The change of land use patterns and cover on the surface run-off in Krueng Meuraksa sub-watershed

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Abstract. The increasing population and the development of Lhokseumawe city from 2008-2018 resulted in changes in land use, therefore the type of land cover will be a benchmark for how much the surface run-off will occur. In this study there are six categories of land use types, thus are shrubs, plantations, settlements, open land, dryland farming and rice field. Krueng Meuraksa sub-watershed is in Lhokseumawe, North Aceh Regency, Aceh Province. The area of Krueng Meuraksa sub-watershed is 9,958.56 ha. This study aims to observe how the pattern of land use change and run-off in 2008–2018. This study uses secondary data collection methods obtained from related resources. The result shows that there is a change in land use where the area of land cover continues to increase in the residential area, on the contrary the area of land cover continues to decrease in dryland farming area. These changes lead to an increase in the coefficient of surface run-off in Krueng Meuraksa sub-watershed in 2008–2018, where in 2008 it was 0.726 and in 2018 it was 0.787. Based on the run-off coefficient, rainfall intensity and sub-watershed in Krueng Meuraksa, the amount of run-off was 333.403 m\textsuperscript{3}/d in 2008 and 361.765 m\textsuperscript{3}/d in 2018. The increase in the amount of run-off occurs as the run-off coefficient increases every year

1. Introduction
Lhokseumawe is an area which is potential for disasters such as earthquakes, tsunamis, floods, abrasion, and tidal waves. The growth population in Lhokseumawe from 2008 to 2018 has increased. The average growth rate of the population of Lhokseumawe is 8%. Lhokseumawe has an area of 181.06 km\textsuperscript{2} with various land used. The highest portion used as a residential area with amount of 2,861.79 ha \cite{1}.

The increasing number of residents and the development of Lhokseumawe have resulted in the conversion of land functions, therefore, the type of land cover will be a benchmark for how much surface run-off will occur. Land cover types such as open land areas will have small surface run-off because they have a large infiltration capacity. Changes in land use damage the natural vegetation cover \cite{2}, if the open land is converted into a built-up area, it will cause the reduction of infiltration capacity, as a consequence, the water will flow more easily into rivers and the volume of river water will rise faster and will cause the flood. Considering that, it is necessary to do a research on the affect of the changes in land use on the surface run-off in Lhokseumawe. There are 3 (three) sub-watersheds
in Lhokseumawe thus are Krueng Geukuh sub-watershed, Krueng Meuraksa sub-watershed and Krueng Pase sub-watershed. In this study took a place in the Krueng Meuraksa sub-watershed which is the largest sub-watershed covering the city of Lhokseumawe.

Concerning the surface run-off, the type of land cover will be the measurement of how much surface run-off will occur. For instance, forest areas have small surface run-off due to their large infiltration capacity. If the forest area is converted into open land or settlements, it will reduce the infiltration capacity due to soil surface compression. As consequence water will flow more easily into the river, the water volume in the river will rise faster and will cause a flood [3].

This research will be focused in Lhokseumawe, Krueng Meuraksa sub-watershed, where no research has been conducted regarding the change of land use on the surface water run-off before. So the authors are interested to study in detailed about the effect of surface water run-off due to land conversion in 2008 to 2018 by using map data in the form of a shapefile and based on the hydrological aspect. The results show the increase amount of run-off occurs as the run-off coefficient increases every year. This information can be useful to mitigate the flood by realizing the right RTRW for Lhokseumawe.

2. Materials and methods

2.1. Study location

This research conducted in Krueng Meuraksa sub-watershed. It located near urban areas, thus the distribution of land use types in the Krueng Meuraksa sub-watershed is varied. Meuraksa sub-watershed located in Lhokseumawe and North Aceh District, Aceh Province. The area of Krueng Meuraksa sub-watershed is 9958.56 ha. Astronomically, the Krueng Meuraksa sub-watershed is located in 5 ° 12'57.14 "U - 97° 6'59.23" E and 5 ° 3'36.27 °U - 97 ° 10'50.08° E. The following can be seen the Krueng Meuraksa sub-watershed map in Figure 1.

