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Effects of Soil Compaction upon the Vegetation Environment around the Trails in Pukhansan National Park[1]

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ABSTRACT

This study was conducted to examine the effects of trampling on the changes in soil and vegetation around the trails. The study areas were established both on the trails and in the forested areas located in Ui and Jeongnung valleys at Pukhansan National Park. Soil core sampling, measurements of vegetations and counts of persons visited per hour were done during the period from April 6 to October 9, 1986. The physical properties of soils became better with increasing distances from the trail, and the best conditions were observed in the forested areas. The differences were not significant among the zones within the trailside. More number of individuals and basal area (or coverage) in woody plants were observed in the forested areas than at trailsides. For the herb layer, however, more number of individuals and coverage were shown at the trailside. In the Ui valley, the quantitative measures of herbaceous plants decreased as the bulk density and penetration resistance increased. In the Jeongnung valley, however, only bulk density was negatively related to the quantitative measures. The fact that there were poor relations between soil factors and quantitative measures of herbaceous plants in Jeongnung valley might be influenced by other factors rather than soil compaction. Thus, more research would be needed to understand the critical factors affecting the vegetational changes in recreation areas.

Key words: trail, trampling, soil compaction, bulk density, vegetation environment.

요 약

본 연구는 등산로 주변의 토양 및 식생에 대한 답압의 영향을 알아 보기 위하여 수행되었다. 야외 조사는 1986년 4월 6일과 10월 9일 사이에 11회에 걸쳐 북한산 국립공원 내의 우이 계곡과 정릉 계곡에 위치한 등산로 및 삼림 지역에서 실시되었다. Core를 이용하여 채취한 토양의 물리적 성질들을 측정하고, 식생 조사를 실시하여 현존 식생의 상태를 조사함으로써 등산로 주변과 사람들에 의해 이용되지 않은 삼림과의 토양 및 식생 상태를 비교·분석하였다. 또한 각 등산로별 이용량을 시간당 이용 인원수로 산정하여 이용량의 차이에 의한 변화량의 차이도 분석하고자 시도하였는 데 그 결과는 다음과 같다. 토양의 물리적

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성질은 등산로에서 거리가 멀어짐에 따라 점차 호전되어 삼림지역에서 가장 좋은 상태였다. 삼림지역에서는 등산로 주변보다 더 많은 수의 목본류가 나타났으며 흉고 단면적도 더 컸다. 그러나 초본류의 경우는 등산로 주변에 더 많은 개체가 나타났으며 피도도 더 컸다. 우이 계곡에서는 토양의 가비중 및 토양 경도가 증가함에 따라 식생량이 감소했다. 그러나 정릉 계곡에서는 가비중 만이 식생의 변화에 영향을 끼칠 뿐 다른 토양 인자는 식생량의 변화에 크게 관여하지 않은 것으로 나타났다. 결국 정릉 계곡의 식생은 토양 인자보다는 다른 인자에 의해 영향을 받았음을 뜻하는 데, 이러한 점에서 볼 때 휴양지의 식생에 영향을 끼치는 인자에 대한 종합적 연구가 필요하다고 생각된다.

INTRODUCTION

Rapid increase in populations, in the standard of living and leisure time creates overuse of the natural areas. Overuse of the natural areas causes deterioration of the forest ecosystems, and the deterioration occurs within short period of time. Cole (1982), and Frissell and Duncan (1965) have shown that considerable resource alteration occurred even at low levels of recreational use.

Whenever trampling occurs, vegetation and soil are disturbed. The general impacts of trampling are to decrease plant growth and ground cover, and to increase soil compaction and erosion (Dotzenko *et al.* 1967). Vegetation cover is reduced by trampling but some plants are more resistant to trampling than others (Frissell and Duncan 1965; Settergren and Cole 1970; Dawson *et al.* 1978; Cole 1982). Young (1978) discovered that grasses are less damaged by trampling than dicots.

The heavily trampled center of the trail was usually bare, but cover increased with distance from the trail to a maximum, reaching approximately 1 meter from the trail (Bayfield 1971; Dale and Weaver 1974; Dawon *et al.* 1974).

Soil compaction appeared with intensity and duration of use (LaPage 1961; Burden and Randerson 1972; Bayfield 1973; Cole 1985), the time of year at which the use takes place and on the topography of the area (Burden and Randerson 1972; Bayfield 1973; Cole 1985).

