Siltation, satellite imagery, tourism, drainage basin, Kendari Bay.

1. INTRODUCTION

Kendari bay is a strategic area, where there is the central government of Kendari province. Several watersheds drain the river carrying eroded material into this bay. Research relating to materials eroded and their impact on the silting of the bay needs to be done. The results of the research can be a reference for the conservation design so that Kendari bay can be sustainable and provide comfort for the people in the province.

The tourism potential that can be developed varies greatly, from mountain tourism to marine tourism. Kendari City Government is trying to develop Kendari Bay to become a reliable tourist attraction (Kompas. Com, 2011). One thing that becomes an obstacle for the management of tourism objects is the boundary of the coastal tourism area. In the area around the bay there are still several fishing boats that are no longer functioning. One reason is silting in some areas of the bay which is relatively fast.

Geomorphology of Kendari Basin is very unique. Kendari city is located in the plains of the Kendari Basin, surrounded by high topographic relief. The northern part of the basin is Nipa-Nipa Mountains trending east – west. These mountains are bounded by the Banda Sea in the west and Kendari Bay in the south. Nipa-Nipa foothills lay the Kendari old city and became the centre of the old settlements is dense. Nipa-Nipa Mountains have a height about of 238 m above sea level. On the west side bounded by range of hills Bondoala, extends from North to South, where the Northern ranks Bondoala hills bordering the western part of the Mountains Nipa-Nipa. Bondoala hills have an average altitude of 141 m above sea level. In the southern part of the Kendari Basin there Wolasi Mountains that extends from West to East, where the Western part of Wolasi Mountains bordering with Southern Hills Bondoala. Mountains Wolasi has an average altitude of 617 m above sea level. Last is Abeli hills in the West part of Kendari Basin where the Northern part of this Abeli hills bordering with Kendari Bay and in the Southern parts bordering Wolasi Mountains. Abeli hills have an average altitude of 188 m above sea level (Figure 1). Kendari basin is a water catchment area or watershed with an estimated area 629 sq km and perimeter 187.91 km. Kendari Basin can be divided into four sub watershed, i.e. Wanggu river, Mandonga river, Kambu river and Abeli river. A watershed is the area of land where all of

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the water that falls in it and drains off of it goes to a common outlet. Kendari Basin outlet is Kendari Bay, that why mostly of all material from Kendari erosion goes to sedimentation there.

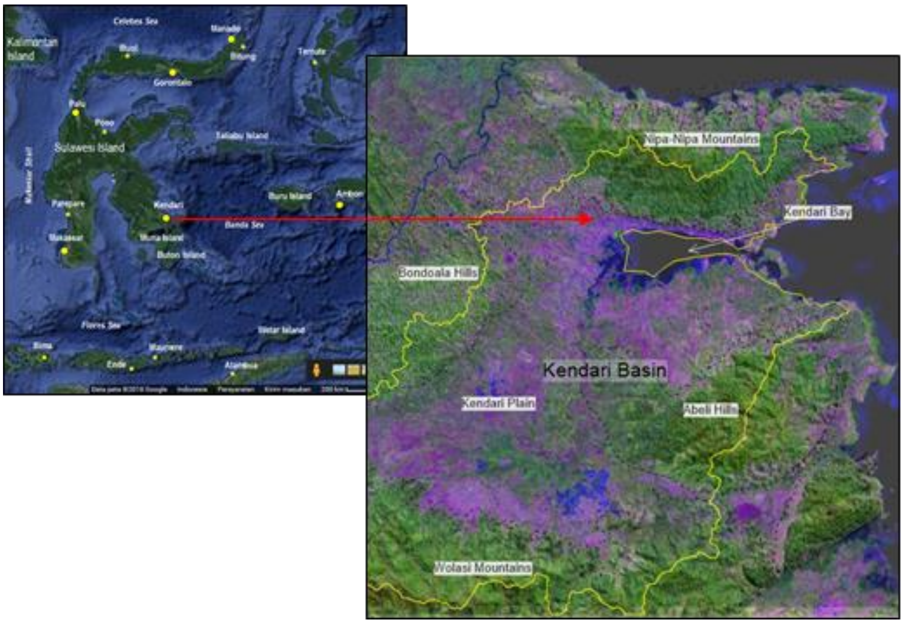

Figure 1. Location of research in Kendari Basin

2. LITERATURE STUDY

Geological setting of Kendari Basin is laying by various lithology formations. Dominantly, Kendari Basin is laying metamorphic rock and clastic sediment such as meta sandstones known as Meluhu Formation (pre Tertiary age), Sulawesi Molasse (Tertiary age), coral limestone, and alluvium deposit (Quaternary) (Surono 2013). Sulawesi Molasses mainly composite by quartz sandstone with characterize very thick deposit and uncompact condition.

Erosion is one of the geomorphological processes that play a role in the development of landforms. Erosion events are controlled by exogenous force through geomorphological agent (Ashari, 2013). The utilization of satellite data can help improve the accuracy of some of the input parameters such as increasing land cover information of detail and get a complex topography on a large area, such as in the watershed (Trisakti, 2014).

