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Geomorphic change cause of spatial dynamics at Kendari Bay area

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Abstract: Remote sensing systems have developed very well nowadays. Previously, it was very difficult to observe geomorphological changes due to the high cost of terrestrial mapping. Approaches through remote sensing are very helpful, especially in observing geomorphological changes, both natural and as a result of current human activities. In this paper, the discussion will focus on the elements of geomorphological change observed from a morphometric perspective, which are derived from remote sensing imagery. Assisted by model analysis from digital elevation models and quantitative interpretation of remote sensing images in the study area, it shows that the morphometric landscape of the study area has experienced significant erosion, with a hypsometric integral (Hi) value of 0.12. There are two sub-watersheds in the Kendari Bay area, which are circular (Rc > 0.5) and elongated (Rc < 0.5). The elongated watershed occupies the northern part of Kendari Bay, while the circular watershed is located in the southern part. In the circular watershed, there are fluvial geomorphological units, and in the estuary, there are wet plains and several flood plains. Based on multisensor analysis of Landsat images using the MNDWI method, a landscape change was observed in the Gulf estuary area from 2001 to 2019. The wet area in Kendari, where the wet plains in 2001 covered 185.56 hectares, has significantly shrunk to only 39.06 hectares in 2019. This land use change has disrupted the function of the estuary landscape as a water catchment area, which, if not addressed, could lead to problems such as flooding and sedimentation in Kendari Bay.
Keywords: *Hypsometrics, Landscape, MNDWI, Remote sensing.*

1. Introduction

Remote Sensing System has been very well developed today. Previously, it was very difficult to see geomorphological changes, especially in Kendari Bay due to the vast area of Kendari Bay, the development of Kendari City and the high cost of existing terrestrial mapping. It is important to look at the geomorphological aspect because the physical environment is a factor of the carrying capacity and capacity of an area to develop. Physical factors of the natural environment that will sustain population dynamics, especially in urban areas, can be called the natural boundry of urban growth. García-Soriano, et al. [1]; Yousefi, et al. [2]; Quesada-Román, et al. [3] and Zhang, et al. [4] state that many disaster on urban area related to geomorphologic factor such flooding and landslide. The physical environment due to geomorphological characteristics will cause side effects that will become the limitations of the development of a city. Floods, landslides and land subsidence are some of the problems with this limitation. In 2017 when floods hit Kendari City, data released by the Disaster Management Agency recorded a material loss of 75 billion rupiah. Than in 2018, the flood hit the city of Kendari again and the loss was estimated at 30 billion rupiah. Andriamamonjisoa and Hubert-Ferrari [5] suggest combining geomorphological, geotechnical and geological studies in urban areas in order to provide direction for urban development and development. Mangan, et al. [6] and García-Soriano, et al. [1]

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using Morphometric analysis with remote sensing and GIS. They studies about The interrelationship between the various morphometric factors of the basin has been studied using a correlation matrix.

For this reason, seeing the characteristics of geomorphological changes in an area from the beginning to the present is important as a policy direction in managing the social and environment of an area. The approach through Remote Sensing is very helpful, especially in seeing these changes on an annual basis quickly, accurately, low cost and sustainably. On the other hand, geomorphology is a part of geological science, where geology has also developed into the focus of studies such as environmental geology. Urban environmental geology or urban geology is one of the studies in environmental geology and is an interdisciplinary field between geology (earth science) and urban planning.

Geomorphology, which begins with the division of the earth's surface through a qualitative aspect approach, namely morphography or known as physiography to be more quantitative with the term morphometric. Geomorphometric aspects have been measured manually for decades by Horton, 1945; Hammond, 1954, 1964; Verstappen and Van Zuidam, 1968; Kristen and Stewart, 1953 in Khanapurkar, et al. [7] and Yousefi, et al. [2]. Geomorphological or geomorphometric methods at the beginning of its development classified the shape of the earth's surface based on numbers such as aspects of height difference, slope and drainage system, all of which were derived from topographic map derivatives.

