# Effect of land-use on urban landslide in heavy rainfall

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In Korea, the climate shows typical summer Monsoon with concentrated rainfall, which results in many landslides.

During July 26-27, 2011, a heavy rainfall particularly occurred in Seoul with 30% amount of the annual precipitation for that region.

Especially, the landslide debris from Mt. Woomyeon at Seocho-gu, Seoul resulted in death of 17 persons on July 27, 2011.

However, no landslides occurred at Mt. Gooryong and Mt. Daemo near Mt. Woomyeon whose precipitation is more than that of Mt. Woomyeon.

Therefore, the purpose of this research is to investigate the topographic and meteorological characteristics of both Mt. Woomyeon, Mt. Daemo and Mt. Gooryong, and identify the reason of landslides event of Mt. Woomyeon to minimize the property damage and casualties caused by urban heavy rainfall.

## 2.1 Study site


Figure 1. Study site

## Real damaged area - Raemee'an Apartment


Figure 2. One of the study site was damaged by landslide

- The study sites, Mt. Woomyeon (293m) and Mt. Daemo (306m), are located in the southern part of Seoul, Korea (Figure 1). Yangjae River flow from southern part of Mt. Woomyeon to northern part of Mt. Daemo and Mt. Goo-ryong.
- The summer is generally hot and humid and mean annual precipitation is 1344.4mm, and precipitation in the summer occupies approximately 72% of annual precipitation in Seoul.

## 2.2 Data used

Table 1.Data Used for slope susceptibility analysis in this study

| Type | Thematic map | Source | Scale | Period |
|---|---|---|---|---|
| | Precipitation data | Korea Meteorological Administration | | 2011. 07.26 16:00 - 2011.07.27 14:20 |
| | | Observed by Environmental Climate Lab, SKKU | | 2011. 07.26 16:00 - 2011.07.27 14:20 |
| | Weather map | Korea Meteorological Administration | 1:5000 | 2011. 07.27 09:00 |
| Topography | Digital topographic data | National Geography Institute | | |
| Lithology | Geological map | Korea Institute of Geosciences and Mineral Resources | 1:25000 | |
| Vegetation | Vegetation map | Korea Forest Service | 1:25000 | |
| Soil | Soil map | Rural Development Administration | 1:25000 | |
| Land use | Digital land use map | National Geography Institute | 1:25000 | |

## 2.3 Method

- In order to investigate the difference between Mt. Woomyeon and Mt.’s Daemo and Gooryong, the following methods were used.

1) To compare meteorological characteristics of two sites

cumulative precipitation until landslide occurrence

precipitation per unit time, total precipitation

2) To derive slope susceptibility analysis using Korea Forest Service Criteria

For the detailed analysis four sites (Sites A1, B1, C and D) at Mt. Woomyeon and two sites (Site A2, Site B2) at Mt.'s Gooryong and Daemo were selected to analy ze susceptibility of landslides for comparison.

- Sites A1 and A2 are  adjacent to road.
- Sites B1 and B2 are adjacent to residential area.
- Sites C and D are developed area along valley.

3) To analyze the topographic, landuse characterisitics of landslide occurred area

4) To derive conclusions after synthesizing analysis results

Table 2.The landslide risk criteria from Korea Forest Service

| Distinguish | Risk factor scores | | | | |
|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** |
| **Slope length(m)** | < 50 | 51~100 | 100~200 | 201 < | |
| **Point** | **0** | **19** | **36** | **74** | |
| **Geological Structure** | Sedimentary rock (mudstone, shale, limestone, sendstone) | Igneous rock (granite, others) | Metamorphic rock (phyllite, slate , others) | Metamorphic rock (gneisses, schistes) | Igneous rock (porphyries, andesites) |
| **Point** | **0** | **5** | **12** | **19** | **56** |
| **Slope location** | 0-1/10 | 2-6/10 | 7-10/10 | | |
| **Point** | **0** | **9** | **26** | | |
| **Vegetation** | •coniferous forest (shrub forest, S DBH) •unstocked forest | • coniferous forest (medium hard wood, large DBH) • hardwood-forest • mixed forest , shrub forest) | •hardwood-forest •mixed forest (S, M, L DBH) | | |
| **Point** | **18** | **26** | **0** | | |
| **Slope type** | Convex slope | Strait slope | Concave slope | Complex slope | |
| **point** | **0** | **5** | **12** | **23** | |
| **Slope depth(cm)** | < 20 | 21~100 | 101 < | | |
| **point** | **0** | **7** | **21** | | |
| **Slope gradient(°)** | < 25 | 26~40 | 41 < | | |
| **point** | **16** | **9** | **0** | | |
| **Land use** | **Deciduous forest** | **Coniferous forest** | **Arable land** | **Bare ground** | **Residential area** |
| | **0** | **26** | **60** | **65** | **70** |