Oh (1979) reported about the soil compressibility of summer green forests in central Korea. And he also said that the vegetation change resulted from recreational use is more critical at the mountainous area in Korea because of the poor living vegetation, intensive precipitation and granite material.

Therefore, it is necessary to study the impacts of recreational use and to build a counterplan. However, the lack of definitive guidelines to determine the optimum capacity of recreational area has resulted in a trial and error approaches to recreational area planning management (Kuss and Morgan 1980). Understanding the factors which affect the deterioration of recreation areas may lead to solutions for problem concerned with planning, development, maintenance and rehabilitation of recreation areas.

The objectives of this study were (1) to measure the amount of changes in vegetation compositions and soil compaction at the trailside, and (2) to examine the effect of soil compaction upon the trailside vegetation. Consequently, the results may provide a basic information to determine the carrying capacity of mountainous national park.

MATERIALS AND METHODS

Study Area

Pukhansan National Park was selected as a study area. This national Park covers from the northern part of Seoul to Euijeongbu City, Kyounggi-Do and its total area is 78.45km^2

Since the Pukhansan National Park is located near Seoul, the number of visitors has increased rapidly. According to the data reported by the Ministry of Construction (1984), visitors to this mountain amounted to be 5,600,000 people in 1982. Such excessively frequent uses severely deteriorated the natural environment. The trails are subject to deterioration because soils are easily exposed. Thus, two trails used frequently by many people were chosen as a survey area. Other two forested areas which have never or nearly not been used were chosen as control.

One of trail areas and one of forested areas were located in Ui valley and the others in Jeongnung valley (Fig. 1). Ui valley has been more used by many people than Jeongnung valley (Ministry of Construction 1984). In this study, the amount of use was calculated on the basis of persons visited per hour.

General information about the survey area and the number of visitors per hour are shown in Table 2.

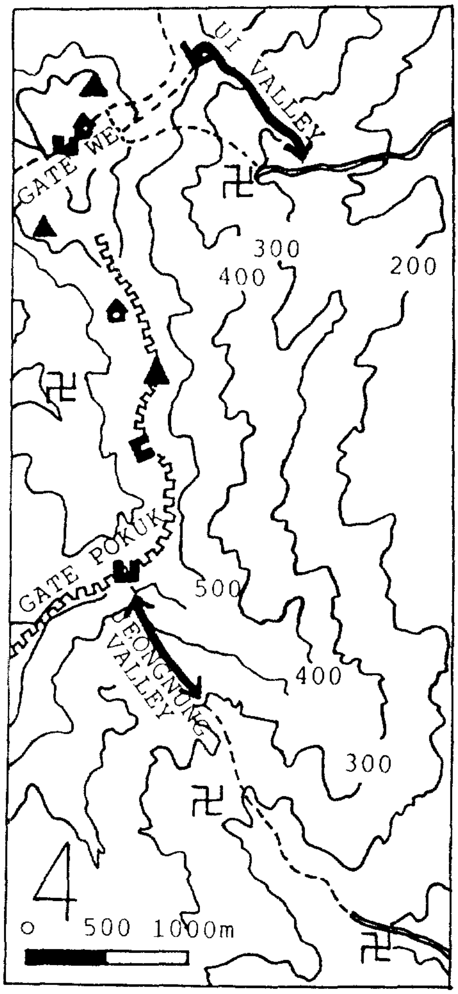

Fig. 1. Location map of the study area.

Measurement of Vegetation

Three sample plots per each trail were established at different altitudes. First plot was made at 300m above sea level, and second and third plots at 400m and 500m, respectively. For the forested areas (control), three sample plots were also established with different altitudes.

Sample plots on trailside were located at both sides of the trail, and its size was 10m x 5m. Six subplots were established within each plot, of which size was 1m x 1m: two subplots (first zone in other word) were arranged 1m from the trail, two subplots (second zone) 1 to 3m from the trail and two subplots (third zone) 4 to 5m from the trail. Therefore, each plot at each side consisted of three zones. (Fig. 2) In forested area, one plot of which size was 10m x 10m and six subplots of which size 1m x 1m within the plot were established.

For each plot, the number of individual trees, diameter at breast height, and the tree hight were measured and the crown projection diagrams were drawn. For the subplots, the number of individuals and the coverage of herbaceous plants were observed.