Now quantitative geomorphological analysis has developed quite well and started around the 1970s, where quantitative analysis is obtained from digital terrain derivatives in the form of DEM, GDEM, DTM and others. To date, important advances have been made in improving accuracy by developing new algorithms and new processing software for calculating the morphometrics of remote sensing system derivatives from satellites and radars. Bajracharya, et al. [8] and Quesada-Román, et al. [3] for an understanding of the erosion process & hydrodynamics can be approached based on the quantitative characterization of the distribution of the elevation or the hypsometry of a basin.

Quantitative geomorphology (geomorphometrics) can be an algorithmic language because it uses numbers so that computer technology can be used as a tool in analyzing data. Geographical information system (GIS) is a computer algorithm program that has been widely used in compiling, analyzing and storing information. Quantitative geomorphology can use this GIS program to carry out automatic analysis and decisions with simple assumptions. Geomorphological aspects that can be quantified in the form of height difference, slope, river length, river order, river basin area, river gradient, etc. can be input into GIS.

Along with the development of digital technology, including satellite and radar technology, which is increasingly advanced, quantitative geomorphology is increasingly developing as well. Satellite and radar technology has been able to map the surface of the earth with a fairly wide range, with fast data processing times and produce more detailed resolution data.

2. Methodology

The remote sensing approach in this paper is an approach based on multisensor analysis and an analytical approach using radar. Wu, et al. [9]; Zhang, et al. [10] and Lu, et al. [11] using image sourced from multisensor satellite images for visualization techniques and certain algorithms, while images sourced from radar use numerical calculations and mathematical equations to be analyzed. these analytical techniques are described further below. The two results will be superimposed as a form of evaluation related to the development of the city of Kendari and the hope is that they can be used as a reference in using regional development evaluation techniques and geomorphological studies in the future.

2.1. Image Analysis Technique

The technique used in analyzing the image is modified normalized difference water index. Specific method in analyzing satellite imagery to recognize the character of the Kendari Bay geomorphological unit by compiling the RGB channel with the selected bands and Alogarithma certain. Bands visible and short wave infrared is commonly using for detect wetlands or water body, vagetation and landuse.

Mokhtari, et al. [12]; Zhang, et al. [4] and Andriamamonjisoa and Hubert-Ferrari [5] using Modified Normalize different water index to studi aboiut water body extract from imagery. Modified Normalize different water index or MNDWI is an index showing the wetland of an area based on the value of the wavelength of an image. The wavelengths used were visible Green and swir wavelengths. multitemporal imagery analysis is used to provide an overview of geomorphological changes at Kendari wetland, so that it can be give predictions of the potential flooding area cause of geomorphological changes for development of Kendari city.
MNDWI algorithma is based on two band, whose equations are as follows:

$$\text{MNDWI}=(\text{Green-SWIR})/\ (\text{Green+SWIR}) \qquad (1)$$

2.2. Morphometric Indices

The morphometrics indices used in this paper are hypsometric curves and and circularity ratios. Hypsometric curve is a curve that is formed from the ratio of the height (elevation) to the area in an region such as water basin or watershed. Hypsometric curve is a form of response to the dynamics of erosion or the age of a basin and its relation to flooding. The hypsometric shape of the curve, geomorphological processes that occur in basin can be interpreted. The convex shape of the hypsometric curve shows that there is building process in a basin such as intensif deposisional and the concave shape of the curve shows a descending process which is interpreted as a process of erosion in a basin.

Makrari, et al. [13]; Wu, et al. [9]; Das [14] and Zhang, et al. [10] using Circularity Ratio (Rc) for study morphology of watershed. Circularity ratio is influenced by the length and frequency of streams, geological structures, land use/ land cover, climate and slope of the basin. The hipsometric and circularity ratio curves were obtained from the DEM data taken from the DEMNAS data with an accuracy of 5 m. Equtiton for Rc as follows;

$$Rc=4\pi A/p2 \qquad (2)$$

Where:
Rc = Circularity ratio
A = Area of watershed (km2)
p = Parimeter watershed (km).