Source: Korea Forest Service, 2009

Table 3. The standard of landslide risk level From Korea Forest Service

| Zone | Landslide hazard factor | Zone description |
|---|---|---|
| I | 60> | Very low hazard |
| II | 60-120 | Low hazard |
| III | 120-180 | High hazard |
| IV | >180 | Very high hazard |

Source: Korea Forest Service, 2009

Table 4. The characteristics of heavy rainfall of Namhyeon station and Yangjae stream on July 27, 2011

| | Namhyeon Station | Yangjae Station |
|---|---|---|
| Max. precipitation per unit time | 112.5mm/hr(125-yr frequency) | 92mm/hr(45-yr frequency) |
| Cumulative precipitation before landslide | 266.5mm | 300mm |
| Total precipitation | 424.5mm(95-yr frequency) | 452.5mm(150-yr frequency) |

Table 5.The influence factors of landslide occurred area at the Mt. Woomyeon, Mt. Daemo and Mt. Gooryong

| | Mt. Woomyeon | | | | Mt. Daemo and Mt. Gooryong | |
|---|---|---|---|---|---|---|
| | Site A1 | Site B1 | Site C | Site D | Site A2 | Site B2 |
| Geological Structure | gneisses | gneisses | gneisses | gneisses | gneisses | gneisses |
| Forest stand | Oak | Oak | Oak | Oak | Oak | Oak |
| Slope type | Concave | Concave | Concave | Concave | Straight | straight |
| Drainage density | 0.001615 | None | 0.0048497 | 0.00204 | None | 0.001367 |
| Stream order | 1 | None | 3 | 2 | None | 2 |

There is no significant difference between Mt. Woomyeon, Mt. Daemo and Mt. Gooryong

