SLUMS DETECTION ON WORLDVIEW-3 IMAGERY BASED-ON INTEGRATION OF IMAGE SHARPENING AND LACUNARITY ALGORITHM

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Abstract: Population growth and the increasing movement of people in the city will grow new residential area. Ease of access to employment and public facilities location could trigger illegal occupancy in certain areas. Remote sensing data is able to present spatial information in great detail so it can be used as a data source in evaluating the condition of urban settlements. The purpose of this study were to detect the slums resulting from lacunarity algorithm, and determine the accuracy of the resulting image WorldView-3 in the detection and identification of slums with lacunarity algorithm. The method used was remote sensing method with qualitative and quantitative analysis of the lacunarity algorithm and slum variables from Ministry of Public Works (PU). The image Sharpening Worldview 3 (recorded July 27,2015) was used to interpretation of the utilization of settlement blocs. A field survey on April 5 to May 10, 2016 was conducted to examine the results of the classification and utilization of settlement blocs, slums from algorithms lacunarity and slums from PU. The results showed that the image of WorldView-3 provides moderate accuracy in the detection of slums (33.3% on a moving window 7x7, 50.0% on a moving window 5x5, and 58.3% on a moving window 3x3). The smaller size of the moving window that is used will increase the ability of the algorithm to detect slums.

Keywords: lacunarity algorithm, image sharpening, WorldView-3, slum

1. Introduction

Development of the cities in Indonesia are generally supported by continuous population movements both on a short distance and long distance. This condition significantly related to the job location (Sohn, 2005 in Rachmawati, 2014).Population movements that occur continuously can led to increased amount of urban settlements annually. This will increase land conversion, due to increasing price of land in strategic urban areas. Residential land requirements increased, but the decreases land availability. Its will develop new residential area on all spatial aspects in the city, especially at locations utilized asmigrant entrance.

Identification of slums if performed overall with terrestrial method on each parameter will require a lot of time, effort and considerable costs. The presence of image processing technology integrated with remote sensing can improve potential benefits of satellite imagery, that is no longer based solely on spectral aspects, but has changed from per pixel became per object so as to facilitate the analysis of urban studies (Danoedoro, 2012).

WorldView-3 satellite with excellent spatial resolution 0.31 meters (31 cm)can be used in the identification of the slums. Slums research using high-resolution satellite imagery during its development has been done in the last decade (Patino and Duque, 2013). That is because the more detail appearance of settlement objects in an image will more easy to differentiating slum settlements around it. Good spatial aspects will also assist in the identification of the parameters of slums in relation to the physical aspects of the settlement.

Lacunarity algorithm can be used as a substitute for a field survey in the detection and classification of slums settlement. This algorithm has the ability to detect the slums efficiently by minimizing presence of intensive field surveys (Kit et. al., 2012). Another advantage of this approach can be utilized on a limited resource, the absence of specific requirements regarding software and hardware techniques developed is feasible and suitable for use in developing countries (Kit. et. al., 2013). Lacunarity algorithms require binary data that can be generated from existing methods of image binarization. Image binarization method was using a line detection algorithm. According to Martinez and Cupitt (2005), line detection has elaborated/separate the individual objects (in this case the size of the house) so it is more suitable to be used in the algorithm.

So far, the main use of high-resolution imagery in Indonesia is still within the limits of helping the interpretation of visual appearance which is considered slum settlements, and not use the automated identification methods such as lacunarity algorithm. Slum differentiator identification can be used as a reference in knowing the extent and slumsdistribution, especially in Wonokromo District. Identification of slums in Indonesia can refer to the slum parameter identification of the Ministry of Public Works for determining urban slums in five criteria (PU, 2014).

2. Study Area

Surabaya as the second largest city in Indonesia has increase in population from 2000 to 2010, by 0.6% from 2,588,816 became 2,765,908 with an average population density is 8,463 inhabitants per km2 (Central Bureau of Statistics, 2011). The population density is quite high, has not been spread evenly on all sides of the city because of the different distance and ease of access to public facilities and job location. Such situations will cause dense settlements concentration only in certain areas. Based on data from RP4D Kota Surabaya in 2008-2014, distribution locations of slums are spread evenly in the Surabaya.

