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Tracked vehicle effects on vegetation and soil characteristics

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Abstract

A 3-year experiment to evaluate tracked vehicle effects on vegetation and soil characteristics was established on the Gilbert C. Grafton South State Military Reservation (CGS) in North Dakota. Study objectives were to evaluate the effects of 3 tracked vehicle use intensity treatments on plant species cover and frequency, and soil compaction. The 3 treatments evaluated include heavy use (74 passes), moderate use (37 passes) and no use. The moderate use treatment represents a typical use of 1 battalion unit at CGS with the heavy use treatment classified as 2 battalion units. This land area comprised a 50 by 150 meter block subdivided into three, 50 by 50 meter blocks. Each 50 by 50 meter block was subdivided into three, 16.7 by 50 meter blocks with each block treated with 1 of the 3 treatments. Soil bulk density increased ($P < 0.05$) on the moderate and heavy use treatments in the 0 to 15, 30 to 45, and 45 to 60 cm soil depths. Kentucky bluegrass (*Poa pratensis* L.) cover ($P < 0.05$) decreased in 1996 on both the moderate and heavy use treatments but was not ($P > 0.05$) different among all treatments in 1997. The tracked vehicle use on the heavy and moderate treatments did not change species composition or litter amounts after 2 years; however, bulk density and bare ground increased on both treatments in 1996 and 1997.

Resumen

Se estableció un experimento de 3 años en la Reservación Militar Estatal Gilbert C. Grafon (CGS) de North Dakota para evaluar los efectos del paso de veháculos militares en la vegetación y suelo. Los objetivos del estudio fueron evaluar los efectos de 3 intensidades de paso de veháculos militares en la cobertura y frecuencia de especies vegetales y la compactación del suelo. Los 3 tratamientos evaluados fueron: uso alto (74 pasos), uso moderado (37 pasos) y sin uso. El uso moderado representa el uso tápico de una unidad de batallón en el CGS y el tratamiento de uso alto representa el paso de dos unidades de batallón. El áea experimental fue un bloque de 50 x 150 m dividido en tres bloques, cada bloque de 50 x 50 m se subdividido en 3 bloques de 16.7 x 50 m y en cada uno de estos bloque se aplico uno de los tratamientos. La densidad aparente del suelo a las profundidades de 0–15, 30–45 y 45–60 cm aumento ($P < 0.05$) en los tratamientos de uso moderado y alto. En 1996, la cobertura del zacate "Kentucky bluegrass" (*Poa pratensis* L.) disminuyó ($P < 0.05$) en los tratamientos de uso moderado y alto, pero en 1997 la cobertura de esta especie no difirió entre tratamientos ($P > 0.05$). Después de 2 años, el uso moderado y alto de veháculos militares no cambio la composición de especies ni la cantidad de mantillo; sin embargo, la densidad aparente y el suelo desnudo aumentó en ambos tratamientos en 1996 y 1997.

Key Words: Soil dry bulk density, plant community, personnel carrier, *Poa pratensis, Bromus inermis*

The acreage of army training lands is limited; therefore, care and maintenance of these lands is required to keep them viable for future training. The army's requirements for training lands have likewise increased, stressing the existing land bases. It is in the army's best interest to maintain the soils and vegetation on current training lands to sustain a realistic training environment. Without proper management, lands that receive intense use become devoid of vegetation and do not provide sufficient cover for troops and vehicles.

The National Environmental Policy Act of 1969 (NEPA) and Army Regulation 200–2 require that the Army minimize any significant short-term and long-term environmental impacts on natural resources (Goran et al. 1983). The army is responsible for maintaining ecological diversity and viability of the lands in its care. Furthermore, rare and endangered species, and the habitat necessary to maintain those species on army land are protected by the Threatened and Endangered Species Act (U.S. Dept. of Interior 1973).