Measurement of Soil Compaction

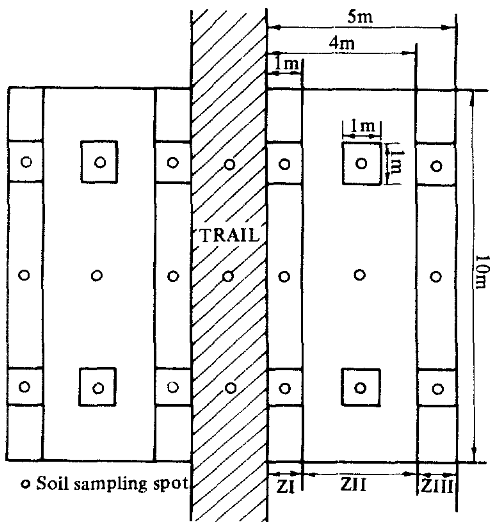

Fig. 2. Layout of the sampling plot.

Table 1. General meteorological data of Seoul area during the period of 1976-1985.

Avg. Temp. (°C)	Avg. Max. Temp. (°C)	Avg. Min. Temp. (°C)	Precipitation (mm/yr.)	Evaporation (mm/yr.)
11.9	16.7	7.8	1210.3	1090.5

Table 2. General information about the study area.

Site	Altitude (m)	Direction of slope	Grade of trail (°)	Trail width (m)	Number of users (persons/hr)
I	300	S40°W	9	1.8	
II	400	S 7°W	24	8.0	254
III	470	S61°W	17	2.0	
I	300	S52°W			
II	400	S 3°W			
III	500	S80°E			
I	300	S55°W	3	2.5	
II	400	S41°W	17	1.9	154
III	500	S80°W	15	1.9	
I	300	N65°E			
II	400	N75°E			
III	500	S85°E			

Key: TS – trailside FA – forested area Site I, II and III indicate that altitude 300m, 400m and 500m, respectively.

Cylindrical soil cores (100cm^3 in volume) were used to take soil samples from each zone (Figure2). Three soil samples were taken from each plot.

To reduce the variation of soil bulk density caused by roots and rocks, five penetrometer (Yamanaka type) readings were taken at each zone.

Data Analysis

Importance value of each species and species diversity of each plot were computed based on the vegetation sampling data. Importance value was calculated as a sum of relative cover, relative density and relative frequency. Shannon-Weiner diversity index was used to calculate the species diversity. For woody plants, basal area of trees with greater than 2cm in diameter was calculated.

Soil samples were dried at 105°C for 24 hours and its dry weights were measured to determine the bulk density. Particle density was determined using the specific gravity bottle method. Then, porosity was calculated from the bulk density and particle density.

RESULTS AND DISCUSSION

Variations in Soil and Vegetation by the Amount of Use

Changes in Soil Compaction Figure 3 shows the changes in physical properties of soils by the amount of use. Bulk density and penetration resistance at the trailside were higher than those in the forested area in both Ui and Jeongnung valleys. These results agreed with the many other studies that there was differences in bulk density between used and unused areas at campsite, picnic area or trail (Lutz 1945; Dotzenko *et al.* 1967; Settergren and Cole 1970; Liddle and Greig-Smith 1975; Legg and Schneider 1977; Monti and Mackintosh 1979; Lockaby and Dunn 1984; Marion and Merriam 1985). Penetration resistance was an another indicator of soil compaction. In this study, its average values at the trailsides were 2.79kg/cm^2 and 1.33kg/cm^2 in forested areas. However, Young and Gilmore (1976) reported that the penetration resistance was 8.79kg/cm^2 in heavy used campsites and 3.46kg/

cm² in non-used area. Severe compaction and high bulk density are characteristics of the surface mineral soils resulted from the high used areas (Monti and Mackintosh 1979). There were no significant differences in bulk density between Ui and Jeongnung valleys. However, differences in penetration resistance at the trailsides were significant between Ui and Jeongnung valleys (Figure 3). Correlation coefficients between bulk density and penetration resistance were significantly high in both Ui and Jeongnung valleys (Table 3).