One of the District in southern Surabaya is Wonokromo. It has an area of ± 6.283 km^2. This district has six sub districts namely Wonokromo (0.895 km2), Ngagel (0.684 km2), Ngagelrejo (1.023 km2), Darmo (1.295 km2), Sawunggaling (1.62 km2), and Jagir (0.766 km2). District Wonokromo is the central main crowds in the south, such as Wonokromo Train Station, Joyoboyo Bus Terminal, Artery Road Ahmad Yani, Ahmad Yani CBD Corridor, and the center for trade and services. It also became the main entrance of migrants from the Mojokerto, Sidoarjo, Malang, and surrounding cities. This will encourage the development of slums in this district will be more intensive while compared with the other districts. The existence of slums in District Wonokromo in 2008 located on Ngagel Rejo and Jagir Sub-Districts with total area 8% (± 0.5 km2) (Environmental Bureau of Surabaya, 2008).

The automated slum detection was used lacunarity algorithm that has been applied to WorldView-3 imagery acquire on July 27, 2015. It was delivered by the data provider as a level standard 2A which was radiomatrically calibrated, corrected for sensor- and platform- induced distortions and mapped to a UTM Zone 49S. The data covers approximately 100 km^2 of Wonokromo administrative boundary and surrounding districts.

3. Methodology

3.1 Image Sharpening

Image enhancement using algorithms on remote sensing data to generate the appearance of the image, which makes it easier for visual analysis or further processing (Jensen, 2004). Image enhancement can be done by incorporating multispectral and panchromatic imagery called "pan-sharpened color composite". Therefore, the panchromatic image is generally less attractive to the visualization despite having excellent spatial resolution. Hence, a method of image sharpening can combine excellence in aspects of color multispectral with panchromatic image in detail spatial aspect (Danoedoro, 2012). Image enhancement worldview-3 performed with Gram-Schmidt image fusion between multispectral and panchromatic channel in order to obtain images with better visual and spatial quality (Susanti, 2015).

3.2 Edge-Detection

Edge sharpening is very good to present the appearance of the object vary considerably each other so the image can be distinguished easily (Danoedoro, 2012). To produce images using edge filtering, the existing image should perform the edge detection method by using one of the algorithms, such as linear detector, nonlinear detector, and semilinear detector. The use of line detection using the linear detector can improve the filtering results in edge detector (Eberlein, 1974). Edge detector acquisition, obtained from the Laplacian sharpening edge enhancement method to generate binary data as primary input to the lacunarity algorithm. The filter has been successfully used to analyze satellite imagery of urban areas and perform feature extraction (Kit, 2013).

3.3 Lacunarity Algorithms

Lacunarity provided by Malhi and Roman-Cuesta (2008) is defined as:

$$\Lambda = \sigma_r / \overline{x}_r^2 + 1$$

Λ is the lacunarity, σr is the variance and xr is the arithmetic mean of the number of filled pixels within all r-sized unique square subsets (referred to as sampling window) of the larger subset P of the original binary image. As the sampling window of size r traverses through P, the number of filled pixels within every position of this window is counted and stored in an array. After all unique sampling window positions are processed the algorithm calculates variance s and arithmetical mean x for P and then computes Λ single lacunarity value L for this subset (Kit, 2012).

Lacunarity can observe the size of the fractal dimension or deviation complementary geometric structure of the translational invariance (Gefen et. al., 1984). This makes it possible to distinguish the spatial patterns through the gap analysis, with distribution at different scales (Plotnick et. Al., 1996). Texture analysis on urban space using satellite images for example using lacunarity is a good analysis tool as it has a multi-scalar measure making it possible to do the analysis of density, packing or dispersion through specific equations. In the case of slums in Malhi (2008) showed that if the value of the resulting low lacunarity referring to the dense and irregular settlements that show the probability of slums higher. Lacunarity fractal analysis in this study using a moving window algorithm types/Gliding box/moving window. Gliding-Box when it is applied to a binary image (image with only 1 bit) counting only the pixels in the foreground. This is because each pixel in the binary image can have only one of two possible values (either background or foreground) (Karperien, 2007). So that, if applied to the slums analysis will show binary information, contain potentially slums and not.

3.4 PU (Ministry of Public Works) Slum Parameters

The phases on slum area identification were using certain criteria. Determination of criteria on slum area performed by considering various aspects or dimensions. In addition, the criteria used as a buffer zone of metropolitan cities such as slum area identified in adjacent or directly adjacent to the area that became part of the metropolitan city. Slum location identification and classification using five major criteriasare the economic, non-economic, infrastructure, land status, and commitment of the local government (PU, 2014). Assessment of slum area is conducted with a weighting method on each criterion.