The study objective was to evaluate the ecological effects of tracked vehicle use on plant species cover and frequency, and soil compaction. The hypothesis was that tracked vehicle use on a Kentucky bluegrass-smooth bromegrass (*Poa pratensis-Bromus inermis*) plant community in a transitional grassland would adversely affect soil dry bulk density and plant species composition. The results from this study will allow land managers and installation officials to understand the impacts that tracked vehicles have on the land base and adjust their training appropriately.

Materials and Methods

An experiment to evaluate the effects of an M113 full tracked personnel carrier on the vegetation plant community and soil characteristics was established in August 1995 in east-central North Dakota. Three tracked vehicle intensity treatments were evaluated including heavy use (74 passes), moderate use (37 passes), and no use (0 passes).

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M113 personnel carrier.

The study site was on the Gilbert C. Grafton South State Military Reservation (CGS) near McHenry, N.D. (47º40'N, 98º40'W). This area is located in an area known as the Transition Grasslands (Küchler 1964, Whitman and Wali 1975, Barker and Whitman 1989). The study site occupied concave footslopes which receive additional runoff from upper slopes. This was evident by the buried soil horizons in the soil profiles. The soil series included Embden, Hecla, and Maddock with soils characterized as "coarse loamy" or "coarse silty", mixed Pachic Udic Haploborolls. The vegetative plant community was classified as a Kentucky bluegrass/smooth bromegrass (*Poa pratensis/Bromus inermis*) vegetative type dominated by Kentucky bluegrass (*Poa pratensis* L.) and smooth bromegrass (*Bromus inermis* Leyss. subsp. *inermis*). Other major plants associated with the study site included western snowberry (*Symphoricarpos occidentalis* Hook.), yarrow (*Achillea millefolium* L.), white sage (*Artemisia ludoviciana* Nutt.), yellow sweetclover (*Melilotus officinalis* L.), heath aster (*Aster ericoides* L.), and soft goldenrod (*Solidago mollis* Bartl.).

Average annual precipitation (29-year average) at the McHenry weather station was 47.3 cm per year (NOAA 1995–1997). Annual precipitation was 63.2 cm, 47.5 cm, and 29.4 cm for 1995, 1996, and 1997, respectively. The 29-year average precipitation was 8.7 cm in June, 6.7 cm in July, and 6.9 cm in August. Precipitation was below the 29-year average for June and above the average for July for all 3 years. Precipitation was below the 29-year average for August with 5.5 cm, 3.1 cm, and 3.5 cm for 1995, 1996, and 1997, respectively. Data were collected in August and September for all 3 years of the study.

Tracked Vehicle Experiment

A M113 personnel carrier tracked vehicle was used in the experiment. This tracked vehicle has a flexible track driven by sprockets at the front of the vehicle. Consequently, the top and bottom rear portions of the track are under tension while the lower forward sections are relatively slack, thus, enabling the vehicle to traverse rough terrain. Rubber bushings provide torsional flexibility of the track segments which are 38 cm wide with a central rubber pad 15 cm wide. The M113 is equipped with 5 bogie wheels that are 71 cm on center, 1 drive socket and 1 idle sprocket. The length and width of the track are 305 and 38 cm, respectively. The gross full load weight of an M113 is 11,353 kg, exerting a ground pressure of 54.9 kPa (U.S. Dept. of Army 1990).

The one time application of a M113 personnel carrier was conducted on 2 different use treatments on 7 August 1996. The moderate use treatment (37 passes) was derived from the typical use of 1 battalion unit at this military installation. The heavy use treatment (74 passes) was essentially doubling the rate of 1 battalion unit to see if any adverse effects would be observed. The control was considered a non use treatment (0 passes). A 50 by 150 meter tract of rangeland was selected by conducting a reconnaissance of the area in the summer of 1995 to select a typical landscape utilized by a battalion with tracked vehicles. This 50 by 150 meter tract of land was subdivided into three, 50 by 50 meter blocks of similar soil and vegetation to achieve 3 replicates. Each 50 by 50 meter block was subdivided into three, 16.7 by 50 meter plots with each plot treated with 1 of the 3 treatments using a randomized complete block design replicated 3 times.

