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Optimal Allocation of Land for Training and Non-training Uses

OPAL Land Condition Model

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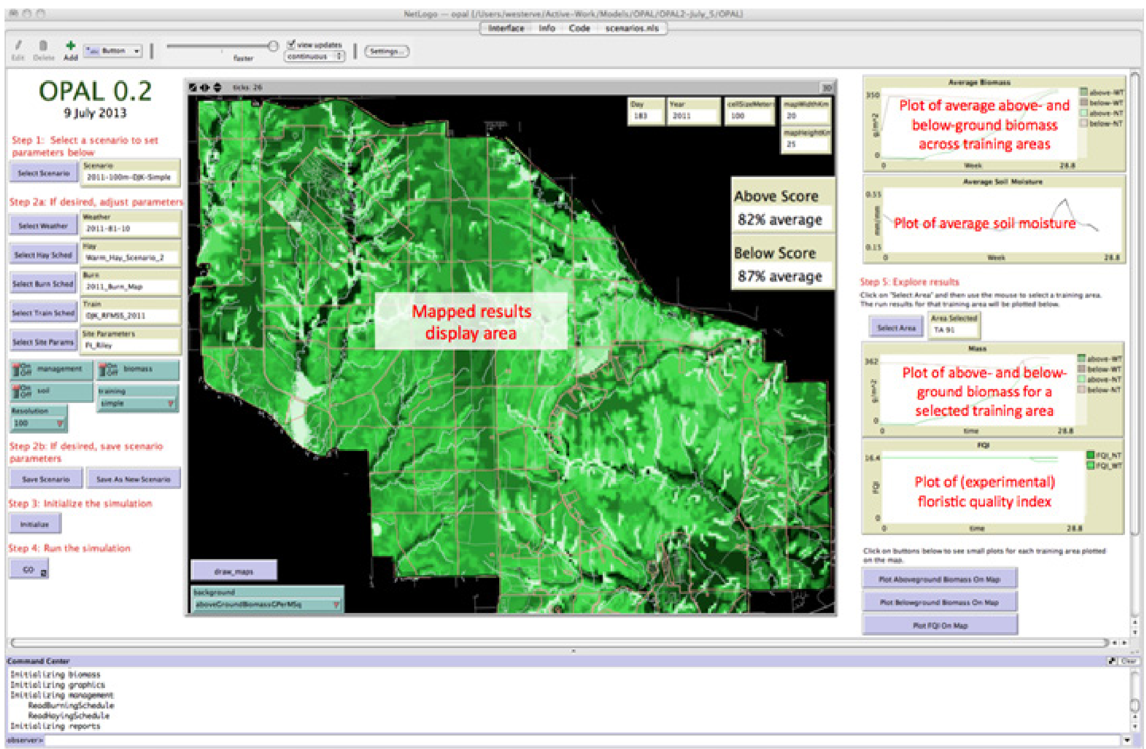
Natalie Myers, and Heidi Howard

August 2014



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Final Report

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Abstract

This report provides user and programmer information supporting the Optimal Programming of Army Lands (OPAL) model, which was designed for use by trainers, Integrated Training Area Management (ITAM) coordinators, and land rehabilitation offices. The model provides an environment for testing how different combinations of training schedules, haying and burning schedules, and weather affects the quality of the lands vegetation, which provides training realism and erosion protection.

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Preface

This study was conducted for the Assistant Secretary of the Army for Acquisition, Logistics, and Technology (ASAALT), under A896 Project (AMSCO 622720089600), "Optimal Allocation of Land for Training and Non-training Uses." The technical reviewer was Alan B. Anderson, CEERD-CV-T.

The work was performed by the Ecological Processes Branch (CN-N) of the Installations Division (CN), Construction Engineering Research Laboratory (ERDC-CERL). At the time of publication, William Meyer was Chief, CEERD-CN-N; Michelle Hanson was Chief, CEERD-CN; and Alan Anderson was Technical Director, CEERD-CV-T. The Deputy Director of ERDC-CERL was Dr. Kirankumar V. Topudurti and the Director was Dr. Ilker R. Adiguzel.

The Commander and Executive Director of ERDC is COL Jeffrey R. Eckstein, and the Director of ERDC is Dr. Jeffery P. Holland.

1 Introduction

1.1 Background

Proper management of military training lands is critical to ensure availability of training lands, and thereby ensure mission readiness. Sustainable training land management complements the military mission by minimizing detrimental environmental impacts of maneuver training. Army Regulation (AR) 350-19 assigns responsibilities and prescribes policies for maximizing the capability, availability, and accessibility of ranges through the Sustainable Range Program (SRP). A core component of the SRP is the Integrated Training Area Management (ITAM) Program, which provides the Army the capability to manage and maintain training lands by integrating mission requirements with environmental requirements and appropriate land management practices (HQDA 2005). To date, many studies have estimated the impacts of military training activities on installation lands (Ricci et al. 2012).

However, installation land management practices often support a broader mission than simply maintaining the land in a condition suitable for training. The Army's "ecosystem approach" to land management supports multiple-use activities, when those activities are compatible with mission requirements, including agriculture and grazing outleases (USAEC 2011). As a Federal agency, the Army is also required by the US Endangered Species Act (ESA) to conserve Federally listed Threatened and Endangered Species (TES) on installation lands. The Army often makes proactive management efforts to eliminate potential conflicts between Threatened, Endangered, Proposed, and Candidate (TEPC) species and military mission and management efforts (USAEC 2009). Installations' Integrated Natural Resources Management Plans (INRMPs) include practices that benefit the conservation of species of concern, e.g., by incorporating plans to enhance or preserve critical habitat through such management practices as controlled burns.

Generally, military training land management and maintenance practices support two primary objectives: (1) to maintain lands for military training and (2) to meet environmental requirements. Proactive land management practices that support potentially conflicting land uses must take a systematic approach that considers, coordinates, and integrates complex land impacts. Development of the Optimal Allocation of Land for Training and Non-training Uses (OPAL) Program was undertaken to provide such a systematic approach in the form of modeling software that can provide military land managers and trainers with the capability to estimate biomass responses to historical or planned training/management scenarios, and that can also function as a research tool that will improve the understanding of the influences on military land use (training and non-training) on the dynamic and complex nature of above- and below-ground biomass. This report provides a user manual for the Optimal Programming of Army Lands (OPAL) model.

1.2 Objectives

The overall technical objective of the OPAL project is to develop approaches to estimate cumulative land disturbance on military training lands through above- and below-ground biomass responses by merging current biomass disturbance methods/models with OPAL field data to capture disturbance regimes for military land managers. The specific objective of this phase of work was to provide a step-by-step guide to install the OPAL software and to run the model.

1.3 Approach

1. Researchers investigated how above- and below-ground biomass responded to military installation land management practices, e.g., burning and haying, and training activities.
2. The OPAL model was designed and programmed to provide military land managers and trainers with the capability to estimate biomass responses to historical or planned training/management scenarios.
3. A separate tool was designed and programmed to aid in the creation of training, burning, and haying schedules for testing scenarios with the Land Condition Model.
4. An accompanying “scenario development” program was outlined to allow users to compare different management/training scenarios, and t o use the results of that comparison to determine optimum management strategies.
5. Stepped processes for using the model were documented with a specific focus on required input data to ease the transfer of the model to alternative installations.

1.4 Scope

Maneuver training and land rehabilitation are interdependent activities that are typically executed separately on military installations; OPAL models both activities in a single simulation environment to reflect the health of the land as well as its ability to sustain safe and realistic maneuver training is a consequence of both activities.

Although the current model prototype was configured for use at Fort Riley, KS maneuver training areas, OPAL was structured to allow rapid development for use at other military installation maneuver areas.

OPAL was not designed to directly support the analysis of habitats for threatened or endangered species, invasive species, or species responses to climate change.

1.5 Mode of technology transfer

It is anticipated that the NetLogo model will be made accessible through the ERDC World Wide Web (WWW). Interested users may request the current developmental version of the NetLogo model from:

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2 Using the OPAL Land Condition Model

2.1 Model description

The OPAL program uses biomass as an indicator of the training land resilience to repeated military training impacts. The model uses simple environmental variables to estimate the quantity and quality of above- and below-ground biomass, after it has factored in the effects of training and other land use impacts (Myers et al. 2013 DRAFT). Additional data sets work "behind the scenes" to provide OPAL with soil characteristics, vegetation growth and soil moisture factors, and training areas; as well as with rules that model the week-by-week consequences of weather and human schedules on the above- and below-ground biomass.

The OPAL model is based on existing vegetation growth and soil moisture models. The overall modeling approach estimates above- and below-ground biomass growth and death that may occur under specified weather conditions and land uses typical for grassland military installations (training, controlled burn, and mowing/haying). For comparison, OPAL also simultaneously models above- and below-ground biomass growth and death under undisturbed conditions (i.e., subject to no land use impacts).

The OPAL biomass modeling approach was based on the plant production submodel of the CENTURY model (NREL 2006; Parton et al. 1993). CENTURY is a computer model of plant-soil ecosystems that simulates the dynamics of grasslands, forest, crops, and savannas with a focus on nutrient (carbon, nitrogen, phosphorous, and sulfur) cycle estimation. The CENTURY model calculates potential plant production as a function of soil temperature, soil moisture, and a self-shading factor.

The OPAL model is designed to enable trainers, ITAM coordinators, and land rehabilitation offices to test and compare different combinations of training schedules, haying and burning schedules, and weather for their effects on the quality of the land's vegetation. Users supply the OPAL model with several inputs, e.g., select weather year(s) (from historic weather); and training, haying, and burning schedules by training area. OPAL then calculates estimated above- and below-ground biomass with and without the scheduled human activities over the course of a calendar year. Modeling results provide a number of "snapshots" of the consequences of alternative scheduling scenarios, which may then be used to optimize land management practices to provide both training realism and erosion protection.

2.2 Model installation

The OPAL model runs on virtually any computer that runs the Java environment. OPAL relies on the NetLogo modeling software platform, which is a multi-agent programmable modeling environment (Wilensky 1999). NetLogo is freely distributable, open-source software that remains under continual development, coordinated through a laboratory at Northwestern University (Chicago, IL). NetLogo extensions are developed worldwide; OPAL uses some of those extensions. For example, OPAL requires the NetLogo Geographic Information System (GIS) extension, which accommodates the use of vector and raster data map files.

