

The Comparison of Vector and Raster Data for The Calculation of Landscape Environment Using a Geographic Information System Approach

Eggy Arya Giofandi¹, Khursatul Munibah², Kraugusteeliana³, Amira Novalinda⁴, Cipta Estri Sekarrini⁵

Master Program of Regional Planning Science, IPB University¹

Department of Soil and Land Resources, IPB University²

Departement of Information Systems, Universitas Pembangunan Nasional Veteran Jakarta³

Master Program of Mathematics Science, Institut Teknologi Bandung⁴

Doctoral Program of Geography Education, Universitas Negeri Malang⁵

eggyarya@apps.ipb.ac.id¹, munibah@apps.ipb.ac.id², kraugusteeliana@upnvj.ac.id³,

miranovalia@gmail.com⁴, ciptaputri123123@gmail.com⁵

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ABSTRACT

GIS-based measurements can combine vector and raster data to produce thematic data obtained from remote sensing data. The data used in this study uses data on land use in the city of Pekanbaru. After the data is obtained, the pixel calculation process is carried out using three methods: the cell center method, the maximum area, and the maximum combined area. This data describes information with multiple raster data resolutions and then interprets the level of distortion in the data. The research findings found that in the process of raster data from 8 different resolution levels for the 5x5 meter category, it is able to provide results that are closest to the area of vector data, where PL 1 code produces 404229 pixels, PL 2 code ranges from 225717 pixels, PL 3 code ranges from 160323 pixels, code PL 4 ranges from 92268 pixels, PL 5 code reaches 73384 pixels, PL 6 code reaches 57237 pixels, and PL 7 code reaches 48315 pixels. Meanwhile, of the 3 methods that were compared to determine distortion with vector data, the cell center approach was the closest to raster data by calculation through eight levels of raster resolution compared to the other two methods. In choosing the right pixel resolution for further use in mathematical modeling, it is necessary to pay attention to the level of resolution by generalizing the resolution of satellite imagery data so that the data can have the same resolution. The weakness of the three methods lies in increasing the resolution the greater it will make the data coarser. This research is expected to be used as a consideration in future research to add a more precise process and be able to produce less storage capacity.

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Corresponding Author:

Eggy Arya Giofandi
Master Program of Regional Planning Science, Graduate School
IPB University
IPB Darmaga Campus, Bogor, West Java, Indonesia
Email: eggyarya@apps.ipb.ac.id

1. INTRODUCTION

Vector data is what most people think of when they think about spatial data [1][2]. Data in this format consists of points, lines, or polygons [3]. At the simplest level, vector data consists of individual points stored as coordinate pairs that represent physical locations in the world [4][5][6]. The points can be connected in any order to form a line, or combined into a closed area to form a polygon [7][8]. Vector data is useful for storing and representing data with discrete boundaries, such as building boundaries or footprints, roads and other traffic routes, and point locations [9]. Whereas, raster data has represented the world as a surface which is divided into squares or regular grid cells, where each cell has an associated value [10]. Dealing with each cell, it is mentioned as a pixel, corresponds to a specific color value [11]. When transferred into a GIS setting, cells in a raster grid can represent other data values, such as temperature, precipitation, or altitude [12][13]. The main difference between a digital photo and a GIS representation is that in a GIS, the following data details where the earth's cells can be found and the size that has been found [14].

One of the acquisitions of raster data is by satellite imagery which provides a perfect background example of this GIS image and setup [15]. Simply put, a satellite image can be thought of as a digital photograph of the world's surface, with each cell showing a specific color [16]. However, when it emerges geographic context, we can set it correctly on Earth and then analyze cell values which can be thought of as color wavelength bands [17]. Raster datasets can be used to store a continuous representation of data, such as weather events and climate or surface elevation forecasts [18]. In this context, the grid representation is more closely related to the representation of physical properties or phenomena found in the world [19].

