Optimizing Military Training Land Use into the Future

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Outline

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Military lands, sustainability & conservation
Future land uses and DoD Energy policy
Importance of climate change
Why Alaska is so important?

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US Army Cold Regions Research and Engineering Laboratory

50 years strong!

Hanover, New Hampshire
CRREL Facilities in Alaska

Ft. Richardson

Ft. Wainwright
Permafrost Tunnel
Mission Statement

Advance and apply cold regions science and engineering providing all-season solutions for the Army, DoD and the Nation
CRREL

Cold Regions Research and Engineering Laboratory

- USACE Engineer R&D Center (ERDC)
- 110 engineers & scientists
- 120 technicians & support staff
- $250M annual budget, 95% reimbursible
- Work in Antarctica, Alaska, Arctic Ocean, Continental US, Afghanistan, Iraq, Korea, etc.
CRREL Research Areas

Military
- Battlespace Environments
- Military Engineering
- Infrastructure Technology
- Environmental Quality

Civil Works
- Remote Sensing
- Geographical Info Sys
- Cold Regions Engineering
Seasonal Effects

Annual Freeze-Thaw Cycles
Technical Staff Capabilities

**SCIENTISTS**
- Physical Scientist
- Physicist
- Geophysicist
- Geologist
- Chemist
- Geochemist
- Meteorologist
- Hydrologist
- Biologist
- Glaciologist
- Geographer
- Agronomist

**ENGINEERS**
- Civil Engineers
- Foundations
- Hydraulics
- Pavements
- Environmental
- Snow and Ice Mechanics
- Soil Mechanics
- Mechanical
- General
- Electrical
- Electronic
- Materials
Objective

Optimize military lands in light of future uses and an uncertain climate
Military training lands must accommodate a wide variety of activities (training, harvest & timber, wildlife and hunting, etc.).

These uses have complex, inter-related land impacts and will include as yet unforeseen new land uses as well as changes to normal climate.

Methodology to model a wide variety of inter-related land uses and the ability to adapt the model to new uses and climate drivers is need.
Background

- **Military lands, sustainability & conservation**
- **Future land uses and DoD Energy policy**
- **Importance of climate change**
- **Why Alaska is so important?**
Training Land Management

Given limited resources and availability of training lands, an effective management of military lands is needed that will

- meet training requirements
- meet present and future land uses
- preserve and enhance ecosystems

Westervelt, et al., 2010
Some land uses could include
- vehicle training
- threatened and endangered plants and animals
- control burns
- hunting and fishing
- harvesting grain and timber
- recreation (boating, camping)
Future Military Land Uses

- New vehicle fleets
- New tactics and techniques
- Energy

*DoD is the single largest user of energy in the US and will reduce infrastructure energy consumption by 30% (545,700 bldgs), and fossil fuel consumption by 65% by 2015;*

- solar grids
- wind farms
- geothermal energy
- bio fuel production

The Importance of Climate Change to DoD (the QDR)

Climate change will reshape the operating environment and impact our facilities and mission.

Conduct assessment of installations to determine the potential impacts of climate on mission and how to adapt.

Climate change will stress already stressed systems.

Some ecosystems/regions are more vulnerable than others.

DoD has 545,700 buildings and 30 M acres of training lands (Army manages about half of those).

Quadrennial Defense Review Report, 2010
DoD Strategic Sustainability Performance Plan

- Serve as a model of sustainability for the nation
- Sustain operation into the future without decline of mission or environment
- Maintain readiness in the face of climate change

Phase 1. Develop a decision framework

Phase 2. Climate change impact assessment
In the context of climate change, what will it mean to “maintain” and “restore”:

- Biodiversity
- Wetland and aquatic systems
- Erosion control
- Invasive species control
- Forest management
- Sensitive species, communities and features
- Recreational hunting and fishing
- Changes in fire patterns and hydrologic conditions

Hayden, et al., 2009
Why is Alaska so Important?

- Large military land holdings
- Multiple land uses (hunting, camping, fishing, others)
- Home of Stryker Brigade 3 and current warfare and training techniques
- Already impacted by climate change

Alaska training lands serve as a test bed for optimizing land use into the future
Importance of Alaska . . . .

- Only Arctic State
- 33,900 miles of coastline
- 20% of US land
- 40% of US surface water
- 50% of US wetlands
- $1/2$ is underlain by permafrost
- remote communities w/o highway infrastructure
- 229 tribes of native peoples
- 50% of US seafood
- 25% of US crude oil

Hartig, Commissioner, Alaska Dept. of Env. Conservation, 2009
Alaska is warming greater and more rapidly than anywhere else!