3. Result and Discussion

The research location is in the east of the southeastern arm of the island of Sulawesi, with a geographic position extending from north to south 03 ° -54'30"- 4 ° 3'11" south and stretching from west to between 122 ° 23'-122 ° 39 ' East (Figure 1). The research area is 473.95 km2 with a morphological maximum height of 617.69 meters and a minimum height of 0.65 meters [11, 15]. The altitude distribution shows the altitude of the study area which is dominated by elevation more than 50 m above sea level. (Table 1).

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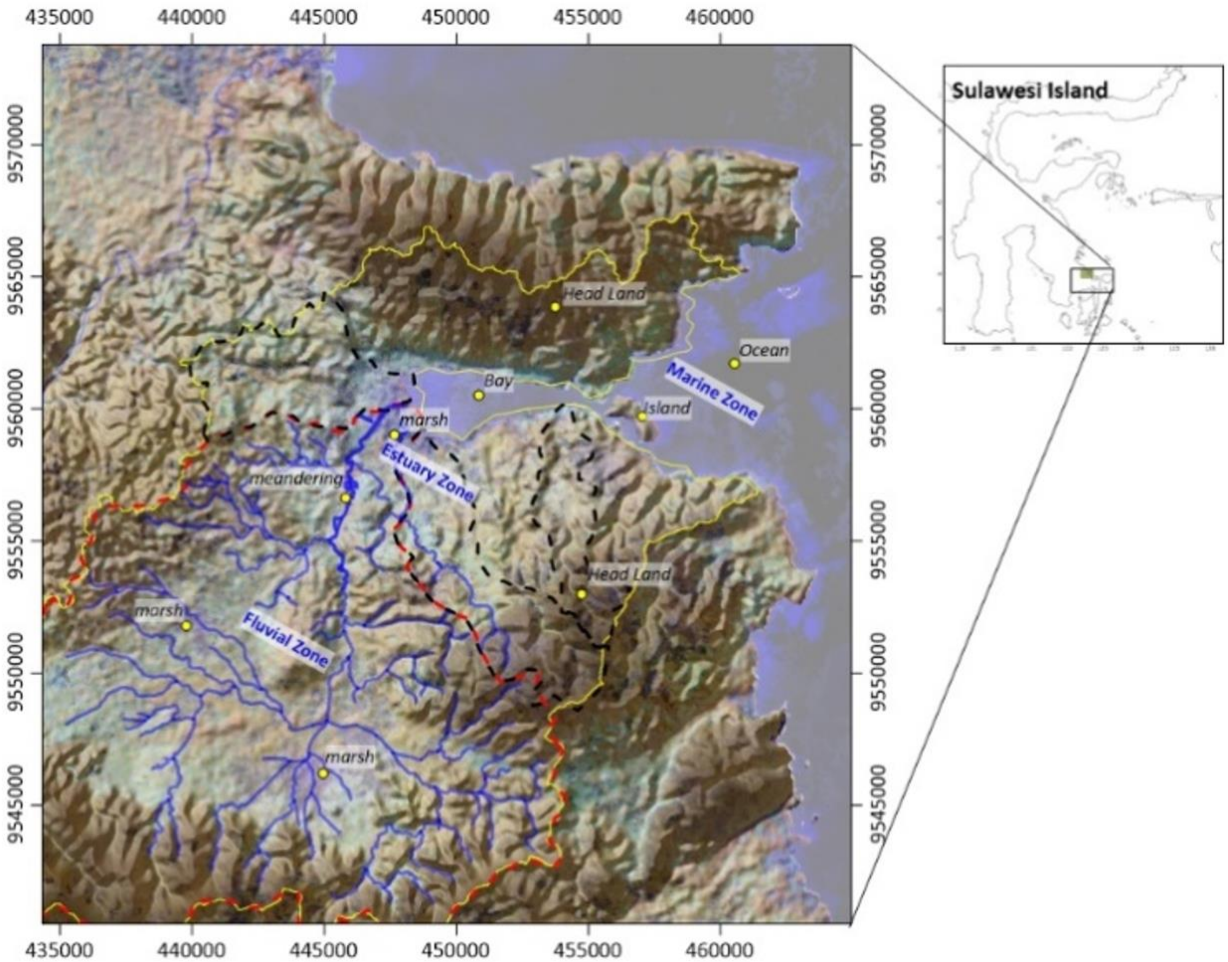

Figure 1.
Geomorpholgy and system land at Kendari. Boundry of Kendari Basin (yellow line) and Sub-Watershed as Wanggu Sub-Watershed (red line), Mandonga, Kambu also Abeli Sub-Watershed (black line).