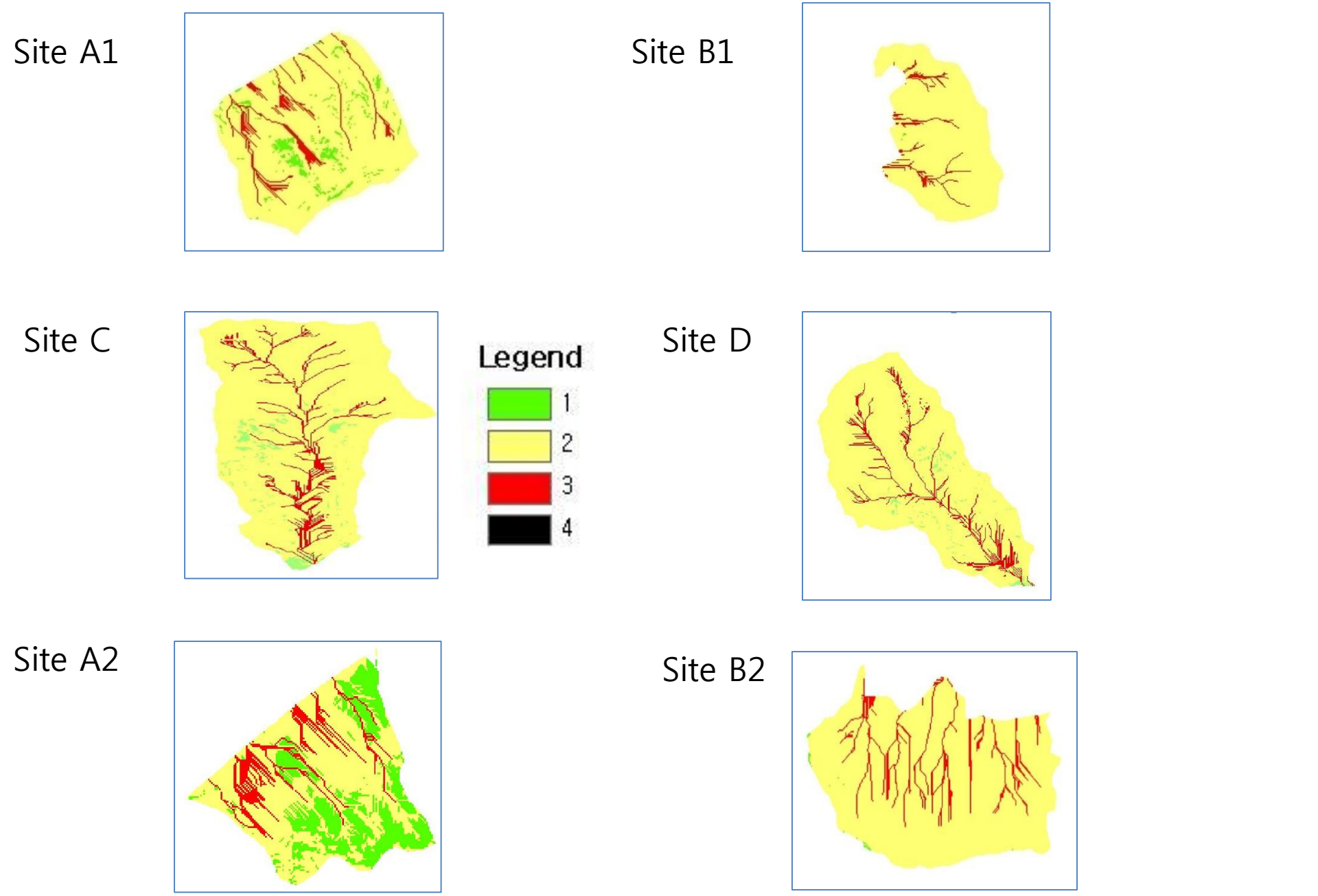



Figure 3. The slope susceptibility map of each study site according to the Forest Service Criteria

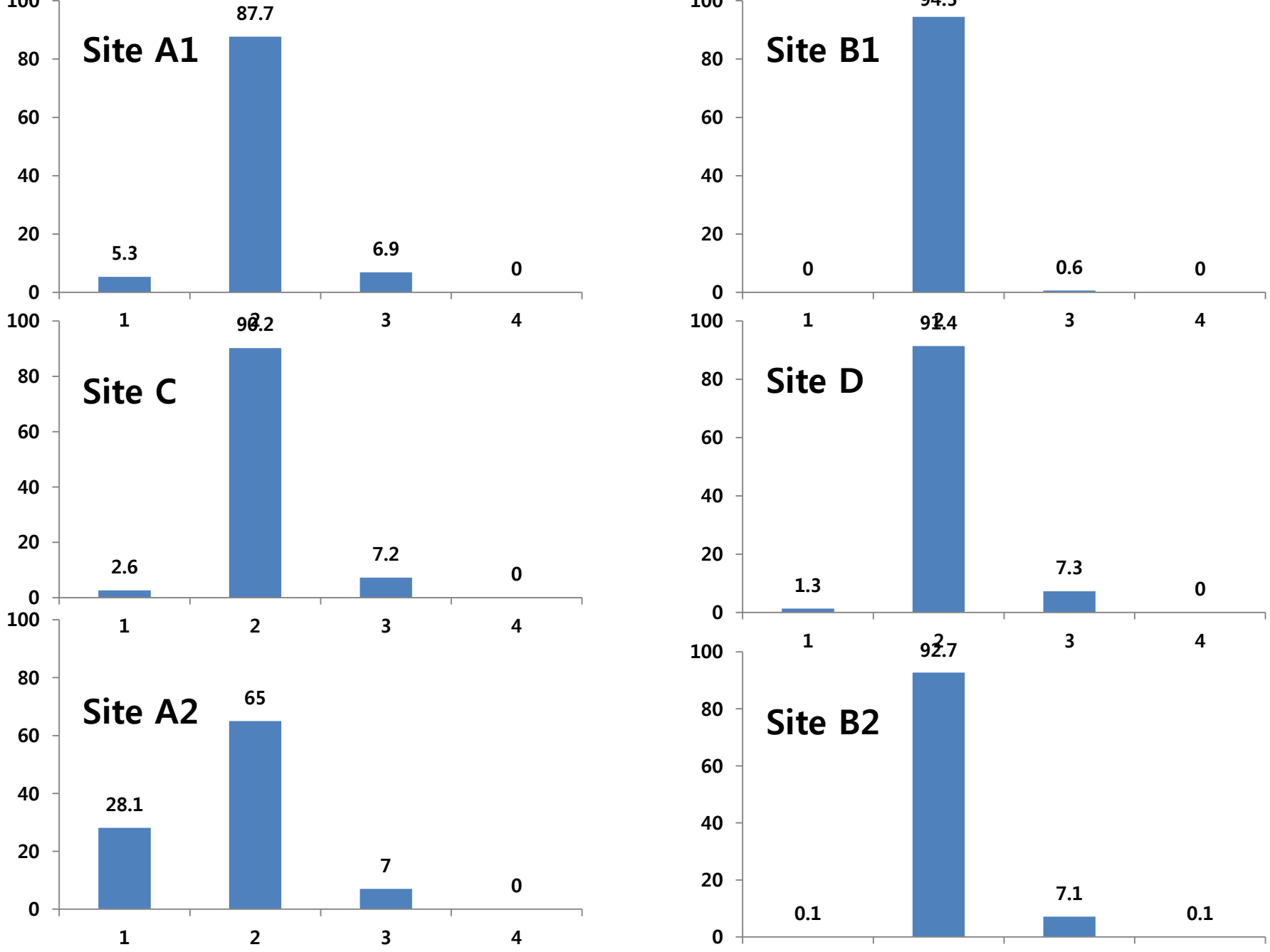



Figure 4. The percentage of slope susceptibility at each study site according to Korean Forest Service Criteria

