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The Effect of Geosynthetic Mulching Mat on Surficial Soil Slope Stabilization

토목섬유 식생매트를 이용한 흙사면의 표토안정화

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요 지

본 연구에서는 종자와 비료, 부직포 지오텍스타일, 마 네트로 구성된 토목섬유 식생매트 시스템을 개발하였다. 개발된 식생매트를 흙 사면에 설치한 결과 사면의 식생성장과 사면안정에 긍정적인 효과를 얻었으며 이것은 실물시험을 통하여 강우와 사면에서의 유출수량, 부유물질, 토사침식량 등을 8개의 시험구에 식생매트를 분석하였다. 유출수량은 모든 시험구에서 강우량이 클수록 증가하였으며 식생매트를 설치한 곳이 안한 곳보다 유출수량이 작았으며 총부유물질은 유출수량에 크게 영향을 받는다. 식생매트는 흙 침식과 부유물질의 이동을 감소시켜 흙사면의 안정에 매우 유익하다. 또한 식생성장환경을 개선하며 특히 가뭄시에 성장에 매우 효과적이다.

Abstract

In this study, a geosynthetic mulching mat was devised to contain seeds as a part of a mulching mat system, which consisted of a non-woven geotextile, a jute net and a geotextile mat. The mulching mat produced gave good plant growth and adequately stabilized soil slopes. Relationships between rainfall and runoff, runoff-water and suspended sediment, soil erosion, and other effects of the mulching mat were monitored in eight plots fitted with mulching mats and containing plants for one year. The amount of runoff-water increased with precipitation increment in all test plots, and the runoff-water of mulching mat treated plots was smaller than that of untreated plots. The total amount of suspended sediments was greatly affected by the amount of runoff-water. The use of mulching mats proved effective at physically stabilizing slopes by preventing sediment movement, and they markedly contributed to the growth of plants by improving the environmental conditions particularly during dry periods.

Keywords : Geosynthetic mulching mat, Rainfall, Slope, Stabilization

1. Introduction

Several slope protection methods are currently used to stabilize slopes. Among these methods, biotechnical ones are emerging technology because environmental and ecological restoration is considered to be more important these days (Barker, 1994). Biotechnical method stabilizes soil slopes surface by allowing the intertwining of roots, which minimizes seepage of runoff of soil by intercepting rainfall, and retarding the runoff velocity.

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In addition, it is considered that vegetation may have an indirect influence on deeper stability issues by depleting soil moisture, attenuating the depth of frost penetration, and by providing a favorable habitat for the establishment of deeply rooted vegetation (Gray and Sotir, 1992). Vegetation is multifunctional, relatively inexpensive, self-repairing, visually attractive, and does not require heavy or elaborate equipment for its installation. However, there are certain limitations: vegetation is susceptible to drought, difficult to get established on steep slopes, unable to resist severe scour or wave action, and slow to establish (Abramson et al, 1995). The main reasons of slope· vegetation failure are drought, sterility, and heavy rainfall, which cause slope soil erosion and flushe out seeds. In this study, we devised a new geosynthetic vegetation mat as a method to allow slopes to be cultivated more successfully. The developed mat is comprised of a geotextiles, and includes seeds and fertilizer. Jute netting is biodegradable and strong enough for workman to install easily. The performance of the geosynthetic mat was evaluated by plant growth and mock testing. Various seeds were used, including herbaceous plant and woody plants which were examined during the course of this study, and the mat effects on soil erosion resistance, runoff rainfall, sediments and plant growth were studied.

2. Geosynthetic Mulching Mat

In general, plant restoration of soil slopes is considerably influenced by sunlight, the moisture of soils, nutrients, and the temperature. When above factors are present in the right combination, vegetation flourishes and plant roots reinforce the shear strength of the soil slope (Wu and Beal, 1988). Soil slopes are easily eroded by flooding, which causes instability, especially for weathered granite soils. Granite soil is somewhat difficult to vegetate, and are commonly found in Korea. In this study, a geosynthetic mulching mat was devised to overcome the difficult conditions of vegetation presented by granite soil slopes. In order to stabilize and conserve the soil slope and regenerate plants with a mulching mat, the geosynthetic mulching mat was designed to have the following properties:

