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MONITORING OF VEGETATION COVER CHANGES IN RELATIONSHIP TO GEOMORPHOLOGICAL FORMS USING GOOGLE EARTH ENGINE IN KENDARI CITY

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ABSTRACT

Vegetation cover plays an important role in controlling the view, boundaries, air temperature, living place, and aesthetics in an area. Vegetation cover changes can be caused by changes in temperature, rainfall, and human activities. Google Earth Engine (GEE) provides machine learning algorithms such as NDVI which are very useful in extracting vegetation density levels from imagery. The purpose of this study was to analyze vegetation cover change by human activities with the geomorphological form of Kendari City based on the distribution of land use/land cover. The imagery used in multi-temporal monitoring is Landsat-7 ETM in 2000, Landsat-5 TM in 2005 and 2010, and Landsat 8 OLI in 2015 and 2020. Input machine learning using near-infrared (NIR) and red (Red) for the NDVI Algorithm while the geomorphological form uses SRTM imagery. The classification of vegetation cover consists of water bodies, open fields, built areas and roads covered with asphalt, paving or soil, plantations/agriculture, bushes, grass, reeds, green open space, and forests. Each sub-district experienced a decrease in vegetation cover in the form of plantations/agriculture, bushes, grass, reeds, green open space except for the West Kendari District which tended to be varied. The forest area is getting better every year. Vegetation cover in the lowlands has decreased every 5 years in an area of 824.25 ha into other forms of land use. This number is greater when compared to other geomorphological forms. Machine learning in GEE is very helpful in monitoring vegetation cover changes and has an NDVI algorithm that is quite easy to apply.

Keywords: Vegetation Cover Changes, Machine Learning, Google Earth Engine, Geomorphological Form

INTRODUCTION

The utilization of remote sensing technology for the manufacture of vegetation data can be used for identification, monitoring, and evaluation of an area. Remote sensing has been widely used to overcome problems related to spatial analysis (Comber et al., 2012), protection of environmental stability (Rahman et al., 2014), and efforts to maintain consistency of land use (Liping et al., 2018). Geomorphology is also known as landform or landscape. Geomorphological forms are caused by forces originating from within the earth or from outside the earth. Types of geomorphological forms can be hills, valleys, or headlands. Geomorphological forms that tend to be flat with almost flat slopes have a high potential for land conversion compared to hilly or mountainous areas (Adinugroho, 2016:

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Hidayanti, 2020). The vegetation in this area is more prone to land conversion (Zhao et al., 2016) so that the area with this geomorphological form is an area prone to annual flooding and prone to landslides (van Zuidam, 1986). The conversion of vegetation cover to other uses is a source of problems because it can cause an increase in air temperature (Santi et al., 2017; Santi et al, 2019), floods (Adiatma & Yuliastuti, 2011; Gandri et al., 2019), landslides (Saleh et al., 2019). Vegetation cover has a very important role in controlling views, boundaries, controlling air temperature, living places, and aesthetics in densely built areas (Carpenter et al., 1975; Clouston, 2013) so its existence must be maintained.

Monitoring of vegetation cover using the Normalized Difference Vegetation Index (NDVI) method has been widely used because it has a high level of sensitivity to vegetation cover changes. NDVI works by looking at the distribution of vegetation and soil which is characterized by the reflectance pattern of the surface of the vegetation (Gandhi et al., 2015). Vegetation cover change has a positive relationship between NDVI and temperature (Chuai et al., 2013; Fu & Burgher, 2015; Bagherzadeh et al., 2020), NDVI and rainfall (Chuai et al., 2013; Fashea et al., 2017; Kundu et al., 2018), NDVI and Geomorphology (Valente et al., 2013; Zhao et al., 2016). However, the impact of human presence in changing land has also been considered (Chuai et al., 2013; Wang et al., 2015; Zhao et al., 2016; Sun et al., 2020). Climate change and human activities affect vegetation cover change (Wang et al., 2015; Li et al., 2017; Sun al., 2020). Increased agricultural production can increase vegetation cover but increased regional economic growth is also negatively correlated with Gross Domestic Product (GDP)/km2 and Regional Gross Domestic Product (RGDP) (Bakri & Santoso, 2017).