4. Result

4.1 Image Sharpening

Multispectral resolution of Worldview-3 at 1.24 m enlarged four times so that same with a panchromatic band pixel size of 0.31 m. The type of image sharpening that used was the transformation of Gram-Schmidt. This transformation can maintain the spectral aspect thus enhancing image visualization aspects (Liu and Mason (2009) in Danoedoro (2012)) and has been proven in the research by Susanti (2015).

The results of image sharpening in figure 1, inform that panchromatic image with high resolution are less able to distinguish the type of roofs, because the grayish hue complicate the visual interpretation in complex urban objects. This type of roof becomes an important point that helps and became the fastest observed because in addition to assisting in the identification of settlements, also play a part in determine the overall unity of a home. Therefore, not all house consists of one roof only. The advantages are shown from clarity aspect of the roof pattern boundary on each house because it supported by the excellent spatial aspects.

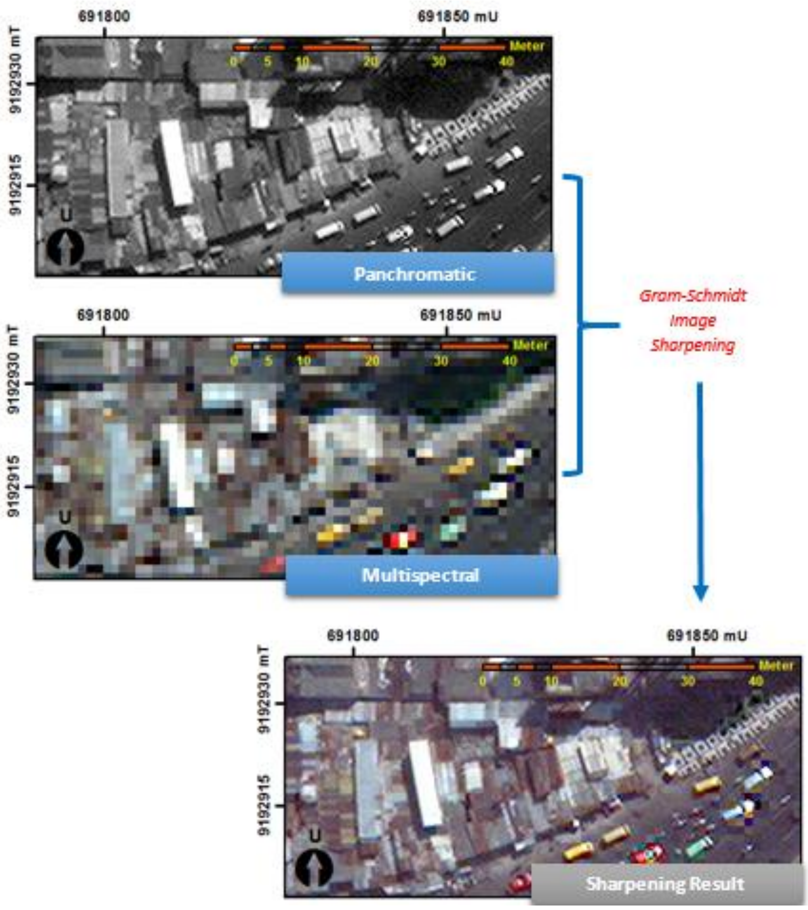
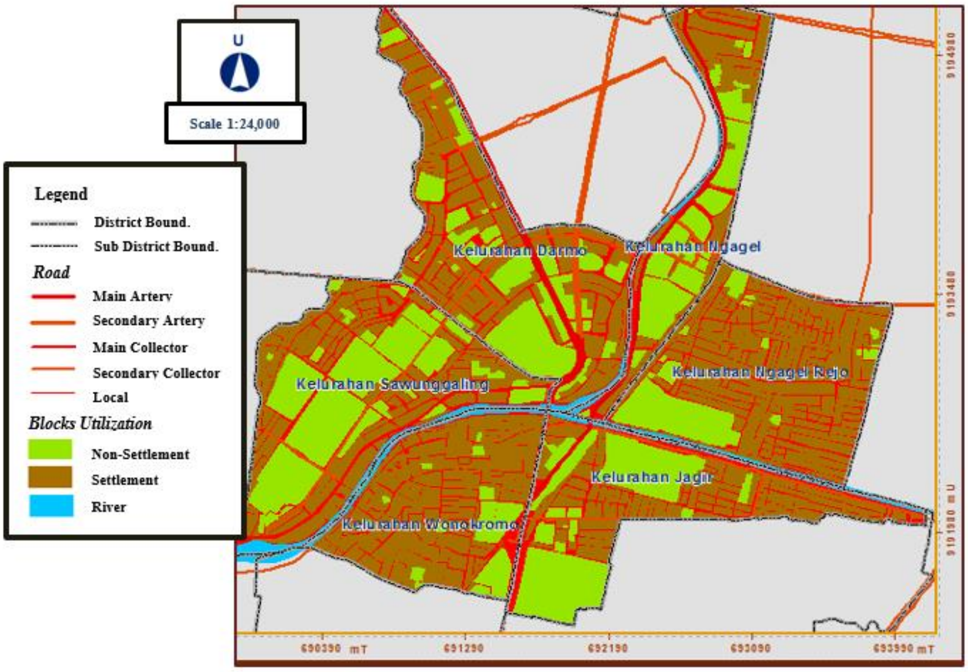