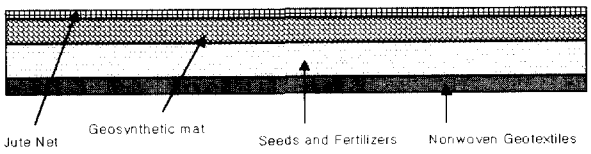

Fig. 1 The schematic diagram of the mulching mat

(1) It should be biodegradable.
(2) It should be very light and portable.
(3) It should be capable of holding water but remain substantially unaffected.
(4) It should be capable of holding seeds and fertilizer to prevent them being washed away by rain and wind.

Mulching mat with above properties has several advantages. First, since seeds and fertilizers are tied into the mat, the seeds are not washed or blown away from the soil slope. Second, the mulching mat prevents evaporation from the soil slope and helps plants to grow more successfully. Third, the mulching mat maintains ground temperature and reduces damage during winter.

The mat developed in this study is shown in Fig. 1. A jute net on the surface intercepts light to help the seed sprout at the germination, and prevent evaporation of water from the soil. It also helps workers to hold onto the slope, and therefore, increases workability. The mat is degradable, and is capable of holding moisture. Since seeds and fertilizers adhered to the mat, they are not washed away. D is a nonwoven rayon geotextile which secures the whole system in one body.

3. Experiments

Eight lysimeters were made with a slope degree of 31°, with an area of 3.0 m^2 apiece. The lysimeters were prepared with decomposed granite soils (Photo 1). Four slopes (i.e. even numbers) were treated with mulching mats on granite soils, and the other four slopes (odd numbers) were not treated. The decomposed granite soils allow water to permeate easily, therefore, the soils are comparatively barren when they are in the dry condition. In order to investigate the ability of the mulching mats

Table 1. Test model and treated method

Model Slope Number	Name of Seeds and	Number of Seeds	Use of mulching Mat
1	No Seeds, No mulching Mats	None	No
2	No Seeds, Mulching Mats	None	Yes
3	Indigofera pseudo-tinctorica, Iris nertschinskia, Lespedeza cuneata	500 500 500	No
4	Indigofera pseudo-tinctorica, Iris nertschinskia, Lespedeza cuneata	500 500 500	Yes
5	Rhododendron schlippenbachii, Lespedeza cyrtobotrya	500 500	No
6	Rhododendron schlippenbachii, Lespedeza cyrtobotrya	500 500	Yes
7	Aster scaber, Iris nertschinskia, Pulsatilla koreana Capesella bursa-pastoris, Indigofera pseudo-tinctorica Lespedeza cuneata, Rhododendron schlippenbachii Lespedeza cyrtobotrya, Spiraea trichocarpa, Spiraea blumei, Berberis amurensis, Staphylea bumalda, Lindera obtusiloba	500 500 500 500 500 500 500 500 100 100 250 90 100	No
8	Same as No. 7	Same as No. 7	Yes

with various plants, herbaceous and woody plants were planted. Two lysimeters were not planted at all and allowed to seed naturally, herbaceous plants were planted in two, woody plants in two, and other two were planted with both herbaceous and woody plants simultaneously. Details of the seeds used are shown in Table 1. In this study, two aspects were examined, namely, the ecological effects, and the effect of the mulching mat on the growth of plants. The survivals of the plants listed in Table 1 were monitored, and the various results were compared to determine the advantages of the mulching mat treatment on chosen slopes. The other aspect was concerned with the physical effects of the mulching mat, which includes analyzing soil erosion, efflux water amount, runoff water, and runoff sediments. In order to perform these studies, magnetic rain gauges were installed on the slopes to monitor the rainfall, which naturally affects the performance of the mulching mat effects. At the bottom of each slope, a pan was installed to collect sediments and efflux water. The suspended sediments and the amount efflux soils were determined after oven drying.

While the tests were performed, rainfall ranging from 10~600mm was measured 10 times, as shown in Table 2. Soil erosion and other physical change of the eight lysimeters were measured and examined with respect to these rainfalls.