Google Earth Engine (GEE) is a cloud-based platform that can process large amounts of multi-temporal data. GEE provides a sophisticated set of pixel-based functions that can be used for mapping vegetation cover through the distribution of vegetation density levels. This study aims to analyze vegetation cover change by human activities with the geomorphological form of Kendari City. Identification of the relationship between vegetation cover change and geomorphological forms is carried out based on the area of land use/land cover in the geomorphological formation of the region.

RESEARCH METHOD

Monitoring vegetation cover change in Kendari City utilizes remote sensing in the form of Landsat imagery. Temporal in monitoring vegetation cover change is carried out in a span of 20 years, namely from 2000-2020 with 5 years intervals. Landsat-7 ETM in 2000, Landsat-5 TM in 2005 and 2010 and Landsat 8 OLI in 2015 and 2020. Landsat imagery data was processed using Google Earth Engine. Records of vegetation cover in 2005 and 2010 used Landsat-5 TM data because the Landsat-7 ETM data had been damaged by stripping.

In pre-processing, *filterDate* is first performed to produce an *image collection* for 1 year with a cloud cover of less than 10%. Furthermore, a selection is made from several imageries that have been listed to get Landsat imagery data that is free from cloud cover. After getting the best imagery, the imagery is cut using the Kendari City administrative boundary. *Cloud removal/cloud masking* is also carried out to obtain imagery that is free from cloud cover.

The classification of vegetation cover uses machine learning with the NDVI method. NDVI calculation using machine learning uses the following basic equation: $NDVI = (\rho_{NIR} - \rho_{RED}) / (\rho_{NIR} + \rho_{RED})$ (1) where NDVI is the BV Value of the Normalized Difference Vegetation Index. ρ_{NIR} or (Near Infra-Red) which is the value of the near-

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infrared spectral band and ρ_{RED} is the value of the red spectral band.

The use of the Red band and the NIR band adjusts to the Landsat imagery used. The NDVI value ranges from -1 to 1 from all *image collections* obtained from masking results and the lowest average value.

Classification using the NDVI class was carried out with the help of ArcMap 10.4, while the identification of vegetation cover types was analyzed using Google Earth. The classification obtained from this method consists of five classes which are presented in **Table 1.**

Table. 1 Classification of Vegetation Cover by NDVI value

Class	NDVI Density	Types of Vegetation Cover
< 0	Non-Vegetation	Water body
0 – 0,10	Very Low	Open field
0,11 – 0,50	Low	Built areas and roads covered with asphalt, paving or soil
0,51 – 0,70	Medium	Plantations/agriculture, bushes, grass, reeds, green open space
> 0,70	High	Forest

Source: Data Analysis (2021)

The NDVI classification results from each Landsat imagery will be used for the analysis of vegetation cover changes. The geomorphological form of Kendari City was extracted from the STRM imagery which was derived into topographic and elevation maps. This data is obtained from USGS in Raster format. Topographic maps are classified into several classes including lowlands (<50 m), low hills (50 m - 200 m), and hills (200 m - 500 m). Elevation is classified as flat or nearly flat (0% - 2%), sloping (8% - 13%), and steep (21% - 55%). Classification refers to Takeuchi & Yamada (in Widyatmanti et al., 2016). The map is then overlay to get a geomorphological map. The resulting Geomorphological Map has a classification of landforms in the form of lowlands, sloping plains, low flat hills, low sloping hills, steep low hills, low hills, sloping hills, and steep hills. Geomorphological data is used in the analysis of the effect on vegetation cover. This analysis was conducted to determine the constraint factors and driving factors for vegetation cover change based on the distribution area of vegetation cover in geomorphological forms. **Figure. 1** shows the research flow chart.