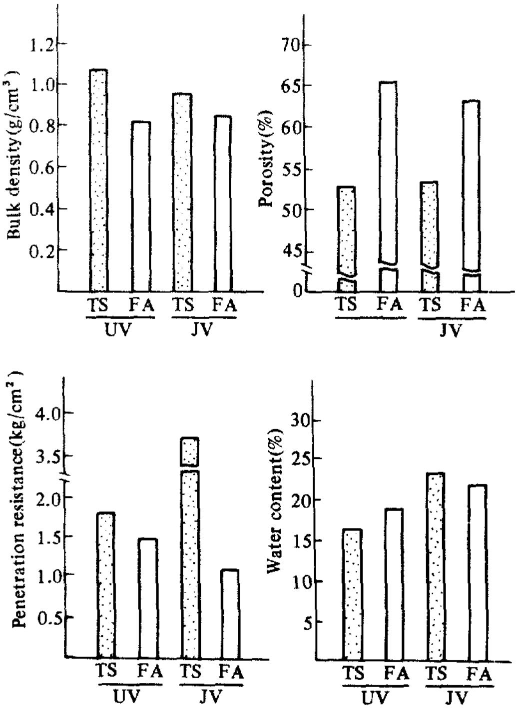

Fig. 3. Changes in physical properties of soils by amount of use
Key: TS-trailside FA-forested area
UV-Ui valley JV-Jeongnung valley

Porosity at trailsides was lower than that in the forested areas in both of two valleys, of which result was considerably similar to those published by Lutz (1945), by Legg and Schneider (1977) and by Dawson *et al.* (1978). Its differences were not obvious between two valleys. Correlation coefficients between bulk density and porosity were significantly high at 1% level (Table 3). Bulk density gives a gross meassure of compaction. As porosity changes, changes in the distribution of aggregate sizes provide a measure of soil structural changes (Chappell *et al.* 1971).

Water content at the trailsides of Jeongnung valley was higher than that in forested area (Figure 3). The result was not similar to that reported by Lockaby and Dunn (1984) who mentioned that the soil moisture at campsites was lower than that in unused area. Since soil samples were taken from the surface layers of soils in this study, lower water content in the forested area was resulted from the different percentages in forest canopy or sampling time.

Changes in soil properties by the distance from the trail are shown in Figure 4. Bulk densities in the center of the trails were 38% and 40% higher than those in the forested areas of Ui valley and Jeongnung valley, respectively. Cole (1982) reported that high organic matter content and litter layer in the less used areas at campsite mitigate the soil compaction, and resulted lower bulk density. Its differences were not significant among the zones within the trailsides. This result agreed with that reported by Oh (1979) who mentioned bulk density along the path center and path margin was higher than along the forest area in Mt. Pukhan. Penetra-

Table 3. Correlation coefficients among the physical properties of soil.

	Ui valley			Jeongnung valley		
	Porosity	Penetration resistance	Water content	Porosity	Penetration resistance	Water content
Bulk density	−.9084**	.3611*	−.6012**	−.7668**	.3290*	−.4676*
Porosity	·	−.3195†	.7045**	·	−.3334*	.1115
Penetration resistance	·	·	−.1113	·	·	−.0942

†, * and ** indicate significant difference at 10%, 5% and 1% levels, respectively.

tion resistances at the trail center were 15 times and 23 times greater than those in the forested areas of Ui and Jeongnung valleys, respectively. LaPage (1962) reported that soil compaction increased with increasing intensity and duration of use and soil penetration resistance in trampled sites was eighteen times greater than that in untrampled areas.

There was a significant difference in porosity between trailside and forested area at both of the valleys, but there were no differences among the zones within trailsides (Figure 4). The difference in water content between trail center and first zone of trailside was obvious but was not significant among the zones within trailside and forested area.

Consequently, soil conditions became better as the distances from the trail increased. However, its differences were not obvious among the zones within trailsides.