![Figure 1. Study location: Krueng Meuraksa sub-watershed](image)

2.2. Research methodology

This research is a case study of the change of land use and surface run-off in the Krueng Meuraksa sub-watershed. The data collection method used in this research is secondary data, where:
• Secondary data is obtained through literature study and collecting secondary data or information from various resources and related agencies, such as: topographic maps, both printed and digital maps, aerial photographs, administrative boundary maps or regional maps, land use maps, data climate, hydrological data and previous research journals.
• Map data in the form of shapefiles obtained from Krueng Aceh Watershed and Protected Forest Management Center (BPDAS-HL).
• Data of Hydrology is taken from rainfall data from Malikussaleh Meteorological Station in North Aceh and the Lhokseumawe BPBD Rain Post.
• Population data is obtained from the Central Statistics Agency (BPS) of Aceh Province.

The data used to determine the use of land cover consists of a map in the form of a shapefile obtained from Krueng Aceh Watershed and Protected Forest Management Center (BPDAS-HL). The type of land use is the most dominant land use [4] it consists of shrubs, plantations, settlements, open land, dryland farming and rice fields. The Calculation of rainfall used the amount of daily rainfall and the amount of monthly rainfall which collected from Malikussaleh Meteorological Station in North Aceh from 2008–2018.

3. Results and discussions

3.1. Results
3.1.1. The change in land use
The change in land use is a transition process from previous land use to another. It caused by humans adaptation to the conditions that change overtime. Land use change analysis carried out with the help of ArcGIS 10.5. By comparing the results of the land use analysis in 2008–2018, the changes in land use area are as shown in Table 1:

| Types of Land Cover | 2008 | 2018 | Change of Land 2008–2018 |
|---------------------|------|------|-------------------------|
| Shrub               | 314.771 | 3.161 | Shrub                   | 18.076 | 0.182 | -296.695 (-2.979) |
| Plantation          | 26.752  | 0.269 | Plantation              | 2,127.880 | 21.367 | 2,101.129 (21.099) |
| Settlement          | 2,080.292 | 20.889 | Settlement             | 3,257.241 | 32.708 | 1,176.950 (11.818) |
| Open Land           | 14.742  | 0.148 | Open Land               | 6.450  | 0.065 | -8.293 (-0.083)  |
| Dryland Farming     | 5,107.438 | 51.287 | Dryland Farming       | 2,074.901 | 20.835 | -3,032.536 (-30.452) |
| Rice Field          | 1,583.109 | 15.897 | Rice Field             | 1,659.277 | 16.662 | 76.169 (0.765)    |
| Water Body and Pond | 831.455  | 8.349 | Water Body and Pond    | 814.732 | 8.181 | -16.723 (-0.168) |
| Total               | 9,958.558 | 100.000 | Total                 | 9,958.558 | 100.000 | 0.000 0.000      |

Based on Table 1, it can be seen that in the period of 2008–2018 there was a change in land cover which is an increase in plantation area by 2,101.129 ha, settlements by 1,176.950 ha and rice fields by 76.169 ha. On the other hand, there was a reduction in the area of dryland farming by 3,032.536 ha, shrub by 296.695 ha and open land by 8.293 ha. Significant changes that occur are the increase amount of plantation area and the reduction of dryland farming area. The picture of the change of land
use in 2008 and 2018 can be seen in Figure 2. This is the same as in the Keduang watershed where the most striking changes in this period is the addition of dry fields and the reduction of mixed gardens. In percentage terms, the largest area increase was in the cover/use of open land (739.13%) [6].