Figure 1. Illustration of image sharpening on WorldView-3 imagery

4.1.1. Blocs Utilization Analysis. Classification of the settlement performed visually in the pan-sharpened imagery to distinguish settlements with other uses such as vegetation, vacant land, cemeteries, parks, and more. The classification generates residential area blocs as the basis for further analysis stage. The use of visual interpretation is based on the appearance of the image of the study area, with mostly built-up area that would be more efficient if done visually than digital.The interpretation utilization in a bloc of settlements assumed several things, the first emphasizes the shape of the roof, the second emphasizes the areal extents of the building, and the third is local knowledge in the study area. A field survey in each block only serves as a conclusion when the bloc is not intended as a settled area. Utilization of blocks besides settled land will be classified as non-settlement block (Figure 2). So that, the final stage of the pan-sharpened image interpretation generates settlement blocs which functioned only as residence.



4.2 Edge Detection

The basic data that is absolutely necessary in the lacunarity analysis is binary data. The binary data used was the result of line detection binarization method. Kit (2012) states that there is no standard reference regarding the type of most appropriate line detection binarization method for use in the fractal dimension calculation. Further in Danoedoro (2012) explains that the Laplacian edge enhancement can help clarify building block to the class identification of urban settlements.

The size of moving window used size 7x7, 5x5, and 3x3. Moving window size 7x7 is used as the initial size. The use of the kernel selection refers to moving window size on Niebergall (2008) that the house size of slum is not more than a few meters, then this indicates to use the kernel size/window moves increasingly smaller than the initial size to be able enhance the detection capabilities of slum. The smaller size of the kernel, then detection rate of irregularities in the settlement with the smallest size of an areawill be better detectable.

Laplace filter shows edge sharpening results in Figure 3, the type of data as an input at each filter is binary data. The resulting edge sharpening filter is generated from the pixel values of the original image reduced by the value on Laplace filter matrix produce the edge sharpening of all objects. In the image that has the window size 3x3, 5x5, and 7x7 gives different appearance on every output binary image.

Edge sharpening effect only affects the sides / edges of objects that exist in the image. The type of data that generated the binary data with two values. That is because Laplace has done a spectral selection at the edges of the objects and omit information on the another part. The value of 1 representing a value of clear (in Figure 3 represented a yellow background color), indicating the presence of the edge pixels, whereas pixels instead of the edge has a dark color or value is 0. For example, in the image in Figure 3, the solid block with a built-up area that has a roof does not show the whole block has a dark color, but has a bright color that is fairly evenly distributed. That's because each edge of the roof gained the sharpening effect.