Makkawaru, et al. [16] describe that the geomorphology of Kendari city can be divided into geomorphological units, namely the coastal zone, estuary zone, plain zone, hilly zone, and mountainous zone (Head land). The lithology composition is dominated by quaternary deposits, sandstone and limestone of tertiary age, as well as a small portion of the hill ridge of triassic-aged metamorphic rocks.

3.1. Hypsometric Landscape

The Kendari Basin can be divided into several smaller watersheds known as sub-watersheds. There are 4 sub-watersheds that can be identified and delineated through SRTM data analysis, namely the Wanggu sub-watershed, the Mandonga sub-watershed, the Kambu sub-watershed and the Abeli sub-watershed. Hypsometric analysis of each sub-watershed was made and plotted into a sub-watershed map in the Kendari basin to see the extent of the sub-watershed profile to the Kendari basin profile (Fig.2).

Table 1.
Elevation values and area of Wanggu Sub-Watershed.

Elevation (m)	Area (Km2)	a/A	h/H
0	473.95	1.00	0.00
50	232.87	0.49	0.08
100	130.47	0.28	0.17
150	90.76	0.19	0.25
200	62.87	0.13	0.33
250	41.93	0.09	0.41
300	24.80	0.05	0.50
350	12.47	0.03	0.58
400	5.59	0.01	0.66
450	3.00	0.01	0.74
500	1.59	0.00	0.83
550	0.49	0.00	0.91
600	0.01	0.00	0.99
606	0.00	0.00	1.00

The hypsometric integral (Hi) value of the research area is 0.12, indicating that the hypsometric value is close to 0, indicating a low Hi value and the curve tends to be concave. Hi values close to zero illustrate the occurrence of denudation processes from rocks and the large potential for erosion of a basin.