Six soil cores were extracted from each treatment plot to determine soil dry bulk density as defined by Blake and Hartge (1986). Soil cores were collected from the center of the tracked vehicle lanes using a hydraulic coring machine (Giddings). A 7.5 cm metal core cylinder was fitted with a removable plastic sleeve which protected the sample during transport. The soil cores were taken at ground surface, minimizing compression of soil columns from within 3 dm (J. Richardson personal communication). Although this technique assured

Table 1. Soil particle size analysis for personnel carrier use treatments.

Treatment	Depth	Sand	Silt	Clay
	(cm)	(%)	(%)	(%)
Control	0–15	63.7	33.4	2.9
	15–30	61.2	35.3	3.5
Moderate	0–15	53.8	42.1	4.1
	15–30	51.3	44.8	3.9
Heavy	0–15	59.7	37.9	2.4
	15–30	57.5	39.7	2.8

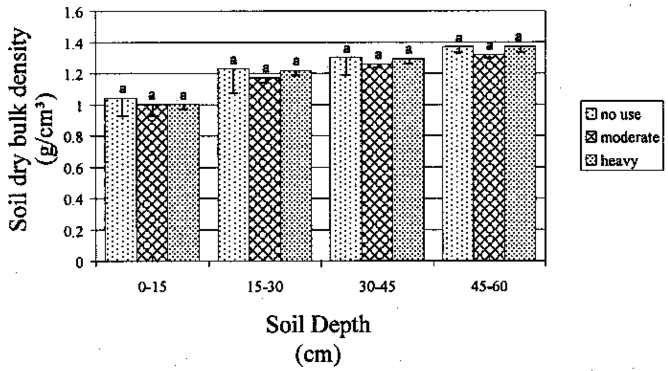

Fig. 1. Soil dry bulk density (g/cm^3) prior to each tracked-vehicle use treatment in 1996. Within soil depths, treatments with the same letter are not significantly different (P > 0.05).

minimal compression of samples at 3 dm, it is uncertain on the effects of the substrate below 3 dm. However, if a compression effect did occur it was equally represented among treatments. (J. Richardson, personal communication). The soil profile at each sampling site was classified and described. Soil cores were taken prior to and after application of the tracked vehicle use treatments in August 1996 allowing for comparisons of soil dry bulk density before and after each treatment. Soil water content was less than field capacity with soils characterized as instantly drained due to particle to particle contact (Wright and Sweeney 1977). Soils had water stable aggregates with excellent macroporosity in terms of soil structure due to high sands and bulk density levels 1 to 1.3 g cm^{-3}. These were loosely compacted granular soils with high infiltration rates. Seasonal air temperatures were slightly below the long-term averages during this period. Soil cores were collected in August 1997 using the same procedures following a 1-year freeze-thaw cycle.

A 50 m transect was placed on 1 of the 2 tracked vehicle lanes by a randomly selected process for each treatment. Presence/absence of graminoid species were collected every 2.5 m along the transect using a 0.1 m^2 frame, while forb and shrub density was determined using a 0.25 m^2 frame. The 10-pin point frame was used to determine basal and litter cover as modified by Smith (1959) and described by Mueller-Dombois and Ellenberg (1974). Plant species data were collected in September 1996, four weeks after treatment to allow for plant recovery and again in August 1997 to determine effects 1 year after treatment to monitor compositional changes.

The study results are restricted to straight tracks. A single pivot turn has an immediate and obvious impact on vegetation by exposing bare ground, destroying native plants, and allowing primary succession plants to establish. The soils all had less than 5 percent clay content and were "coarse loamy" or "coarse silty" (Table 1). Although 3 soil series comprised the study site, no observed differences in soil composition were found between series. Attempts to select for only 1 series were thwarted due to the natural changes in soil profile components, short distances, and ablation till landscapes (M. Sweeney, personal communication).