In the two forms of data comparison, there are certain advantages and disadvantages to use. Vector data is considered a more traditional method of cartographic representation, which provides sharp, clear and scalable representations [20]. It is also more interesting visually. Data is stored without loss or generalization and retains accurate geolocation information [21]. Besides, some attributes and data fields can be stored in feature vectors. However, the processing and storage of vector data can be intensive [22]. Since vector data is stored as a series of dots, each item needs to be stored and registered. In addition, each point or set of points can have associated data that can be added to the vector storage and processing time [23]. Topological representations can be useful in vector data, but can often be processed intensively. Depending on the size and number of features, editing and processing of vector data in topological or other formats.

2. RESEARCH METHOD

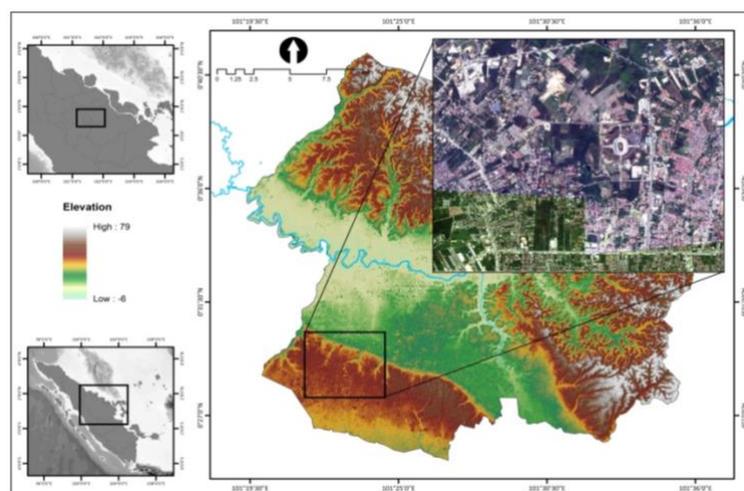


Figure 1. Research location

The calculation of vector - raster - vector values used land use data of Pekanbaru in 2021. This data was obtained from object-based analysis calculations that took into account the values between pixels. SPOT 7 imagery was used to create land use data with rectangle boundaries, this was used to produce more detailed information with a total area of 2569 hectares smaller than the administrative boundary of Pekanbaru City. Whereas, the total area of Pekanbaru city has an area of 402.32 Km², with a total population of 983,356 people in the 2020 population census [24]. After the remote sensing data was processed, the data entered the vector analysis section into three stages, namely analysis of points, lines, and areas.

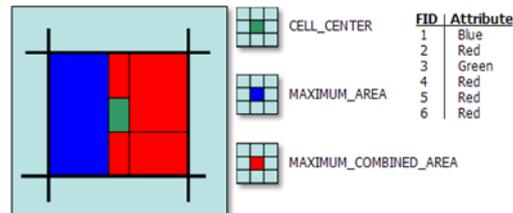


Figure 2. The Calculation model of pixel polygon method level
Source: ESRI, 2022 [25]

The area analysis stage used three methods (cell center, maximum area, and maximum combined area) with a resolution range of 5 meters, 10 meters, 30 meters, 50 meters, 70 meters, 100 meters, 130 meters, and 150 meters. The land use classes used in this study were categorized as (1) built up land, (2) shrubs, (3) mixed gardens, (4) open land, (5) plantations, (6) fields/moorlands, and (7) forest. If it is assumed that the coordinates of each polygon (P) are (x₁,y₁), (x₂,y₂),..., (x_n,y_n). Then the polygon for the use of the three methods can be calculated using the formula [26] as follows.

$$Sp = \sum_{k=1}^{+\infty} S_{\Delta P_0 P_k P_{k+1}} = \frac{1}{2} \sum_{k=1}^{+\infty} (x_k y_{k+1} - x_{k+1} y_k) \quad (1)$$

3. RESULTS

One of the approaches used in polygon to raster analysis at this stage is by using the cell center method, where the cell center implies information in the middle of the polygon and if the land use is around the pixel cell center, then what is categorized in one land use unit is the one whose position is located in the middle side. The next method is the maximum area method, in which it produces information that dominates the polygon and if the land use does not refer to the polygon that hits the center of the pixel, then what is categorized in one land use unit is the position where more information appears in one pixel, and the last method is the maximum combined area method and it is obtained from the combined process between the dominance of polygon information and the middle of the data. This method is a combination of the maximum area and cell center methods, so what is categorized in one land use unit is the one whose position appears more and also the center of the information is in one pixel. The results of the calculation of the cell center method, maximum area, and maximum combined area at a resolution of 5 meters to 150 meters are shown in the following figure.