2.2.1 Installing NetLogo

At the time of this writing, the OPAL NetLogo Land Condition Model ran on NetLogo versions 4.1.3 and 5.0.4. The NetLogo multi-agent programmable modeling environment may be downloaded from the NetLogo website (http://ccl.northwestern.edu/netlogo/download.shtml) for installation for Windows, Linux, and Apple OSX (Macintosh Operating System) computers. Make sure you choose the version that matches your computer's operating system. Run the installer (e.g., NetLogo.4.1.3Installer.exe) as an administrator. Further information on NetLogo software installation is available from the NetLogo website (http://ccl.northwestern.edu/netlogo/index.shtml). Before running the OPAL program, ensure that NetLogo is operating properly. It is advisable to spend some time running sample models found by clicking on "Models Library" under the "Files" pull down menu.

2.2.2 Installing the OPAL Programs

The OPAL Vegetation Condition Model, the OPAL Schedule Editor, and all required data are contained within a single directory (e.g., OPAL). You might have acquired this as files on a compact disk (CD) or digital video disk (DVD), or as a compressed (e.g., zipped) file. If appropriate, unzip the files and place the OPAL directory at any disk location on your system. The directory contains the following directories: input, model, and scenarios (Table 1).

Table 1. OPAL high-level directory organization.

Directory Hierarchy	Purpose
OPAL/	Main directory containing the OPAL model
model/	Model software directory
opal.nlogo	The NetLogo OPAL model
schedule-editor.nlogo	The NetLogo program for editing schedules
nls/	Model support software files
pathdir/	A NetLogo extension package
images/	Images used in the internal OPAL documentation
input/	Directory containing model inputs
burning/	Directory of optional burn schedules
haying/	Directory of optional haying schedules
training/	Directory of optional training schedules
weather/	Directory of historic annual weather files
maps/	Directory of raster and vector maps
siteparameters/	Directory of local growth and soil parameters
scenarios/	Directory containing various scenarios

The input directory contains directories for each of the different management/training scenario options (burning, haying, training, and weather). It also contains a directory with vector and raster maps and a directory with a site-specific parameter file. The scenario directory contains a directory for each scenario created with the model. Each scenario directory contains an American Standard Code for Information Interchange (ASCII) file with the scenario input selections and a directory with any output data created by the scenario.

The model directory in the main directory contains the two NetLogo model files used to run the Schedule Editor model (schedule-editor.nlogo) and the Land Condition Model (opal.nlogo). The model directory also contains an nls directory that contains the NetLogo source files (*.nls) used by both schedule-editor.nlogo and opal.nlogo. The entire OPAL directory must be copied as the model contains references to input and output directories relative to the location of the NetLogo model files.

2.3 OPAL model step-by-step instructions

This section provides a step-by-step method for setting up and running the OPAL NetLogo Land Condition Model. These steps assume the model has been installed and opened correctly using the methods described in Sections 2.2.1 and 2.2.2.

The OPAL Land Condition Model can be loaded by starting the NetLogo software, and selecting “Open …” from the drop-down “File” menu (Figure 1). Navigate to the “opal.nlogo” file in the OPAL NetLogo directory structure (Table 1) and select Open. The OPAL model will open as a graphical user interface (GUI) in the NetLogo window (Figure 2).

Figure 1. Loading the OPAL NetLogo Land Condition Model.

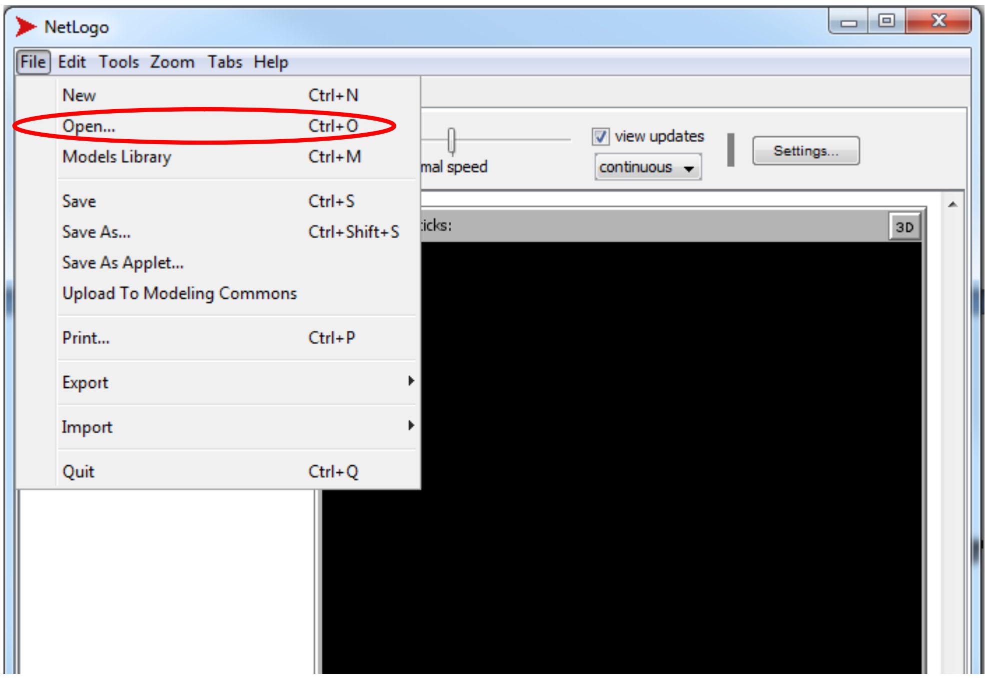
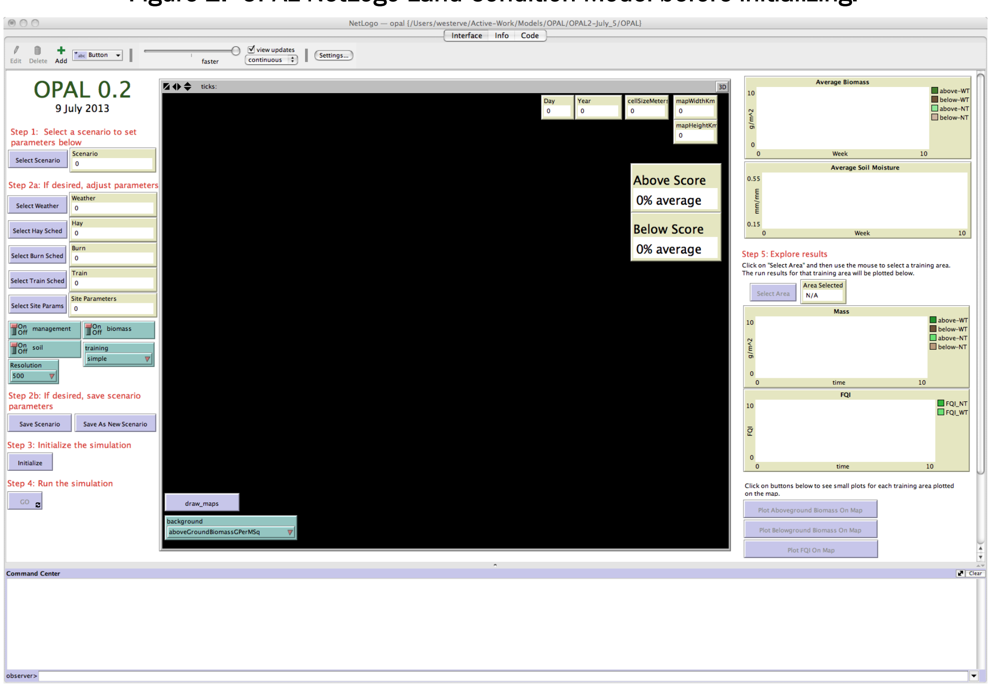


Figure 2. OPAL NetLogo Land Condition Model before initializing.



The user interface suggests five main steps (described in detail in following sections), displayed in red letters on the main interface (Figure 2), involved with running the model:

1. *Select a scenario*. Sets of parameters are saved and available as scenarios. By selecting a scenario, you establish the parameters to be tested.
2. *Adjust/Save parameters*. This optional step allows you to essentially edit an existing scenario or create a new scenario.
3. *Initialize the simulation*. Based on the selected parameters, the simulation is fully initialized, including setting various schedules and map-based information.
4. *Run the simulation*. Kick off the just-initialized simulation.
5. *Explore results*. Explore the above- and below-ground biomass consequences over the simulation.

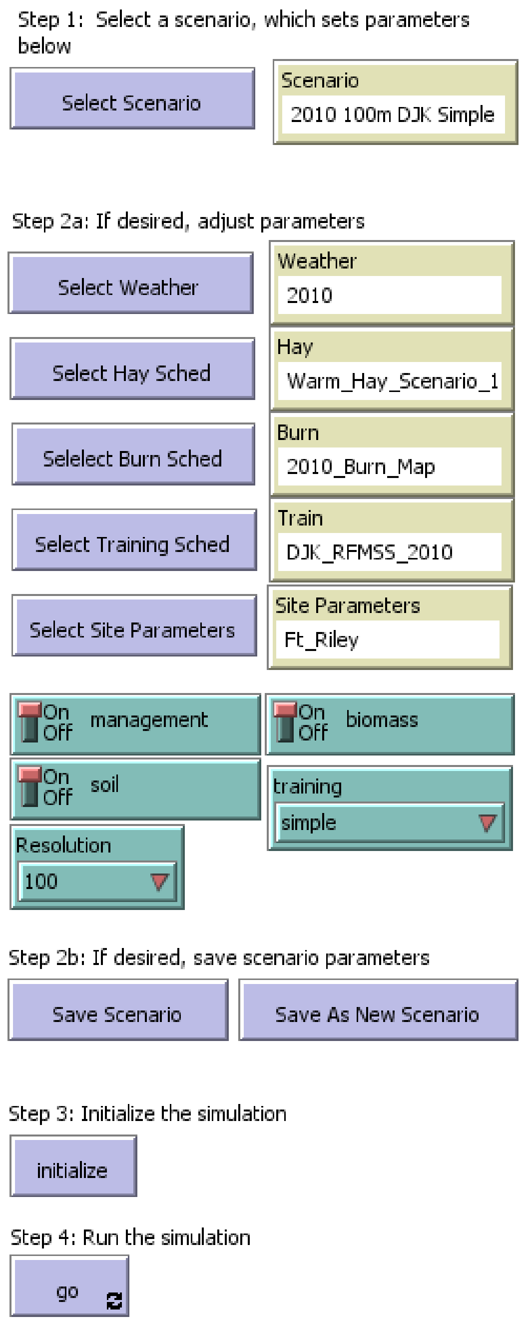
2.3.1 Select a Scenario

Click on the “Select Scenario” button (Figure 3). This brings up a dialog box with a drop-down menu with all available scenarios for testing. Each specific scenario in the directory will be displayed in the drop-down menu.

