# LANDSLIDE SUSCEPTIBILITY STUDY IN AMBON CITY, INDONESIA

Aril ADITIAN[1] and Tetsuya KUBOTA[2]
[1*]Laboratory of Forest Conservation and Erosion Control, Kyushu University (corresponding author email: aril@kyudai.jp)
[2]Forest Environment Science Department, Faculty of Agriculture, Kyushu University

## 1. INTRODUCTION

The city of Ambon plays dominant administrative and economic roles in the Maluku province, Indonesia. The city of Ambon has an area of 377 km$^2$ with population of 310,241 people. The population density in the city is 820/km$^2$. However, as the results of development and natural resources exploitation this city is becoming prone to landslide disasters.

During the period of 2011 – 2014 the Indonesian National Board for Disaster Management recorded 15 landslide events with fatality of 42 people. In the 2012 Ambon landslide disaster alone, the landslide-caused loss is estimated at 3 million USD.

The city of Ambon is characterized with varied topography. This is shown with elevation variation of 0 m.a.s.l on coastline area and > 900 m.a.s.l for the inner mountainous area. This topographical factor affects the slope distribution throughout Ambon. Slope class of 0 to > 50 degree is distributed in the entire area of Ambon City.

This study aims to create a landslide susceptibility map in the city of Ambon by using frequency ratio method.

## 2. STUDY SITE & METHODOLOGY

The City of Ambon is located in the Ambon Island at the 3°- 4° south latitude and 128° - 129° east longitude. (Fig 1.) The study is conducted in all area of Ambon City which includes 5 sub-districts: Nusaniwe sub-district, Sirimau sub-district, South Leitimur sub-district, Baguala sub-district, and Ambon Bay sub-district totaling to 50 villages.

The geology of Ambon is represented by multiple rock conglomerates, such as aluvium, kanikeh formation, ultramafic, volcanic ash, and granites. The fault lines direction is mainly from northeast to southwest and northwest to southeast. The structural element that was made by the tectonic process is the fault lines, reverse fault lines, and strike-slip fault.

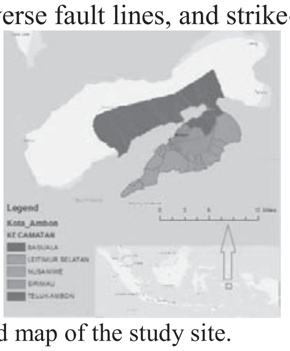


Fig.1 Simplified map of the study site.

Extensive field works were conducted during the period of January 2015 to collect necessary data, such as landslide inventory map and other GIS data. 80% of the total landslide cases (101 landslide cases) were used to create the landslide susceptibility index. 20% of the total landslide cases (25 landslide cases) were used to validate the results.

For the landslide susceptibility analysis, slope, aspect, elevation, proximity to faults, proximity to river, proximity to road, lithology, and geodensity (the density of geological unit per unit area) parameters were used (Fig.2). Frequency ratio analyses were conducted in every parameters to landslide occurrences and non-landslide occurrences.

Fig 2. GIS datasets used in this study. Top: elevation, aspects, slope, lithology. Bot: proximity to fault, proximity to road, proximity to river, geodensity.

Frequency ratio (FR) model was applied in order to evaluate quantitatively the landslide susceptibility of the area based on the spatial relationship between landslide location and each predisposing factors. The landslide occurrence and non-occurrence in each factor's class were used to obtain the area FR value. The obtained FR values were assigned as weight to produce the Landslide Susceptibility Index (LSI) using the eq.1:

$$LSI = Wm1 + Wm2 + Wm3 + \cdots . + Wmn \qquad (1)$$

Where:
LSI = Landslide Susceptibility Index
Wm = Weighted thematic maps of causative factors

The LSI map of the study area produced by FR model was verified by comparing it with known landslides. The success rate curve was calculated to evaluate the capability of of FR model and factors to predict landslides. The LSI map was also assessed in terms of its predictive power validity by calculating the prediction rate curve.

## 3. RESULTS

The FR values of each landslide causative factors are shown in table 1.