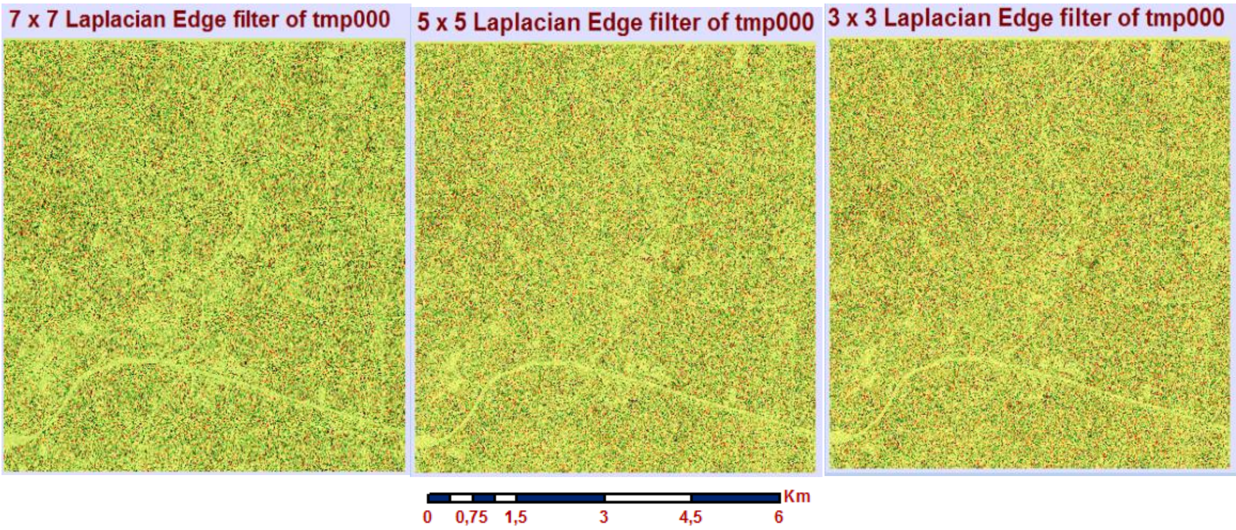


Figure 3. Laplacian edge enhancement result in three different size of moving window.

Smaller size of the filter will have more sharpened edge of the roof. This is related to the ability of a window with a smaller size will be able to detect the roofs with a smaller size than the bigger one. The difference can be observed from the three types of existing window size is the density detection from produced output. In the 7x7 window size with the largest size has the effect of sharpening the edges are less detailed than filter size 3x3. The basic properties of the filter Laplace implementing local engineering operation that converts the pixel values of the central kernel value depends on the pixel values in the surrounding areas or considering the value of neighbouring pixels.

4.3 Lacunarity

Lacunarity is another name for calculation on fractal dimension algorithm at a series of spatial filtering process on textural filter. The use of this filter is useful in extracting a portion of the data in the image, by eliminating unwanted data section. Whereas the choice of texture filter aims to facilitate the identification of irregularities / discrepancies settlement density from the objects in the image.

Figure 4 shows the image result of the lacunarity to obtain information about the location of settlements irregularity roof contained in Laplace sharpening results. The lacunarity image produce output a binary data. Black spots that appear in the image indicates the possibility of irregularity objects that allows greater probability of slums.

Fractal image shows the range of values between 2 and 3. Referring to Kit (2012) smaller pixel values in the fractal image, then the possibility of the presence of slum location will increase. The results obtained pixel values of 2, represented by the color black. The pixel values of 3, shown by the light blue color, so the black spots on the image shows the potential location of slums are located. The whole image in Figure 4 has a number of different density black spots. The smaller size of the moving window being used, the presence of black spots more and vice versa.

Usage the 3x3 kernel will be able to detect irregularities on the object of settlement than the kernel size 5x5 and 7x7. However, hundreds of points that are detected by the algorithm needs to be analyzed one by one to give an exact location of slums, due to the detection results are not fully able to identify slums or slums directly.