Changes in Vegetation Table 4 shows general information about the vegetation in study areas. As shown in Table 4, there were no significant differences in number of species between trailside and

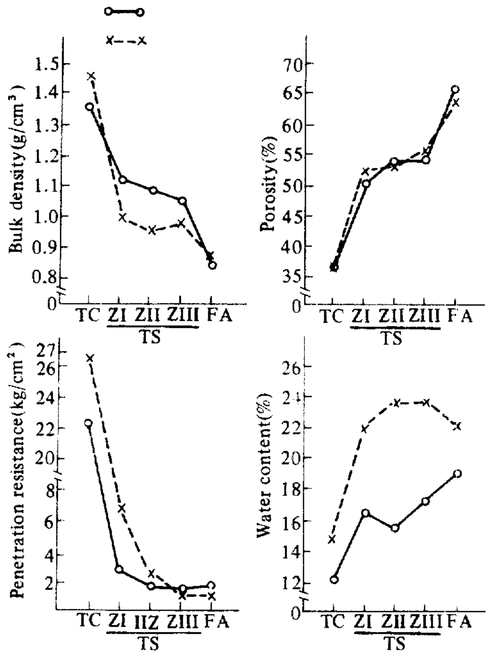

Fig. 4. Changes in physical properties of soils with the distances from the trail.
Key: TC-trail center TS-trailside
FA-forested area

Table 4. The vegetation in study areas.

		Ui valley		Jeongnung valley	
		Trailside	Forested area	Trailside	Forested area
No. of species	UL	5(19)*	3(24)	7(31)	6(23)
	ML	11(16)	8(33)	7(32)	8(32)
	LL	23(220)	17(457)	20(365)	30(638)
	TOTAL	27(255)	19(514)	25(428)	30(693)
	HL	23(897)	23(695)	14(368)	12(263)
Basal area($m^2/100m^2$)	UL	0.0918	0.1024	0.0838	0.1213
	ML	0.0033	0.0026	0.0124	0.0063
Coverage(%)	LL	47.7	77.8	78.7	126.0
	HL	25.7	29.2	18.6	16.1
Species diversity	UL	0.5174	0.1981	0.6642	0.6218
	ML	0.9879	0.8623	0.7131	0.6749
	LL	1.1136	0.9817	0.8544	1.0336
	HL	0.9693	0.9918	1.0304	0.8609
Species dominance	UL	0.3961	0.7743	0.2799	0.3233
	ML	0.0859	0.1442	0.2207	0.2910
	LL	0.1036	0.1516	0.4268	0.1471
	HL	0.1683	0.1228	0.1101	0.1732

* The number in parenthesis indicate the number of individuals.
Key: UL – upper layer ML – middle layer LL – lower layer HL – herb layer

Table 5. Importance value of the major herbaceous plants.

Scientific name	Ui valley		Jeongnung valley	
	Trailside	Forested area	Trailside	Forested area
Calamagrostis arundinaceae	24.6	52.0	17.3	32.7
Miscanthus sinensis var. *purpurascens*	57.2	–	19.1	–
Spodipogon sibiricus	17.9	2.0	–	20.9
Carex humilus	18.9	18.2	33.9	80.2
Cerex ciliato-marginata	6.7	28.4	26.2	22.1
Hemerocallis lilioasphodelus	–	–	–	14.0
Disporum smilacinum	1.0	43.2	37.6	60.1
Potentilla fragarioides var. *major*	4.6	3.7	19.5	–
Viola orientalis	16.4	32.8	27.8	31.4
Melampyrum reseum var. *ovalifolium*	12.0	7.7	14.4	–
Artemisia keikeana	67.8	32.5	40.1	–
Artemisia japonica	37.0	23.5	–	–

forested area. For the lower layer, more number of individuals appeared in the forested area than at trailsides. For the herb layer, however, more number of individuals were observed at trailsides than at forested areas, of which result was caused by the fact that most of herbaceous plants appeared at trailsides were resistant to trampling (Table 5). Basal area of woody plants occupying the upper layer in forested areas was larger than that at trailsides. The mean basal area in upper layer was $0.0998m^2/100m^2$.

Coverage for the lower layer in the forested area was higher than that at the trailside. More coverage for the lower layer was shown in the Jeongnung ralley than in the Ui valley. Comparing the four levels of camping use, Young (1978) did not find and differences in the percentage of crown cover or in basal area between the different campsites in uses, but more shrub cover was significantly observed on unused sites than on used sites. There was more herb cover in the forested area than at the trailside in Ui valley, but more at the trailside than in the forested area of Jeongnung valley. Negative correlation (r = -0.9157) between basal area of woody plants and coverage of herbecause plants was significantly high at the 5% level. This agreed with the result reported by Young (1978). He reported that the smaller amount of crown cover on lightly-used sites resulted in less shading and better growing conditions for ground vegetation.

