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VEHICLE IMPACTS ON VEGETATION COVER AT CAMP ATTERBURY, INDIANA, USA: PART 3. PREDICTING CUMULATIVE IMPACT OF A MILITARY TRAINING EVENT

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ABSTRACT. Vehicle and troop tracking systems are increasingly being used during military training events to improve the quality of the training by providing detailed information for real-time and post training analysis. The Deployable Force-on-Force Instrumented Range System (DFIRST^{TM}) is an example of one of these systems currently being used by U.S. Army National Guard units. Information from these vehicle tracking systems can be used to improve Army installation environmental impact assessments and monitoring programs. DFIRST^{TM} vehicle tracking systems were installed on over 80 military vehicles as part of a 12-day live training exercise at Camp Atterbury, Indiana. From the original DFIRST^{TM} dataset one training day was selected for detailed analysis. Vehicle tracking systems monitored vehicle locations while actively participating in a training exercise. Vehicle locations were used to calculate vehicle dynamic properties (velocity and turning radius). Vehicle dynamic and static (weight, type) properties and were used to predict vegetation loss using models previously developed for use at Camp Atterbury. USEPA 1979 AP-42 dust model was used to estimate dust emissions. Average distance traveled per vehicle was 17.2 km/day with an average of 0.2 km/day off-road. The training event resulted in an estimated 2662.8 m^2 of vegetation loss and 465.1 kg of PM 2.5 dust generated for the period of analysis. This study demonstrates the use of emerging vehicle tracking systems, fielded to support improved training, can be used to assess environmental impacts associated with training.

Keywords: Vehicle impacts, off-road traffic, vegetation impact, impact assessment

The Department of Defense (DoD) is responsible for administering more than 10,000,000 ha of federally-owned land in the United States. Much of this land is used for vehicle-based training activities. Continued management of DoD lands requires assessing the impact of vehicles on installation natural resources and air quality. These assessments are often mandated by the National Environmental Policy Act of 1969 (NEPA) PL. 91-190, which requires analysis and documentation of potential environmental effects associated with all major Federal decisions. The fielding of new weapon systems or the relocation of military units and their vehicles to new locations are activities that require assessments of potential environmental impacts.

The impact of off-road vehicle use on soil and vegetation has been extensively studied and often results in loss of vegetation, soil compaction, rut formation and increased erosion (Anderson et al. 2005). However, predicting the impact of individual vehicle based training events has been difficult due to: 1) the diverse manner in which vehicles are operated during

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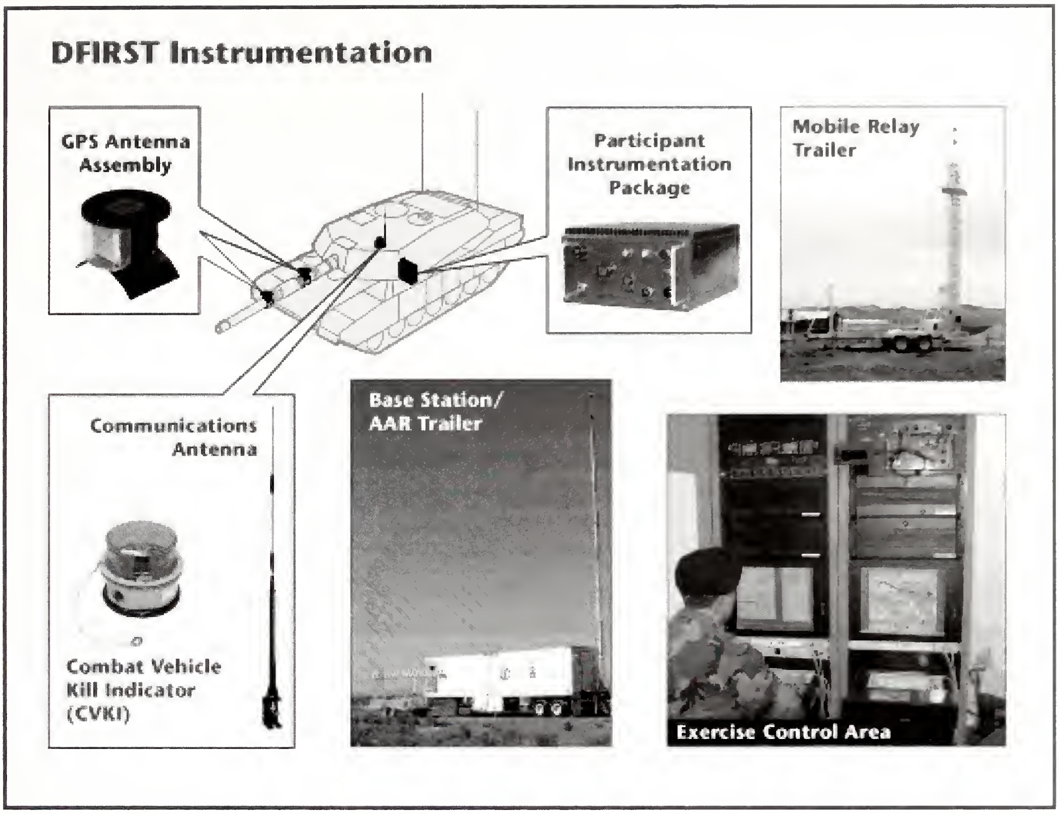