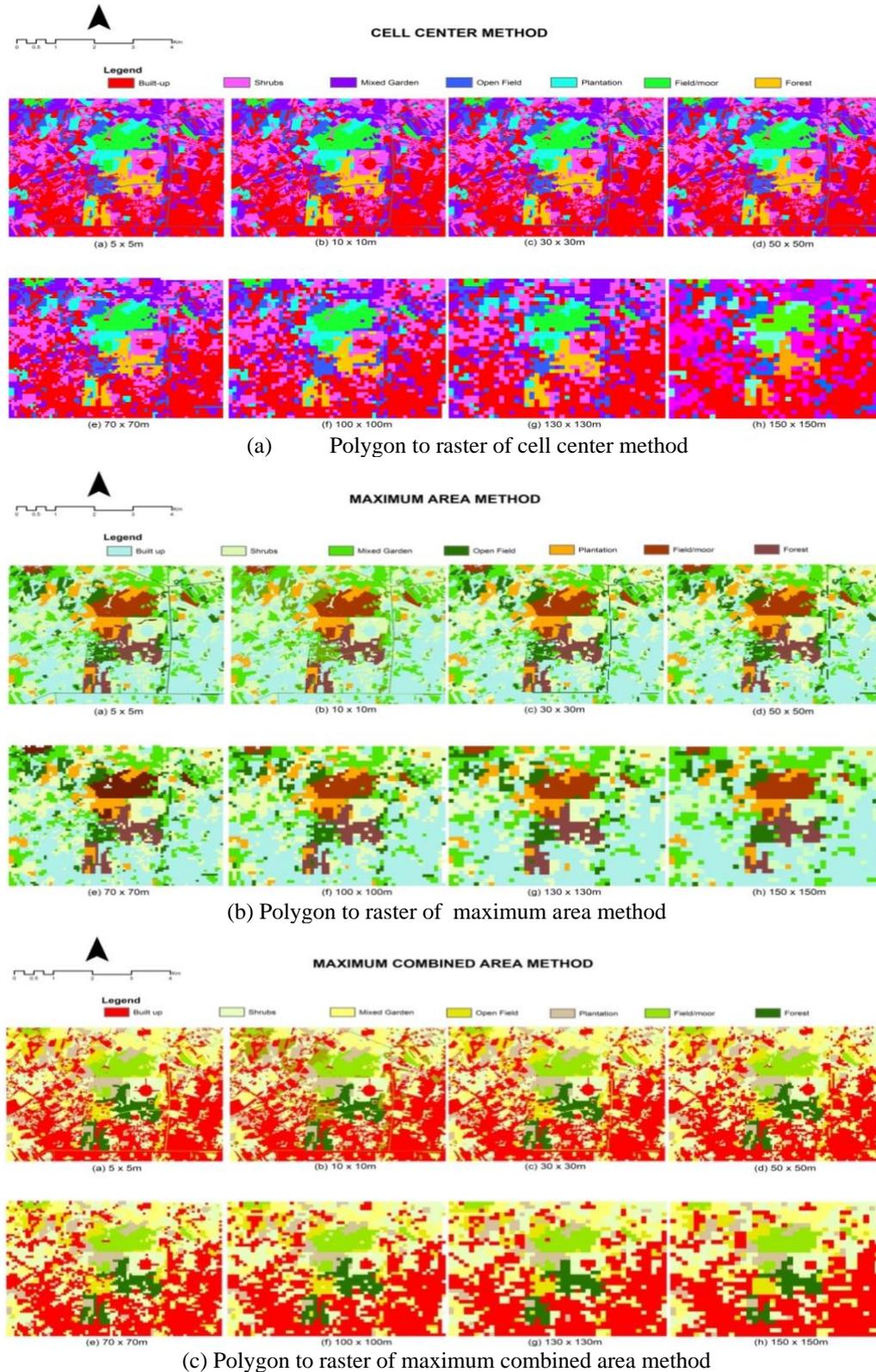


Figure 3. The pixel change of (a) cell center, (b) maximum area, and (c) maximum combined area method

The value of the change detection indicator for all pixels is calculated by the formula [27], further, the results can be created a map of the magnitude of change and a statistical histogram as

shown in Figure 3. produces values that undergo generalization of vector information. The vector land use class that has a more dominant area will have an influence on other land use classes. Where land use codes 6 and 7 are eliminated in the data change section to raster at a smaller resolution level (100, 130, 150 meters). Furthermore, there is no significant difference between the raster methods for all types of land cover at the 5 meter resolution level.

This condition can be seen between the vector and the three conversion methods to raster so as to produce a difference in value close to the value contained in the vector data, although there is no significant difference, but in terms of the value of the cell center method, it produces an area value that is closest to the vector data. When the conversion algorithm is different, the important point for implementing spatial operations lies in the level of output used in both fine and coarse. In appearance, Figure 3 has a fairly small difference from the three methods where the application of the algorithm becomes the main key determinant in causing quite different results. These area and pixel changes values shown in (table 1) with the assignment distance changes applied by the rules in vector to raster conversion can result in large differences in the output data set, even with the same input vector data.

Table 1. Pixel values and changes in resolution level area with three methods

Number of Pixel and Large based on the pixel resolution level of call center method							
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
Resolution 5 meters	1	404229	1010.57	Resolution 70 meters	1	2030	994.7
	2	225717	564.29		2	1172	574.28
	3	160323	400.8		3	827	405.23
	4	92268	230.67		4	469	229.81