Species diversity for the upper layer was lower than that for the other layers in both of two valleys. It was considered that this result was ascribed to the fact that most of the sampling plots were placed at *Quercus mongolica* stands.

Dawson *et al.* (1978) and Young (1978) found that the percentage of monocots increased as the amounts of uses increased and campgrounds had a greater percentage of grass cover than forested area. The results obtained from this study, however, were not similar to their results (Figure 5). Forested areas showed greater percentage of monocots than trailsides. Particularly, it was true in Jeongnung valley. The result that greater percentage of monocots was observed in the forested areas could be explained by a major composition of herbaceous

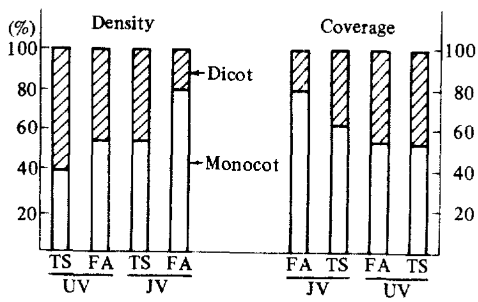

Fig. 5. Density and coverage of both monocots and dicots with different amounts of use.

plants in this study area (Table 5). That is, *Disporum smilacinum* which is sensitive to trampling mostly occupied at the composition of monocots in the forested areas. However, most of the monocots appearing at campsites were grass species belonging to Gramineae and Cyperaceae recognized as resistant to trampling (Dale and Weaver 1974; Dawson *et al.* 1978; Young 1978; Cole 1982; Cole 1985). Therefore the species included in Gramineae, Cyperaceae and Compositae occurred more common at campsites and trailsides than sensitive species. Some researchers suggested that the major species which increased along the trails were all small plants which have either ground level leaves or protected perennating tissues, features which facilitate survival under trampling stress (Bates 1935; Dale and Weaver 1974; Liddle and Greig-Smith 1975).

The major dicots found in this study area were *Viola orientalis, Artemisia keikeana* and *A. japonica.* Of these species *Artemisia* belonged to family Compositae. The major monocots were *Calamagrostis arundinacea, Miscanthus sinensis* var. *purpurascens, Carex humilus* and *Disporum smilacinum*. Among these species, *Disporum smilacinum* recognized as a sensitive species (Cole 1985) did not belong to either Gramineae or Cyperaceae. Thus, such species composition resulted in the presence of many dicots at trailsides and in the presence of many monocots in the forested areas. If *Artemisia keikeana* and *A. japonica* were excluded from vegetation composition at trailsides and *Hemerocallis lilioasphodelus* and *Disporum smilacinum* excluded from vegetation composition in the forested area, the composition of herbaceous plants would be changed into the following result shown in Figure 6. Compared with the result shown in Figure 5, the percentage of monocots in Figure 6 increased at the trailsides while the percentage of dicots increased at the forested areas.

Figure 7 shows that the changing patterns were not similar with increasing distances from the trail, and its differences in most of the variables were not

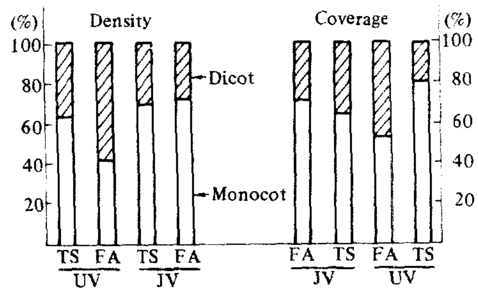

Fig. 6. Density and coverage of both monocots and dicots with different amounts of use – Modified from Figure 5.