Remote sensing is earth surface feature data collecting from high ground. Earth surface data is visual data from picture of object on earth ground. There are two kinds of data collecting by remote sensing; image data and numerical data (Sulaksana & Hamdani, 2014).

Some models of soil erosion have been developed as Water Erosion Prediction Project (WEPP); The Chemical, Runoff, and Erosion for Agricultural Management System (Creams); Universal Soil Loss Equation (USLE); the Revised Universal Soil Loss Equation (RUSLE). Models are often used to predict erosion is USLE or RUSLE, due to the simple model and efficient (Wibowo et al, 2015).

Based on the ratio between silt to clay content of soil mass, the validation of the erosion formula generated the modification of USLE for both silt soils (symbolized MH) EMH = 0.77 RKLSCP and clay soils (CH) ECH = 0.51 RKLSCP respectively. These new formulas, possessing the errors about 6%, represent the grain size distribution proportion and also cohesion of soil mass which explain the characteristic of its erodibility (Sukiyah et al, 2010). The study uses a model USLE with support of ArcGIS for calculating the rate of erosion in Kendari Basin.

The local government is intensifying tourism in Central Sulawesi. This is reflected in various development outcomes that support tourism activities. Among them are access roads to tourist sites, arrangement of traders around tourist attractions, development of superior products, and so on. Everything provides comfort for tourists who visit.

3. MATERIAL AND METHOD

The study uses a model USLE with support of ArcGIS for calculating the rate of erosion in Kendari Basin. Geographical Information

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System has been used for data preparation, data manipulation, and analysis of data. The on screen digitizing technique has been used to delineate Kendari Basin using SRTM 30 m for extract the boundaries. The drainage basin boundaries have been identified through a toolset (fill, flow direction, flow accumulation and snap pour point) in ArcGIS software.

The basin morphometric such as elevation, length of slope, and degree of slope of the study area was geo-referenced and digitized from SRTM 30 63_13. The image can be downloaded at http://srtm.csi.cgiar.org and using the capabilities of Arc Info and ArcGIS tools. The Digital Elevation Model (DEM) representing the watershed terrain topology. Further, the developed DEM was processed to generate or delineate the watershed and sub-watersheds using the hydrology tool of spatial analyst module.

Landsat 8 (provisionally named the Landsat Data Continuity Mission) was finally launched on 12th February 2013, acquired its first images in March 2013 and is now officially named Landsat 8. Imagery is available free of charge through the standard Landsat sites.

Remote sensing techniques have reduced field work to a considerable extent and land use boundaries are more precisely delineated than in conventional methods. Visual interpretation is based on shape, size, tone, shadow, texture, pattern, site and association. This has the advantage of being relatively simple and inexpensive.

Analyses of land use cover using the Normalized Difference Vegetation Index (NDVI). It is based on the fact that chlorophyll absorbs visible waves Red while containing mesophyll leaf structure reflects wave NIR (Emil and Kamila, 2013). Equation NDVI as follows:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad \ldots\ldots\ldots\ldots (1)$$

Landsat 8 OLI have different band wavelength than others Landsat image product. Landsat 8 OLI has more band than others with high number of their bit (Table 1).

Table 1. Spectral characteristics of Landsat 8 (OLI)

Band	Explanation	Wavelength (μm)	resolution
1	Coastal aerosol	0.43 – 0.45	30 m
2	Blue	0.45 – 0.51	30 m
3	Green	0.53 – 0.59	30 m
4	Red	0.64 – 0.67	30 m
5	Near Infrared (NIR)	0.85 – 0.88	30 m
6	Short Wavelength Infrared (SWIR-1)	1.57 – 1.65	30 m
7	Short Wavelength Infrared (SWIR-2)	2.11 – 2.29	30 m
8	Panchromatic	0.50 – 0.68	15 m
9	Cirrus	1.36 – 1.38	30 m
10	Thermal Infrared (TIR-1)	10.60 – 11.19	100 m
11	Thermal Infrared (TIR-2)	11.50 – 12.51	100 m

Sources: Iron et al (2017)

Extracting image information, from various objects are identified through a process of image patterns interpretation. The response values of visible spectrum of pixel values are contained in each band image are various. It is not always easy to analyse and interpret them. The classification of image covering preparation, sorting, and grouping all the pixels into multiple classes (groups) based on object criteria. The purpose of grouping process is extracting the patterns of the dominant spectral response in the image itself, generally in the form of land use classes. Classification method in the image is divided into two kinds: unsupervised and supervised classifications.