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to test for differences in soil dry bulk density among treatments (SPSS 1994). This procedure was used to determine differences using the graminoid presence/absence data, 10-pin point frame data, and forb and shrub composition data. Where significant differences were detected using a one-way ANOVA, a multiple comparisons test using the Tukey's procedure was carried out (Steel and Torrie 1980) with mean differences considered significant at the $P < 0.05$ level.

Results and Discussion

Soil dry bulk densities for each tracked vehicle use treatment (control, moderate, heavy) were not different prior to treatment application in 1996, thus eliminating any site biases between treatments (Fig. 1). Soil dry bulk density did not differ between pre- and post- treatment on the moderate or heavy use treatments in 1996 (Figs. 2 and 3, respectively). However, the moderate and heavy use treatments had a greater soil bulk density at the 0 to 15, 30 to 45, and 45 to 60 cm depths when compared to the control following 1 year of treatment (Figs. 2 and 3). Soil dry bulk density increased with depth and tracked vehicle use, independent of number of vehicle passes when compared to the control. The exception was at the 15 to 30 cm depth where no differences were noted in either the moderate or heavy use treatment (Figs. 2 and 3). Similarly, Braunack (1986) and Wolf and Hadas (1984) found most change in soil dry bulk density occurred after pass, with subsequent passes having less effect. Braunack (1986) noted the area of disturbance, both in terms of depth and width of ruts, was greater with an increasing number of vehicle passes.

Subsoil compaction under heavy axle loads of military vehicles has been reported at depths > 50 cm (Gliemeroth 1948, Ericksson 1976, Voorhees et al. 1986).

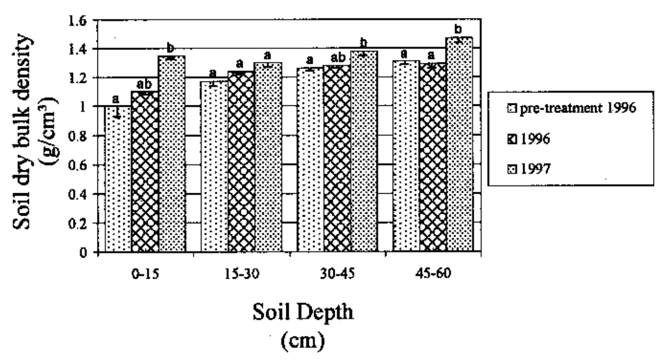

Fig. 2. Soil dry bulk density (g/cm^3) on the moderate use treatment in 1996 and 1997. Within soil depths, time periods with the same letter are not significantly different (P > 0.05).

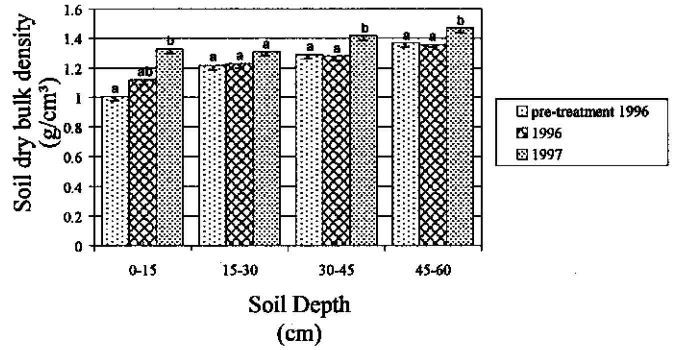

Fig. 3. Soil dry bulk density (g/cm^3) on the heavy use treatment in 1996 and 1997. Within soil depths, time periods with the same letter are not significantly different (P > 0.05).

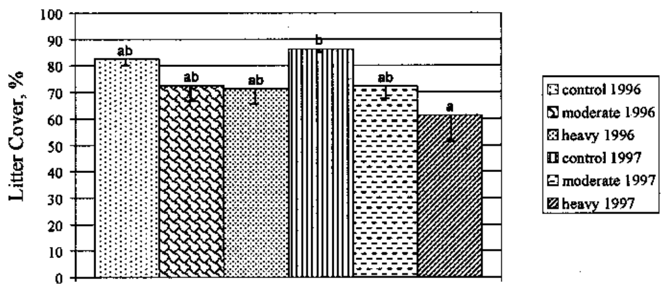

Fig. 4. Percent litter on treatment plots in 1996 and 1997. Treatments by year with the same letter are not significantly different (P > 0.05).