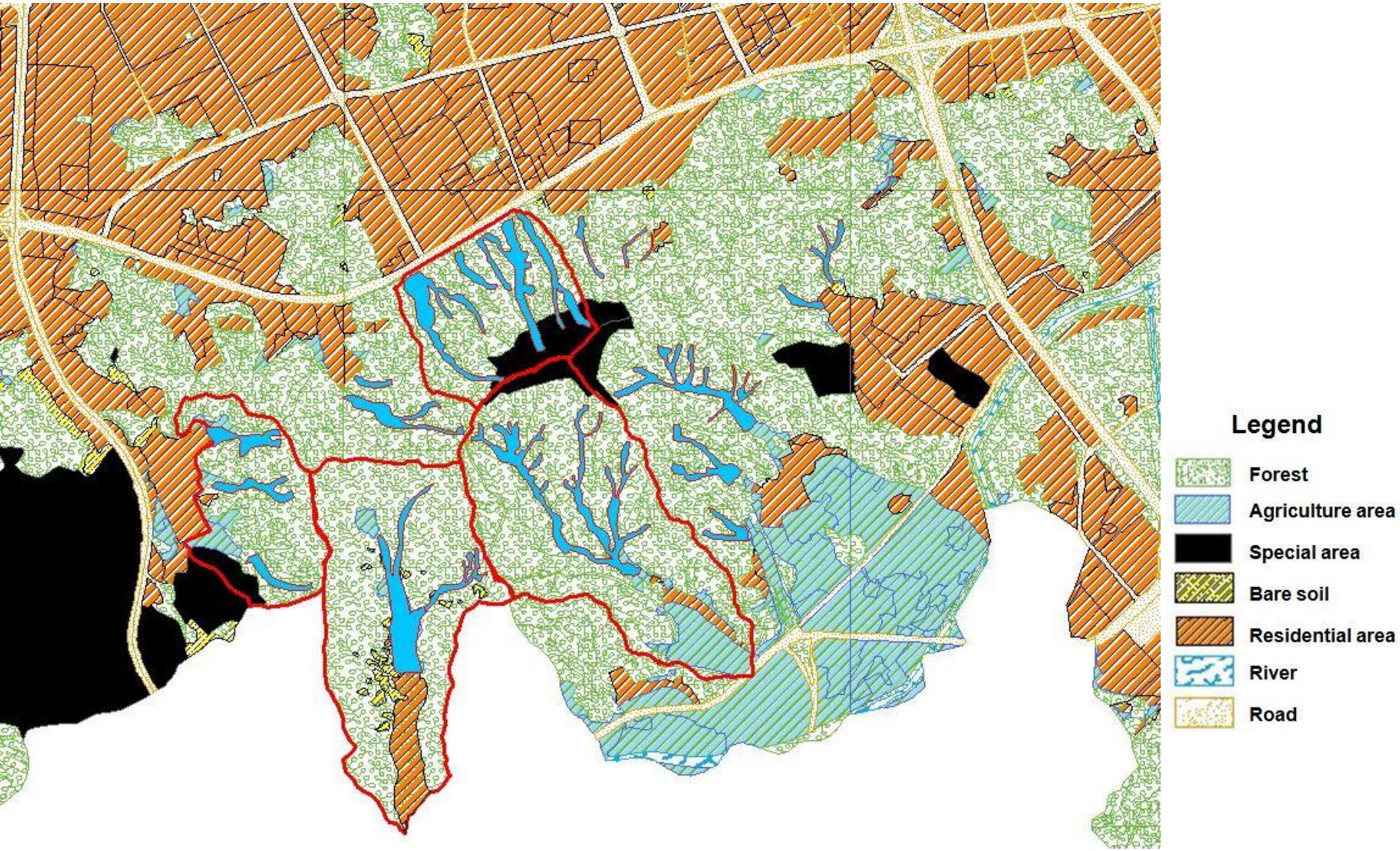



Figure 5. Land-use and landslide occurred positions of four sites at the Mt. Woomyeon