The unsupervised classification processes used classify the pixels on the image based on the statistical aspects alone, without defining a class by user. While on supervised classification refers to the classes defined by the user (training site or area). The classes are meant containing samples are assumed to have homogeneous properties. Band 4, as Red spectral, with wavelength are 0.64 – 0.67 μm. It is characteristic for vegetation absorbs nearly all red lights (it is sometimes called the chlorophyll absorption band). This band can be useful for distinguishing between vegetation and soil in monitoring vegetation health (Figure 2). Band 5 as Near Infrared (NIR) with wavelength is 0.85 until 0.88 μm (Figure 2). It is looking shown Figure 3. Since water absorbs nearly all light at this wavelength, water bodies appear very dark. This contrasts with bright reflectance for soil and vegetation so it is a good band for defining the water or land interface

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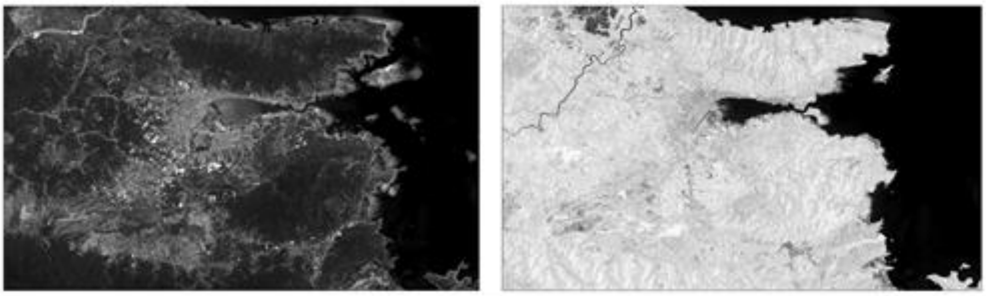

Figure 2. Band 4 as R-visible wave from Landsat 8 OLI (left) and Band 5 as NIR visible wave from Landsat 8 OLI (right)

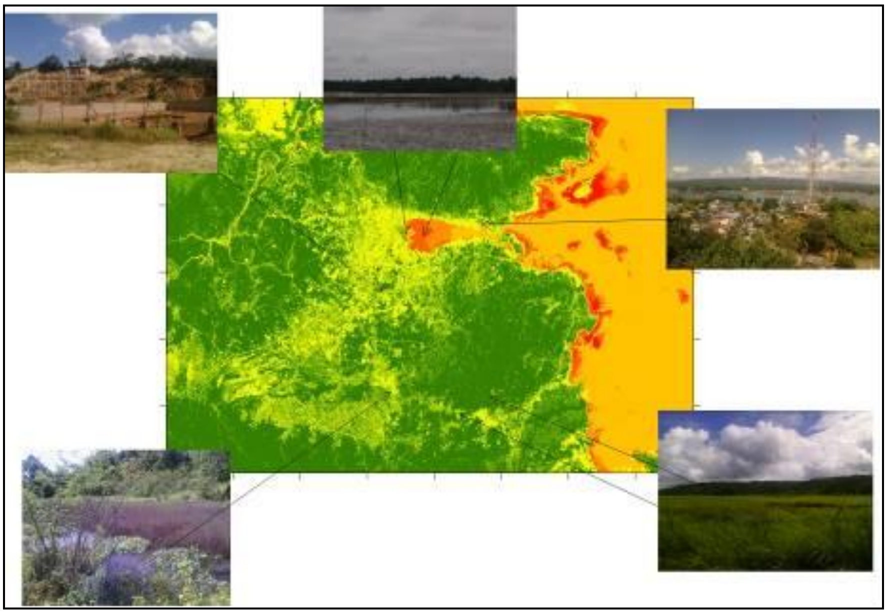

Figure 3. Image of NDVI result 10 classes of land use covering map. Dark green as high density of vegetation and very light green as low density of vegetation.

The Landsat 8 imagery is analysis use the equation 1. The result from NDVI analysis can be grouped into 10 classes. The 10 classes were identified by using the method of supervision classification. The classes can be shown by Figure 3.

The results of Landsat 8 OLI imagery analysis use the NDVI, on though using ArcGIS 10 tools. The class that have been identified can be computed area and the proportion of the area. It will be used to get the CP value of Kendari Basin. The results are validated in the field so as to produce guided classification and simultaneously show that the results of analysis through NDVI can be used further to determine CP value in the erosion susceptibility analysis by USLE method later known as supervised classification. The result from delineation with supervised classification after NDVI analysis can be shown at Table 2. Index of colour be used for identified object at the field. The colour index is known as digital number (DN) like finger print in human or known as DNA of image.

Table 2. The result of NDVI analysis for land use classification

Landuse	Color NDVI	Index of Colour NDVI	Area (Ha)	Proportion of total area overall
Reed		120	8,595.72	0.14
Thicket		87	9,240.99	0.15
Dense forest		97	2,268.90	0.04
Mixed farms		72	5,557.47	0.09
Settlement		57	12,647.10	0.20

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Plantation		79	16,103.26	0.26
paddy field		67	1,128.27	0.02
Thicket		62	1,271.66	0.02
Fishpond		42	81.67	0.00
Moor		49	6,005.44	0.10
		Total	62,900.48	1.00

Research method can be drawing shown by Figure 4. The soil erosion is prediction using USLE equation. The topographic factors and cropping management factors from SRTM 30 m and Landsat 8 OLI using remote sensing analysis.