- 1 to 5 degree increase in mean annual temperature since 1949
- 50% increase in growing season length since 1905
- Drying of arctic lakes
- 20% Increase in forest fire severity index since 1950
- Increase in mean annual ground temperature (permafrost loss)
- 9% decrease in sea ice since 1979
- Increase in cyclones and severe weather affecting coastline (causing coastal erosion)
- IPCC projects increase in precipitation and runoff and evaporation and a decrease in soil moisture

Walsh, 2009, International Arctic Research Center
Total Change in Mean Annual Temperature (°F), 1949 - 2008

Statewide Average: 3.1°F
50% increase in growing season length

[from G. Juday, UAF]
Drying of Arctic lakes
[from L. Hinzman et al.]
Example: Coastal Erosion

Projected Coastal Erosion at Newtok, Alaska (USACE, 2006)

Landing Strip
Community Buildings

Coastal Storm Activity Undermines Foundations in Western Alaska (USACE,
Observed and Anticipated Ecosystem Impacts from Warming

- Will lose as much as the top 30 ft of discontinuous permafrost
- Recent warming has increased beetle infestation and subsequent forest loss
- Increases in fire frequency and intensity due to trees stressed by warming and insects
- Expansion of boreal forest into the tundra zone (along with fire risks and invasive species)
- Threat to subsistence livelihoods due to warming land and thinning sea ice.

Hayden, et al., 2009
How this Impacts Military Training

- A warming climate initiates a cascade of impacts that affect soil thermal, physical, hydrological, biological and other systems in the far North.
Terrain Impacts from Dynamic Vehicle Systems

- Frozen ground and rivers serve as critical mobility corridors
- Frost and snow covered ground protects sensitive arctic terrain
- Frozen ground once capability of supporting vehicle traffic may now freeze later, thaw earlier, or be subjected to freeze/thaw cycling, thus;
  - affecting soil strength
  - Changing (reducing) environmentally windows of opportunity for training and other recreational land uses
Major Alaska Army Installations

ALCOM (Alaska Command)
- 1.5 million acres
- 21,000 service members
- Fort Richardson - Anchorage
- Fort Wainwright – Fairbanks, Delta Junction
- Elmendorf AFB – adjacent to Fort Richardson
- Eielson AFB – Fairbanks

Stryker Brigade 3
- 7600 Personnel
- 1600 Vehicles
- 132,902 Soldier User Days (training days x no. soldiers)

From USAG – Alaska INRMP
Vision

Land Assessment Toolkit for the Future

- Flexible modules to incorporate a wide variety of land activities including
  - as yet unknown land uses
  - changes in doctrine and training objectives
  - future vehicles and fleet configurations

- Adaptable to an uncertain climate, particularly fluctuations in temperature and precipitation that deviate from historical norms
Expected Results

- Means to project future impact to training lands under alternative climate scenarios
- Tools that can be used as decision aids for adjusting rotations and schedule to optimize land use
- Metrics and monitoring requirements leading to early warning climate and land use indicators
Geospatial data layers
- Digital Elevation Model
- Vegetation
- Slopes
- Geomorphology
- Drainage
- Wetlands
- Soil profiles
- Ecotopes

State-of-the-Ground Models
- Seasonal ground strength
- Frost/Thaw depths
- Snow depth/density

Vehicle Models

Mobility Model

Impact Curves
- Land Condition Curves

Early Warning Indicators
- Temp
- Precip

Global Climate Model

Land Carrying Capacity

Maneuver sensitivity maps
Global Climate Models
Temperature and Precipitation Drivers

SNAP – Scenarios Network for Alaska Planning
Ground Frost Modeling, Central Alaska
Ground Frost Modeling, Central Alaska

12-inch Frost for 6 Months!
Vehicle Mobility Models

VEHICLE DATA

TERRAIN DATA

DRIVER

SCENARIO

Off-Road

On-Road

Gap Crossing

Vehicle Performance

Speed

NATO Reference Mobility Model
Vehicle Data

- Tire Information
- Engine/Power-Train
- Dimensions
- Roughness, Ride
- Obstacle Crossing Ability
- Weight on Each Axle
- Ground Clearance
Terrain Data

- Soil type
- Soil strength
- Slope
- Vegetation
- Surface Roughness
- Recognition Distance
- Obstacle Dimensions
Winter Mobility Corridors

Required Depth of Frozen Ground

- Frost Depth (in.)
- Vehicle Weight (lbs)
- HMMWV and SUSV
- STRYKER
- HEMTT

Dry Condition

Wet Condition
Seasonal Maneuver Maps

Fort Wainwright

Summer Maneuverability Map

- NO GO

Winter Maneuverability Map

- GO
Vehicle-Terrain Impact Curves

Cumulative Impact Width

CIW = 141.86TR^{-0.5211}
R^2 = 0.6982

CIW = 1293.8TR^{-0.8112}
R^2 = 0.8794

CIW = 139.61TR^{-0.4411}
R^2 = 0.7149

CIW = 14.959TR^{-0.0747}
R^2 = 0.0552

Turning Radius (m)

Power (Combat Tank M1A1) — Power (APC M577) — Power (HM M978) — Power (HM M988)
Seasonal Rut Potential Maps

RUT DEPTHS
FORT WAINWRIGHT
YUKON TRAINING AREA

NOGO

1 ft

<1 in

>1 ft

Site 2: Lowland Wet Needle Leaf Forest

Site 3: Upland Mixed Forest (north facing)

Site 4: Upland Mixed Forest (south facing)

Rut Depth (inches)
0 - 25 inches
25 - 6 inches
6+ inches

1 0 1 2 3 4 Kilometers

Site 1: Upland Forest (south facing)