Table 2. Rainfall during tests

Rainfall	Period (hr)	Amount (mm)	Rainfall	Period (hr)	Amount (mm)
1	17	24.9	6	22	91.0
2	21	9.0	7	27	72.2
3	5	13.5	8	22	23.5
4	23	78.5	9	21	38.0
5	23	141.5	10	26	601.5

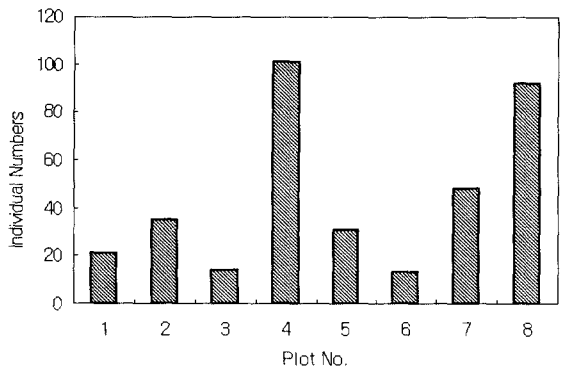

Fig. 2 Number of plant species

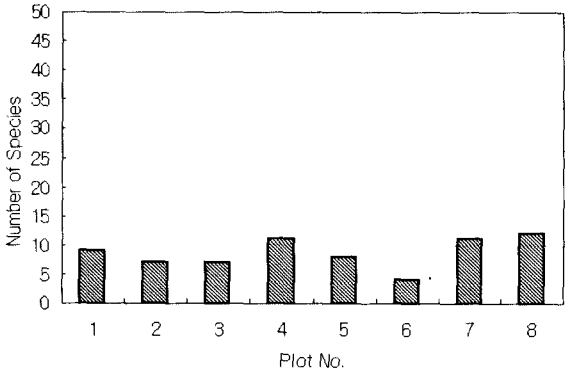

Fig. 3 Number of plant species found

4. Effects of Mulching Mats on the Growth of Plants

4.1 Number of Plant Species

The number of plant species found in the test slopes is shown in Fig. 2. As described in the previous section, some herbaceous and woody plants were planted for the purposes of this study, and other wild plants were also found in the test plots. The number of species ranged 5~10. Even numbered slopes (i.e., mulching mat treated slopes), did not show different effects on number of plant species, and Fig. 3 shows the number of plants in the slopes. Mulching mat treated slopes showed much larger number of plants than the untreated slopes. This result demonstrated the effectiveness of the mulching mat with respect to herbaceous plant survival, and we believe that the mulching mat proved its effectiveness in terms of providing an suitable base for seed growth.

4.2 Plant Growth

The number of surviving seeds was considerably higher in the mulching mat treated slope for the herbaceous plants, but there was no significant difference in terms of the woody plants, as shown in Fig. 4.

The slope cover rate was very low 2 months after seeding, but the mulching mat treated slopes showed much higher comparative growth rates, approximately 3~5 times as those of unused slopes (Fig. 5). Slope cover rate is defined as the ratio between the area of plant from the view of plan and total slope area. Since the experimented slopes were originally in poor condition as candidate soils for vegetation, the highest growth rate did not exceed 50%.

5. Physical Effects of the Mulching Mats

The effects of the mulching mats were studied from the viewpoint of plant growth on each slope and relationship between rainfall, runoff and efflux water quality, slope erosion.