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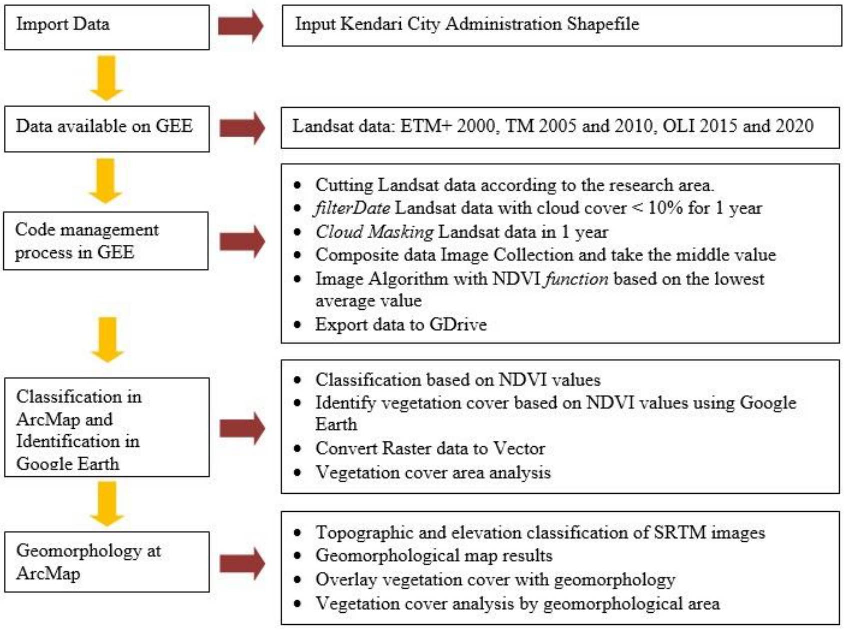

Figure 1. Research Flowchart

FINDINGS AND DISCUSSION

Identification of vegetation cover using Google Earth for 2020 is shown in **Figure 2**. The interpretation results show a match between the classification of vegetation cover and the NDVI value shown by Google Earth. **Figure 3** and **Table 2** show the vegetation cover which has decreased in the area to double in the last 20 years. There was an area clearing of 90,121 ha on plantations/agriculture, land consisting of bushes, grasses, reeds, and green open space. This indicates that around 15,643 ha of land clearing have been converted into buildings or roads either covered with asphalt, paving, or soil in the last 20 year.

