





Under the 20 cm depth, the bulk density gradually increased by the first to the fifth passes. After fifth tractor passes, the bulk density was slightly affected any further by subsequent passes. The surface bulk density of undisturbed condition was 0.89 g/cm<sup>3</sup> and after the third, fifth and eighth pass, the bulk density increased to 1.08, 1.30, and 1.33 g/cm<sup>3</sup>, respectively. The percentage of increasing in bulk density from undisturbed to the third, fifth, and eighth passes was 21.3, 46.1, and 49.4%, respectively.

In the Fig. 5, the soil hardness at the skid trail compared with those at the center and 50 cm from the side of trails. The result showed that the soil under the trail was more compacted than those under the center and 50 cm from the side of trails. The degree of soil hardness at the center was nearly the same with the 50 cm from the side of the trail and both of them increased slightly with the increase of the tractor passes. The bulk density at the center and 50 cm from the side of trails after tractor passes was higher than that at the undisturbed area. The percentage of increasing bulk density of the center and 50 cm from the side of trails from undisturbed to the eighth passes was 13.5% and 14.9%, respectively.

The rut is the visual impact which directly can be seen after logging operation. In Fig. 6, it was recognized that the number of tractor passes influenced the rut formation. After the second passes, the average rut was 7.3 cm, and increased to 12.95 cm after eight passes. According to another research about the rut, the wider tires caused smaller ruts (5). The number of skidder passes was also the significant factor influencing the increasing of rut formation. Changes in rut profile could be a function of number of passes, soil type and tire size.

#### 4. Conclusions

In the natural forest of Tokyo University Forest in Hokkaido, the bulk density increased with the increase of tractor passes. The bulk density increased until eight passes at least. It increased by 49% from the undisturbed condition. The bulk density at the center and 50 cm from the side of trails also increased slightly with the increase of tractor passes. However, the bulk density under the trails was higher than the center and

50 cm from the side of trails. The cone index showed that the soil was compacted from the surface down to 50 cm depth. The trend of increase in soil hardness affected by the multiple pass could be explained by cone index even though some data were deviated. The crawler tractor D40A Komatsu with ground pressure 36 kPa created about 13 cm-depth ruts after eight passes on the sandy loam soil. The soil compaction needs attention in relation to the stand growth, especially for the natural regeneration. The next study should be conducted to find out the natural regeneration and seedling growth response in this site.

The rut is the visual impact which is easy to measure. If we find out the relationship between the rut and the physical condition of soil, we can easily identify the magnitude of soil compaction. This information will be used to restrict soil compaction impact on the site. In the future discussion, the rut formation will be examined with the physical condition of soil such as bulk density and cone index.

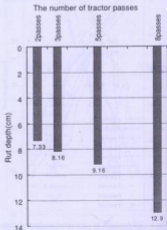


Fig. 6 Rut depth after tractor passes

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