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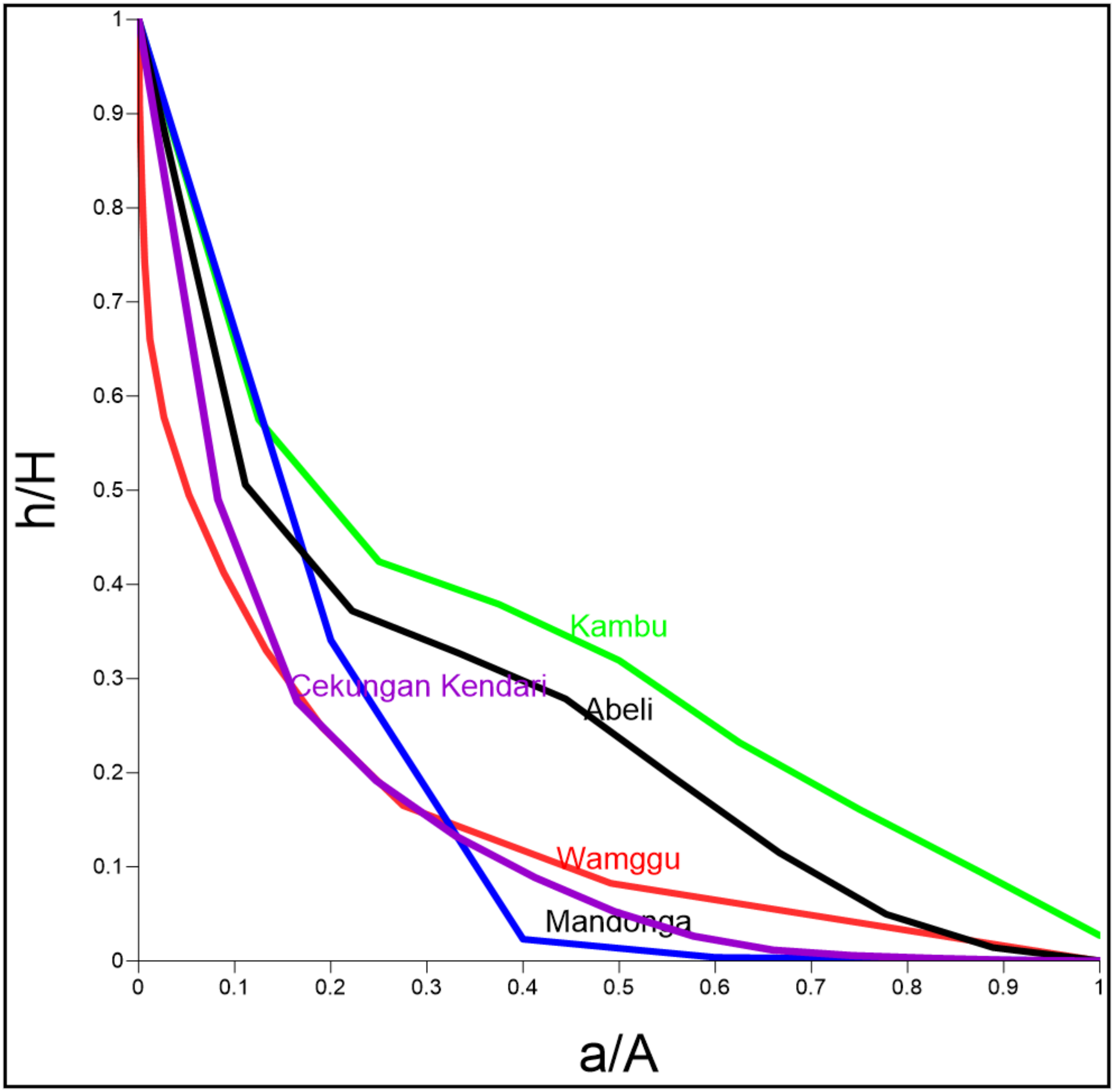

Figure 2.
Shape compare of the sub-watershed hypsometric curve between Wanggu to another subwatershed. Hypsometric curve of Wanggu Sub-watershed area showing a relatively concave curve profile.

The shape of the hypsometric curve of the study area shows a concave shape. The convex hypsometric curve (convex) describes the area that tends to be young, the shape of the curve similar to the letter S describes the moderate level of erosion, and the concave curve shape shows strong erosion [12, 17]. The area under the hypsometric curve is known as the hypsometric integral with a value between 0-1, where the value close to 0 is a strongly eroded area and if it is close to 1, it is weak erosion according to Jassin [18] and Makrari, et al. [13].

3.2. Circularity Ratio Forms

The shape of the sub-watersheds in the Kendari Bay shows there are two circularity ratio forms, namely rounded (Rc> 0.5) and elongated ((Rc <0.5) see table 2. The dominant circular shape is rounded for the Wanggu watershed where this watershed is very wide and has a large river that flows directly into Kendari Bay and divides Kendari City which is on the edge of Kendari BayWanggu Sub-Watershed have value 0.55 and if connected to flood discharge, Rc> 0.5 shows that the peak flood discharge comes long and so does the decrease in flood discharge last a long time. The implication is that the peak of flooding in the Kendari city area will be long and the flood receding will be long. then the estuary area of the river outlet and inlet of the Kendari bay will naturally become inundated areas or wetlands.

The different circularity ratio values between sub-watersheds in the Kendari basin is a reflection of the erosion stadia which has been shown by the hypsometric curve profile in the studied sub-watersheds. To better understand the level of erosion potential in the Kendari Basin due to the geomorphology of the Kendari Bay area, it is also necessary to research the erosion rate of the Kendari Bay area, especially the Kendari Basin as the place where erosion and sedimentation processes occur.