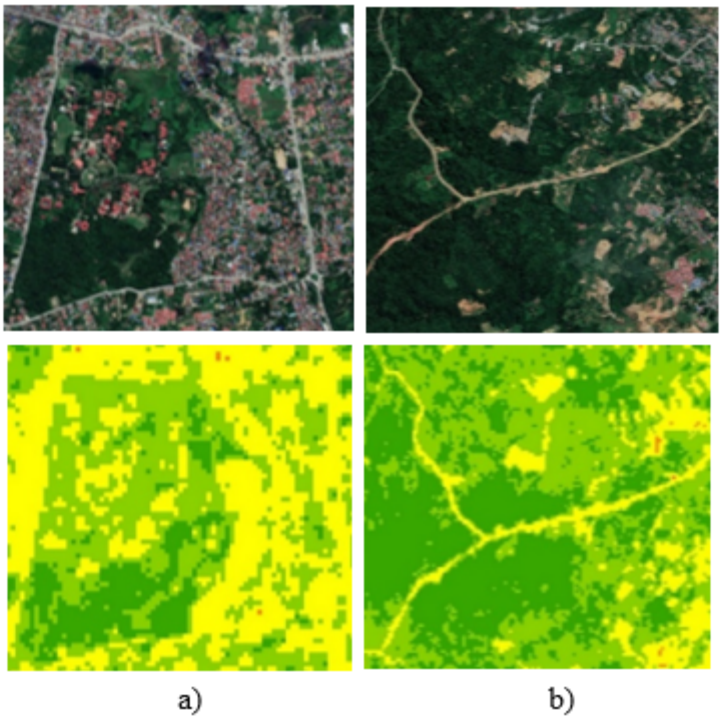

Figure 2. Identification of Current Area Vegetation Cover a) Built-up Area/Roads, Forest, land with grass, bushes and green open space at Halu Oleo University New Campus and b) Built-up Area/Road and Forest in Puuwatu Sub-district.

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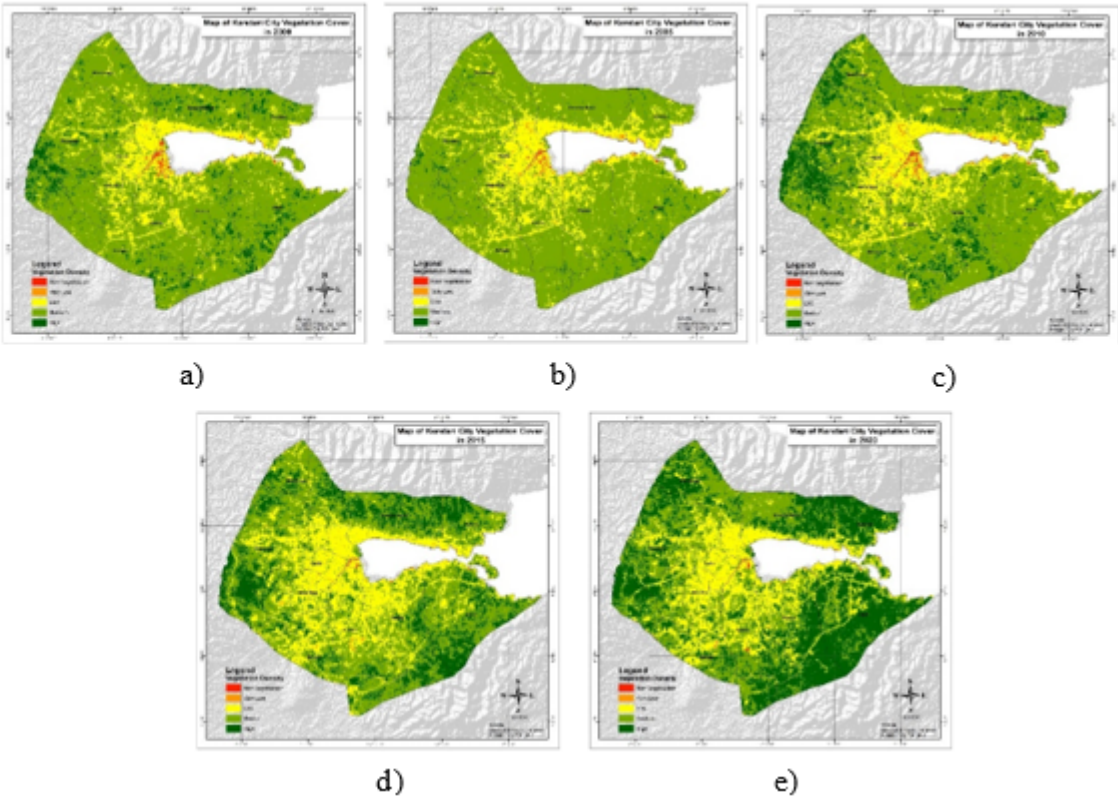

Figure 3. Vegetation Cover of Kendari City in a) 2000; b) 2005; c) 2010; d) 2015 and e) 2020