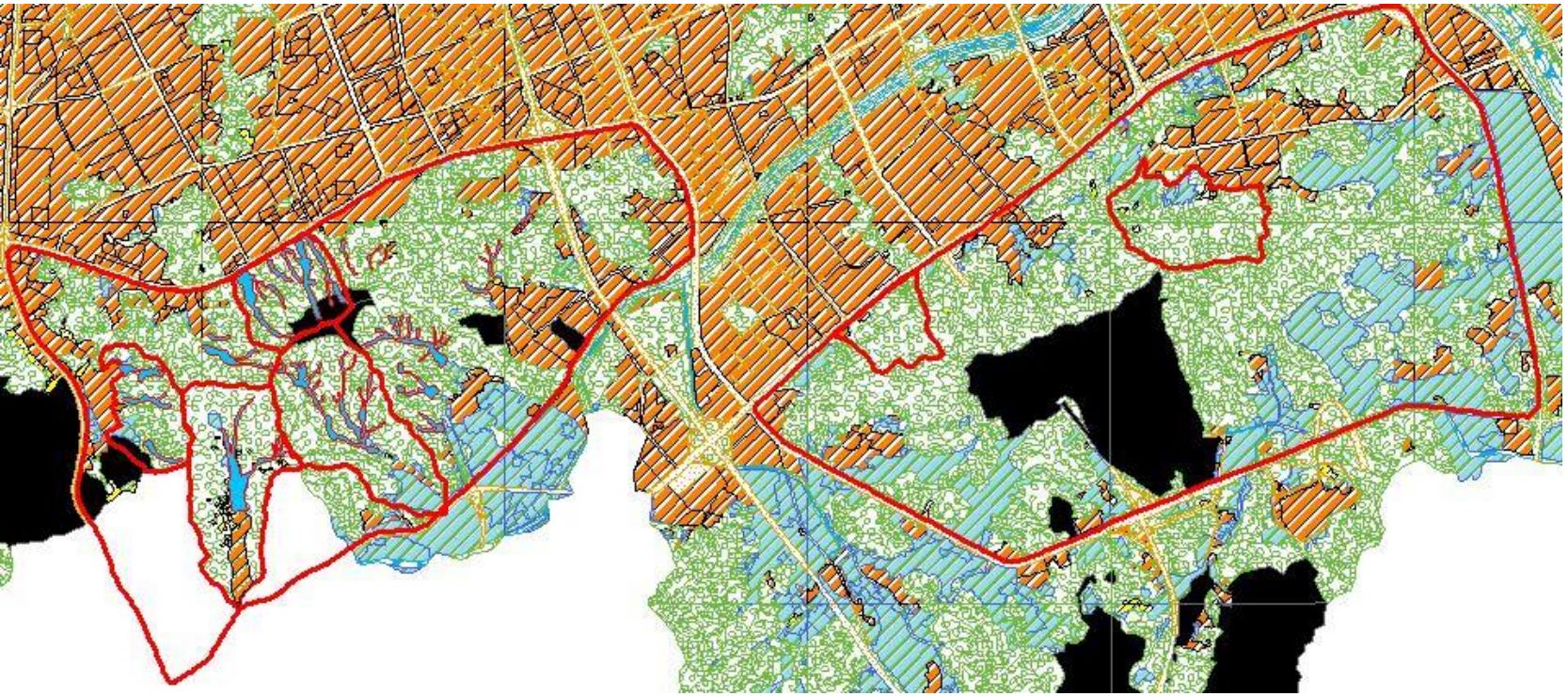
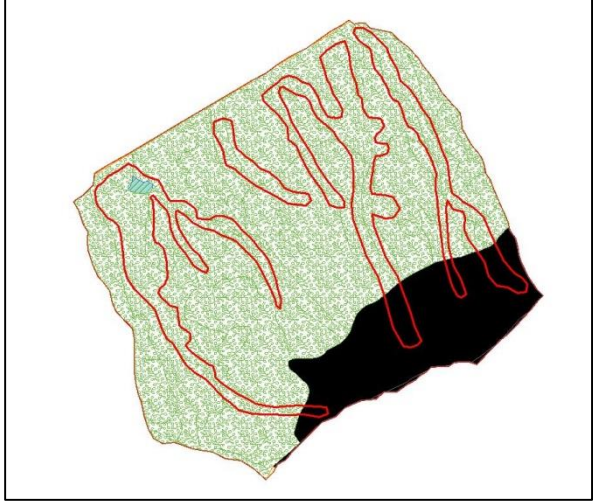