![Figure 2. The change of land use in 2008 and 2018](image)

### 3.1.2. Rain intensity
The intensity of rain used to calculate the run-off in this study is the plan rain intensity for 10 years. The average amount of rainfall in the Krueng Meuraksa sub-watershed for 10 years from 2008 to 2018 can be seen in Table 2 as follows:

| Month | Average Rainfall (mm) |
|-------|-----------------------|
|       | 2008  | 2009  | 2010  | 2011  | 2013  | 2014  | 2015  | 2016  | 2017  | 2018  |
| Jan   | 6.7   | 13.6  | 25.6  | 6.8   | 8.0   | 3.9   | 12.2  | 15.8  | 11.8  | 4.7   |
| Feb   | 1.0   | 3.5   | 8.3   | 9.0   | 8.0   | 19.0  | 14.8  | 9.7   | 8.5   | 12.7  |
| Mar   | 12.2  | 12.4  | 13.8  | 25.2  | 15.2  | 39.8  | 1.5   | 6.4   | 7.7   | 8.8   |
| Apr   | 8.7   | 13.9  | 24.7  | 5.3   | 22.8  | 16.7  | 5.1   | 8.0   | 6.0   | 12.6  |
| May   | 6.3   | 10.0  | 11.6  | 9.3   | 12.8  | 13.2  | 9.1   | 7.1   | 8.8   | 12.1  |
Table 2. Average monthly rainfall in sub-watershed Krueng Meuraksa from 2008–2018 (contd.)

| Month | Average Rainfall (mm) |
|-------|-----------------------|
|       | 2008 | 2009 | 2010 | 2011 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
| June  | 2.0  | 29.3 | 25.6 | 7.3  | 16.7 | 5.8  | 9.4  | 9.0  | 11.3 | 9.1  |
| July  | 13.3 | 8.4  | 5.9  | 9.3  | 13.0 | 10.4 | 6.0  | 7.4  | 7.1  | 22.6 |
| August| 12.8 | 12.4 | 12.9 | 13.5 | 9.8  | 17.8 | 9.8  | 2.8  | 11.5 | 16.2 |
| Sept  | 8.0  | 5.7  | 11.3 | 3.8  | 6.3  | 9.5  | 12.9 | 6.5  | 8.1  | 4.8  |
| Oct   | 6.3  | 7.3  | 7.1  | 17.5 | 8.1  | 13.9 | 6.0  | 2.8  | 16.1 | 13.5 |
| Nov   | 23.8 | 26.8 | 15.5 | 12.0 | 4.3  | 13.1 | 21.7 | 13.1 | 10.0 | 14.7 |
| Dec   | 12.6 | 10.2 | 13.5 | 21.8 | 12.6 | 30.1 | 9.6  | 10.3 | 18.6 | 4.5  |
| Total | 113.6| 153.5| 175.6| 140.7| 137.4| 193.1| 117.9| 98.9 | 125.7| 136.2|

Source: Malikussaleh Station Meteorology, North Aceh, 2011 [7]

The rainfall plan is obtained from rainfall data from the Malikussaleh Station Meteorology, North Aceh. The selection of distribution used is the log person 3 distribution, after the test of Ck and Cs. The concentration time (tc) is 5.023 hours. The return period used is 10 years. The peak flow rate estimation model generally used in the rain interval of 10 years [8]. The results of the rainfall plan calculation using the Log Person III method can be seen in Table 3 as follows:

Table 3. The value of rainfall plan log-pearson III method

| No | Reset Period | Xi   | Kt   | S   | R34 (mm) |
|----|--------------|------|------|-----|----------|
| 1  | 2 yrs.       | -0.003|      |     | 106.817  |
| 2  | 5 yrs.       | 110.75| 0.841| 0.122| 135.313  |
| 3  | 10 yrs.      | 1.284 |      |     | 153.177  |

3.2. Discussion
3.2.1. The increasing and decreasing rate of land cover use
The change of land use is a form of transition from previous land uses to another. Data of land use in this study obtained from the Center for Watershed Management and Protection Forest (BPDAS-HL) Krueng Aceh, the type of land use and change in land use area from 2008 to 2018 in sub-watershed Krueng Meuraksa can be seen at Figure 3 as follows:
There was an additional amount of shrub land area as much as 296,695 ha from 2008 to 2018. The shrub land change into the development of residential land area. The reduction in plantation land from 2008 to 2018 as much as 2,101,129 comes from the changes in dryland farming. Residential land used from 2008 to 2018 was also increased by 1,176,950 ha. The addition of this residential land increase every year along with the increase in population, it comes from changes in dryland farming, ponds, rice fields and shrubs. The use of open land is decreasing from 2008 to 2018 as much as 8,293 ha. The reduction of the open land area is because it changes to pond. The reduction use of dryland farming from 2008 to 2018 is 3,032,536 ha. The reduction take place in 2015–2016 because it changes to residential land, plantations, and rice fields. The use of rice fields from 2008 to 2018 was increase in the rice field area as much as 76,169 ha. The addition of rice fields comes from changes in dryland farming, ponds and shrubs.