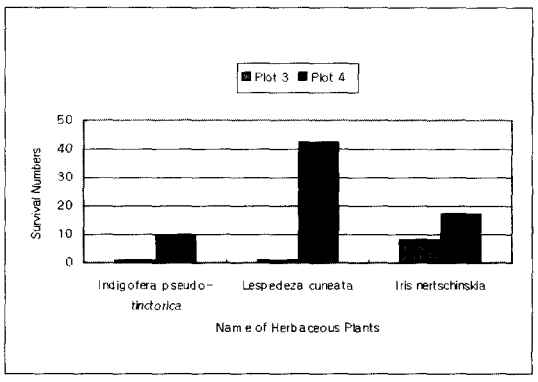

Fig. 4 Number of surviving seeds, herbaceous plants

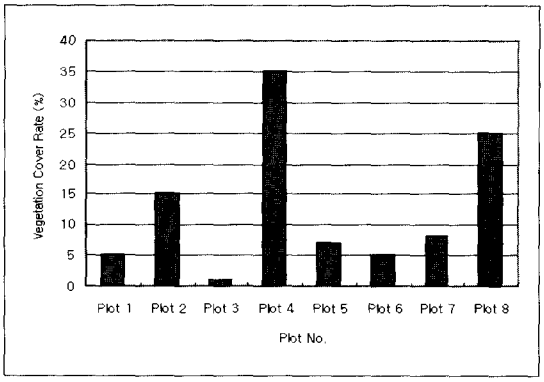

Fig. 5 The slope cover rate

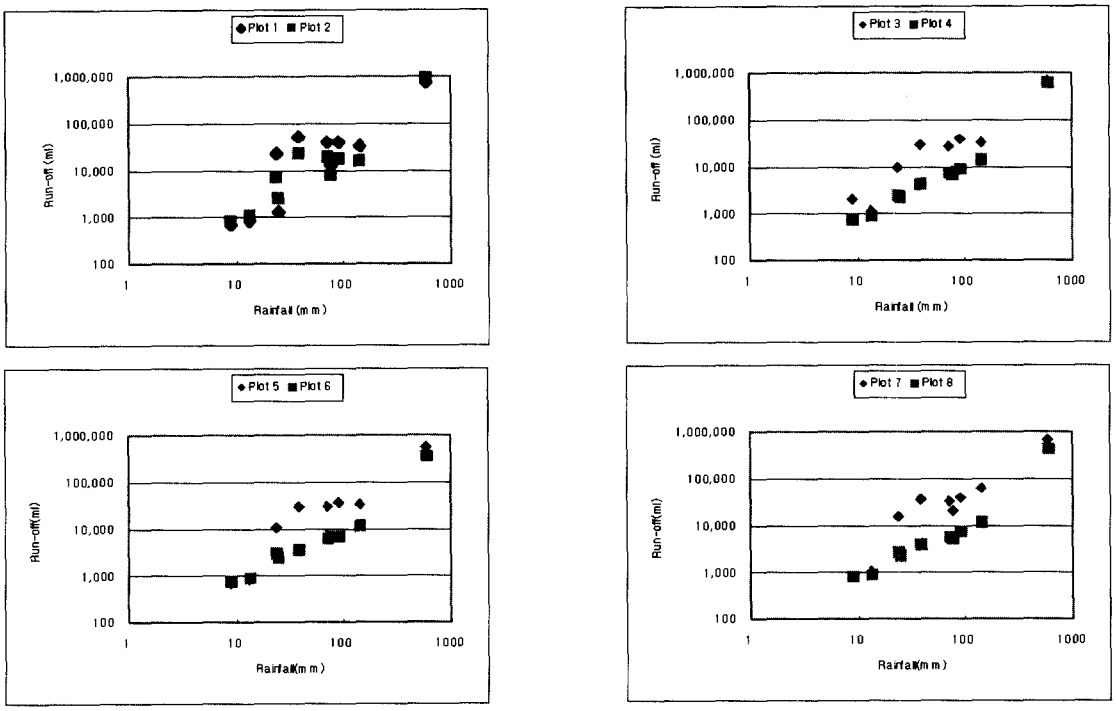

Fig. 6 Relationship between rainfall and run-off

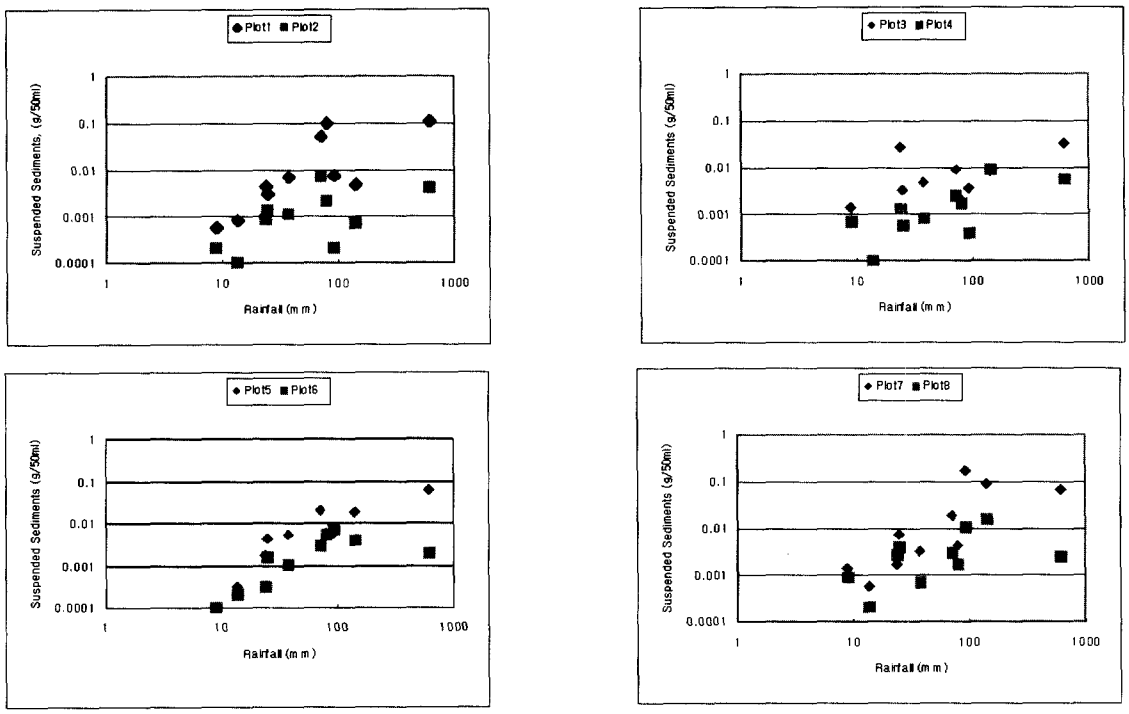

Fig. 7 Rainfall and suspended sediments

5.1 Rainfall and Runoff

While testing was underway, rainfall was measured 10 times. The amount of runoff increased as the rainfall increased, as shown in Fig. 6. As shown in Fig. 6, eight plots are described and show the relationship between rainfall and runoff. The even numbers (i.e., with open square legend) that were treated with mulching mats show significantly reduced (roughly 50% less) amounts of runoff. When rainfall was very high (600 mm), the