Prediction of soil erosion is calculated using the equation as proposed by Wischmeir and Smith (1978; in El-Swaify et al, 1982), and is known as USLE equation:

$A = RKLSCP$ .... (2)

A = the number of eroded soil

R = factors erosivity rain

K = soil erodibility

LS= length and slope factor

C = crop management factors

P = land management factors

The values of K, LS, CP is a conversion of a map of soil types, slope maps and land use maps using the tables by comparing studies that have been done before by considering the suitability of areas such as the tropics and others. Tables used for the conversion of the values of K (Table 3), LS (Table 4), and CP (Table 5) derived from research Efrodina (2015).

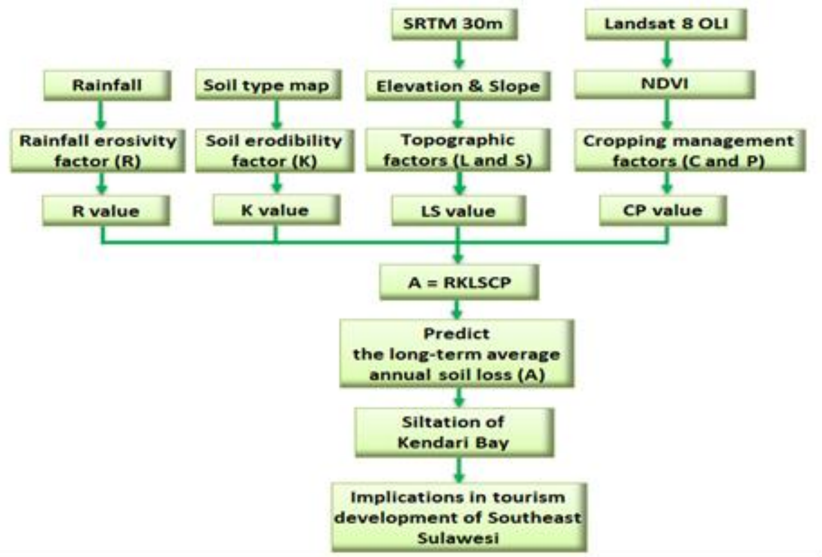

Figure 4. Research method diagram

Table 3. Soil erodibility index (K)

Number	Soil Type	K-value
1	Reddish brown latosols and lithosol	0.43
2	Reddish yellow latosols and lithosol	0.36
3	Mediterranean complex and lithosol	0.46
4	Reddish yellow latosols	0.56
5	Grumusol	0.20
6	Alluvial	0.47
7	Regosol	0.40
8	Latosols	0.31

Source: Efrodina (2015)

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Table 4. Geomorphology index (LS)

Slope class	Slope degree (°)	LS-value
I	0-8	0.40
II	8-15	1.40
III	15-25	3.10
IV	25-40	6.80
V	>40	9.50

Source: Efrodina (2015)

Table 5. Index of crop and land management (CP)

Crop and Land Management	CP Value
Forest: without undergrowth and litter	0.50
Thicket:	
a. Undisturbed	0.01
b. Partly grassy	0.10
Garden:	
a. Farm	0.02
b. Yard	0.20
Plantation:	
a. Perfect ground cover	0.01
b. Ground cover partially	0.07
Grassland:	
a. Perfect ground cover	0.01
b. Ground cover partially, covered with weeds	0.02
c. Weeds	0.06
d. Citronella	0.65
Agricultural crops:	
a. Tubers	0.51
b. Grains	0.51
c. Nuts	0.36
d. Mix	0.43
e. Irrigated paddy	0.02
Cultivation:	
a. 1:1	0.28
b. 1:2	0.19
Agriculture and conservation:	
a. Mulsa	0.14
b. Terrace bench	0.04
c. Contour cropping	0.14

4. RESULT AND DISCUSSION

Rainfall is driving force agent in USLE method knowing as erosivity rain factor (R). The R value for Kendari Basin shown as 836 comes from 4.03 mm rainfall daily (data sources from BMKG Southeast Sulawesi). To obtain the LS then first make a map of slope that developed in the Kendari Basin. Map of slope obtained from the processing of SRTM 30 m DEM data. Paningbatan, Jr. (2001) noted that the LS factor can also be derived simultaneously from a map of the percentage of slope (S) generated by using a digital elevation model (Schmidt et al). The L and S factors in USLE reflect the effect of topography on erosion. It has been demonstrated that increases in slope length and slope steepness can produce higher overland flow higher erosion. The greater the slope, then the rate of erosion will be greater than in the flat.