The selected scenario will pre-populate the correct parameters under Step 2a in the model. The scenario parameters and controls include:

- *Weather*. This parameter selects from the list of available weather files (described in Section 3.3).
- *Hay Schedule*. This parameter selects from the list of available haying schedules (described in Section 3.2.3) created using the OPAL Schedule Editor (Chapter 4).
- *Burn Schedule*. This parameter selects from the list of available burn schedules (described in Section 3.2.2) created using the OPAL Schedule Editor (Chapter 4).
- *Training Schedule*. This parameter selects from the list of available training schedules (described in Section 3.2.1) created using the OPAL Schedule Editor (Chapter 4).
- *Site Parameters*. This parameter selects from the list of available site-specific parameter files (described in Section 3.5)
- *On/Off Selector Switches*. These switches turn the land management function, the biomass growth function, and the soil moisture modeling function on or off. The default selection on these switches is “On.”

Figure 3. Modeling parameter selection interface.



- *Training data type selector*. This allows the user to define if the training schedule is the simple (created with OPAL Schedule Editor), detailed (table of information from Range Facility Management Support System [RFMSS]), or not modeled (off).
- *Modeling Resolution Selector*. This parameter selects the modeling resolution (100m, 250m, 500m, and 1000m). A resolution of 500m is recommended.

2.3.2 Adjust/Save Parameters

You can change any of the parameters defined in Step 2 (parameters a-h) and then save the scenario with the current settings or save the settings as a new scenario by selecting the appropriate button. If the "Save Scenario" button is chosen, the scenario file will automatically be updated. If the "Save As New Scenario" button is chosen, a User Input dialog box will be displayed asking for the new scenario name. This will create a new scenario folder with that name in the scenario directory, which will be available in subsequent model runs.

2.3.3 Initialize the Simulation

Initialize the simulation by selecting the "initialize" button. This will run through the initialization of each model process. The initialization progress is displayed in the command center at the bottom of the GUI. Once the "initialize" button is no longer black and the command center says "Initializing complete," the model is ready to be run.

2.3.4 Run the Simulation

Select the "go" button to begin the model simulation. The user may press the "go" button at any time to pause the model. Pressing the "go" button again resumes the model simulation at the point where it was paused. Over time, the user will see the above-ground biomass level (or whatever variable is selected from the drop-down menu in the bottom corner of the map) displayed on the map. Training areas may flash red, brown, or yellow signifying that area was burned, trained on, or hayed during that weekly time step. While the model is being run, the user can perform several functions:

- Increase or decrease model speed with the speed selection bar above the GUI.
- Get real-time above- and below-ground biomass values for any training area by clicking on the "Select Area" button located under "Step 5: Explore results" and then clicking on the area of interest on the map.
- Record a movie of the model by clicking either the "Start Movie: Map" or "Start Movie: Full" buttons. The first will start a recording of the map area, while the second initiates a movie of the entire GUI area. After running the model as usual, click on the corresponding "Stop Movie" buttons. You will be asked to provide a file name for the new movie. This movie can be used in presentations or on websites.

When the end of the weather file has been reached, an alert box will state that the modeling simulation is “All Done!”

2.3.5 Explore Model Results

The most prominent output is the map, which by default shows above-ground biomass for each square area (at your chosen resolution). This map changes over the simulation time. Two scores are displayed to the upper right of the Fort Riley map area: the “above score” and “below score.” These represent the average value over the entire simulation time of the ratio of the amount of above- and below-ground biomass with the human activity (maneuver training plus land rehabilitation activities) to the biomass modeled without the human activity. A value of 75% indicates that, on average, over simulation time and space, the training areas maintained 75% of the biomass expected without human activities. These values provide a bottom-line performance metric that scores the collective consequences of the chosen scenario, consisting of weather, training, haying, and burning schedules.

To plot the average above- and below-ground biomass (with and without training/land management impacts) over the modeling period for a training area click on the “Select Area” button and then choose any click on any training area on the map. The above- and below-ground biomass values for that training area are stored in memory and are plotted on the graph below the “Select Area” button (Figure 4).

An above- or below-ground biomass chart can be plotted directly on the map for each training area by selecting the “Plot Above-ground Biomass on Map” or “Plot Below-ground Biomass on Map” buttons. This will plot both the biomass with and without training/land management impacts for the duration of the simulation (Figure 5).

Navigate to the biomass directory in OPAL main directory/scenario directory/outputs directory where “scenario directory” is the scenario selected for evaluation to obtain exported biomass raster files (if the data export option selected). The ASCII raster grids can then be analyzed in a GIS environment such as ArcGIS (Figure 6).

Figure 4. Above- and below-ground biomass (WT indicates with training and land management impacts as indicated in scenario, NT indicates no training or land management impacts for comparison purposes).

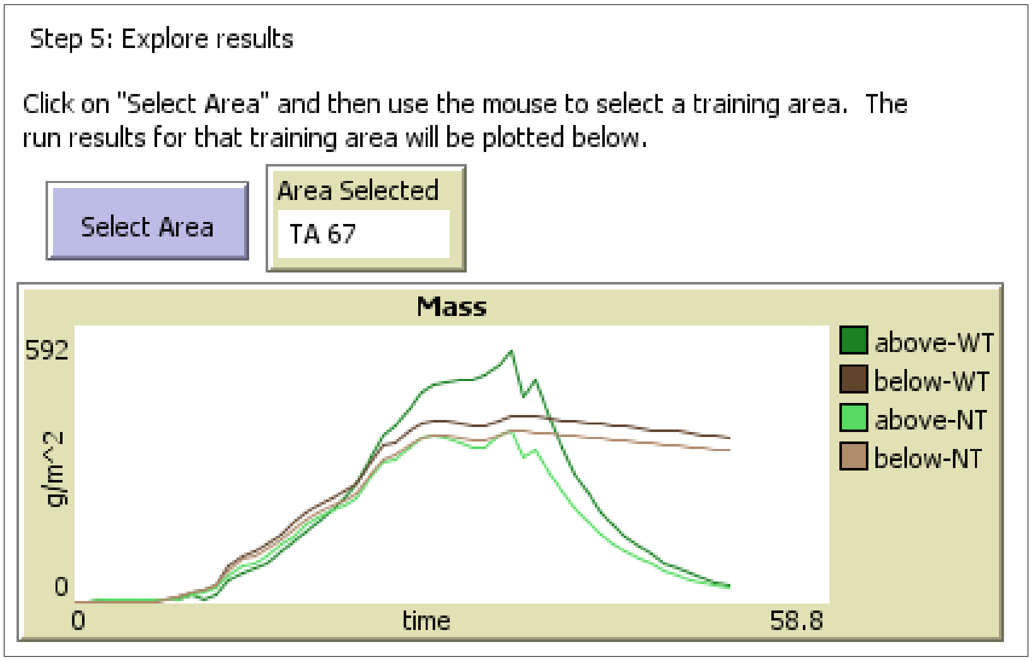


Figure 5. Above- ground biomass for each training area for the modeling duration plotted directly on NetLogo map interface.

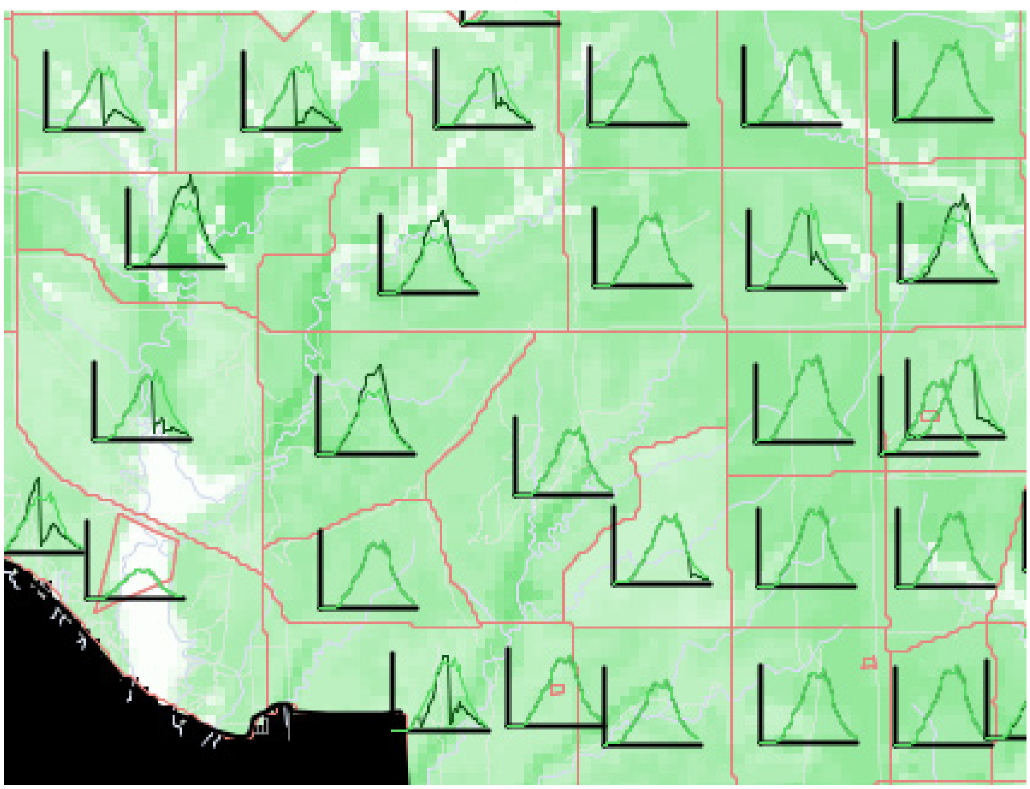
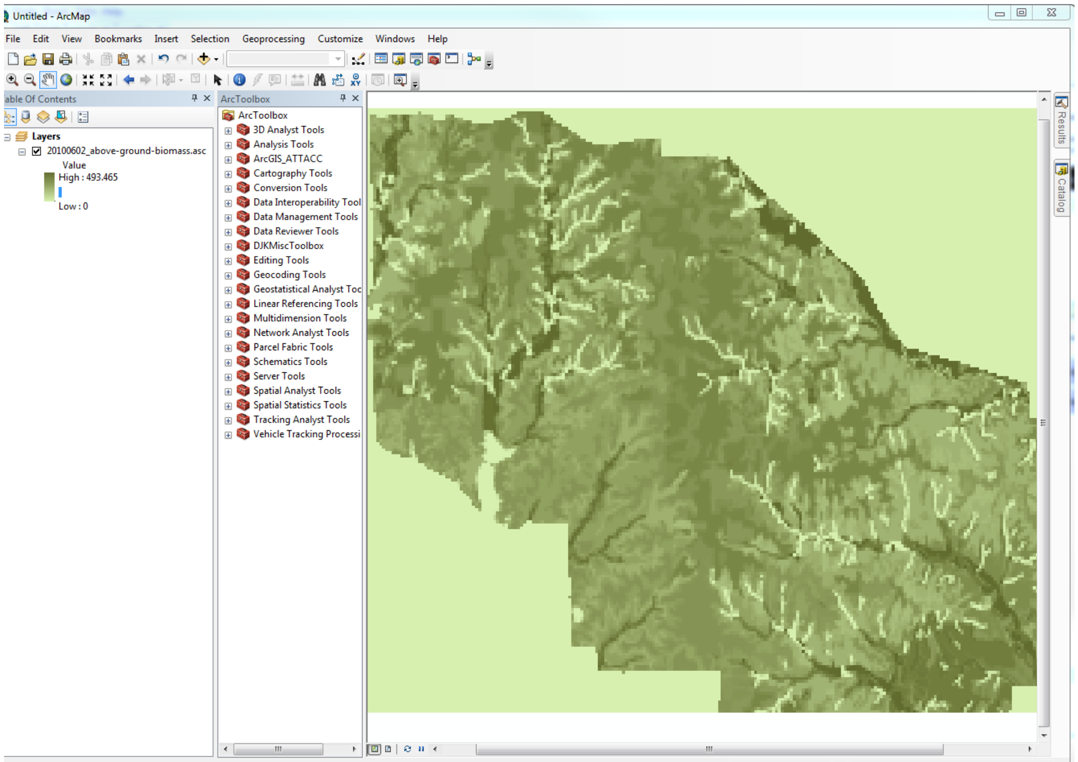