Table. 2 Vegetation Cover Area based on NDVI value

Vegetation Cover	Area (ha)				
	2000	**2005**	**2010**	**2015**	**2020**
Water body	822	678	940	378	386
Open field	1608	2156	817	1193	684
Built areas and roads covered with asphalt, paving or soil	42298	52152	50279	71842	57941
Plantations/agriculture, bushes, grass, reeds, green open space	192964	197436	172107	131561	102843
Forest	20521	5791	32432	53239	96359

Source: Data Analysis (2021)

The land conversion that occurs is carried out on land use/land cover in the form of plantation/agricultural areas, expanses of bushes, grasses, and reeds. The shrinkage of plantation/agricultural areas will lead to the emergence of new problems in the future such as food needs. According to a study by Prihatin (2015) in Bandung City and Yogyakarta City, changes in an area have an impact not only spatially, but also socially, economically, and culturally. Changes in the vegetated area are made into non-vegetated areas. Agricultural land, moor, or fields turn into built-up areas such as housing complexes, single settlements, as well as trade and service complexes. These changes will affect the production and related aspects of the results of an area that is closely related to socio-economic conditions. Land conversion is a logical consequence of increasing activity and population as well as other development processes. Land conversion at a certain stage is normal, but on the other hand, if it is not controlled, it will be increasingly problematic because generally, the conversion of functions

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occurs on agricultural land that is still productive.

Tabel 3. Area of Plantation/Agriculture, Bushes, Grass, Reeds, Green Open Space for each Sub-district in Kendari City

Sub-district	Area (ha)				
	2000	**2005**	**2010**	**2015**	**2020**
Abeli	2874,76	2949,10	2915,36	2027,31	924,46
Baruga	1943,26	1951,55	1691,01	1312,58	1116,46
Kadia	1079,23	1071,70	808,62	613,89	615,79
Kambu	1619,07	1554,80	1368,84	1124,61	1065,15
Kendari	956,27	918,26	875,20	661,22	304,47
Kendari Barat	1609,40	1739,10	1588,75	1077,24	1095,81
Mandonga	1617,23	1594,73	1412,99	1213,56	1026,96
Poasia	2349,42	2381,33	2165,15	1515,09	949,65
Puuwatu	2853,15	3143,32	2335,74	2020,04	1817,09
Wua-wua	399,34	348,00	280,01	187,76	198,62
Total	17301,14	17651,88	15441,67	11753,29	9114,45

Source: Data Analysis (2021)

Tabel 4. Forest Area of each Sub-district in Kendari City

Sub-district	Area (ha)				
	2000	**2005**	**2010**	**2015**	**2020**
Abeli	294,86	133,91	127,73	948,11	2139,71
Baruga	157,79	26,94	191,45	324,31	670,60
Kadia	95,03	34,18	255,29	198,03	246,27
Kambu	59,48	13,16	220,80	140,98	460,95
Kendari	115,03	16,69	175,98	364,83	797,75
Kendari Barat	199,37	8,67	133,89	741,87	762,31
Mandonga	43,15	25,78	268,14	404,44	675,17
Poasia	241,65	55,99	361,86	560,96	1426,47
Puuwatu	492,62	121,07	988,05	922,04	1322,58
Wua-wua	4,44	3,30	23,04	15,89	16,95
Total	1703,41	439,68	2746,23	4621,45	8518,76

Source: Data Analysis (2021)

Based on the data that significant land conversion occurs at a conversion rate of 500-300 ha/5 years. These data indicate that the decline in vegetation cover occurred in areas on the outskirts of the city and areas dominated by agricultural/plantation land and expanses of land overgrown by grass, reeds, shrubs, and some green open spaces. Rules regarding land conversion have been stipulated, especially Food Agriculture land in Undang-Undang Nomor 41 Tahun 2009 tentang Perlindungan Lahan Pertanian Pangan Berkelanjutan Pasal 44 ayat (3) that the conversion of land that has been designated as sustainable food agricultural land for the public interest as referred to in ayat (2) it can be carried out by taking into account the requirements of a strategic feasibility study, the preparation of a land conversion plan, free ownership of rights from the owner and the availability of substitute land for the converted food agricultural land There have been many regulations related to land conversion, but agricultural land is