Wet areas at the downstream of the Wanggu river are naturally a "water stopover" landscape before being released into the bay area. Besides that, the estuary area is also a place for sedimentation from the river to be trapped in this estuary area. So the landscape of the wet area at the mouth of the Wanggu river provides an important function for the area to hold water and become a sediment bag.

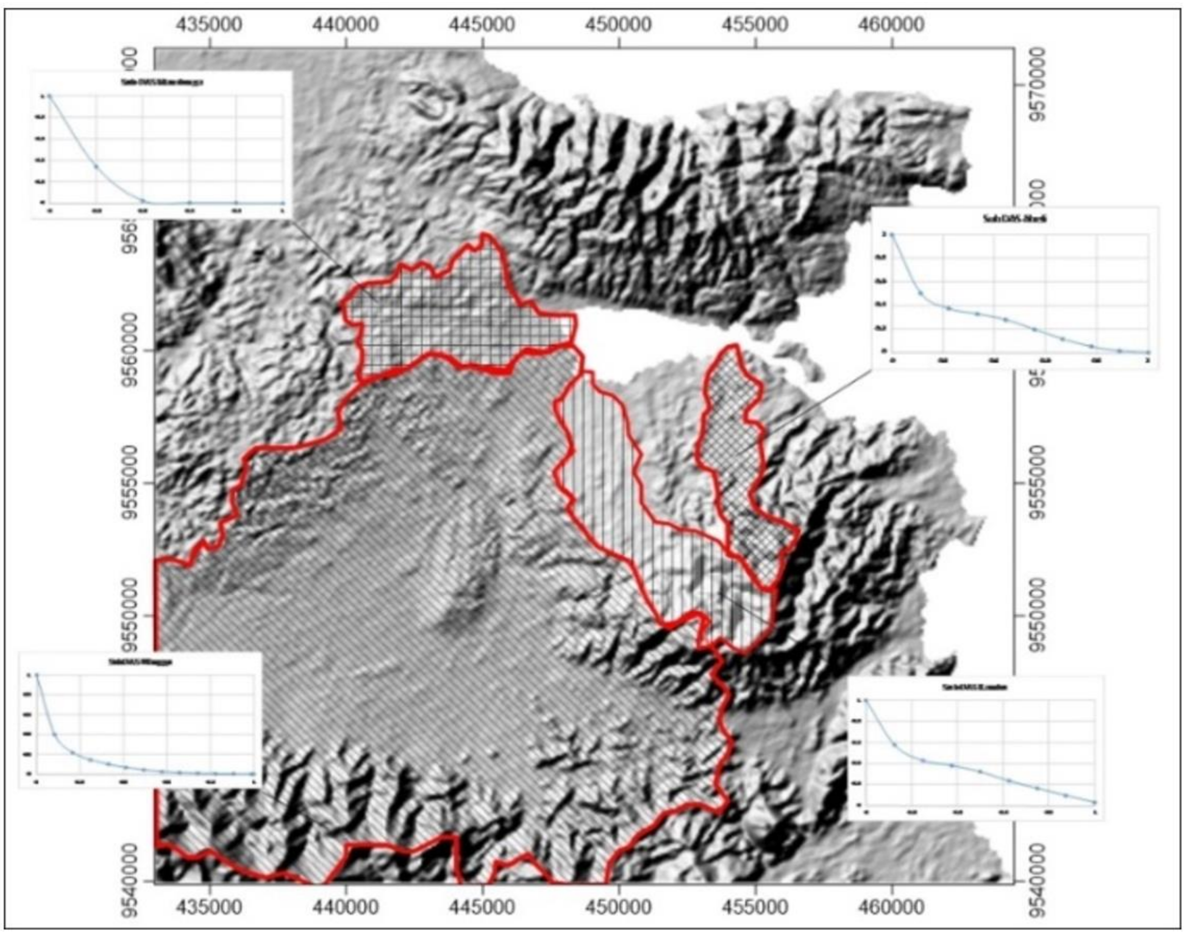

Figure 3.
Shape and Circularity Ratio (Rc) of the sub-watershed near Kendari Bay, Extraction from DEMNAS using gray shadding.

