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Quantifying vegetation biomass impacts on vehicle mobility

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Abstract

Soil impacts on vehicle mobility are well known; however, most data are for bare soil or the type and amount of vegetation is not documented. This study summarizes results from experiments to quantify the effect of above ground and below ground vegetation biomass on vehicle performance. Soil–vegetation combinations of three soils and three grasses were used. The vegetation was tested at various growth stages and was also subjected to stressors such as trafficking, burning, and cutting. Vegetation measurements included above ground (leaves and shoots) and below ground (root) biomass weights, lengths, diameters and surface area parameters. The soils were characterized for size distribution, moisture, density and terrain strength for each test condition. Vehicle traction and motion resistance were measured for each soil–grass combination using the CRREL Instrumented Vehicle. Results showed an increase in net traction biomass in sandy soils. For clay soils above ground biomass generally increased resistance while increased root diameter clearly decreased resistance. This study represents the first measurements quantifying the impacts of specific biomass parameters on vehicle mobility. The results will serve to guide new experimental methods, improve datasets, and develop physics-based models for years to come.
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Keywords: Grass; Roots; Trafficability; Terrain; Traction; Motion resistance; Soil strength; Rolling resistance

1. Issue and objective

An understanding of the dynamic and complex nature of the soil and how it interacts with vegetation is needed to predict the ability of the land to withstand impacts related to off-road vehicle travel (i.e. trafficability) for sustainable land management as well as how the vegetation impacts vehicle performance (mobility). Currently, the contribution of plant biomass to mobility and trafficability is not well understood and no quantifiable measurements have been recorded to establish the changes in mobility or trafficability as caused by associated changes in above ground (leaves, shoots and thatch) and below ground (roots) plant biomass. To this purpose, a study was designed to obtain test data for vehicle mobility parameters on various vegetation and soil combinations. Full scale testing was primarily in a controlled environment to provide the basic data needed to quantify the impact of vegetation biomass on vehicle mobility.

The objective of this paper was to quantify how vegetation impacts vehicle mobility and trafficability by experimentally measuring the vehicle performance response to plant biomass parameters. Future research will apply these results to physics-based predictive models to incorporate biomass impacts on soil strength and mobility.

2. Method

The vehicle mobility parameters used as response variables are net traction coefficient and motion resistance coefficient (ISTVS, 1977) and the factors are the soil properties and the plant biomass as characterized by several different measurements of the above ground and below

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ground biomass. Three test sections were constructed to capture key variables relating to soil type and biomass. Details on the experiments and information on the vehicle and plant biomass measurements follow. The test sections and multi-pass trafficking experiments are further described in Shoop et al. (2010) and Buck et al. (2012).

2.1. Test sections

The key variables considered for the experimental design were the soil type, vegetation type and growth stage, vegetation treatment; and vehicle mobility response measures of traction and motion resistance. In order to address these in a controlled fashion three different test sections were constructed. The first test section was an outdoor test plot of a predominantly Perennial Ryegrass (*Lolium perenne*) mixed with red clover (*Trifolium pretense* L.) on silty sand. Two vegetation treatment segments were used in this test section; cut and un-cut grasses. The two segments of the test section were each approximately 7.3 m (24 ft) wide by 10 m (36 ft) long. Grass in the un-cut segment reached a height of approximately 0.5 m (1.6 ft).

The other two test sections were indoor plots, each containing two soil types: sand and silty-clay soils. These test sections were built inside the Frost Effects Research Facility (FERF) so that the light and temperature could be controlled while growing, testing and monitoring the soil and vegetation year round. Each of the indoor test sections was 4.5 m (15 ft) wide by 12.2 m (40 ft) long, and these could be further subdivided to accommodate additional treatments (cutting, burning, etc.). The test section on the West side of the FERF was planted with Perennial Ryegrass with four treatments for each soil type: bare soil, grass, cut grass, and burned grass. The test section on the East side inside the FERF consisted of the same two soil types, sand and silty-clay, and was planted with Kentucky Bluegrass in two treatments; half was planted with sod and the other half with seed. All characterization and soil or vegetation measurements were uniformly performed for all test sections (with accommodations for test plot size). A summary of the three test areas and the major variables is given in Table 1. Fig. 1 shows the outdoor test section and the indoor test section on the West side of the FERF.

2.2. Soil conditions and strength

Three soil types were used in the test areas. The outdoor test area consisted of a silty sand soil with a Unified Soil

Table 1
Summary of the configuration of the three test sections.

	Outdoor	FERF West	FERF East
Vegetation	Perennial Ryegrass mix	Perennial Ryegrass	Kentucky Bluegrass
Treatments (in addition to trafficking)	Mowed and uncut	Mowed, burned, no vegetation (bare), various growth stages	Various growth stages
Soil type	Charlton silt loam	Clay-Loam, Fine Sand	Clay-Loam, Fine Sand

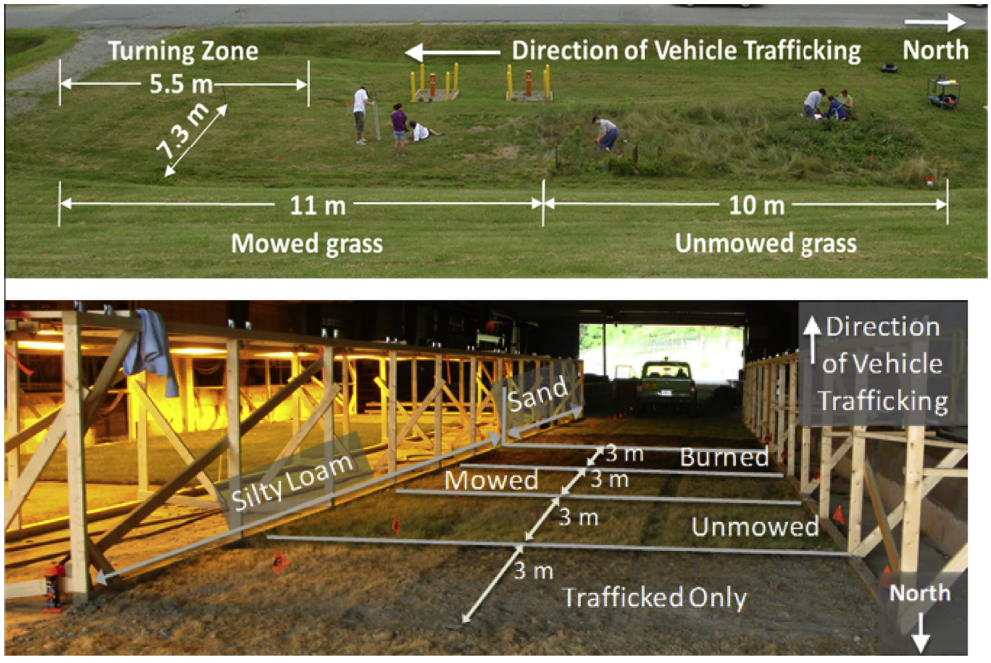

Fig. 1. Outdoor test section (top) showing cut and un-cut grasses. View of West FERF test section (bottom) of ten 3-m test sections: trafficked only, cut, un-cut, burned grass, and bare soil, in two soil types: sand and silt–clay. The vehicle shown is the CRREL Instrumented Vehicle completing the motion resistance test.