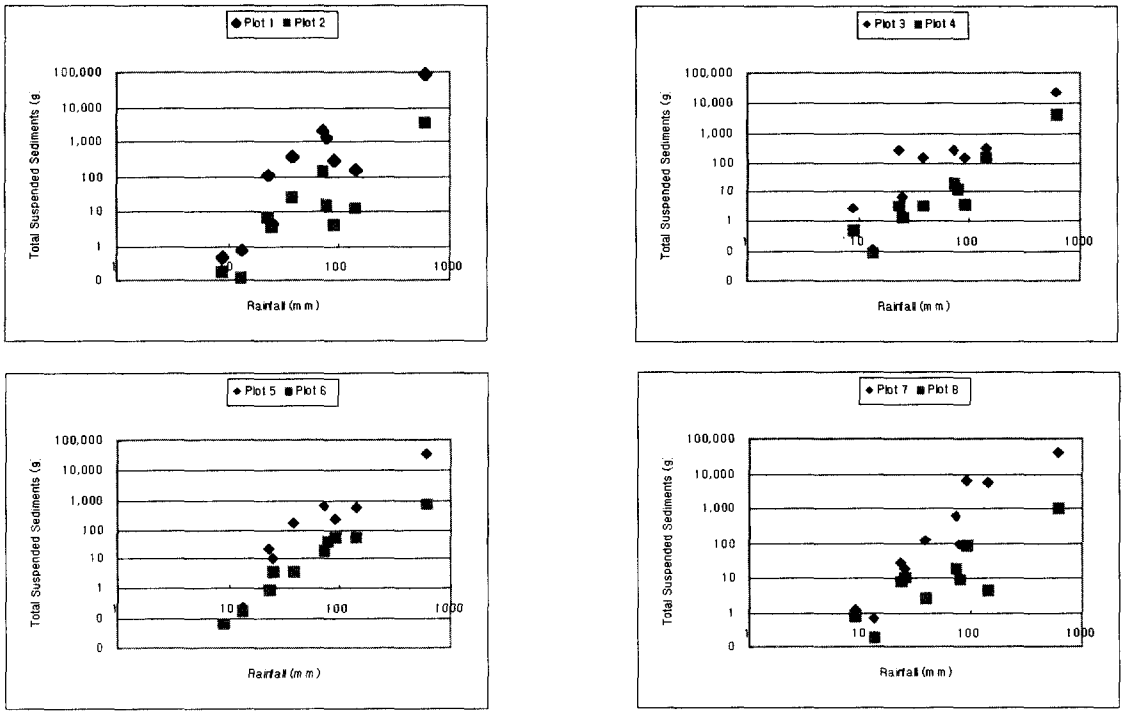

Fig. 8 Rainfall and total suspended sediments

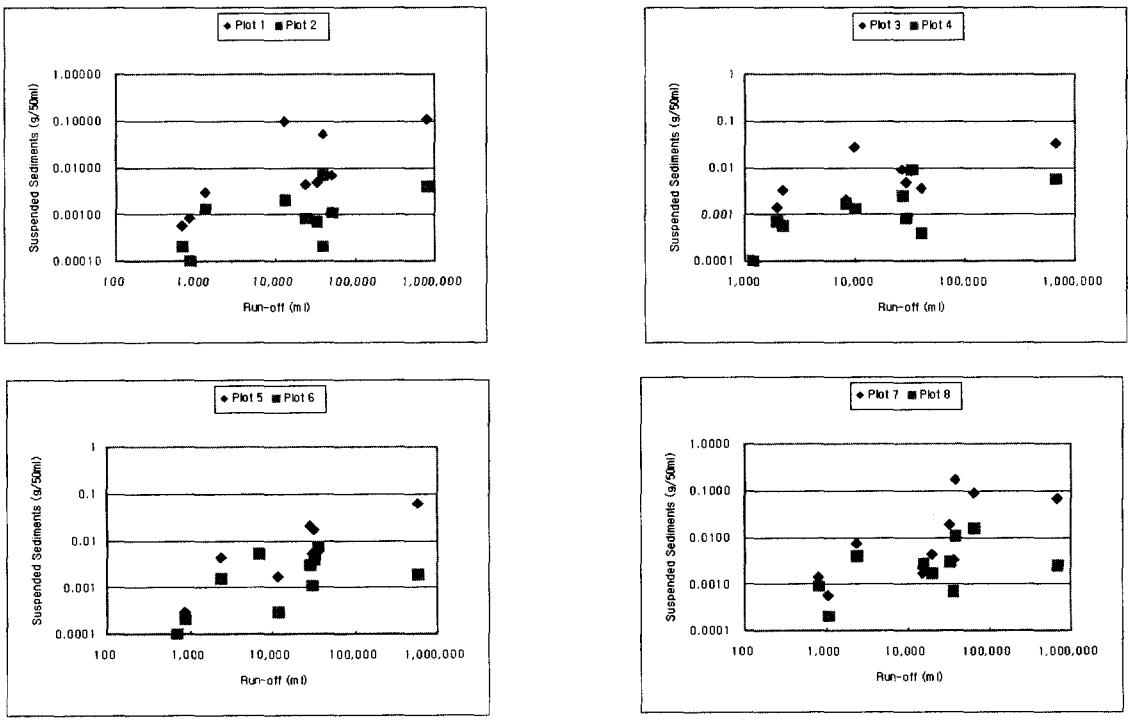

Fig. 9 Run-off and suspended sediments

mulching mats did not contribute to the runoff reduction. Since runoff brings about seed loss, soil erosion, and slope instability, mulching mat contributed to slope stabilization.