Figure 1.—Deployable Force-On-Force Instrumented Range System (DFIRST™).

training, 2) the number of different vehicle types used during training, and 3) the dispersed spatial pattern of vehicle training. Anderson et al. (2007a) demonstrated in a field study at Camp Atterbury, Indiana that vegetation loss from vehicle use could be predicted using vehicle type and dynamic properties (velocity and turning radius). In a subsequent study at the same installation Anderson et al. (2007b) demonstrated that vehicle static properties for untested vehicles could be used to predict impacts for a range of vehicle types and operating conditions. Haugen et al. (2003) demonstrated custom-made GPS tracking units as vehicle tracking systems could be used to characterize the spatial pattern of military operations. The combination of impact prediction models and vehicle tracking systems provides a means to assess overall cumulative impact of individual military training events.

Vehicle and troop GPS tracking systems are increasingly being used during military training exercises to improve training quality. These Army unique GPS tracking systems provide location and velocity information for military vehicles, similar to data used to historically quantify vehicle impact by the authors (Anderson et al. 2007a, b; Haugen et al. 2003). In this study, location data from the Deployable Force-on-Force Instrumented Range System (DFIRST™), a vehicle tracking system used for training by the National Guard, was used to associated with a typical annual training exercise. DFIRST™ data provided input into site impact models developed by Anderson et al. (2007b) to quantify the cumulative impact of large military training event on installation natural resources.

METHODS

Study site.—The study was conducted at Camp Atterbury Joint Maneuver Training Area (CAJMTA), an Army National Guard training facility that encompasses 144 km^2 in central Indiana (Tetra Tech 2000). The terrain ranges from fairly flat historically-agricultural land forms on the north, rolling hills in the central portion, to steep hills and valleys in the extreme southern portion with elevations ranging from 195–297 m above sea level. Predominant vegetation communities range from open grasslands to hardwood forests. A detailed description of terrain, soil and vegetation typical of the installation can be found in Anderson et al. (2007a).

DFIRST™ System.—The Deployable Force-On-Force Instrumented Range System (DFIRST™) system combines Global Positioning System (GPS), high-speed wireless communications, and data visualization tools. DFIRST™ allows Army National Guard personnel to engage in sophisticated training exercises and play back the events in an after-action review (AAR) facility. The DFIRST™ system consists of a Base Station and one Participant Instrumentation Package (PIP) for each vehicle in the training event (Fig. 1). The Base Station provides training exercise control, data recording, and AAR equipment. The PIP contains GPS receivers, digital communications radios, and processing equipment.