	5	73384	183.46		5	379	185.71
	6	57237	143.09		6	298	146.02
	7	48315	120.78		7	242	118.58
Resolution 10 meters	PL Code	Number of Pixel	Large (Ha)	Resolution 100 meters	PL Code	Number of Pixel	Large (Ha)
	1	100980	1009.8		1	1025	1025
	2	56419	564.19		2	567	567
	3	40100	401		3	398	398
	4	23056	230.56		4	228	228
	5	18378	183.78		5	188	188
	6	14302	143.02		6	149	149
7	12107	121.07	7	120	120		
Resolution of 30 meters	PL Code	Number of Pixel	Large (Ha)	Resolution of 130 meters	PL Code	Number of Pixel	Large (Ha)
	1	11298	1016.82		1	613	1035.97
	2	6257	563.13		2	322	544.18
	3	4444	399.96		3	239	403.91
	4	2537	228.33		4	144	243.36
	5	2047	184.23		5	101	170.69
	6	1597	143.73		6	89	150.41
7	1354	121.86	7	76	128.44		

	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	4102	1025.5		1	479	1077.75
Resolution	2	2226	556.5	Resolution	2	236	531
50	3	1597	399.25	150	3	178	400.5
meters	4	905	226.25	meters	4	102	229.5
	5	748	187		5	72	162
	6	566	141.5		6	66	148.5
	7	488	122		7	49	110.25
Number of Pixel and Large based on pixel resolution level of maximum area method							
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	404143	1010.36		1	2026	992.74
Resolution	2	225730	564.33	Resolution	2	1180	578.2
5 meters	3	160347	400.87	70	3	824	403.76
	4	92288	230.72	meters	4	434	212.66
	5	73387	183.47		5	378	185.22
	6	57242	143.11		6	299	146.51
	7	48319	120.8		7	265	129.85
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	100856	1008.56		1	1028	1028
Resolution	2	56451	564.51	Resolution	2	565	565
10	3	40118	401.18	100	3	392	392
meters	4	23076	230.76	meters	4	207	207
	5	18382	183.82		5	182	182
	6	14312	143.12		6	150	150
	7	12113	121.13		7	134	134
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	11174	1005.66		1	617	1042.73
Resolution	2	6323	569.07	Resolution	2	334	564.46
of	3	4471	402.39	of	3	230	388.7
30	4	2549	229.41	130	4	105	177.45
meters	5	2054	184.86	meters	5	94	158.86
	6	1602	144.18		6	86	145.34
	7	1367	123.03		7	86	145.34
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	3980	995		1	468	1053
Resolution	2	2335	583.75	Resolution	2	254	571.5
50	3	1612	403	150	3	181	407.25