Figure 6. Exported above-ground biomass data simulated for 02 June 2010 viewed in ArcGIS 10.1 environment for data analysis.



2.4 Hidden options

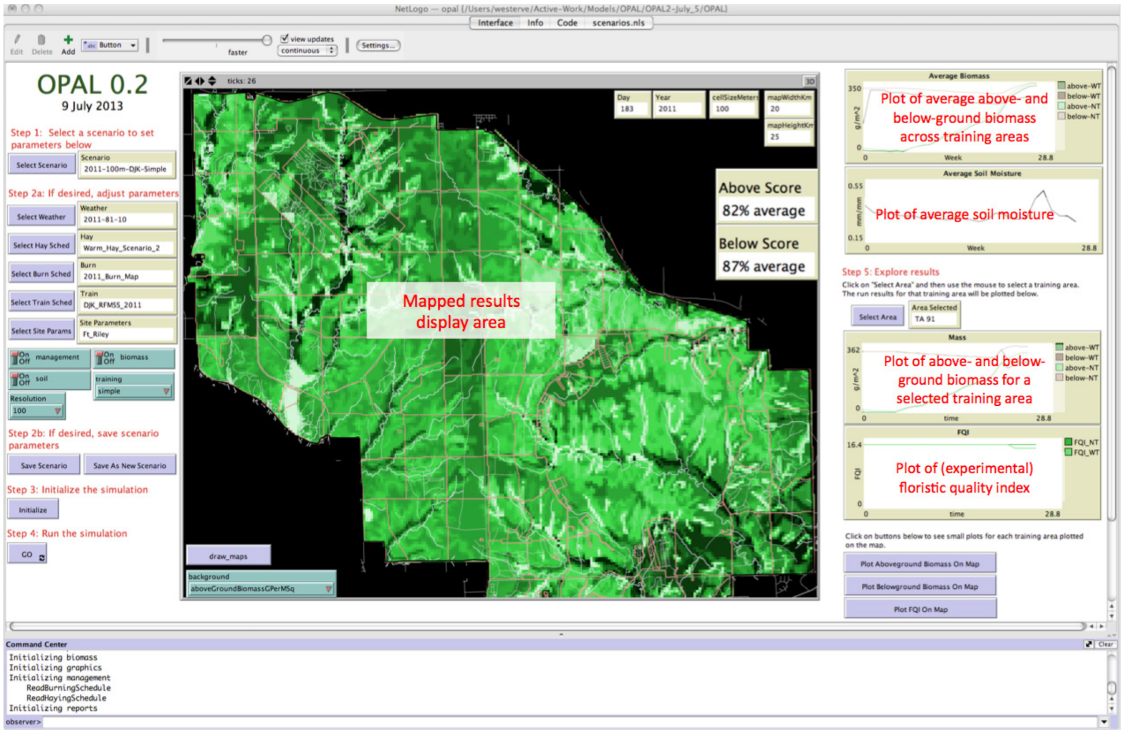
If desired, optional model parameters (below the main map area) can be selected. You may need to scroll the GUI window down to reveal these extra options, which include:

- *BiomassExportInterval*. This input box allows the user to export biomass at a constant interval in weeks. The default condition is “0,” which indicates that biomass will not be exported. Values of 1, 2, and 10 indicate biomass values would be exported to an ASCII grid every 1, 2, and 10 weeks throughout the modeling period, respectively.
- *runOnePatchOnly Switch*. This switch allows the user to run the model only for a single patch as defined in the x and y input boxes. This is generally only used for debugging purposes.

2.5 Model output

The overall objective of the model is to estimate above- and below-ground biomass given weather conditions, training schedules, and land management (burning and haying) schedules. The primary output of this data is on the model GUI visual model representation (Figure 7).

Figure 7. OPAL NetLogo Land Condition Model results display.



A drop-down selection box allows the user to select the following dynamic background displays: above-ground biomass (g/m^2), below-ground biomass (g/m^2), soil moisture (cm/cm), and training amount in week. This display provides the user a view of above- or below-ground biomass status as the model is being run. A monitor plot allows the user to plot above- and below-ground biomass conditions with and without land management treatments for any selected training area for the duration of the period modeled. A second plot displays the average soil moisture through time. After the model has finished running, the user can plot above- or below-ground biomass through the model period for each training area directly on the model GUI display. Above- and below-ground across all of the training areas are reported as the ratio of estimated biomass resulting from all disturbance inputs in the model (e.g., training, burning, haying) to estimated biomass in the absence of these same disturbance inputs.

In addition to graphical representations of model results, NetLogo's GIS extensions allow model parameters (e.g., above- and below-ground biomass quantities) to be exported into ASCII grid files. The model allows the user to export ASCII grid data in set weekly intervals, or according to dates specified by the user in an input text file. The model currently is set up to export above- and below-ground biomass for the defined time steps. However, the user can simply select different variables to be exported in the reports.nls code. The output ASCII biomass files can be analyzed in any GIS software package.

2.6 Running some simple experiments

2.6.1 Experiment 1: Intensive Training, Hot and Dry

This is a good introductory experiment that will allow you to substantially destroy the installation by scheduling intensive training on a hot dry year. The experimental year is 1983, when the average Jun-August temp was 85 °F with very little rainfall. “Intensive” training means that every training area is artificially scheduled with heavy tracked vehicle maneuver exercises every week of the year.

Begin with the following steps:

- Start the **OPAL** program by double-clicking on the program **opal.nlogo**
- Click on the **Select Scenario** button
- Select the scenario **Exp1-Intense-Hot-Dry**
- Click on **Initialize**
- Click on **GO.**

The results will show traces of the average above- and below-ground biomass and the soil moisture over the simulation run. Note that, with the training, the above-ground biomass peaks around April at about 150 grams/m^2 (Figure 8). Without training it peaks at about 300 grams/m^2.

Now, trade the hot dry year for a cool wet year, continuing the above- steps with these:

- Click on the **Select Weather** button
- Select the **2009-74-20** weather
- Click on **Initialize**
- Click on **GO**
- This cooler and wetter summer weather results in elevated soil moisture during the summer that causes biomass growth well into July, peaking at over 600 grams/m^2 without training and over 250 grams/m^2 with training (Figure 9).

Figure 8. Experiment 1a results.