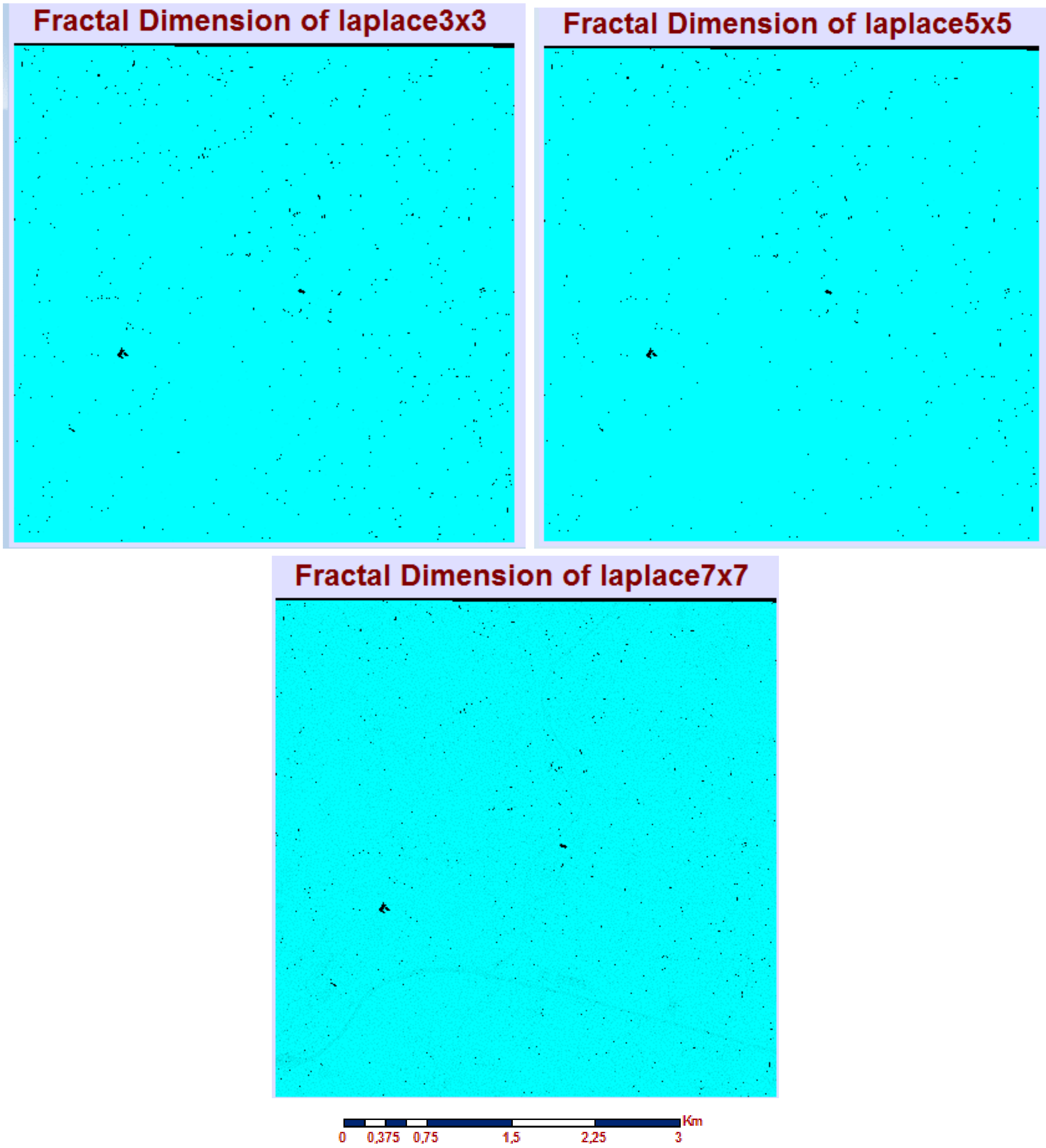


Figure 4. Lacunarity images on different sizes of kernel

Analysis on each fractal image, giving the number of differences in points / locations were categorized as slums. Slum detection reckoned in the detection category for slums only in settlement blocs. Table 1 inform that the window size 7x7 has a number of detection location is less than the window size 5x5 and the 3x3. More least location detection obtained in a 7x7 window size caused by the result of edge sharpening from the previous process generates a sharpening effect that is less detailed than smaller kernel size.

Table 1. The amount of slum detection location by the algorithm on different moving window size.