meters	4	886	221.5	meters	4	76	171
	5	754	188.5		5	80	180
	6	580	145		6	68	153
	7	491	122.75		7	57	128.25
Number of Pixel and Large based on pixel resolution level of maximum combined area method							
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	404141	1010.35		1	2049	1004.01
	2	225732	564.33		2	1185	580.65
Resolution	3	160350	400.88	Resolution	3	819	401.31
5 meters	4	92289	230.72	70	4	413	202.37
	5	73386	183.47	meters	5	376	184.24
	6	57241	143.1		6	298	146.02
	7	48318	120.8		7	267	130.83
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	100859	1008.59		1	1032	1032
	2	56458	564.58		2	566	566
Resolution	3	40116	401.16	Resolution	3	394	394
10	4	23077	230.77	100	4	203	203
meters	5	18382	183.82	meters	5	178	178
	6	14311	143.11		6	150	150
	7	12113	121.13		7	135	135
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	11191	1007.19		1	624	1054.56
	2	6319	568.71		2	334	564.46
Resolution of	3	4469	402.21	Resolution of	3	230	388.7
30	4	2540	228.6	130	4	120	202.8
meters	5	2053	184.77	meters	5	106	179.14
	6	1601	144.09		6	94	158.86
	7	1367	123.03		7	83	140.27
	PL Code	Number of Pixel	Large (Ha)		PL Code	Number of Pixel	Large (Ha)
	1	3991	997.75		1	470	1057.5
Resolution	2	2339	584.75	Resolution	2	251	564.75
50	3	1607	401.75	150	3	180	405
meters	4	877	219.25	meters	4	79	177.75
	5	753	188.25		5	78	175.5
	6	579	144.75		6	69	155.25
	7	492	123		7	57	128.25

It often raises doubts in the selection of the best method priority. The empirical tests of previous research are useful guides for determining the best method with spatial data regarding the problem of data sets or data conversion. Where (Table 1) groups the various levels of pixel resolution from the use of three different methods. From these findings, it is found that the application of raster resolution at 5x5 meters is a value that better describes information on the earth's surface, conditions in the use of geographic spatial data cannot be separated from remote sensing data. Therefore, in selecting the raster data resolution level, it is necessary to adjust the value of the remote sensing pixel resolution. If the use of geographic data uses medium resolution satellite imagery, the vector data used in additional information requires the data conversion operation process to use a resolution of 30 to 50 meters. Even though in table 1 the distortion level of the raster area value is greater, it is often a tolerant value in modeling geographic phenomena.

The study of the discussion of converting vector data into raster data is still a consideration in selecting the right data conversion method to express land use at a representative level in more detail. The appearance of changes in the area of vector data in raster data format in this study can be seen in (Figure 4), where from the three methods used, the distortion values differ in reaching the wide limits of vector data. Conversion to vector polygons usually identifies continuously connected cells forming a grid of cells that will become polygons. The grid area value based on land use class obtained from multiple raster resolutions with different methods (figure 4) informs that the maximum area method produces the highest level of distortion compared to other methods, this can be seen at a resolution level of 50 meters. And for the conversion method that is closer or the level of distortion is small, it lies in the cell center method with the overall appearance of the various resolution levels leaning closer to the line graph of the vector data. The value of the distortion level of the three methods (figure 4) can be part of developing a method for converting data to raster by looking at the size of the data and understanding the significant changes that occur when the grid cell size is converted to a larger one.