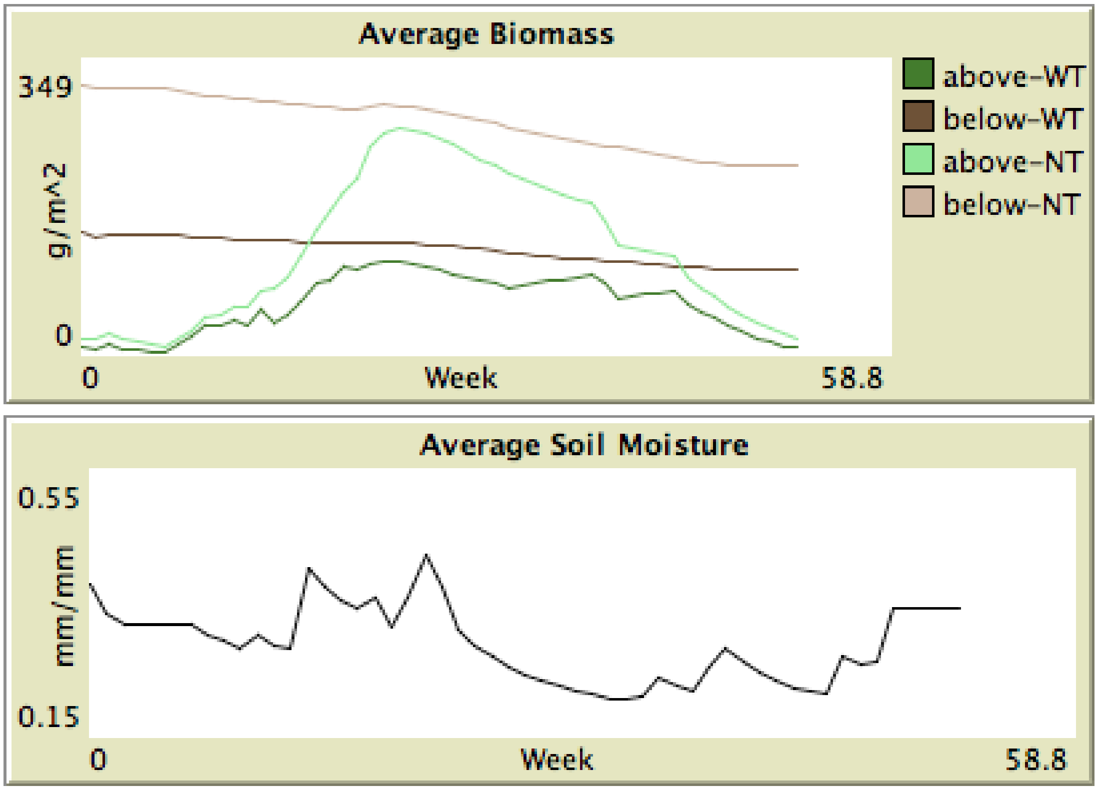
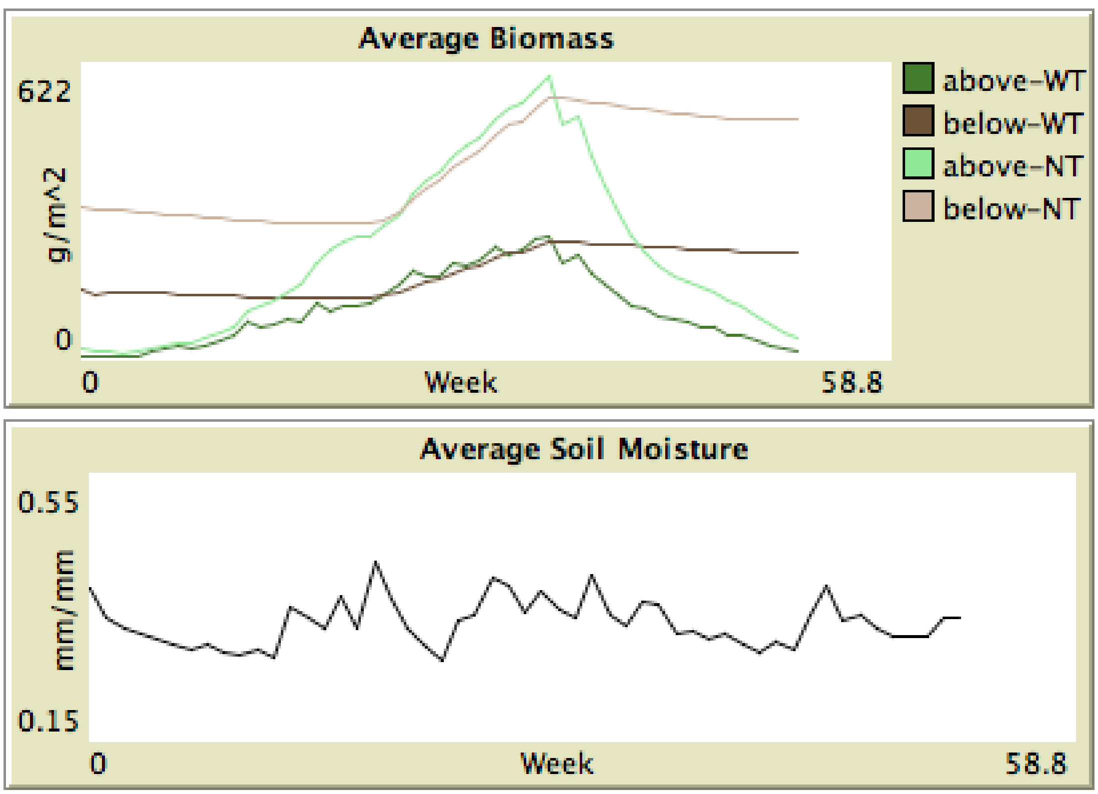


Figure 9. Experiment 1b results.



2.6.2 Experiment 2: Experimenting with 2011

In this experiment we look at weather and schedules associated with the year 2011.

Begin the experiment with the following steps:

- Start the **OPAL** program by double-clicking on the program **opal.nlogo**
- Click on the **Select Scenario** button
- Select the scenario **Exp2-2011**
- Click on **Initialize**
- Click on **GO.**

This scenario uses the following schedules:

- Weather: 2011-81-10
- Haying Schedule: Warm_Hay_Scenario_1
- Burn Schedule: 2011_Burn_Map
- Training Schedule: DJK_RFMSS_2011.

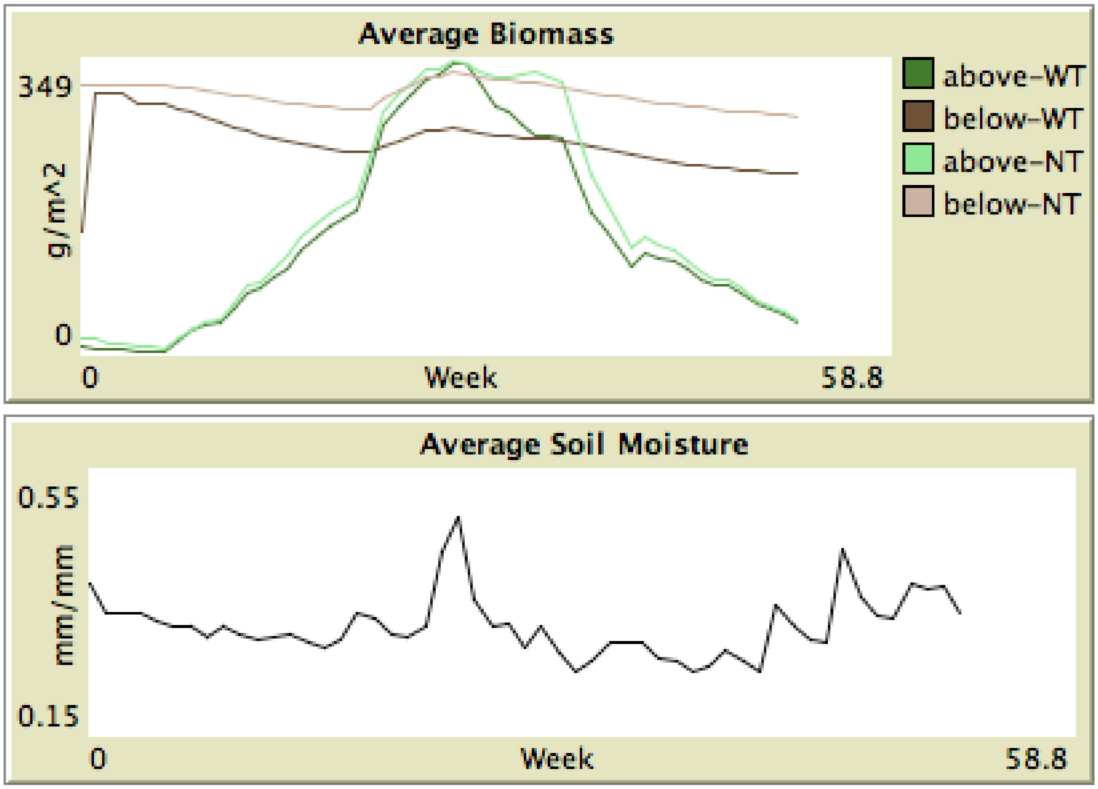
The summer of 2011 was relatively warm and had relatively low rainfall. With many troops deployed, the training requirements at the installation were relatively low, resulting in relatively low damage to the protective vegetation.

The results show that, in general, the impact of training on the vegetation biomass was negligible until midsummer, when it became relatively low (Figure 10).

Explore the modeled results for different training areas by clicking on **Select Area**, then by clicking on one of the training areas. Plots specific to that training area will be displayed. Alternatively, click on **Plot Above-ground Biomass on Map** to plot tiny plots on each training area and quickly compare training areas.

Note that the above- and below-ground ending scores are 85 and 83%, respectively. This means that, on average across all of the training areas, the areas maintained vegetation biomasses at those percentages compared to what would be expected in the absence of human activities.

Figure 10. Experiment 2 results.



Now, let's increase the training intensity. Training intensities are set to be 0 (none), 1 (light), 2 (medium), 3 (medium-heavy), and 4 (heavy). The training schedule "Exp2" is identical to "DJK_RFMSS_2011" except that each scheduled training event is one intensity higher. Continue the above experiment by doing the following:

- Click on the **Select Train Sched** button
- Select **Exp2**
- Click on **Initialize**
- Click on **GO**.

Note that the above-ground ending score drops from 85 to 81%.

3 OPAL Model Inputs

The OPAL NetLogo Land Condition Model estimates the response of above- and below-ground biomass to future or historic training schedules, and of planned or past land management practices based on soil parameters and weather conditions. This section discusses the inputs required to run the model.

3.1 Model scenario selection

The OPAL NetLogo Land Condition Model was developed to allow the user to test the response of above-and below-ground biomass to military training and land management scenarios. The model allows users to create scenarios comprised of different combinations of weather, training, haying, and burning schedules. Each different combination of treatments is saved as a separate scenario file. Each scenario file contains a text file for the input selections and resulting biomass data and graphs generated by the scenario test. These scenario combinations are created by selecting available treatment schedules before model initialization.

3.2 Schedules

3.2.1 Training

Training schedules are created using the OPAL Schedule Editor described in Chapter 4 (Figure 20). This allows the user to create a simplistic training schedule on weekly intervals by applying a generic training intensity ranging from 0–3 for each training area, where:

- 0 = none
- 1 = light
- 2 = medium
- 3 + medium-heavy
- 4 = heavy.

This allows the user to assign an appropriate value to quickly assess estimated future biomass responses given different land management and training scenarios. Training schedules can be created based on actual historic data that may be available from the RFMSS or by anticipated training loads. RFMSS is used by multiple installations for range scheduling and therefore provides a record of training schedules, although actual training location and intensity may vary from what was originally planned in RFMSS (RFMSS web interface).

In addition to the simplistic training schedules, the OPAL NetLogo Land Condition Model allows users the option of using actual RFMSS database derived data for more accurate historic assessments. The data required for this more detailed assessment are:

- date and location each training area was used
- number and type of vehicles using the area
- vehicle severity factor (VSF) and vehicle conversion factor (VCF) for each vehicle used.

This more detailed data allow the model to estimate MIMs (maneuver impact miles) using the US Army Training and Testing Area Carrying Capacity (ATTACC) methodology with an assumption of distance traveled (Sullivan and Anderson 2000).

3.2.2 Burning

The OPAL Schedule Editor allows users to develop weekly burning schedules on a training area resolution. The schedule assigns a value of 1 to burned training areas and 0 to unburned training areas. This method assumes a uniform burning intensity across the training areas. These schedules can be created based on historic installation controlled burning data, documented wildfires, or planned burning schedules.

3.2.3 Haying

The haying schedules used as inputs for the OPAL NetLogo Land Condition Model are created with the OPAL Schedule Editor (Chapter 4). As with the burning schedules, training areas scheduled to receive haying activity for the week are assigned a value of 1 in the schedule. Areas with no haying activity are left with a value of 0.