Site 1: Upland Forest (north facing)
Seasonal Training Area Available

![Seasonal Training Area Available Graph](image-url)

- **FWTA (Current)**: 1,400 acres
- **DTA (SBCT Alt 3)**: 1,200 acres
- **FRTA (SBCT Alt 4)**: 600 acres
- **Winter Maneuverable**: 0 acres
- **Summer Maneuverable**: 0 acres

**Training Area**
- FWTA
- DTA
- FRTA
- Total

**Note**: The chart indicates seasonal availability with a focus on winter training areas.
Summary & Conclusions

✓ Military lands must accommodate a wide variety of activities
  
  Future Uses
  
  Uncertain Climate

✓ Alaska is susceptible to climate change

✓ Land management tools are needed to
  
  • Project future impacts under alternate climate scenarios and uses
  
  • Decision aid to adjust rotation schedule to optimize land use
Recent Associated Research

1) Soil stress & strain under vehicle loading
   - *Measurement techniques*
   - *Predictive modeling*

2) Vegetation impacts on
   - *Soil strength*
   - *Vehicle mobility and impacts*
1) **Soil Measurements**

Soil stress and strain under vehicle loading

- Extensometers
- Stress state transducers
- Pressure distribution

For model development and validation
**Displacement Sensors**

- Soil displacement was measured using Geokon 6 point extensometers buried beneath the wheel path.
Extensometer Results, HEMTT w/ MDT

3.6 Inch Frost in SM 23 Jan 2008

Displacement, inch

Time, sec

EX SM N 0"
EX SM N 2"
EX SM N 4"
Soil Stress State Transducer - SST

National Soil Dynamics Lab
Measures stress state using six pressure sensors
Pressure Sensors

- Soil stress was measured using a Tactilus pressure pad buried at 5.1 cm.
- Pad is a matrix-based series of piezoresistance sensors in a sealed flexible covering.
Pressure Pad - Results

Hard Surface

Buried in Sand

Buried in Frozen Sand
Comparison to calculated values

Boussinesq and Froehlich

\[
\sigma_z(\rho_1, 0, z_1) = \nu \frac{z_1}{2\pi} \int_0^{2\pi} \int_{\tgh^{-1}\left(b' / a'\right)}^0 \frac{\sigma_{z=z_0}(\xi')dS_{\eta', \xi'}}{\rho_1^2 + z_1^2 + \rho'^2(\eta', \xi') - 2\rho_1\rho'(\eta', \xi')\cos\phi'(\eta', \xi')} \]^{\nu+1}

LEAF (Layered Elastic Analysis – FAA)

Assume - circular contact
- uniform loading
Results: 7.5 cm Frost Vertical Displacement Contours
**Vertical Stress on frozen ground**
FEM - Displacement
2) Optimizing land for training and non-training uses

Sustainable land use is critical for military training. Land management techniques (mowing, controlled burn, grazing) and their impact on vegetation & trafficability is not well understood.
**Objectives**

To quantify the effects of land use practices on vegetation (biomass) characteristics

To quantify the effect of vegetation on soil strength, vehicle mobility and trafficability

**Approach:**

Conduct a series of full scale experiments on the effects of land uses, vegetation, and trafficking on mobility and terrain strength parameters
The REAL Issue...

Can the engineer and the agronomist be friends?

1) Agronomists interests are increased crop yields w/o regard for soil engineering properties

2) Civil Engineers remove vegetation before using soil
Trafficking Experiments

Trafficked with 30 ton HEMTT

Outdoor test section
- August 2010
- Straight and turning sections
- 100 passes
Trafficking Experiments

Indoor test section – WEST
12 August - 10 passes
Mobility parameters

For each soil and vegetation combination prior to the trafficking experiments

The CRREL Instrumented Vehicle was used to record:

• Traction
• Motion Resistance
Above Ground Biomass

Collection of above ground vegetation within 50 x 50 cm tossed frame
Below Ground Biomass

Below ground biomass:

Above ground biomass:

Roots washed and imaged

Root morphology examined using imagery analysis
Disturbance measurements

- Rut Volume
- Rut Depth/Width
- Pile Height/Width

- Imprint
- Scrape
- Pile
Vehicle Impact - Rut Profiles

1 pass

5 passes - 8.4

10 passes – 13.7

Mowed rye grass on loamy soil test section
Summary

• Sustainable land use is critical for training
• Interaction between land use stressors and trafficability is not well understood

- Experiments to study effects of land use practices on terrain strength, mobility and trafficability will provide data to quantify impacts and guide land use practices in the future
Questions for Future Work

Questions:

• How does terrain strength relate to below ground biomass?

• What is the best indicator of vegetated soil strength?

• What is the relationship between land management techniques and long term vegetation recovery?

• How do we quantify our results for vehicle mobility and training land carrying capacity models?
Summary

• Sustainable land use is critical for training
• Interaction between land use stressors and trafficability is not well understood

Experiments to study effects of land use practice on terrain strength, mobility and trafficability will provide data to quantify impacts and guide land use practices
Optimizing military lands in light of future uses and an uncertain climate

Questions?