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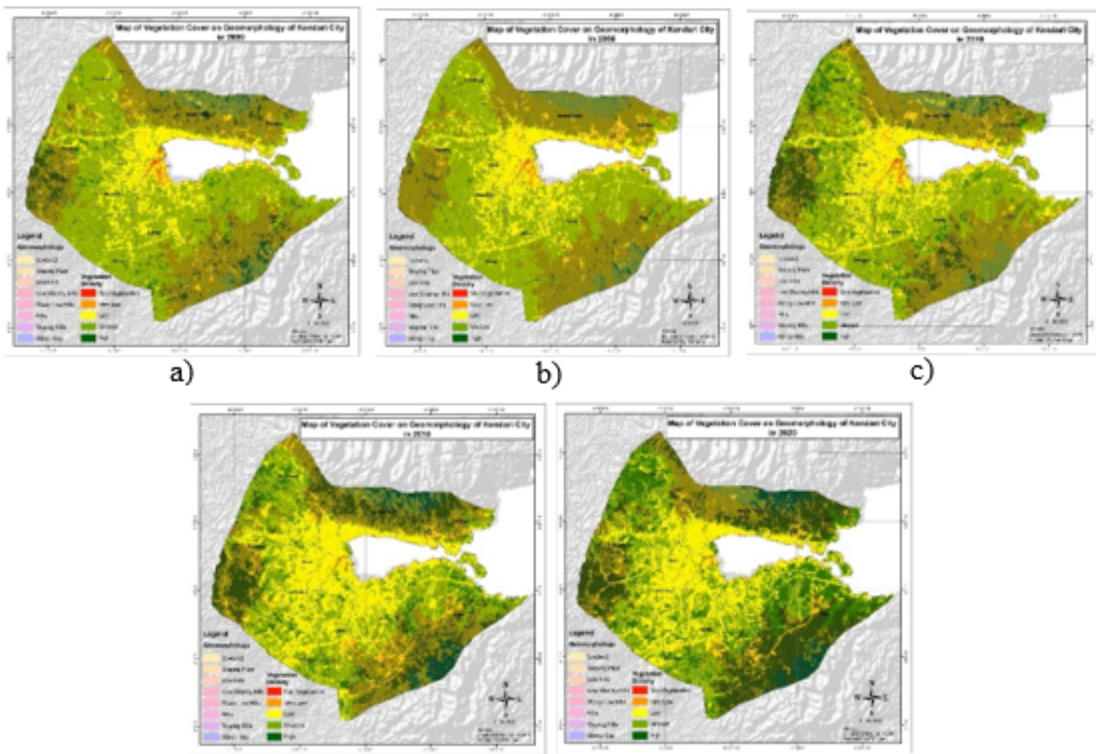
still decreasing every year. One of the factors that influence changes in land use network, and transportation facilities (Cullingswoth, 1997). The city of Kendari which used to be dominated by agricultural land and plantations overtime began to shift into an urban area. The increase in population every year has an impact on increasing the need for built-up land.

Based on **Table 4** shows, in 2000-2005 the forest area in each sub-district experienced a varied decrease in area. However, from 2005-2020 the forest area experienced a sharp increase of up to 8 times except for the Kadia, Kambu, Puuwatu, and Wua-wua sub-districts. The four sub-districts experienced a decrease in area in 2015 and improved in 2020 but were not as good as Wua-wua sub-district which only experienced an increase of 1.06 ha in 5 years. The sub-districts located in the north, such as Kendari Barat and Kendari, and in the south, such as Abeli and Poasia, also have better forest areas.