3.3 Weather

The OPAL NetLogo Land Condition Model uses weather data to estimate temperature and moisture conditions for biomass growth. Daily total precipitation, and maximum, minimum, and average temperatures are summarized to calculate weekly weather conditions. The model was designed to read data downloaded with the Applied Climate Information System (ACIS) Web Services distributed data system. This system weather data can be obtained through an http request from a web browser with a properly formatted Universal Resource Locator (URL) (ACIS 2012a). For example, a comma separated variable text file for the daily maximum temperature, minimum temperature, average temperature, and precipitation at Manhattan, KS for 2009 is available for direct download through URL:

http://data.rcc-acis.org/StnData?sId=144972&sDate=2009-01-01&eDate=2009-12-31&elems=maxt,mint,avgt,pcpn&output=csv

More information on ACIS Web Services URL formatting (ACIS 2012b) is available through URL:

http://data.rcc-acis.org/doc/index.html

The ACIS Web Services distributed data system uses multiple station identification (ID) type codes to identify weather station locations. A list of US Historical Climatology Network (USHCN) ID (Watts 2009) is available through URL:

http://www.surfacestations.org/USHCN_stationlist.htm

The weather data are formatted in an ASCII text file. Figure 11 shows an excerpt of the weather data files and parameters required for inputting into the model.

3.4 Maps and vector files

The NetLogo modeling environment has a GIS extension allowing models to use vector- and raster-based GIS data. The OPAL NetLogo Land Condition Model uses an assortment of GIS data layers for visual display and model input. Figure 12 illustrates the installation boundary, roads layer, and streams layers. These layers are used only for GUI display. The model requires a training area (TA) layer with training area names or IDs included in the attribute table (Figure 13). TA unique identifiers are required to link the training, burning, and haying schedules created in the OPAL Schedule Editor with the correct locations in the OPAL NetLogo Land Condition Model before initializing the model.

```
2005 04 30 62 25 43.5 0.01
2005 05 01 58 33 45.5 0.00
2005 05 02 59 28 43.5 0.00
2005 05 03 65 30 47.5 0.00
2005 05 04 74 38 56.0 0.00
2005 05 05 73 42 57.5 0.00
2005 05 06 84 52 68.0 0.00
2005 05 07 80 61 70.5 0.00
2005 05 08 81 61 71.0 "T"
2005 05 09 81 50 65.5 0.08
2005 05 10 95 54 74.5 0.00
2005 05 11 86 68 77.0 0.00
2005 05 12 82 60 71.0 0.06
2005 05 13 69 57 63.0 0.85
2005 05 14 68 43 55.5 0.18
2005 05 15 69 35 52.0 0.00
2005 05 16 77 49 63.0 0.00
2005 05 17 82 60 71.0 0.00
2005 05 18 86 63 74.5 0.00
2005 05 19 95 50 72.5 0.00
2005 05 20 90 55 72.5 0.00
2005 05 21 94 57 75.5 0.00
2005 05 22 87 62 74.5 0.00
2005 05 23 91 52 71.5 0.00
2005 05 24 86 66 76.0 0.00
```

Figure 11. OPAL NetLogo Land Condition Model weather data. The data required for the model are year, month, day, maximum daily temperature (°F), minimum daily temperature (°F), average daily temperature (°F), and precipitation (in.).

Figure 12. Installation boundary, roads, and streams layers for model display.

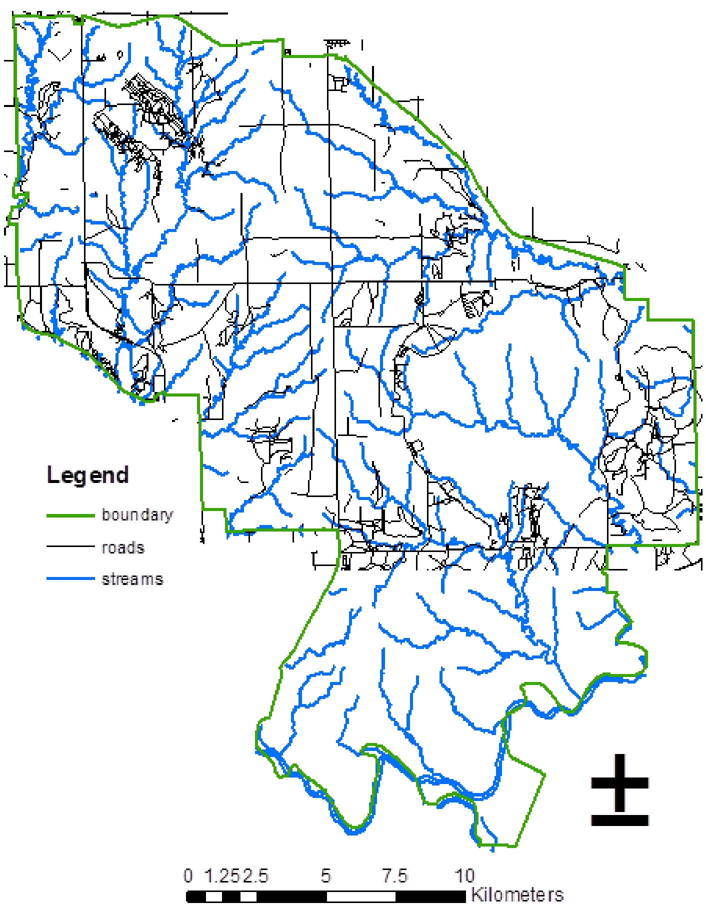


Figure 13. Installation training areas.

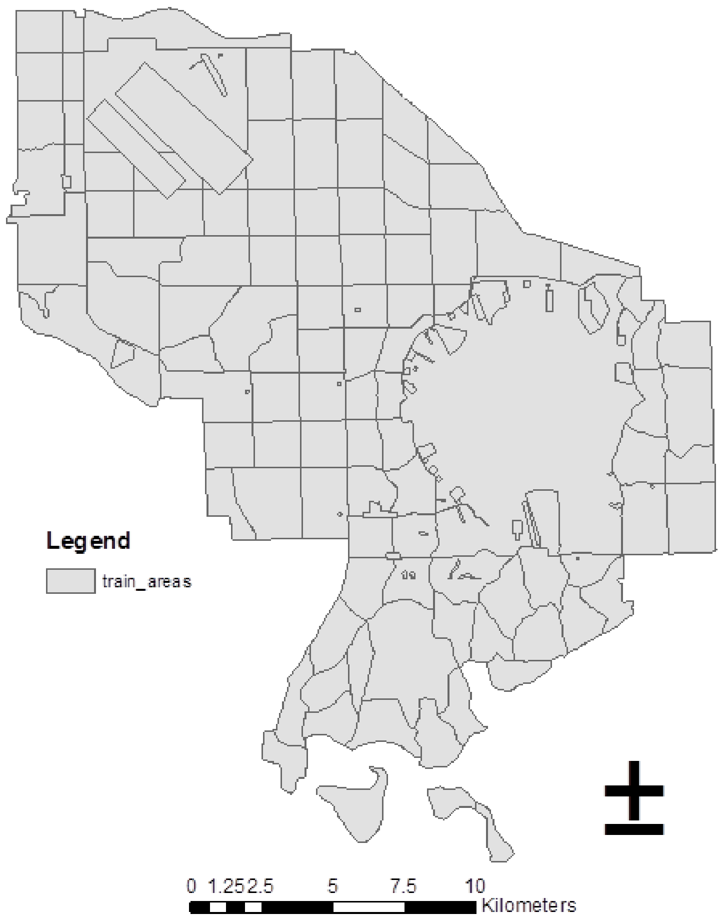
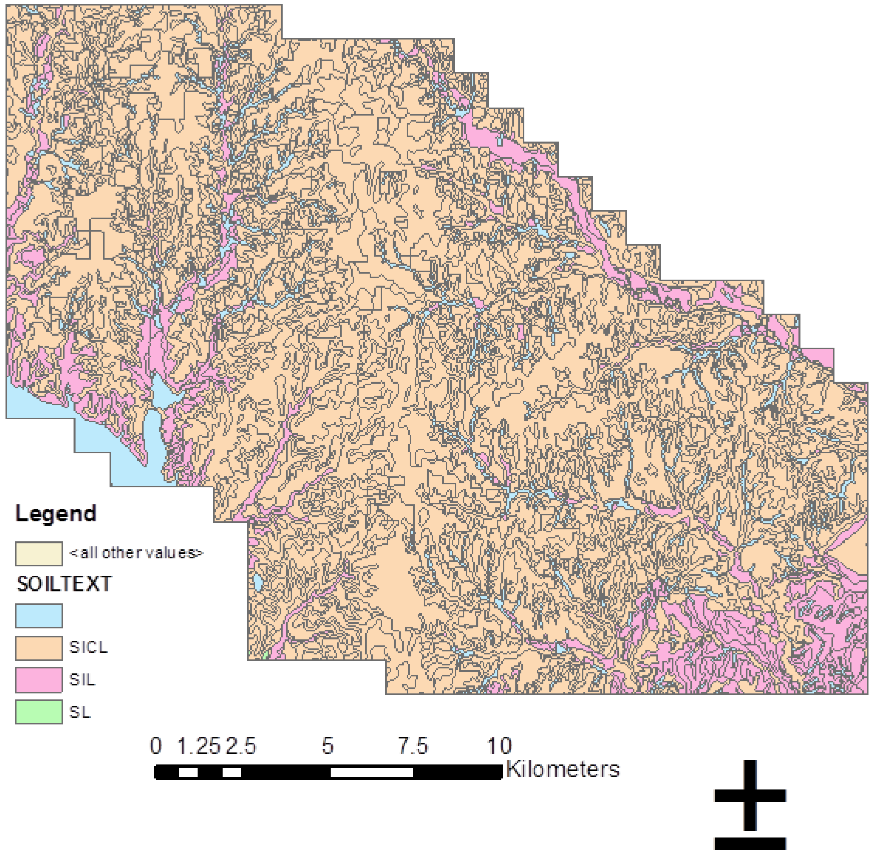


Figure 14 shows the soils data layer required for the model. Due to the nature of the model, the soils vector file requires several attributes including:

- soil depth (`)
- soil permeability (cm/hr)
- soil water holding capacity (cm/cm)
- soil texture
- wilting point (cm/cm)
- saturation point (cm/cm)
- bulk density (g/cm^3)
- average biomass production (g/m^2)
- soil texture abbreviation according to the US Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS) Soil Survey Geographical Database (SSURGO) Standard, e.g., SICL = Silty Clay Loam; SCL = Sandy Clay Loam, etc.
- Unified Soil Classification System (USCS) group symbol, e.g., CH, SP-SM, etc.