Sub District	Settlement Blocks	Moving Window Size		
		3x3	5x5	7x7
1. Darmo	99 Blocks	68	59	47
	Percentage	69%	54,6%	47,5%
2. Ngagel	28 Blocks	24	20	15
	Percentage	85,7%	71,4%	53,6%
3. Ngagel Rejo	158 Blocks	131	119	90
	Percentage	82,9%	75,3%	56,9%
4. Jagir	94 Blocks	73	67	49
	Percentage	77,7%	71,3%	52,1%
5. Wonokromo	98 Blocks	80	68	54
	Percentage	81,6%	69,4%	55,1%
6. Sawunggaling	109 Blocks	86	73	58
	Percentage	78,9%	70%	53,2%
TOTAL	586 Blocks	462	406	313
	Accumulation	78,8%	69,3%	51,4%

Figure 5 shows the point detection algorithm is also found in the object besides settlement. Lacunarity detection not only detects settlements, but also other such as water body and vegetation. The mentioned because of the image which is used as input, has not been conducted image masking process to distinguish between objects settlements with other objects.The algorithm will calculate the object irregularities on object besides settlement. This can reduce the accuracy detection of potential slum area, if the object of vegetation scattered irregularly and water body hasn't quiet surface. In the dark spots that exist at the Figure 5 at the water caused by the difference in water level, so that began to diverge hue as a result of shadows on the surface.Therefore, the object detection by the algorithm are interpreted as a form of irregularity.

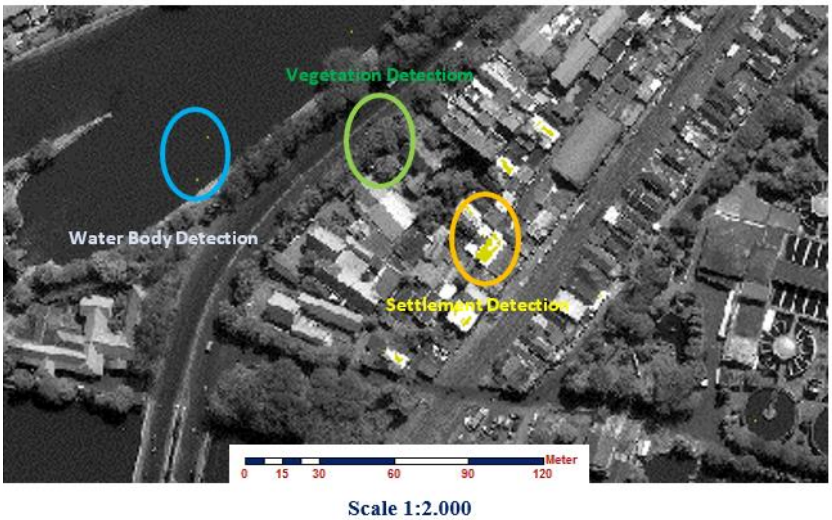


Figure 5. Algorithm detections in Worldview-3 of vegetation, water body, and settlement

The irregularities on vegetation objectdetects when there is inequality in the distribution of vegetation and different sizes on vegetation canopy. However, irregularities on objects besides settlement were not too significant. As indicated at the Figure 6 to the detection result at the object of settlement irregularities tend to have a larger irregularities detection area than another object which were just tiny spots only. Hence, irregularities on settlement objects derived from variations in size that more varied and complex than other objects will be more easily detectable.

Figure 6. Potential slum locations detected by lacunarity algorithm

Field surveys conducted in census method, to overall population, which detected slum by the algorithm. Detectedslum block in the algorithm results was irregularity detection of geometric repetition from the roof shape or form of other objects that exist in the image. Therefore, the location of slum settlements detected by the algorithm does not reflect that all of these locations were slum location, so to determine the accuracy of the detection of algorithms required field testing and standard reference method further slums by PU method.

4.4 Slum Locations

PU slums calculation includes five major criterias there are non-economic, economy, ownership of land, infrastructure, and government commitment. Parameters used include internal and external parameters of a settlement unit. The slum identification is more complex and every region in Indonesia have the same parameters that make this method is more objective. slums calculation was conducted on all existing settlement blocs in Wonokromo using district boundary as a maximum unit administrative analysis. This unit was used because the administrative borders of the sub-district is the smallest administrative boundary data available. Slum identification in every districts are as follows:

4.4.1. Darmo Sub-District. The number of settlement blocs in the Darmo as much as 100 blocks. The number of slum settlement blocs in lower category amounted to 72 blocks, amounted to 22 blocks of medium category, and high slum categories consist of six blocks. Final result of slum in Darmo has a total area of ± 7,479 m2.

4.4.2. Ngagel Sub-District. The number of settlement blocs in the Ngagel as much as 29 blocks. The number of slum settlement blocs in lower category amounted to 13 blocks, amounted to 14 blocks of medium category, and high slum categories consist of two blocks. Final result of slum in Ngagel has a total area of ± 2,445 m2.