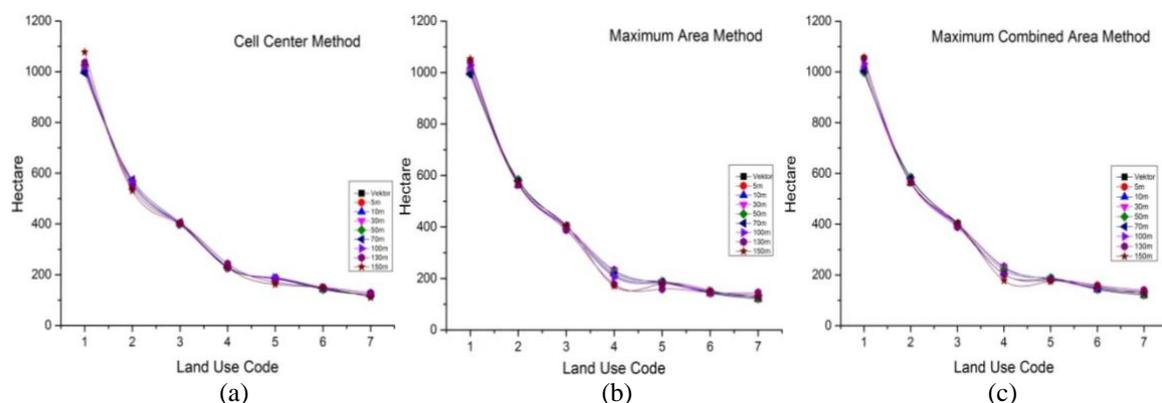


Figure 4. The graph of large change based on pixel resolution level of (a) cell center, (b) maximum area, and (c) maximum combined area method

4. DISCUSSION

The findings indicated that the use of polygon has been converted to raster data results in a more visually interesting interpretation, however, in selecting the level of resolution one must still consider the lowest value of distortion so that data becomes more interesting and still pay attention to the true area of the vector data. When it is viewed from data storage, vector data is relatively more economical in terms of file size and precision in location, however, it is very difficult to use in mathematical computations. In contrast, raster data usually requires larger file storage space and lower location precision, but is easier to use mathematically [28].

Raster data is well suitable for mathematical modeling and analysis. It is due to a raster surface has represented a single attribute or value, calculations, algorithms, and quantitative processing can be performed very quickly and easily. Grid areas are great for displaying and storing continuous values [29]. Raster memory can also be small because of the way geographic

locations are processed and stored [30]. The coordinates of each cell are taken from their position on the grid, it also requires at least a starting point such as the top left corner, grid cell size, number of rows and columns, and more. This condition places the grid surface into a map or globe projection and provides the correct size and appearance [31].

Each data format has advantages and disadvantages. The choice of the data format used is highly dependent on the intended use, the available data, the volume of data generated, the desired accuracy, and the ease of analysis. The smaller the size of the earth's surface represented by a single cell, the higher the resolution. Raster data is very good for representing gradually changing boundaries, such as soil type, soil moisture, vegetation, soil temperature, and so on [32]. The main drawback of raster data is the large file size; The higher the grid resolution, the bigger the file size.

5. CONCLUSION

Changing or converting vector data into a GIS-based raster is carried out using the cell center, maximum area, and maximum combined area methods to produce area values that are different from each other. A comparison of distortion between vector data and the results in raster data results in the cell center method having the smallest difference compared to other conversion methods to raster data. This difference has a significant influence in the next stage of mathematical modeling, so as to reduce the bias for modeling landscape planning in the future. While the difference in area using data comparison through five different pixel resolution levels explains that the five-meter resolution level is able to produce a hectare area value close to the area in vector data, This can be used to better represent spatial data and produce accuracy close to that of data collected in the field.

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