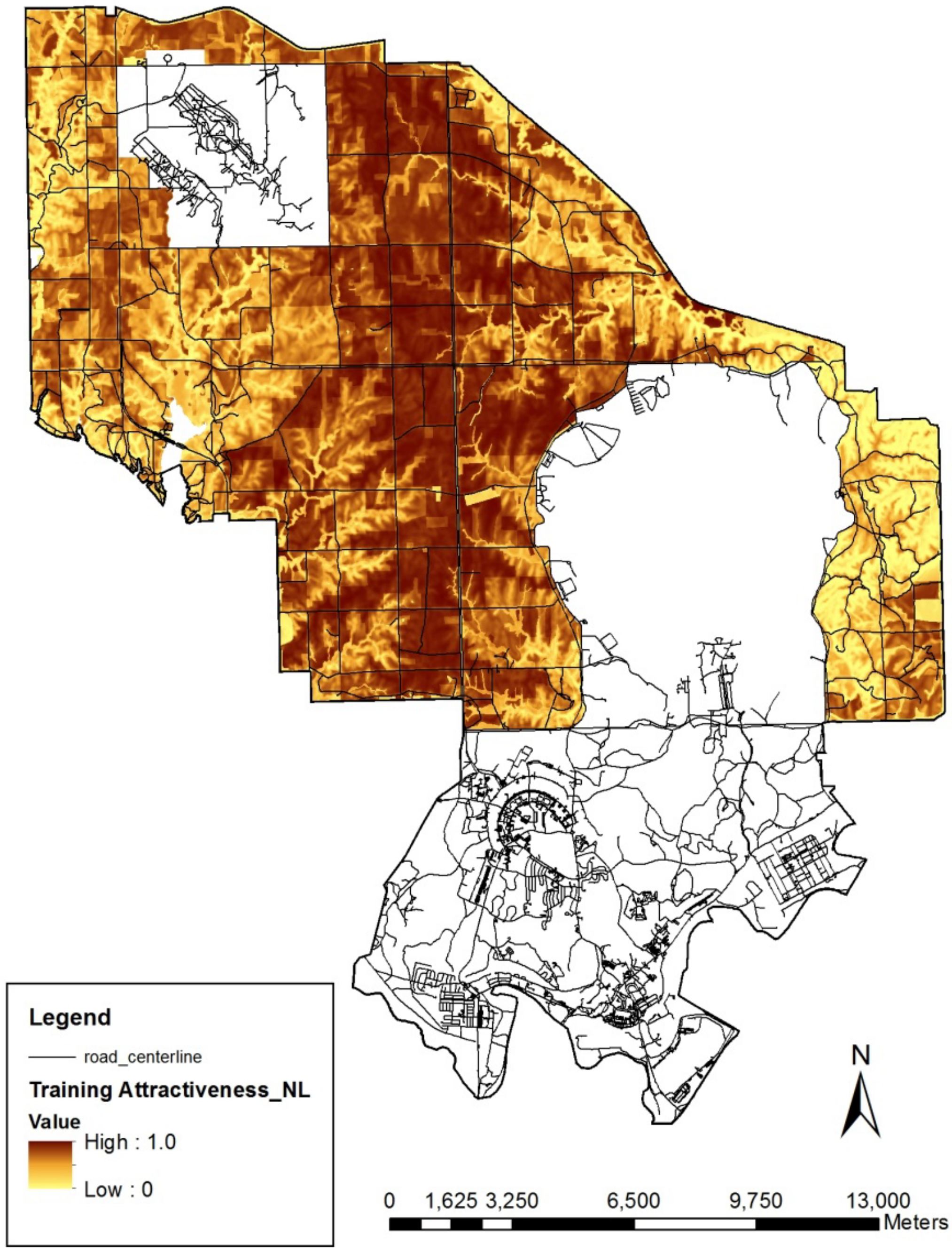
Figure 14. Soils data layer displayed by soil texture.



These data can be obtained from county soil surveys or can be downloaded from SSURGO. Additionally, the model uses the soils layer to determine all of the areas to be modeled. For instance, if a site has no soils data due to surface water or other obstructions, the OPAL NetLogo Land Condition Model does not run for that patch.

The OPAL NetLogo Land Condition Model uses a training attractiveness model that distributes training loads at a large scale (i.e., individual pixels) which are then upsampled to a training area scale. This approach builds on work developed by Guertin (2000) and Fang et al. (2002) which estimate a probability surface that define areas more likely to be impacted by training maneuvers. Figure 15 shows the training attractiveness (on a scale of 0-1) based on a set of independent variables that appear to influence training (slope, vegetation type, and installation region). The training attractiveness model was based on a non-linear regression model that correlated observed military maneuver disturbance data with a set of independent geospatial variables.

Figure 15. Map of Fort Riley's relative training attractiveness. Note: Darker colors indicate areas more likely to be trained on based on historic data. White areas were not included in the estimation as the areas depict impact areas or installation cantonment.



This approach provides a better estimation of training distribution compared with assuming a level distribution of training across each training area. However, if data do not exist for developing training attractiveness estimations, a uniform training attractiveness of 1 could be applied to the model.

3.5 Site calibration files

The OPAL NetLogo Land Condition Model was developed to minimize the site-specific parameters required for input into the model. For example, the soil specific variables discussed in Section 3.4 were selected because they are easily obtained from national datasets (SSURGO). However, some of the vegetation growth parameters and other model parameters could not be obtained from widely available datasets. Additionally, the use of the CENTURY biomass growth model required the use of certain site or crop specific parameter estimations (Parton et al. 1993). This method was used to aid in adaptation of the model to additional locations. Table 2 provides the required site-specific parameters, the parameter definition, the source for each parameter estimate, and the Fort Riley Parameter estimate. Most of these parameters can be estimated from CENTURY documentation, soils data, or the PET (Potential Evapotranspiration) process described in Koch et al. (2013). These data are compiled in a text file for importing into the model and is stored under OPAL main directory (Figure 16): "/input/siteparameters/Ft_Riley".

Table 2. OPAL NetLogo vegetation condition model site-specific parameters.

Site-Specific Parameter*	Parameter Definition	Fort Riley Parameter Estimate	Parameter Estimation Source
ppdf_1	Optimal temperature for vegetation production for parameterization of temperature effect on growth curve.	30	NREL (2006); crop.100 parameter file
ppdf_2	Maximum temperature for vegetation production for parameterization of temperature effect on growth curve.	45	NREL (2006); crop.100 parameter file
ppdf_3	Left curve shape for parameterization of a Poisson Density Function curve to simulate temperature effect on growth.	1	NREL (2006); crop.100 parameter file
ppdf_4	Right curve shape for parameterization of a Poisson Density Function curve to simulate temperature effect on growth.	2.5	NREL (2006); crop.100 parameter file

Site-Specific Parameter*	Parameter Definition	Fort Riley Parameter Estimate	Parameter Estimation Source
pprpts_1	The minimum ratio of available water to monthly PET which would completely limit production.	0	NREL (2006); fix.100 parameter file
pprpts_2	The effect of water content on the intercept allows the user to increase the value of the intercept and thereby increase the slope of the line.	1.0	NREL (2006); fix.100 parameter file
pprpts_3	The lowest ratio of available water to PET at which there is no restriction on production.	0.8	NREL (2006); fix.100 parameter file
pmax	Maximum potential plant production rate per week. [$g\ m^{-2}\ month^{-1}$]	58.0	NREL (2006); crop.100 parameter file
AveProdGmSq	Average maximum biomass production for year from SSURGO or soil survey for Fort Riley area. Modifies pmax by soil type according to the soil capacity to support vegetation growth. [$g\ m^{-2}\ year^{-1}$]	622.4	SSURGO database (NRCS)
PETfunc_1	3rd degree polynomial coefficient for equation estimating mean daily percentage of daytime hours for given latitude (See Appendix A for calculation).	0.000001	Brouwer, C. and M. Heibloem (1986).
PETfunc_2	2nd degree polynomial coefficient for equation estimating mean daily percentage of daytime hours for given latitude (See Appendix A for calculation).	0.0003	Brouwer, C. and M. Heibloem (1986).
PETfunc_3	1st degree polynomial coefficient for equation estimating mean daily percentage of daytime hours for given latitude (See Appendix A for calculation).	0.013	Brouwer, C. and M. Heibloem (1986).
PETfunc_4	Constant term for polynomial equation estimating mean daily percentage of daytime hours for given latitude (See Appendix A for calculation).	0.18	Brouwer, C. and M. Heibloem (1986).

*From Koch et al. 2013

Figure 16. OPAL NetLogo Land Condition Model site-specific parameter file (described in Tbl. 2)

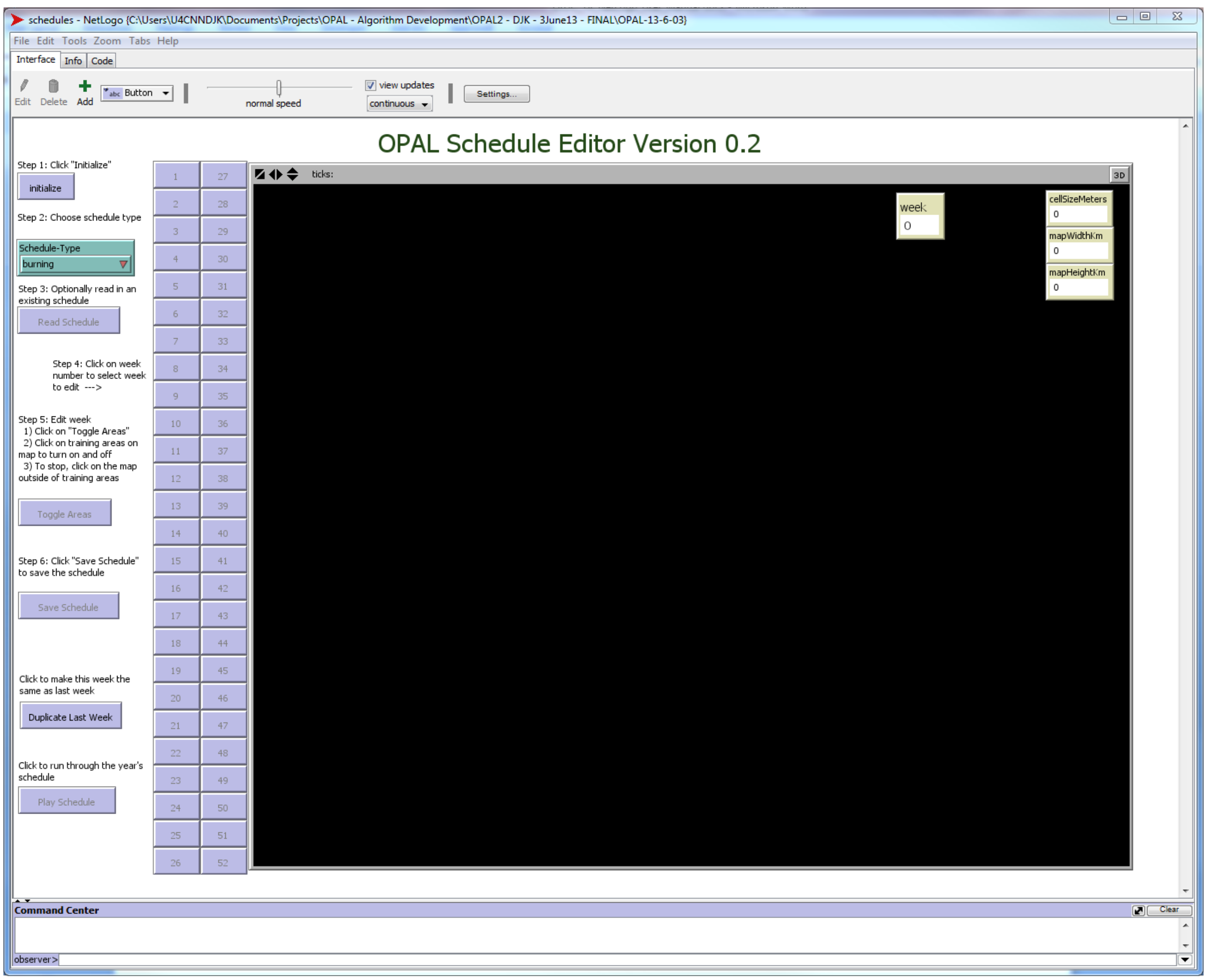
```
ppdf_1:30
ppdf_2:45
ppdf_3:1
ppdf_4:2.5
pprpts_1:0
pprpts_2:1.0
pprpts_3:0.8
pmax:58
AveProdGmSq:622.4
PETfunc_1:0.000001
PETfunc_2:0.0003
PETfunc_3:0.013
PETfunc_4:0.18
```