Study design.—Approximately 750 Guardsmen from the 76th Brigade Combat Team participated in a 12-day training exercise at CAJMTA 14–26 July 2006. Over 80 vehicles were tracked for each of the 12 days with DFIRST™ systems. Vehicles participating in the event included M35, M809, and HMMWV vehicle classes. The M35 vehicle class is a family of cargo trucks frequently referred to as 2½-ton cargo trucks. The M35A3 variant is representative of this vehicle class and is a three-axle six-wheeled vehicle with a 4.50 m total wheelbase, 2.40 m width, and weight of 6.5 tons (Fig. 2). The M809 vehicle class is a family of similar cargo trucks frequently referred to as 5-ton cargo trucks. The M813 is representative of this vehicle class and is a three-axle ten-wheeled vehicle with a 5.23 m total wheelbase, 2.49 m width, and weight of 10.04 tons. (Fig. 3). The High Mobility Multipurpose Wheeled Vehicle (HMMWV) class is a family of small utility vehicles. The M1025 or a M998 is an example with a 3.30 m wheelbase, 2.13 m width, and a weight of 3.7 tons (Fig. 4).

Data analysis.—A subset of 71 vehicles with complete GPS data was used for the analysis. DFIRST™ vehicle-position data were obtained for moving vehicles involved in the training event to determine vehicle movement patterns. Using the vehicle-position data total, on-road, and off-road distance traveled were calculated for each vehicle. Vehicle dynamic properties (velocity, turning radius) were calculated from position data using the methods of Ayers et al. (2000). From these data both dust estimation and vegetation losses were calculated.

Figures 2–4.—Vehicle types used in the tracking study. 2. The M35A3 2 1/2–ton cargo truck; 3. The M813 5-ton cargo truck; 4. The M1025 utility vehicle.

A primary concern with vehicle use on installation road systems is the generation of dust emissions from unpaved roads and trails. EPA 1979 AP-42 unpaved road equation was used to estimate dust emissions based on vehicle velocity obtained from the GPS data

Figures 5, 6.—Typical on and off-road vehicle travel patterns. 5. Dots show on-road vehicle locations derived from DFIRST tracking systems for two vehicles; 6. Dark dots represent vehicle locations in a concentrated use area derived from DFIRST tracking systems.

and vehicle weight (US EPA 2003). The unpaved road emission factor equation for dry condition has the following form:

$$E = 5.9(s/12)(S/30)(W/3)^{0.7}(w/4)^{0.5}$$

where: E = emission factor, pounds per vehicle-mile-traveled (lb/VMT); s = silt content of road surface material (%); S = mean vehicle speed, miles per hour (mph); W = mean vehicle weight (ton); and w = mean number of wheels (dimensionless).

The primary concern with vehicle use off of installation road systems is vegetation loss. Using vehicle impact equations from Anderson et al. (2007b) vegetation loss along each vehicle path was estimated using vehicle weight, velocity and turning radius. Total vegetation loss for each management area was calculated as the sum of each vehicle's estimated vegetation loss in that area.

RESULTS

The average distance traveled per vehicle during the training event was 17.2 km/day. Travel per vehicle varied considerably from less than 1 km/day to over 67 km/day. On-road and off-road vehicle travel averaged 17.0 km/day and 0.2 km/day, respectively. Typical on-road and off-road traffic patterns observed during the training event are shown in Figures 5 and 6. Average on-road and off-road vehicle velocities averaged 8.40 m/s and 2.43 m/s, respectively.

Using vehicle impact models from Anderson et al. (2007b) to predict vegetation loss, an estimated 221.9 m^2 of total vegetation loss for the data set used during this analysis which was for one 24 h period of training. Assuming that the subset of data is a true reflection of the entire 12-day training event, approximately 2662.8 m^2 of vegetation loss occurred during the 12-day training event. Off-road travel was highly concentrated in a few areas. Figure 7 shows the locations of vegetation loss by installation management area for the analyzed data set. Vegetation loss ranged from 0–71.1 m^2 per management area for this one day event. Vegetation loss within management areas was often highly concentrated in certain areas (Fig. 6). Even in the highest impacted management area, the total percentage of area impacted was less than 0.0002% of the management area. The spatial patterns identified from the DFIRST^{TM} data are typical disturbance patterns for many military training events that occur at the installation.