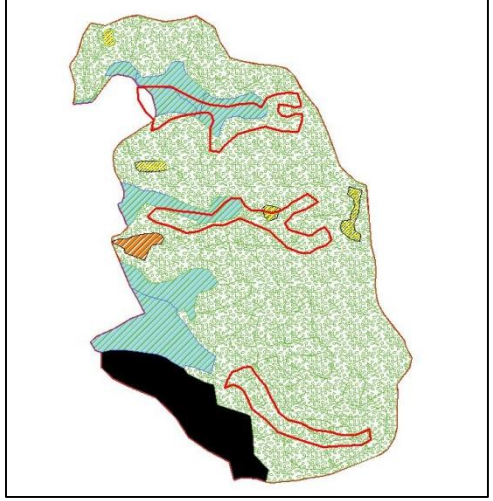

Figure 6. Land-use of six sites

Table 6. Land-use of study sites

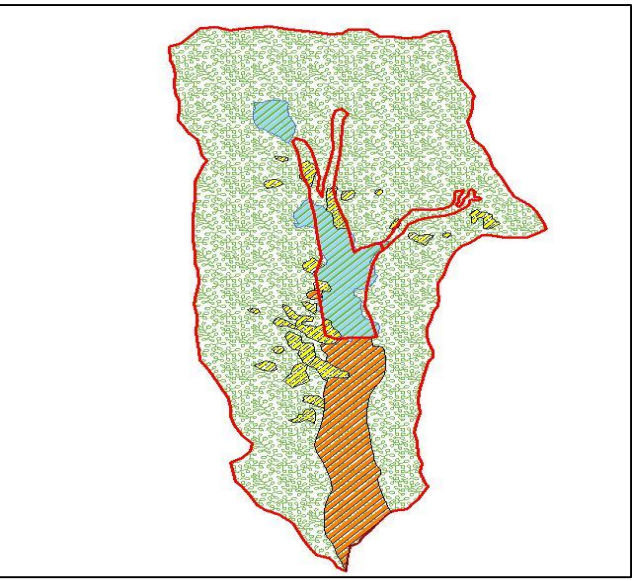
| | Site A1 | | Site B1 | | Site C | |
|---|---|---|---|---|---|---|
| | Area ($m^2$) | % | Area ($m^2$) | % | Area ($m^2$) | % |
| Forest | 386705 | 83.1 | 308525 | 77.3 | 707240 | 81.6 |
| Agriculture area | 945 | 0.2 | 52015 | 13.0 | 49097 | 5.7 |
| Bare soil | 0 | 0.0 | 4714 | 1.2 | 34856 | 4.0 |
| Special area | 77449 | 16.7 | 31071 | 7.8 | 0 | 0.0 |
| Residential area | 0 | 0.0 | 2886 | 0.7 | 75115 | 8.7 |
| Total | 465099 | 100.0 | 399211 | 100.0 | 866308 | 100.0 |
| | Site D | | Site A2 | | Site B2 | |
| | Area ($m^2$) | % | Area ($m^2$) | % | Area ($m^2$) | % |
| Forest | 788527 | 82.3 | 290472 | 99.6 | 658972 | 97.3 |
| Agriculture area | 91745 | 9.6 | 1287 | 0.4 | 1585 | 0.2 |
| Bare soil | 23462 | 2.4 | 0 | 0.0 | 15217 | 2.2 |
| Special area | 31011 | 3.2 | 0 | 0.0 | 0 | 0.0 |
| Residential area | 23286 | 2.4 | 0 | 0.0 | 1752 | 0.3 |
| Total | 958031 | 100.0 | 291759 | 100.0 | 677526 | 100.0 |