Our data would support their findings with subsoil compaction occurring from 0 to 15 cm and 30 to 60 cm under moderate and heavy use tracked vehicle treatments. However, no subsoil compaction occurred in the 15–30 cm layer differing from other studies previously reported. These studies reported soil compaction with high clay (>30%) content throughout the profile. Our study site had < 5% clay content with no over-consolidation or low K_{sat} due to high silt and sand content (Table 1). Soils with high sand and silt content do not express similar subsoil compaction characteristics as those soils having high clay content based on this study.

Litter cover on the control was 83 and 86 percent in 1996 and 1997, respectively (Fig. 4). Plant cover was 15 and 13% in 1996 and 1997, respectively. The moderate use treatment did not show any differences in percent litter composition in 1996 or 1997, or between years compared with the control (Fig. 4). Litter cover was reduced on the heavy use treatment compared to the control in 1997. Since the tracked vehicle in this experiment traveled straight lines (which is typical at CGS), litter present at the time of the experiment was not affected to any significant degree during year of application on the moderate use treatment. However, litter cover was reduced on the heavy use treatment 1 year following application.

Effect of tracked vehicle use on bare ground was different from the effects on litter. Total bare ground on the control was 2 and 1% in 1996 and 1997, respectively. Total bare ground increased to 19 and 18 percent on the moderate and heavy use treatments, respectively, following application in 1996. Bare ground remained greater on the heavy use treatment compared to the control, even 1 year following treatment, increasing to 25 percent on the heavy use treatment in 1997 (Fig. 5). Wilson (1988) found that Leopard tank use during May and June produced high frequencies of bare ground in native prairie, therefore encouraging invasion of introduced species at rates much higher than if driving occurred after 1 July. Wilson (1988) suggested that excluding tank traffic during May and June would decrease damage to the native prairie, reduce opportunities for non-native plant species establishment, and increase the capacity of the vegetation to tolerate traffic at other times of the year. Based on Wilson's (1988) conclusion, this increase in bare ground could lead to an increase in non-native dicot plant species but should be minimal since the treatments occurred in August.

Kentucky bluegrass, classified as an alien species that is naturalized in the United States (Great Plains Flora Association 1986), decreased in basal cover on both tracked vehicle treatments following application in 1996. However, Kentucky bluegrass increased in basal cover by 74 and 126% on the moderate and heavy use treatments, respectively, and was no longer different from the control by 1997 (Fig. 6). Tracked vehicle use, independent of intensity, had a short-term negative impact on Kentucky bluegrass basal cover; however, recovered to pre-treatment levels after 1 year of application. Unlike Kentucky bluegrass, smooth bromegrass basal cover did not change among treatments or between years in this trial (data not shown). It appears smooth bromegrass recovered the high impact of tracked vehicle usage in the short term better than Kentucky bluegrass. However, after 1 year of post treatment, both graminoid species tolerated both levels of tracked vehicle use.

Forb and shrub species showed no negative effects from tracked vehicle use at either intensity level. Total density (stems $0.25m^2$) of forb and shrub species did not change on either moderate or heavy use treatments between post-treatment levels and the control in 1996 or after 1 year of treatment application (Fig. 7). Since this site, as in most upland rangeland sites in the northern Great Plains Region, was graminoid dominant and forbs and shrubs a minor component (< 5 stems per 0.25 m^2 and a confidence interval of 4.9 +\–5.2) of