Using the EPA AP-42 unpaved road equations to estimate dust emissions, an estimated 0.33 kg/km, 0.86 kg/km and 0.46 kg/km of PM 2.5 dust emissions were produced for the HUMVEE, 5-ton truck and 2.5-ton truck, respectively. For the 12-day training event, 5.06 kg, 22.5 kg and 7.7 kg of PM 2.5 dust emissions were produced each day for the HUMVEE, 5-ton truck and 2.5-ton truck, respectively. Average PM 10 estimates were 1.3 kg/km, 3.3 kg/km and 1.8 kg/km for the HUMVEE, 5-ton truck and 2.5-ton truck, respectively. Estimated PM 10 estimates for the 12-day training event are 19.2 kg, 85.4 kg and 29.1 kg for the HUMVEE, 5-ton truck and

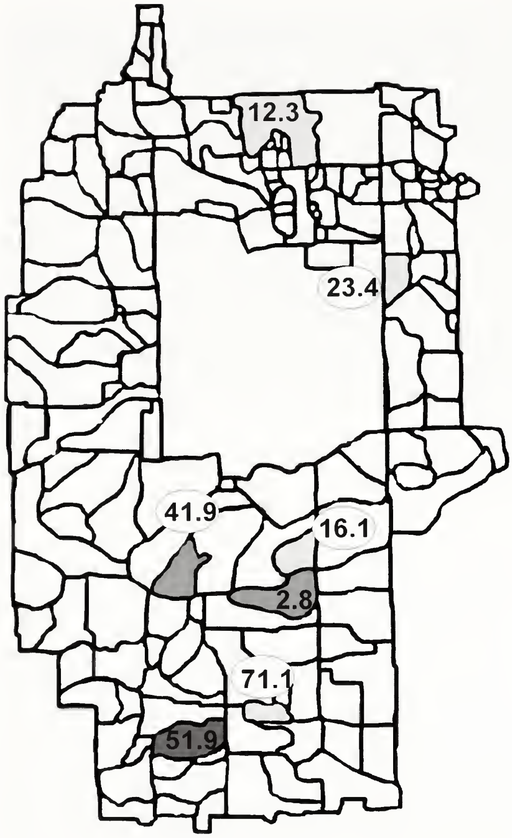

Figure 7.—Vegetation loss by management area for the one day data subset analyzed. Grey lines represent management area boundaries. Shaded training areas represent where the majority of vehicle impacts occurred. Numeric values list actual vegetation loss in m^2 for each training area. Areas less than 2 m^2 are not shown.

2.5-ton truck, respectively. The average weighted dust emissions produced per vehicle day were 6.6 kg PM 2.5, 24.8 kg PM 10, and 31.4 kg total suspended particulate matter (TSP) resulting in a total of 465.1 kg PM 2.5, 1762.5 kg PM 10, and 2227.6 kg TSP emitted by the 71 vehicle days during the training event.

DISCUSSION

GPS technology is currently being used to track vehicles during live training events to improve the quality of the training experience. This study demonstrates that data derived from these training systems can be useful for characterizing how vehicles are actually used in live training exercises to improve vehicle impact assessments. Systems like DFIRST^{TM} provide a foundation for impact assessments that utilize actual field vehicle use data rather than assumptions obtained from subject matter experts or derived from alternative data sources.

Environmental impact statements conducted to assess the impact of changes in vehicle based military training regimes often dictate continued monitoring of vehicle impacts as part of the mitigation strategy of the impact statements (Colorado State University 2004). Systems like DFIRST^{TM}, when combined with vegetation loss models as used in this study, provide a means to monitor vehicle impacts to vegetation over a period of time. Information obtained using this approach provides the foundation to: 1) evaluate if new weapon systems or training doctrine will impact installations lands differently than legacy systems and doctrine, 2) provide spatially and temporally explicit land use impact data for input into other natural resource models, and 3) identify areas of concentrated disturbance often difficult to locate in larger areas of undisturbed lands. Army training systems like DFIRST^{TM} provides a unique capability for the military to assess the impact of vehicle based activities currently unavailable to other land management agencies.

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