Site A1



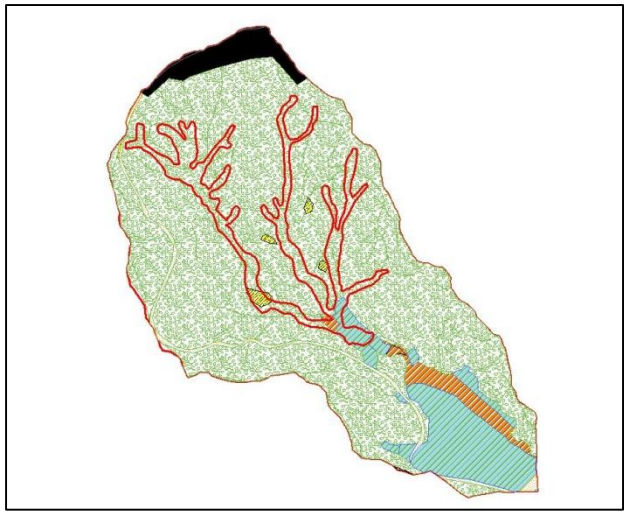
Site B1



Site C

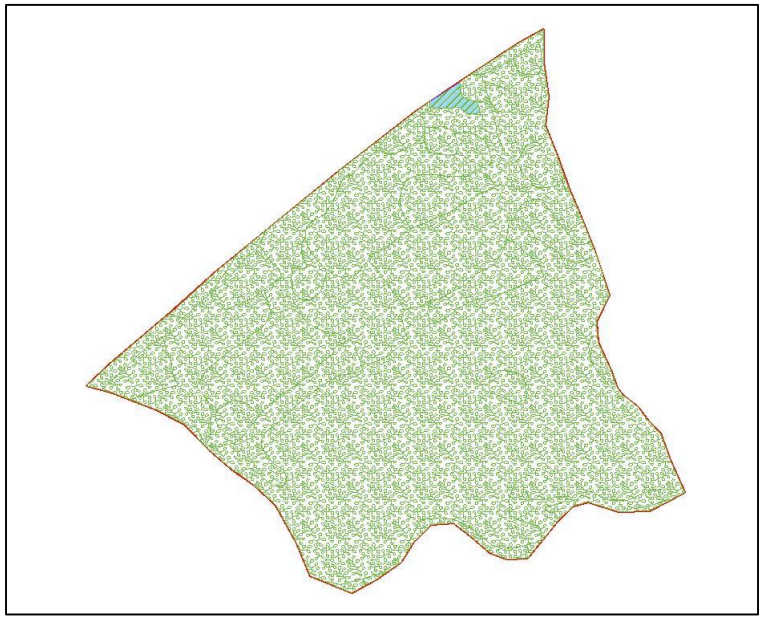
Legend

- Forest
- Agriculture area
- Special area
- Bare soil
- Residential area
- River
- Road

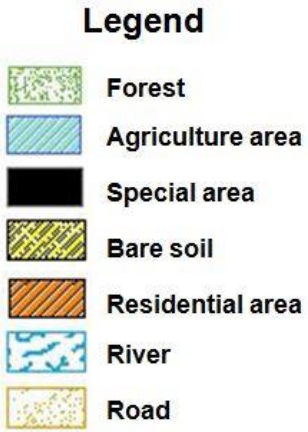


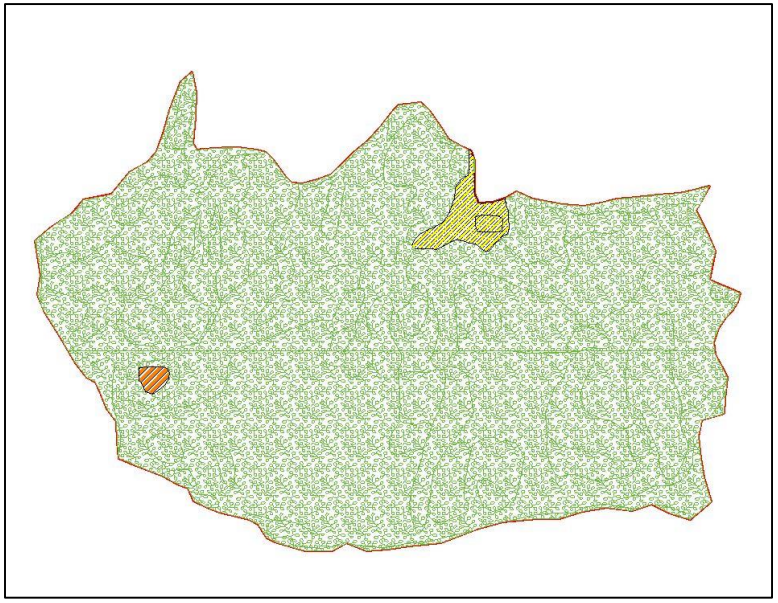
Site D

Figure 7. Land-use of landslide occurred area



Site A2



Site B2

Figure 8. Land-use of Site A2 and B2 which landslide did not occurred area

Table 7. The land use of landslide occurred area

| | Type | Site A1 | Site B1 | Site C | Site D |
|---|---|---|---|---|---|
| Land use of landslide area ($m^2$) | Agriculture area | 945 (0.9%) | 33442 (22.8%) | 23784 (47.3%) | 6049 (7%) |
| | Forest | 93215 (89.3%) | 159 (76.5%) | 26513 (52.7%) | 79587 (91.6%) |
| | Residential area | 0 (0%) | 123 (0.4%) | 0 (0%) | 1269 (1.5%) |
| | Special area | 10221 (9.8%) | 9987 (0.3%) | 0 (0%) | 0 (0%) |
| Landslide area ($m^2$) | | 104381 | 43711 | 84766 | 86905 |