The increase in forest area coincided with a decrease in is influenced by the concentration of the population with all its activities, the road agricultural/plantation land and a stretch of land overgrown with grass, reeds, shrubs, and some green open spaces. Several sub-districts such as Abeli, Baruga, Poasia, and Puuwatu experienced an increase in the area in 2000-2005 and then experienced a significant decrease until 2020. However, this is no more of a concern when compared to the sub-districts of Kadia, Kambu, Kendari, Mandonga which experienced a decline for 20 years. This is in line with the problems faced in the preparation of the Kendari City Settlement Area Implementation Strategy (SPKP), these problems include (1) settlements living on the banks of rivers/times; (2) slum settlements; (3) settlements living in protected areas (Tahura Nipa-Nipa): and (4) settlements located in areas prone to landslides and steep slopes. Kendari City, which is an urban area and the provincial capital, has encouraged a significant vegetation cover change, as presented in **Table 3**.



a) b) c)

d) e)

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Figure 4. Geomorphology of Vegetation Cover in Kendari City in a) 2000; b) 2005; c) 2010; d) 2015 and e) 2020

Table 5. Built-up Areas/Roads in the Lowlands of each Sub-district in Kendari City

Sub-district	Area (ha)				
	2000	2005	2010	2015	2020
Abeli	240,51	295,41	315,63	409,45	331,51
Baruga	243,55	361,98	455,51	692,27	558,78
Kadia	404,09	467,10	501,55	740,22	701,70
Kambu	498,69	625,21	603,21	878,16	674,75
Kendari	132,87	160,44	135,54	160,33	126,93
Kendari Barat	319,13	335,49	316,05	350,62	317,18
Mandonga	359,01	425,19	357,74	433,36	379,22
Poasia	363,83	514,10	467,15	821,82	575,12
Puuwatu	310,63	392,98	362,81	663,05	495,63
Wua-wua	242,80	292,86	339,67	440,81	430,72
Total	3115,13	3870,77	3854,85	5590,10	4591,54

Source: Data Analysis (2021)

Table 6. Area of Plantation/Agriculture, Shrubs, Grasses, Reeds, Green Open Space in the lowlands of each sub-district in Kendari City

Sub-district	Area (ha)				
	2000	2005	2010	2015	2020
Abeli	1532,28	1506,56	1440,69	1136,88	600,35
Baruga	1672,10	1638,90	1424,19	1071,45	1016,11
Kadia	918,44	884,98	720,31	525,18	554,00
Kambu	1121,44	1039,11	949,72	761,84	823,00
Kendari	205,78	184,48	170,76	156,14	88,22
Kendari Barat	84,69	57,22	67,62	56,51	79,10
Mandonga	882,25	819,46	681,97	642,38	442,99
Poasia	1204,32	1113,50	1077,48	693,88	686,59
Puuwatu	1631,30	1627,16	1371,42	1153,90	1041,75
Wua-wua	399,34	348,00	280,01	187,76	198,62
Total	9651,95	9219,36	8184,17	6385,92	5530,72

Source: Data Analysis (2021)

Changes in the relatively urban area are not as fast as what happened in the Districts of West Kendari, Abeli, and Kambu because apart from being a protected forest area, it is also influenced by geomorphological forms in the form of lowlands. Kendari City is dominated by lowlands of 59% of the total area. **Table 6** shows that each sub-district experienced a decrease in the area of plantation/agriculture, land consisting of bushes, grass, reeds, and green open space. However, the West Kendari sub-district has undergone various changes due to the geomorphological form which is dominated by low, flat to steep hills. Vegetation cover change into built-up areas based on Table 5 in the lowlands are quite significant in every sub-district except for the districts of West Kendari, Kendari, Abeli, and Poasia. If it is accumulated every 5 years, there is a decrease in the area of vegetated area of 824.25 ha in Kendari City. This change was followed by the addition of built/road areas such as settlements, offices, government, and infrastructure by 295.28 ha every 5 years. This means that the lowlands are also experiencing land conversion to other forms of non-vegetation into a built area of 528.97 ha.