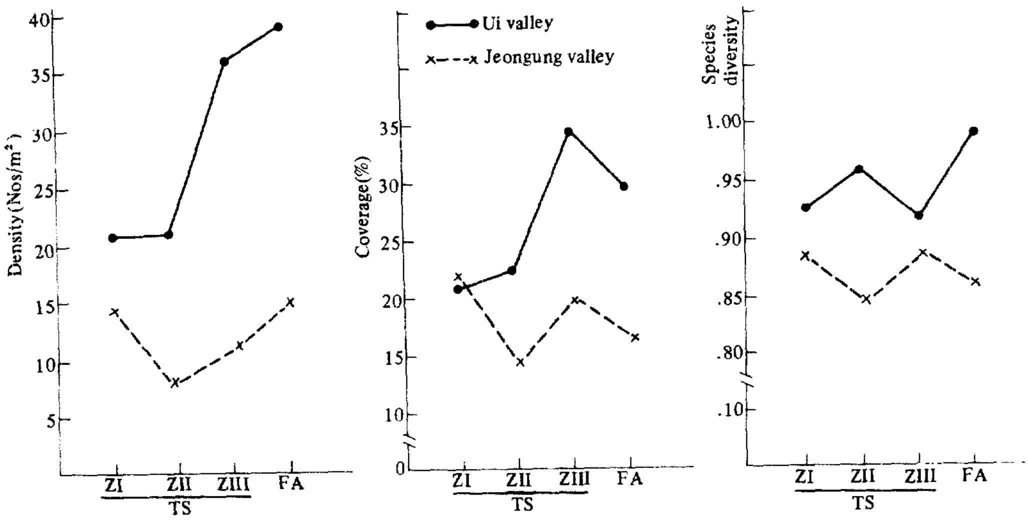

Fig. 7. Changes in herbaceous plants by the distances from the trail.

Table 6. Correlation coefficients(r) between physical properties of soils and quantitative measures of herbaceous plants.

	Ui valley			Jeongnung valley		
	Coverage	Species diversity	Density	Coverage	Species diversity	Density
Bulk density	−.4241**	−.3638*	−.6696**	−.3526*	−.4113*	−.2322
Porosity	.3769*	.2911+	.5691**	.2290	.2887+	.1383
Penetration resistance	−.3694*	−.4088*	−.3289*	−.1503	−.1483	−.1633

+, * and ** indicate significant difference at 10%, 5% and 1% levels, respectively.

large among the zones within trailsides except for the bulk density in the Ui valley. This result did not agreed with those mentioned by Bayfield (1971) and by Dale and Weaver (1974) who have found that coverage of the herbaceous plants was similar in all the distances from the trail except for the distance of 1m and recreational impact was usually confined to 1m on either side of the trails in the forested areas. Cole (1979) also reported that the vegetation responses, such as cover loss and changes in species compositon in only 2m from the trails were negligible when compared with those at trailsides. Dawson *et al.* (1974) reported that the use was concentrated on the path themselves rather than being dispersed over larger areas as in developed campgrounds and picnic areas. Good vegetational conditions apparent at the first zone were related to the openness of forest canopy. The closed canopy were associated with a high percentage of bare ground and little understory cover, and open forest canopy with a good cover of trample resistant species (Dawson *et al.* 1978; Young 1978). Therefore, it was thought that the vegetational changes in this areas resulted from not only by the amount of use but by the other environmental factors such as slope, amount of organic materials, thickness of litter layer and openness of forest canopy.

Effects of Soil Compaction upon the Vegetation

Correlation coefficients between soil factors and quantitative measures of herbaceous plants in both Ui and Jeongnung valleys are shown in Table 6. In the Ui valley, there were significant correlations between soil factors and quantitative measures of herbaceous plants in both Ui and Jeongnung valleys are shown in Table 6. In the Ui valley, there were significant correlations between soil factors and quantitative measures of herbaceous plants at the 10% level. For the Jeongnung valley only bulk density was negatively related to the quantitative measures. This indicates that changes in herbaceous plants in Ui valley were considerably influenced by soil compaction, but such other factors as slope, thickness of litter layer and chemical properties of soils rather than soil compaction would affect the changes in herbaceous plants in Jeongnung valley. Thus, it seemed that more research would be needed to understand the factors affecting vegetational changes in recreational areas.

CONCLUSION

The physical properties of soils became better with increasing distances from the trail, and the best conditions occurred in the forested areas. The differences were not significant among the zones within the trailside.

More number of individuals and basal area (or coverage) in woody plants were observed in the forested areas than at trailsides. For the herb layer, however, more number of individuals and coverage were shown at the trailside.

In the Ui valley, the quantitative measures of herbaceous plants decreased as the bulk density and penetration resistance increased. In the Jeongnung valley, however only bulk density was negatively related to the quantitative measures. The fact that there were poor relations between soil factors and quantitative measures of herbaceous plants in Jeongnung valley might be influenced by other factors rather than soil compaction. Thus, more research would be needed to understand the critical factors affecting hte vegetational changes in recreation areas.

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