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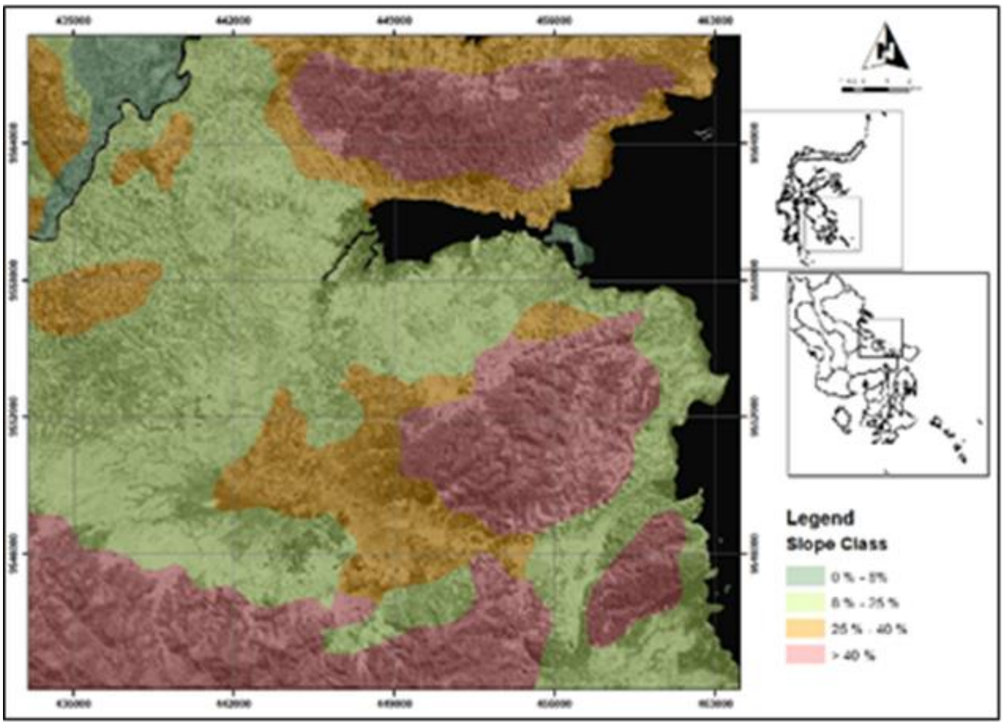

Figure 5. Distribution of slope class in Kendari Basin

There are 5 classes can be derivate from SRTM but only 3 main class that present in Kendari Basin, as follows: 8%- 25%, 25%- 40%, and > 40% Slope degree (Figure 5). To gain LS value than compare with Table 4 to convert and obtain LS value (Table 6). Kendari Basin topography appears dominated by angled slopes (56%) and then a gentle slope (44%). Slopes are slanted have the potential to erode. Erosion rates correlate best with measures of topographic steepness (Sukiyah et al).

Table 6. The proportion of values of LS

Slope class	LS values	Area (Ha)	Proportion of total area overall	Proportion LS values
> 40 %	9.5	24,138.25	0.38	3.65
25 % - 40 %	6.8	11,274.34	0.18	1.22
8 % - 25 %	3.1	27,487.89	0.44	1.35
Total		62,900.48	1.00	6.22

Soil erodibility (K) indicates the level of sensitivity of soil erosion, namely easy of soil to erosion. The value of soil erodibility (K) which have been obtained from the map of soil types issued by National Land Agency Southeast Sulawesi then compared to the Table 3 to determine the category value soil erodibility (K) were obtained.

Distribution and soil type in Kendari Basin from BPN data shown about 7 units soil type (Figure 6), but only 6 soil types present in Kendari Basin. Table 6 show the soil type distribution of Kendari Basin. Same with LS value, to gain K value than the soil type form BPN data must compare to Table 3 for obtain K value at Kendari Basin.

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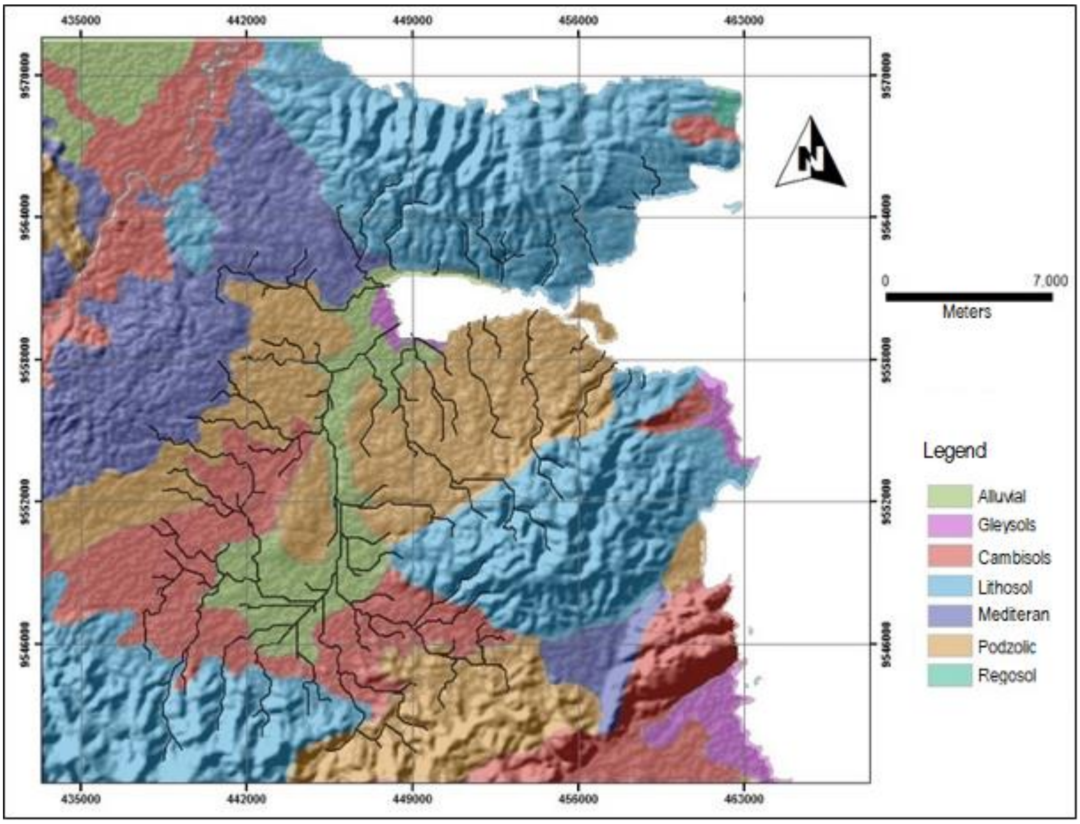