5.2 Rainfall and Suspended Sediments

Suspended sediments include floating particles such as colloidal soil particles and small soils and roots, which are washed from the slope by rain. Mulching mats reduce

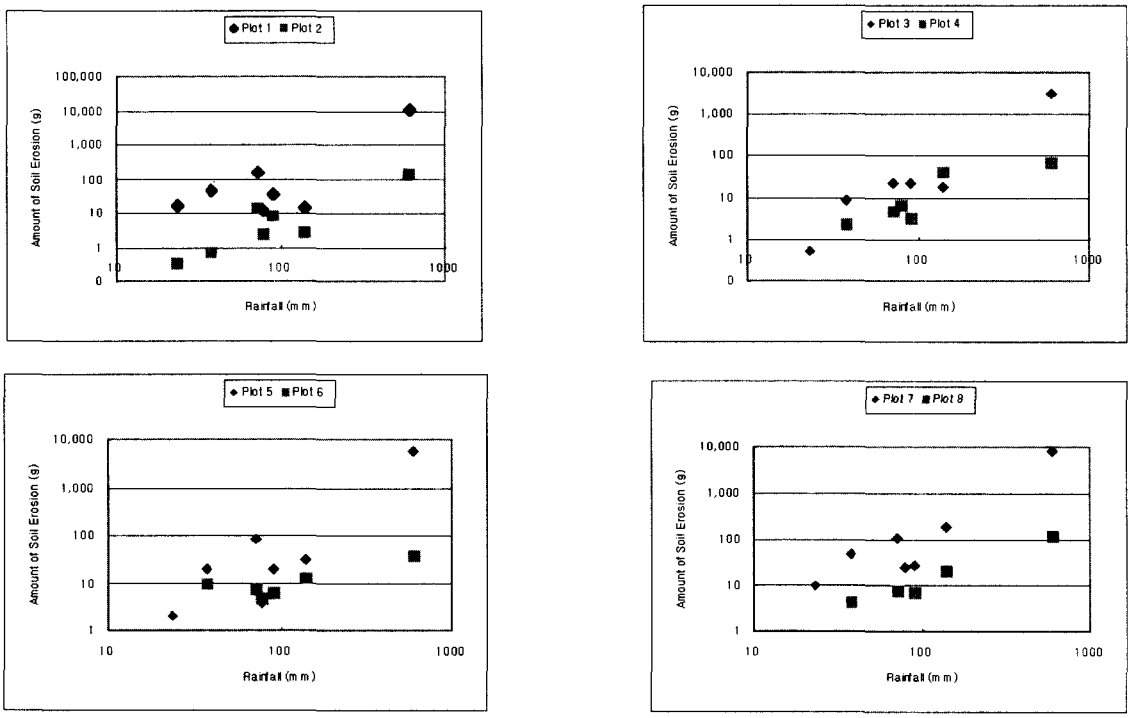

Fig. 10 Rainfall and amount of soil erosion

(i.e., even numbers) the amount of suspended sediments as shown in Fig. 7. For most cases of rainfall, the mulching mat treated slopes (even numbers) always showed 10 0～500 times less suspended sediments (Fig. 7). The total amount of suspended sediments in water was also much less in the case of the treated slopes (even numbers) than the untreated slopes (odd numbers) (Fig. 8).

5.3 Runoff and Suspended Sediments

Suspended sediments accumulate in the measured runoff water, and since suspended sediments as their name implies are suspended in the water, they were collected in the pan at outlet. The mulching mat very effectively reduced the suspended sediments, as shown in Fig. 9. This effect was most marked in plot 8, which contained herbaceous and woody plants, and showed 10 0～1,000 times lower sediment levels (Fig. 9).

5.4 Rainfalls and Soil Erosion

Soil erosion naturally increases as the amount of rainfall increases, as shown in Fig. 10. The mulching mat was also very effective at reducing soil erosion on the soil slope: these slopes showed approximately 100 times less soil erosion under most rainfall conditions (Fig. 10). This result indicates that the mulching mat is able to stabilize slopes and reduce slope erosion. Moreover, if a mulching mat is not used for such barren slopes, soil erosion will progress and result in eventual slope failure.

5.5 Runoff and Soil Erosion

Fig. 11 describes the amount of soil found in the runoff water from slopes as a function of runoff quantity. In lysimeter 6, which was treated with a woody plant mulching mat, eroded soils were only 0.1% of that of the untreated slope after heavy rain. When the rainfall was relatively small, the eroded soils naturally lost a smaller amount because the efflux water was lower. Therefore, the introduction of a mulching mat prevents soil slope erosion, stabilizes the slope physically, and maintains moisture in the slope to benefit plant growth.