Table 1. FR Values of landslide causative factors

| | Area Pixel | LS Pixel | LS Ratio | Area Ratio | FR Value |
|---|---|---|---|---|---|
| ASPECT | | | | | |
| Flat | 74229 | 103 | 0.00139 | 0.00115 | 1.2106 |
| North | 27409 | 42 | 0.00153 | 0.00115 | 1.3369 |
| Northeast | 4975 | 4 | 0.00080 | 0.00115 | 0.7015 |
| East | 10905 | 4 | 0.00037 | 0.00115 | 0.3200 |
| Southeast | 61265 | 41 | 0.00067 | 0.00115 | 0.5839 |
| South | 22703 | 15 | 0.00066 | 0.00115 | 0.5764 |
| Southwest | 64838 | 66 | 0.00102 | 0.00115 | 0.8881 |
| West | 18858 | 27 | 0.00143 | 0.00115 | 1.2491 |
| Northwest | 49836 | 82 | 0.00165 | 0.00115 | 1.4355 |
| ELEVATION | | | | | |
| 0-100 | 102174 | 98 | 0.00096 | 0.00115 | 0.8368 |
| 100-200 | 92528 | 94 | 0.00102 | 0.00115 | 0.8863 |
| 200-300 | 68992 | 93 | 0.00135 | 0.00115 | 1.1760 |
| 300-400 | 35803 | 46 | 0.00128 | 0.00115 | 1.1209 |
| 400-500 | 25512 | 43 | 0.00169 | 0.00115 | 1.4705 |
| >500 | 10008 | 10 | 0.00100 | 0.00115 | 0.8717 |
| Proximity to fault | | | | | |
| 0-250 | 45409 | 37 | 0.00081 | 0.00115 | 0.7109 |
| 250-500 | 42199 | 80 | 0.00190 | 0.00115 | 1.6540 |
| 500-750 | 37491 | 43 | 0.00115 | 0.00115 | 1.0006 |
| 750-1000 | 33150 | 44 | 0.00133 | 0.00115 | 1.1580 |
| 1000-1250 | 30315 | 35 | 0.00115 | 0.00115 | 1.0073 |
| 1250-1500 | 26536 | 35 | 0.00132 | 0.00115 | 1.1507 |
| >1500 | 121501 | 110 | 0.00091 | 0.00115 | 0.7899 |
| Proximity to river | | | | | |
| 0-250 | 107191 | 110 | 0.00103 | 0.00115 | 0.8953 |
| 250-500 | 90429 | 66 | 0.00073 | 0.00115 | 0.6368 |
| 500-750 | 61185 | 78 | 0.00127 | 0.00115 | 1.1122 |
| 750-1000 | 38903 | 50 | 0.00129 | 0.00115 | 1.1213 |
| 1000-1250 | 19675 | 44 | 0.00224 | 0.00115 | 1.9511 |
| 1250-1500 | 9279 | 23 | 0.00248 | 0.00115 | 2.1625 |
| >1500 | 9939 | 13 | 0.00131 | 0.00115 | 1.1411 |
| Proximity to road | | | | | |
| 0-250 | 91792 | 85 | 0.0009 | 0.00114621 | 0.807885661 |
| 250-500 | 39842 | 38 | 0.001 | 0.00114621 | 0.83210527 |
| 500-750 | 25275 | 64 | 0.0025 | 0.00114621 | 2.209147006 |
| 750-1000 | 21171 | 19 | 0.0009 | 0.00114621 | 0.782975253 |
| 1000-1250 | 18996 | 14 | 0.0007 | 0.00114621 | 0.642986244 |
| 1250-1500 | 16533 | 22 | 0.0013 | 0.00114621 | 1.160932106 |
| >1500 | 122992 | 142 | 0.0012 | 0.00114621 | 1.00727322 |
| SLOPE | | | | | |
| 0-10 | 157611 | 142 | 0.00090 | 0.00115 | 0.7860 |
| 10-20 | 91921 | 78 | 0.00085 | 0.00115 | 0.7403 |
| 20-30 | 56264 | 95 | 0.00169 | 0.00115 | 1.4731 |
| 30-40 | 23263 | 58 | 0.00249 | 0.00115 | 2.1752 |
| 40-50 | 5414 | 10 | 0.00185 | 0.00115 | 1.6115 |
| >50 | 545 | 1 | 0.00183 | 0.00115 | 1.6008 |
| Lithology | | | | | |
| Ambon Volcanic Rocks | 232726 | 261 | 0.00112 | 0.00115 | 0.9784 |
| Coral limestone | 50099 | 38 | 0.00076 | 0.00115 | 0.6617 |
| Alluvial | 15527 | 0 | 0.00000 | 0.00115 | 0.0000 |
| Kanikeh Formation | 14924 | 15 | 0.00101 | 0.00115 | 0.8769 |
| Ambon Granite | 2131 | 0 | 0.00000 | 0.00115 | 0.0000 |
| Ultrabasic Rocks | 21766 | 70 | 0.00322 | 0.00115 | 2.8058 |
| Geodensity | | | | | |
| 1 | 138242 | 137 | 0.00099 | 0.00115 | 0.8646 |
| 2 | 96509 | 88 | 0.00091 | 0.00115 | 0.7955 |
| 3 | 71703 | 107 | 0.00149 | 0.00115 | 1.3019 |
| 4 | 24793 | 38 | 0.00153 | 0.00115 | 1.3372 |
| >4 | 5377 | 14 | 0.00260 | 0.00115 | 2.2716 |