4.4.3. Jagir Sub-District. The number of settlement blocs in the Jagir as much as 93 blocks. The number of slum settlement blocs in lower category amounted to 9 blocks, amounted to 82 blocks of medium category, and high slum categories consist of three blocks. Final result of slum in Jagir has no slum because at the settlement with high slum blocks categories has a good dwelling qualities.

4.4.4. Wonokromo Sub-District. The number of settlement blocs in the Wonokromo as much as 98 blocks. The number of slum settlement blocs in lower category amounted to 93 blocks, amounted to three blocks of medium category, and high slum categories consist of two blocks. Final result of slum in Wonokromo has a total area of ± 4,730 m2.

4.4.5. Ngagelrejo Sub-District. The number of settlement blocs in the Ngagelrejo as much as 158 blocks. The number of slum settlement blocs in lower category amounted to 150 blocks, amounted to 5 blocks of medium category, and high slum categories consist of three blocks. Final result of slum in Ngagelrejo has a total area of ± 14,796 m2.

4.4.5. Sawunggaling Sub-District. The number of settlement blocs in the Sawunggaling as much as 109 blocks. The number of slum settlement blocs in lower category amounted to 53 blocks, amounted to 34 blocks of medium category, and high slum categories consist of one blocks. Final result of slum in Sawunggaling has a total area of ± 4,429 m2.

Table 2. Algorithm Accuracy

Algortihm Detection	Lacunarity 7x7 Total Detection: **4 of 12 locations** Accuracy: **33,3%**	Lacunarity 5x5 Total Detection: **6 of 12 locations** Accuracy: **50,0%**	Lacunarity 3x3 Total Detection: **7 of 12 locations** Accuracy: **58,3%**

Accuracy rate result in Table 2 from each moving window size has not met the standards of accuracy in the Jensen (2002) which is a minimum of 85%. Low levels of accuracy obtained is influenced by many things from the roof size factor, until the complexity of slums analytical variables references.One of the factors that most affect the low accuracy is area. The more widespread coverage area being analyzed, potentially lowering the accuracy results of the algorithm. Therefore, not all of the areas that analyzed will be found slum areas. Irregularity shape and size detection of settlement dominating almost all the settlement blocs in Wonokromo. Thus causing the algorithm detect many potential point of slums in the majority of existing blocks.

Settlement characteristic with an irregular pattern in Wonokromo, is a separate obstacle for ease of algorithms analysis. The algorithm used, initially used in the analysis slums in advanced economies country. The different types of settlements between advanced and developing countries lies in the size of the regularity aspects of the settlement. Settlements in developing countries is often irregular mingled with slums led to identification of distinguishing slum require further field surveys.

5. Conclusion

Slums detection in lacunarity algorithm includes all kinds of objects in the image are used as inputs to the algorithm calculation. Mathematical algorithms calculation determines irregularities objects through repetition of geometric shapes, which can lead to potential locations of slum from irregularities in the analysis of the settlements object. The ability of WorldView-3 imagery in settlements irregularity analysis for slums detection in various size of moving window can be seen from the results obtained by accuracy percentage. The biggest moving window size, 7x7, produces an accuracy of 33.3%, moving window 5x5 was 50.0%, and for the smallest moving window 3x3 was 58.3%. It shows that the smaller size of moving window which is used will improve the slums detection accuracy.

For future research, the use of lacunarity algorithms must be preceded by the identification of the characteristic condition of settlement patterns in the study area in order to speed up the selection of the appropriate size of moving window, because it relates to the dominance size of the house roof. In terms of slums parameters, the comparison between physical and social parameters in the slums determination must be balanced, and in addition the body of water and vegetation objects can be identified and eliminated/masked using 'unsupervised image clustering' so that the accuracy detection of the algorithm can be improved. Until now, the most suitable line detection algorithm for fractal analysis is not yet known. Thus need to be tested using various types of edge sharpening algorithms as lacunarity input in order to know the most appropriate binarization method used in fractal analysis. Another thing to note, refers to Kit (2012), a minimum area of use of these algorithms can be calculated if the spatial resolution imagery WorldView-3 was 0.31 m and there are 100 x 100 pixels which translates matrix will produce a 961 m^2 area (as minimum area). That is because the limits of slum rarely intersect with the lacunarity grid cell, causing the algorithm go wrong and did not identify any potential slums.

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