6. Conclusions

In this study, a mulching mat incorporating seeds and fertilizer was developed. This mat is also biodegradable

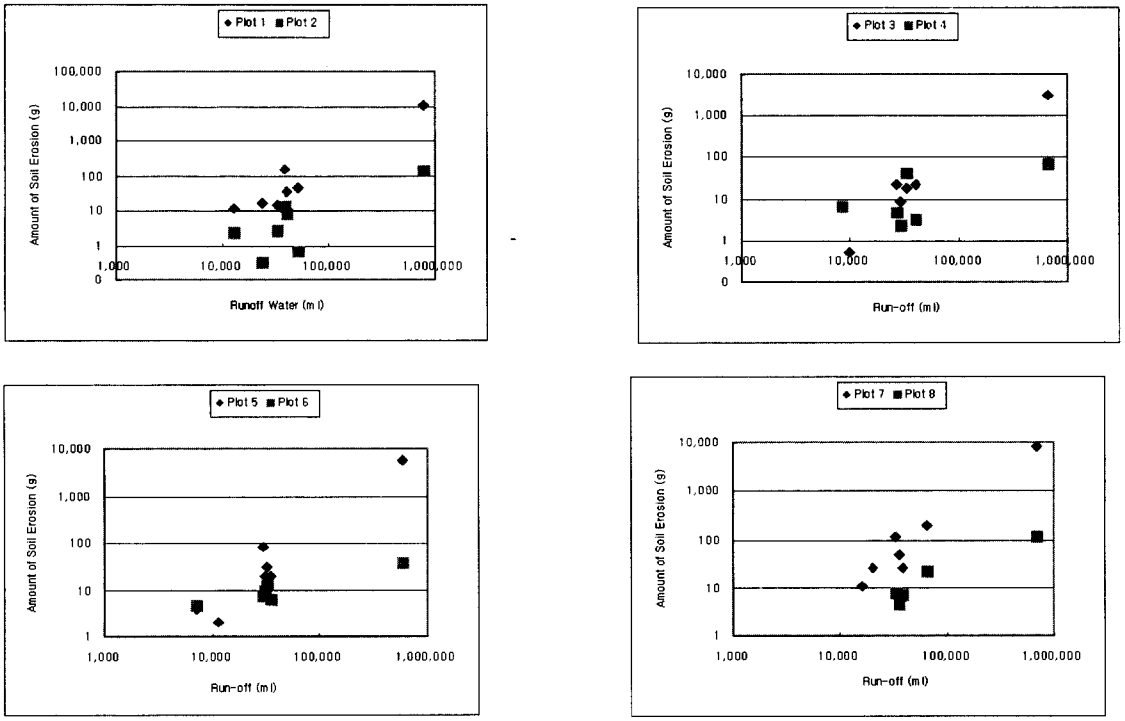

Fig. 11 Run-off and amount of soil erosion

since it is made of geosynthetic mat, and jute net; moreover, it holds seeds and fertilizer. When the mulching mat was installed, it helped stabilize slopes, which were barren and easy to erode such as weathered granite soils.

Soil erosion, plant growth, rainfall, runoff water, and sediments were analyzed during this work. From mock-up experimental studies, the following conclusions can be drawn. The mulching mat treated slopes have a much larger number of plants than untreated slopes, mulching mat treated slopes showed much higher growing rates, approximately 3～5 times as those of untreated slopes, mulching mat treated slopes show lower (roughly 50%) runoff, and 100～500 times less suspended sediments. When herbaceous plants and woody plants were planted together, sediment levels in runoff water decreased by a factor of 100～1,000. Mulching mat treated slopes show approximately 100 times less soil erosion under most rainfall conditions. For slope treated with such mats containing woody plant seeds, the amount of soil erosion was only about 0.1% of that of untreated slopes after heavy rain.

From the above results, it can be concluded that when mulching mats are installed on barren and easy-to-erode slopes, they contribute to the growth of plants, and finally stabilize slope by bioengineering mechanisms. It is considered that mulching mats are especially effective on barren slopes of decomposed granite soils. Since this mulching mat can be manufactured in large amounts, it is desirable that it will be installed on barren soil slope to promote slope stabilization and restoration of slope vegetation.

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