Based on the obtained result ultrabasic rocks (FR value: 2.8058) and geodensity more than 4 (FR value: 2.2716) play dominant role in triggering landslide in Ambon city.

The landslide susceptibility index of Ambon city is produced using GIS system (Fig. 3)

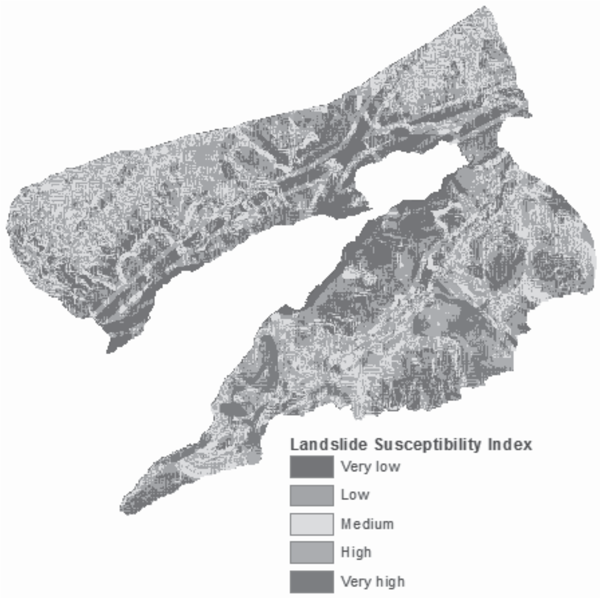


Fig 3. Landslide susceptibility map of Ambon City

The ROC curve analysis was conducted to validate the accuracy of the FR model used in this study for discrimination of landslide occurrences or not. The AUC was recalculated considering the total area equal to 1. The success rate curve is calculated to measure how well the model performs using training data. The prediction rate curve is calculated to measure how well the model predicts using test data. In the case of success rate curve, the area ratio is .707 (70.7% accuracy) while the prediction rate curve area ratio is .677 (67.7% accuracy). (Fig 4.)

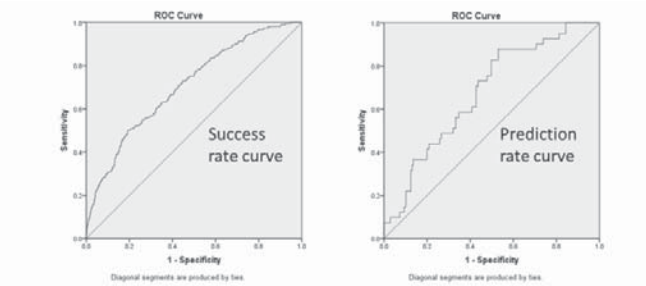


Fig 4. Success rate curve and prediction rate curve

## 4. CONCLUSIONS

Landslide susceptibility map using FR model was produced for Ambon City, Indonesia. The LSI map success rate accuracy is 70.7% and the prediction rate accuracy is 67.7%.

## 5. ACKNOWLEDGEMENTS

Primary data were collected through the help of Ambon Disaster Mitigation Agency.