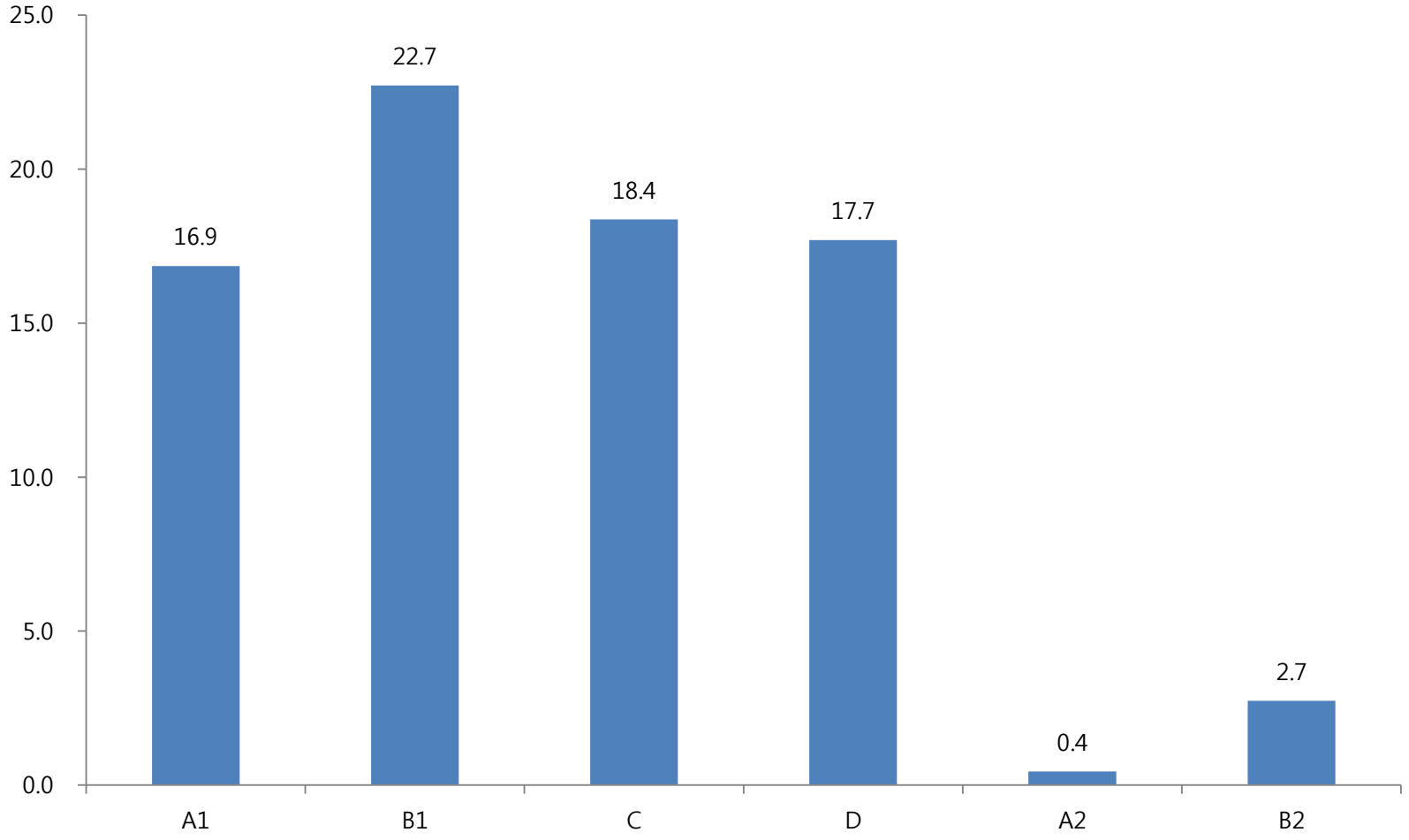



Figure 9. The ratio of developed area

# Summary

After investigating characteristics of urban landslide by heavy rainfall, the follo wing conclusions were derived.

(1) In terms of meteorological characteristics, The heavy rainfall of 266.5mm occurred from 16:20 July 26th to 7:40 July 27th, 2011. Especially 112.5mm/hr amount at Mt. Woomyeon is more than that of Mt’s Daemo and Gooryong by 2 0.5mm/hr while cumulative precipitation and total precipitation are less.

(2) There are no significant differences of landslide factors suggested by Forest Service Criteria between Mt. Woomyeon and Mt.'s Daemo, Gooryong.

(3) In detailed analysis for landslide occurred area, development at ridge area induced the initial landslide. The landslide occurrence at sub sites A1 and D were induced by special area at upper mountain. Furthermore, sub sites B1 and C were induced by agriculture area and bare soil at upper mountain. Also excessive agricultural and residential development induced landslides.

(4) In urban hilly area, careful residential and other land use planning is required.