Figure 6. The distribution of soil type of Kendari Basin

Soil erodibility (K) at Kendari Basin dominant came from lithosol (39%). It means the particle size of soil or component still have a small part of rock. The lithosol layers commonly at mountain and with high slope degree. For geological view seems like cause tectonic activity to rock so rock become brittle and more physic soil product than chemical or biology activity to product this soil layer. After lithosol soil type than second large of soil type is podzols (26%). Podzols are able to occur on almost any parent material but generally derive from either quartz-rich sands and sandstones or sedimentary debris. Distribution area and proportion K value at Kendari Basin shown by Table 6.

Table 7. Proportion Values of K

Soil type	K value	Area (Ha)	Proportion of total area overall	Proportion of K value
Alluvial	0.47	4,503.66	0.0716	0.0337
Gleysols	0.47	408.91	0.0065	0.0031
Cambisols	0.31	8,644.88	0.1374	0.0426
Lithosol	0.31	24,638.81	0.3917	0.1214
Mediteran	0.31	8,165.64	0.1298	0.0402
Podzolic	0.40	16,538.59	0.2629	0.1052
Total		62,900.48	1.0000	0.3462

The CP factor reflects the effects of cropping and management practices on soil erosion rates in agricultural lands and the effects of vegetation canopy and ground covers on reducing the soil erosion in forested regions. CP value of land uses contained in Kendari Basin obtained by comparing land use map from Landsat image that already analysis using NDVI method with CP value in Table 5. The result shown as Kendari Basin dominates by plantation area (26%) than settlement land use (20%) because of mostly Kendari Basin is urban activity (Figure 7). Kendari city is laying and occupied more half part of Kendari Basin. Proportion land use and CP value can be seen in Table 7 below.

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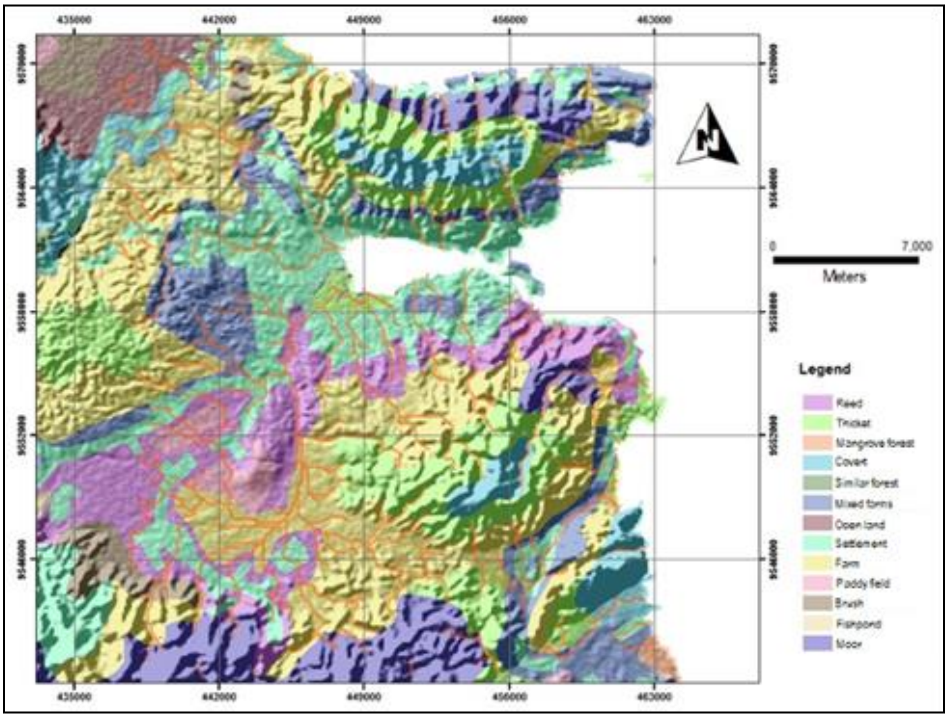