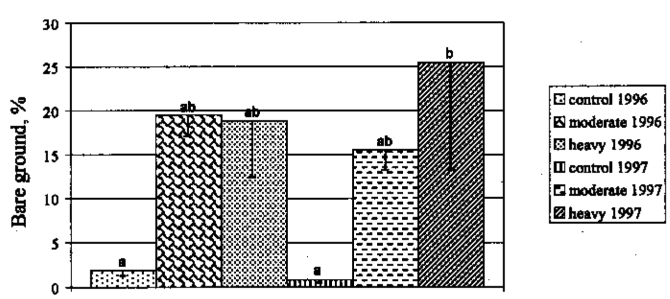

Fig. 5. Percent bare ground on treatment plots in 1996 and 1997. Treatments by year with the same letter are not significantly different (P > 0.05).

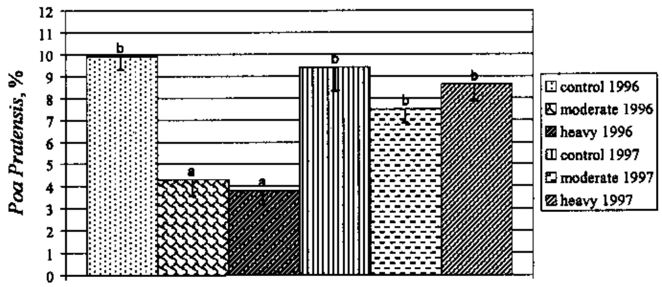

Fig. 6. Percent Kentucky bluegrass (*Poa pratensis*) cover on treatment plots in 1996 and 1997. Treatments by year with the same letter are not significantly different (P > 0.05).

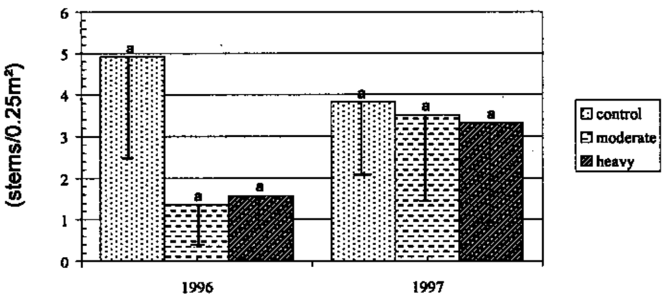

Fig. 7. Density (stems/0.25 m^2) of forb and shrub species on treatment plots in 1996 and 1997. Treatments by year with the same letter are not significantly different (P > 0.05).

the plant community, determining effects on these plant types was non-conclusive.

Conclusion

Soil compaction must be alleviated if compaction has reached the point that root and plant growth and yields are impaired. Historically, soil freezing and thawing were assumed to eliminate compacted surface soil layers in most of the U.S. Corn Belt (Gill 1971) and that no special management was required. However, Voorhees et al. (1986) showed that subsoil compaction can persist for many years after the initial loading, in spite of annual freezing to the 90 cm depth. This study showed subsoil compaction persisted in the following year of tracked vehicle application, agreeing with Voorhees et al. (1986). One of the most direct methods for avoiding compaction is the concept of controlled traffic (Taylor 1983, Gerik et al. 1987). A controlled-traffic system restricts wheel traffic to specific lanes or inter rows. As a result, more of the soil area remains uncompacted than when a random or uncontrolled traffic pattern is used.

Our results indicated that 1 year of tracked vehicle use was not detrimental to the vegetation at CGS after 2 years of data collection. Although Kentucky bluegrass cover was reduced in year of tracked vehicle application, it showed no long-term impacts in 1 year following treatment. Smooth bromegrass and dicot plants were not affected by moderate or heavy lane use of tracked vehicles in this study. There was no effect on litter cover and bare ground using the moderate tracked vehicle use treatment. However, litter cover was reduced and bare ground increased in the subsequent year following the heavy use tracked vehicle treatment. Soil dry bulk densities were significantly increased at the 0 to 15, 30 to 45, and 45 to 60 cm depths even after a freeze-thaw cycle had occurred, but appeared not to affect the vegetation.

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