Table 2.
Circularity Ratio of at Kendari BAy.

Sub Watershed	Perimeter (km)	Area (Km^2)	Rc
Wanggu	83.76	304.80	0.55
Mandonga	26.14	25.33	0.47
Kambu	32.85	30.79	0.36
Abeli	23.00	15.26	0.36

3.3. Wetlands Change

Matlhodi, et al. [19]; Bhaga, et al. [20]; LaRocque, et al. [21]; Mallick and Rudra [22]; Seaton, et al. [23] and Teng, et al. [24] study of land use land cover (LULC) changing specialy on wetland area. Wetland land change as Growth of Kendari city can be analysis with multitemporal image from Landsat satelite. Landsat images 5 TM for 2001 and 2009, and Landsat 8 OLI for 2019. Using MNDWI and band visual colour composite image. MNDWI value with 0 ≤ is non water body and ≥ 0.5 is high water body. MNDWI results show that there is a reduction in wet land. In 2001, the area of the wetlands in the Wanggu River estuary area was 185.56 Ha, then in 2009 it was reduced to 158.58 Ha and in 2019, the wetland area was only 39.06 Ha. This shows that in the past 18 years there has been a land conversion in the.
Wanggu river estuary area (Fig.4). It can be seen that the development direction of Kendari City tends to change the land function massively in the Wanggu sub-watershed, especially the estuary area.