Figure 7. Distribution of land use in Kendari Basin

Table 8. Proportion of CP values

Landuse	CP value	Area (Ha)	Proportion of total area overall	Proportion of CP values
Reed	0.06	8,595.72	0.14	0.008
Thicket	0.01	9,240.99	0.15	0.001
Dense Forest / Covert	0.50	2,268.90	0.04	0.018
Mixed farms	0.20	5,557.47	0.09	0.018
Settlement	0.01	12,647.10	0.20	0.002
Plantation / Farm	0.07	16,103.26	0.26	0.018
Paddy field	0.02	1,128.27	0.02	0.000
Thicket /Brush	0.01	1,271.66	0.02	0.000
Fishpond	0.02	81.67	0.00	0.000
Moor	0.04	6,005.44	0.10	0.004
Total		62,900.48	1.00	0.060

The calculation of the value erosion is done by overlaying a map of each factor generated (R, K, LS, CP) and then do the appropriate calculations. Based on the value rainfall erosivity factor (R) 836, soil erodibility factor (K), topographic factor (LS), and cropping management factor (CP) as to which is appointed by the values above, the prediction rate of erosion (A) in the Kendari Basin using equation (2) as follows:

$$A = 836 \times 0.3462 \times 6.22 \times 0.060$$
$$= 108.01 \text{ tons / ha / year}$$

This result calculation of the rate of erosion with using formulas USLE later are classified into five classes, namely very light, light, moderate, heavy, and very heavy. Maps of erosion hazard level can be using as erosion potential for Kendari Basin. The map was arranged by grade level of potential danger of erosion. The Figure 9 shows the distribution of erosion hazard level in the Kendari Basin. Results of erosion calculation using the data of Landsat 8 imagery are fairly reliable. Besides time and cost efficiency, renewal of erosion data can also be faster. So there is no need to rely on field survey data, which usually takes longer and costs more expensive. Based on the results of previous studies, it is known that the sediments in the Kendari Basin derived from erosion are controlled by the river activity (Jassin et al, 2016). Data used in the study are samples of the field survey and analyzed using statistical approaches.

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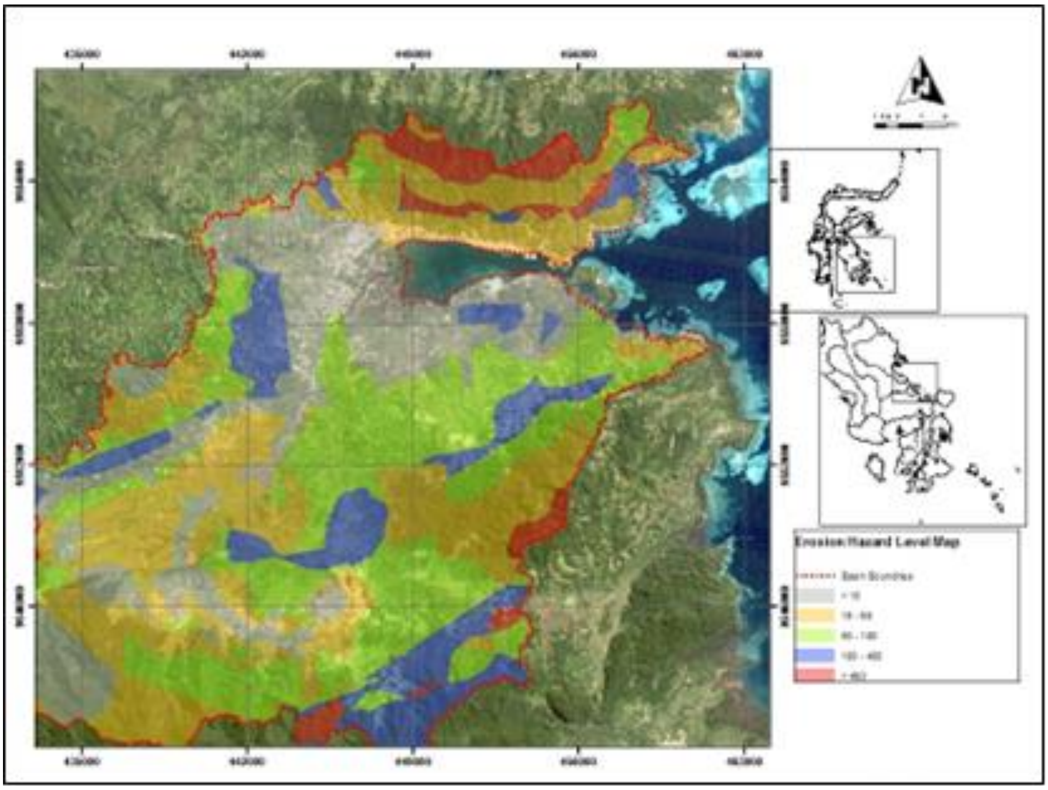

Figure 8. Erosion hazard level map at Kendari Basin

Figure 8 and Figure 9 shown that Kendari Basin erosion hazard level is dominated by class II or category of erosion rate is light, with occupied 21,841.86 ha, this class lay at angle slope and gently slope, dominate land cover by reed and thicket. After class II than class III is known as erosion hazard level moderate with occupied 17,520.16 ha, laying mostly on southern part of Kendari Basin. This area is dominated by plantation and settlement land cover. Data distribution of erosion hazard level land area at each grade level of erosion hazard is presented in Table 9.