In a study conducted by Sari & Dewanti (2019) that the city of Pekanbaru which is dominated by flat topography with a slope of 0-8% is the orientation of city development through housing development both by the government and the private sector. Geomorphological forms with slopes < 8% or sloping and flat are very suitable to be developed as residential locations because they have better environmental quality than those in areas with sloping to steep slopes or in hilly areas as happened in Kulon Progo Regency (Hidayati, 2020). In addition to environmental quality aspects, the geographical configuration of hills and mountains also affects land clearing as a built area or infrastructure. The Geographical Difficulty Index contributes to the acceleration of regional development. Studies in the central part of Gunungkidul Regency have lower geographical difficulties when compared to the northern and southern regions of the region so that village development is relatively faster because it is close to growth centers and complete infrastructure (Adinugroho, 2016). This is further strengthened by research conducted by Maryantika, et al (2018) which found that the value of the vegetation index was positively correlated with the height and slope of the land.

The conversion of vegetation to other uses is quite high because the level of suitability of the area for various forms of land use makes the lowlands a target for expansion of the built-up area for residential areas, but this must be anticipated because the area with low-lying geomorphological forms with almost flat slopes has the potential to become the center of the uncontrolled growth of housing and slums in the future. The study that took place in Pemenang Subdistrict and Tanjung Subdistrict, North Lombok, which are low-lying areas, actually became the center of slum settlements (Pratama et al., 2020). Therefore, a policy on land conversion into built-up areas is needed including: 1) Restrictions and controls are needed residential areas that have already developed around the north of Kendari City (Kendari Barat, Kendari and Mandonga Sub-district) by taking into account physical factors such as the geomorphological shape of the area; 2) The downtown area should increase the intensity to allow development so that on the west side of the center of Kendari City which has a large enough vacant land, it can be considered because it is no longer possible to develop regionally rather than converting vegetated areas to several cultivation areas and protected areas; 3) It is necessary to reconsider residential areas such as industrial areas, terminal areas and ports that have the potential to develop new residential areas; 4) the development of residential areas must be planned as well as possible on a regional scale and of course pay attention to aspects of sustainable development that cannot be separated from the minimum scale of the RTRW; 5) In areas with dense forest vegetation and dominated by agricultural activities, such as in the west of Kendari City, special attention should also be paid to the existence of residential areas as a result of the conversion of vegetated areas while still integrating with the concept of agro-tourism development.

CONCLUSIONS

The classification of vegetation cover was carried out using the NDVI method. The classification of vegetation cover from 2000, 2005, 2010, 2015, and 2020 is divided into 5 classes, namely water bodies, open land, built areas and roads covered with asphalt, paving or soil, plantations/agriculture, bushes, grasses, reeds, green open space, and forest. Each sub-district experienced a decrease in vegetation cover in the form of plantations/agriculture, bushes, grass, reeds, green open space except for West Kendari District which tended to be varied. Meanwhile, the forest area is getting better every year.

The built-up area and streets in Kendari City have increased in the area. This increase was caused by a surge in population and migration that led to land conversion as settlements, shops, hotels, services and trade, and industry.

Geomorphological forms such as lowlands are one of the driving factors for vegetation cover change which experience conversion to other uses covering an area of 824.25 ha every 5 years in Kendari City, while low hills and high hills from flat to steep are inhibiting factors. In addition, the existence of protected forests is also a factor inhibiting vegetation cover changes that is protected by law so that the availability of forests in Kendari is still quite abundant. Land clearing is done on a flat area and avoids hilly areas that are sloping to steep.

The government needs to pay special attention to vegetation cover change in lowland geomorphological forms to avoid serious problems in the future.

GEE is very useful in monitoring changes in multi-temporal vegetation cover with ready-to-use results and has an NDVI algorithm that is quite simple to apply.

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