From Figure 3, there was a reduction in the shrub and dryland farming area in 2015 to 2016. It changed into residential land development, and in that year, there was also a reduction in dryland farming into plantation land. In 2012 to 2013 and 2017 to 2018 there was a reduction of open land into ponds. In 2013 to 2014 there was an increase in rice fields due to the reduction of land from dryland farming, ponds and shrubs.

The change of land use and land use categories indicate that land use is dynamic, closely related to space and time. The change depends on direct human activities and through regulations [9]. From Figure 23, we can see that the area of land cover continues to increase is in residential land use, on the
contrary, the area of land cover that continues to decrease is found in the use of dryland farming. In general, land use changes from low vegetation cover to high vegetation cover resulted in an increase in surface run-off that will occur [10].

3.2.2. Krueng Meuraksa sub-watershed run-off
The decrease in land use area where the land surface becomes a watertight surface resulted in an increase of run-off value [11]. The calculation used in surface run-off is the Rational Method. It calculated based on the run-off coefficient (C) in 2008 which was 0.726. The intensity of the 10-year plan (I) was 18.106 mm/hour. The area of the Krueng Meuraksa sub-watershed in 2008 was 9,127.103 Ha, the correction factor for the hectare area was 0.00278. With these data, the surface run-off obtained in 2008 was 333.403 m³/d. While in 2018 the run-off coefficient (C) in 2018 was 0.787. The intensity of the 10-year plan (I) was 18.106 mm/hour. The area of the Krueng Meuraksa sub-watershed in 2018 was 9,143.826 Ha, with 0.00278 factor correction for the hectare area, the value of surface run-off was 361.765 m³/d.

[12] also observes the effect of changes in land use in the Batang Arau watershed in 2006 and 2012. In this study, it can be seen that there was a change in the coefficient of surface run-off in 2006 and 2012. In 2006 the coefficient of surface run-off was 0.39 and in 2012 it was 0.41. Based on the run-off coefficient, the rainfall plan intensity and the area of the Batang Arau watershed, the run-off in 2006 was 327.20 m³/d and in 2012 was 339.51 m³/d. This study also sees the relationship between land use changes that affect surface run-off;

4. Conclusion
This study observes the change in Krueng Meuraksa sub-watershed land use by monitoring the land cover area using ArcGIS 10.5 in 2008 to 2018. Next step is to identify the relationship between land use changes and run-off. There are six categories of land use types thus are shrubs, plantations, settlements, open land, dryland farming and rice fields. Here are the conclusions from this research:

• In the period 2008–2018 there were changes of land use in Krueng Meuraksa sub-watershed, thus are:
  a. Reduction of shrub land area by 296.695 ha, open land by 8.293 ha and dryland farming by 3,032,536 ha;
  b. The addition of plantation land area is 2,101,129 ha, settlements is 1,176,950 ha and rice fields is 76,169 ha. In this case, the area of land cover that continues to increase every year is the residential land use, on the contrary the area of land cover continues to decrease every year is the use dryland farming.

• There was a change in the surface run-off coefficient of Krueng Meuraksa sub-watershed in 2008–2018, where in 2008 it was 0.726 and in 2018 it was 0.787. Based on the run-off coefficient, rainfall intensity and area of the Krueng Meuraksa sub-watershed, the surface run-off value in 2008 was 333.403 m³/d and in 2018 it was 361.765 m³/d. The increase in the amount of run-off occurs as the run-off coefficient increases.

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