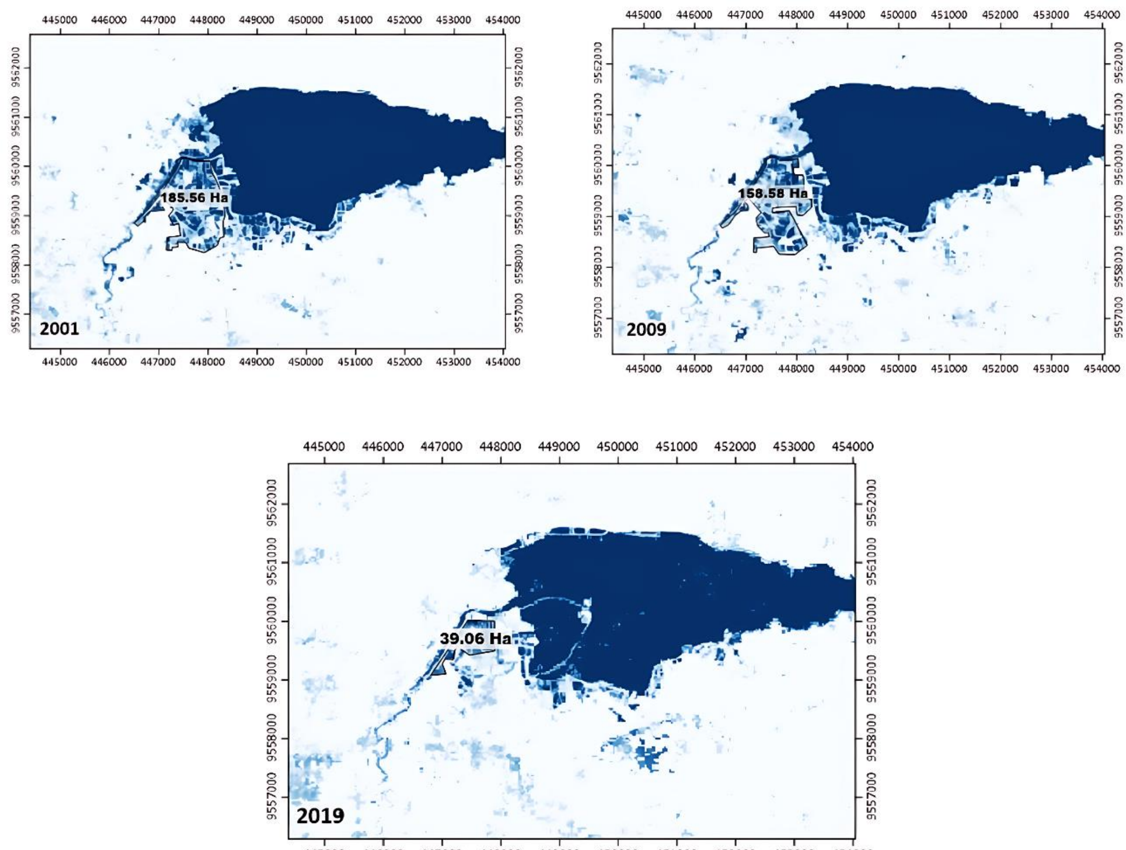

Figure 4.
Multitemporal MNDWI analysis at Wanggu sub watershed. The wetland have been shrinked from 185.56 Ha in 2001 and become only 39.06 Ha at 2019.

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Changes in land function which naturally is where fresh water overflows before heading to the sea has turned into a commercialization function. Buildings such as restaurants and hospitals as well as hotels make this location prone to flooding if it enters the rainy season.. Wanggu sub-watershed area is widely near 30,426.65 hectares and mostly 29,597.34 hectares is antropogenic Landuse/Land Covering (LULC) or 97.27%. Sufrianto, et al. [25] and Das [14] shown green open space in the Wanggu sub-watershed area covering just only around of 829.31 hectares. Based on these data, several allegations can be drawn such as disruption of the hydrological cycle, particularly evapotranspiration (ET) becomes disrupted. Yasin, et al. [15] and Lu, et al. [11] shown sediment contribution from erosion rate at Wanggu sub-watersheds are 66,064.92 tons / year. It will goes directly to the Kendari Bay if the fluvial system not have management well.

The change in LULC in the city is very rapid and does not take into account the natural terrain. Changes in LULC in the City generally focus on the economic aspect alone. The change in LULC, which is only due to the economy, no longer pays attention to environmental problems and the ecosystem services provided by the environment. Such as the ecosystem services of the Wanggu River which have changed due to this change in LULC. The river that is the place for surface water to flow and regulates the water system in the Wanggu Basin is changing rapidly due to human development. Due to the activity of rapid changes, the sedimentation rate is getting faster which should be deposited in the estuary area.

If decrease in wetlands is due to the development of Kendari city which mostly wet land as water catchment areas to become anthropogenic landuse continuesly. The implication is that the antropogenic area will be prone to flooding. Another implication of the reduction in wetlands in estuary areas which are converted into built-up areas, will make the area prone to land subsidence due to soil density and subsurface geological conditions in estuary wetlands composed of sedimentary layers that are not compact and easy to move when it loaded.

According to Jassin [18] and Makkawaru, et al. [16] sedimentation distribution area at Kendari Bay on 2014, 2017 and 2021 as follows 159.50 Ha, 258.15 Ha and 280.90 Ha, respectively. The delta pattern is formed at the mouth of the Wanggu river with a delta area of 2014, 2017 and 2021, namely 17.97 Ha, 27.16 Ha and 19.60 Ha respectively.

From the multi-temporal image, it can be seen that at the edge of Kendari Bay, there was a change in the landscape in 2019 by reclamation and development activities by humans. Development aims at economic and social. From Sukiyah, et al. [26] and Kadhim and Al-kubaisi [17] the geological settings and soil types around Kendari Bay play a role in accelerating erosion. This phenomenon is associated with the presence of an active fault characterized by morphological tectonic units in the form of abrupt faults with steep slopes. These conditions could threaten the very existence of Kendari Bay. In the coming decades, the water of Kendari Bay is expected to shrink. Conservation of various aspects must be done to alleviate the alluvial problem of the bay. Areas with high conservation slopes should be landscaped to reduce the impact of erosion.

4. Conclusion

Hypsometric curves and circularity ratios shown that the Wanggu sub-watershed at erotion stage and flood potential patterns with slow flood water level and very slow to down level the flooding, while from multitemporal imagery using MNDWI found that wetland (marsh) at Wanggu sub watershed has been reduce from 185.56 Ha in 2001 to left only 39.06 Ha wetland in 2019.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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