Table 9. Proportion of CP values erosion hazard level at Kendari Basin

Class	Erosion hazard level	Erosion rate (ton/year)	Area (ha)
I	Very light	< 15	11,005.03
II	Light	15 - 60	21,841.86
III	Moderate	60 - 180	17,520.16
IV	Heavy	180 - 480	9,234.53
V	Very Heavy	> 480	3,298.90
	Total		62,900.48

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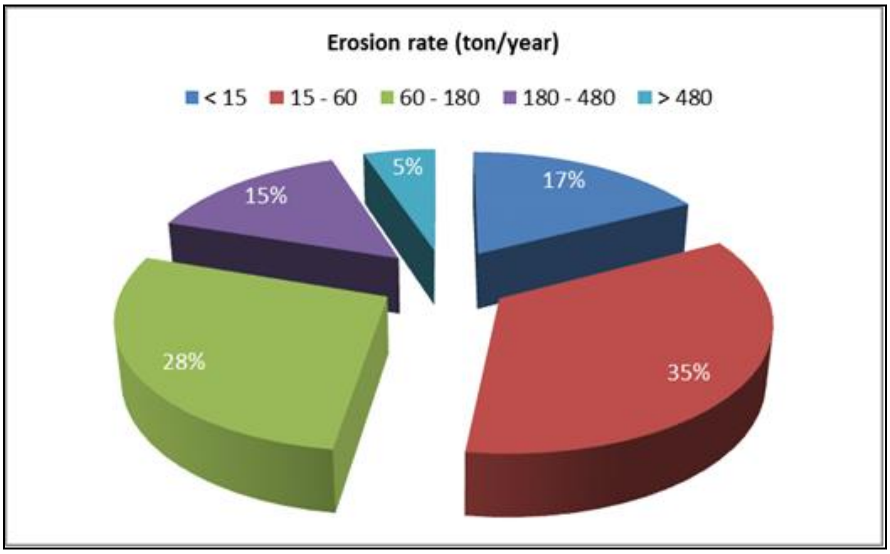

Figure 9. Distribution for each class of erosion rate in Kendari Basin

Based on the rate of erosion seen, known the northern part of the Kendari Basin classified as very heavy or high potential erosion hazard. This is proof that the slope contributes greatly to the erosion rate. This condition can be explained by the geological structure analysis approach.

The rate of erosion resulting from this research turned out in line with geological conditions of Kendari Basin. Some areas have high to very high erosion hazard levels; have been linked to the presence of geological structure control. Results of previous research in the area of alignment patterns show major trending northeast - southwest. This phenomenon believed to be the due to release the results of compression Lawanopo faults, trending northwest - southeast (Jassin et al, 2016). In the fault zone, morphology tends to have slope are steep to very steep. This resulted topographical factor (LS) value is high, so that the rate of erosion also is high. This condition is also supported by the rock properties are deformed due to the complex geological structure. They are formed due to tectonic activity with a range of a specified period, usually over a period of tectonic. Even today, some of the geological structures in the Kendari Basin classified as active.

Sediment supply due to erosion in the northern part of Kendari bay is very high (Figure 9). These conditions can threaten the existence of Kendari bay. In the coming decades, the waters of the Kendari Bay feared to be narrowed. Conservation of the various aspects must be taken to overcome the problem of silting of the bay. The slope areas with high conservation need to be done to reduce the impact of erosion.

The potential for water-based tourism development should be directed at coastal areas that have a low supply of sediment from land erosion products. Construction of artificial vehicles should be limited because they can increase erosion due to increased open land. Recreational rides should prioritize available natural potential. Meanwhile, in the coastal area around the estuary, conservation should be carried out so as not to increase the sediment supply due to riverbank erosion in the downstream area. The combination of conservation and normalization in this area needs to be done. The tree planting of upstream area and sediment dredging in the downstream area is done to slow down the rate of siltation in Kendari Bay.

5. CONCLUSIONS

The rate of erosion can be predicted using USLE formula. This formula involves the rain intensity index (R), soil erodibility (K), morphology (LS), and land use (CP). Most indices in the formula can be obtained through the analysis of remote sensing data. There are three main classes for topoghrapy came from SRTM image analysis in Kendari Basin morphology, as follows : 8 – 25%, 25% - 40, and > 40% slope degree, dominated by lithosol soil type, and land use dominant plantation and settlement.

Overall, the calculation of the rate of erosion using GIS software. Results of the analysis showed that the rate of erosion in Kendari Basin of 108.01 tons / ha / year. The rate erosion classified as moderate. Erosion hazard level map shown very heavy or high potential erosion hazard laying at northern and southeren that mountain morphology and mostly litosol soil type.

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Geological setting of Kendari Basin is contributed to increasing the rate of erosion. These phenomena are related to the presence of active faults characterized by morphotectonic units, in the form of fault scarp with a steep slope.

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