4 Using the OPAL Schedule Editor

4.1 Loading the OPAL Schedule Editor model

This section describes the methods for opening and using the NetLogo OPAL Schedule Editor Model. Start the NetLogo software by selecting "Open…" from the drop-down File menu (Figure 1). Navigate to the "schedule-editor.nlogo" file in the OPAL main directory/model directory (Table 1) and select Open. The OPAL NetLogo Schedule Editor model will open as a GUI in the NetLogo interface tab (Figure 17).

Figure 17. OPAL Schedule Editor Model before initializing.



4.2 Model input

The OPAL Schedule Editor Model is used to create an installation's training, burning, and haying schedules to be combined into management scenarios in the OPAL Land Condition Model (Chapter 2). The Schedule Editor model requires the following inputs in vector file format:

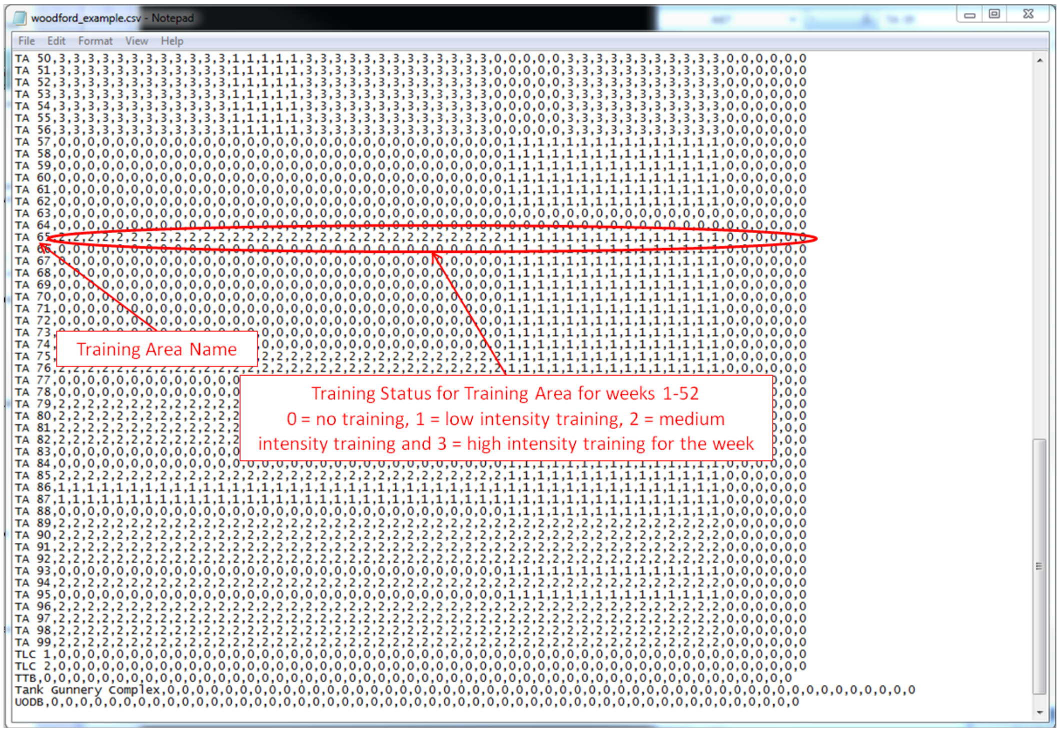
- boundary layer of installation
- installation training area layer (with training area name attributes)
- installation roads layer (for display purposes)
- installation streams layer (for display purposes)
- installation soils layer (used in OPAL Land Condition Model) to establish study area (i.e., if soils data are not available, the area is not included in the model).

While not actually input required to run the model, certain data (historic training, burning, and haying layers; or knowledge of the installation training and land management practices) are required if the intent is to model past impacts. For example, a map of controlled and wildfire burns and their dates would be extremely valuable data input if the user would like to use the OPAL Schedule Editor model to create a schedule of historic burning treatments. The Schedule Editor model also includes the option to "read in" existing schedules created with the model to create modified schedules.

4.3 Model output

The OPAL Schedule Editor software creates a comma separated variable (CSV) file for each yearly training, haying, or burning schedule created (Figure 18). The initial column of the CSV file contains the training area name. Each subsequent column represents the training/land management status for the week. The schedule for every training area in the training area map is represented as a row in the CSV file. For burning and haying schedules, 1 signifies burning or haying for that week, while 0 is used for no land management actions in that training area for the week. In training schedules, each training area receives a value for each week that ranges from 0-3, where the value 0 represents "no training" and 1–3 (respectively) represent low, medium, and high training intensity for the week. The Schedule Editor was developed to provide installation land managers a quick method for testing proposed land management and training schedules or developing optimum land management practices given expected training loads.

Figure 18. Example training schedule output from OPAL Schedule Editor. Burning and haying schedules are in the exact same format but the management levels are only 0 and 1.

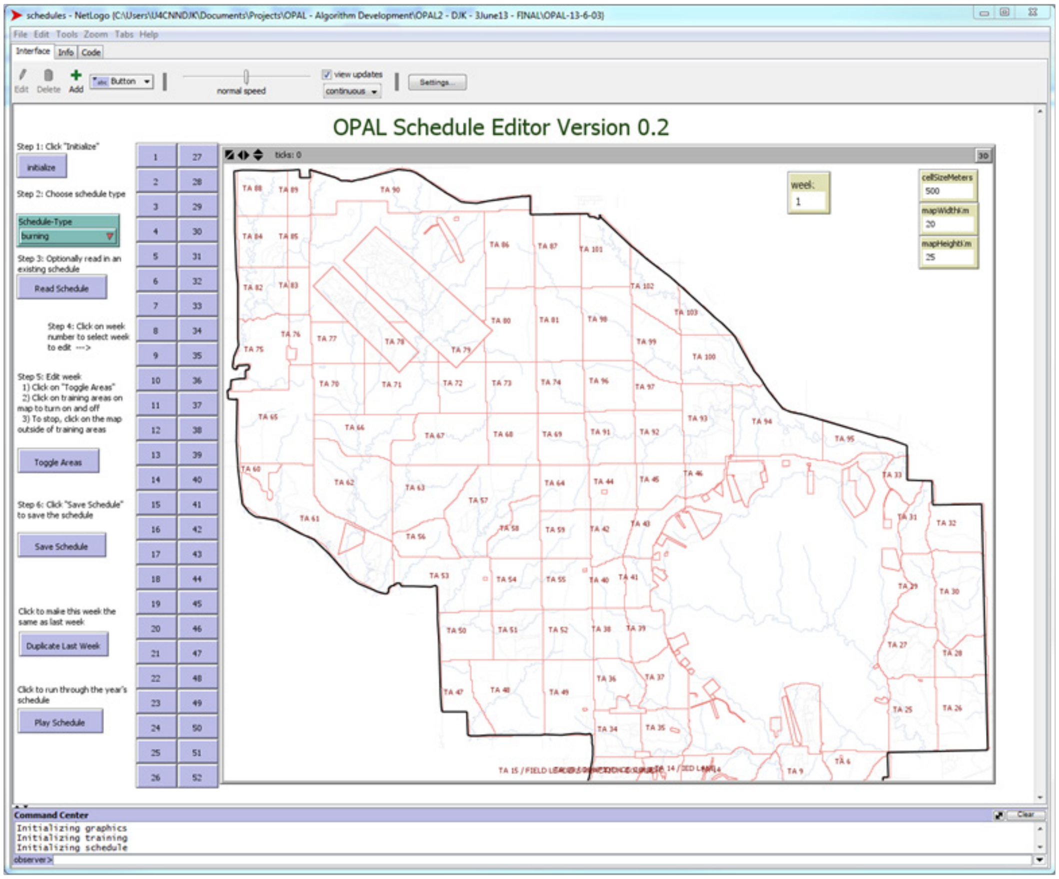


4.4 Step-by-step instructions for model use

The left side of the GUI (Figure 19) contains a step-by-step approach to using the OPAL Schedule Editor:

1. Select the "initialize" button. This initializes and reads the input vector map files and initializes the graphics, training, and schedule modules. Figure 19 shows the OPAL Schedule Editor for Fort Riley.
2. Select the type of schedule you want to create from the schedule-type drop-down box (haying, burning, or training schedules).
3. (Optional). If needed, a schedule created previously can be read in by selecting the "Read Schedule" button and choosing the existing schedule. *Note that the Read Schedule file selector references the burning, haying, or training* directories *(depending on which schedule type was selected in Step 2) in the Input folder of the directory containing the OPAL model and required data.*
4. (and 5). Iterate through all of the weeks for which training/land management treatments are to be scheduled. To begin the scheduling process, click on the week number for which you wish to schedule a training/land management event.

Figure 19. Initialized OPAL Schedule Editor for Fort Riley.

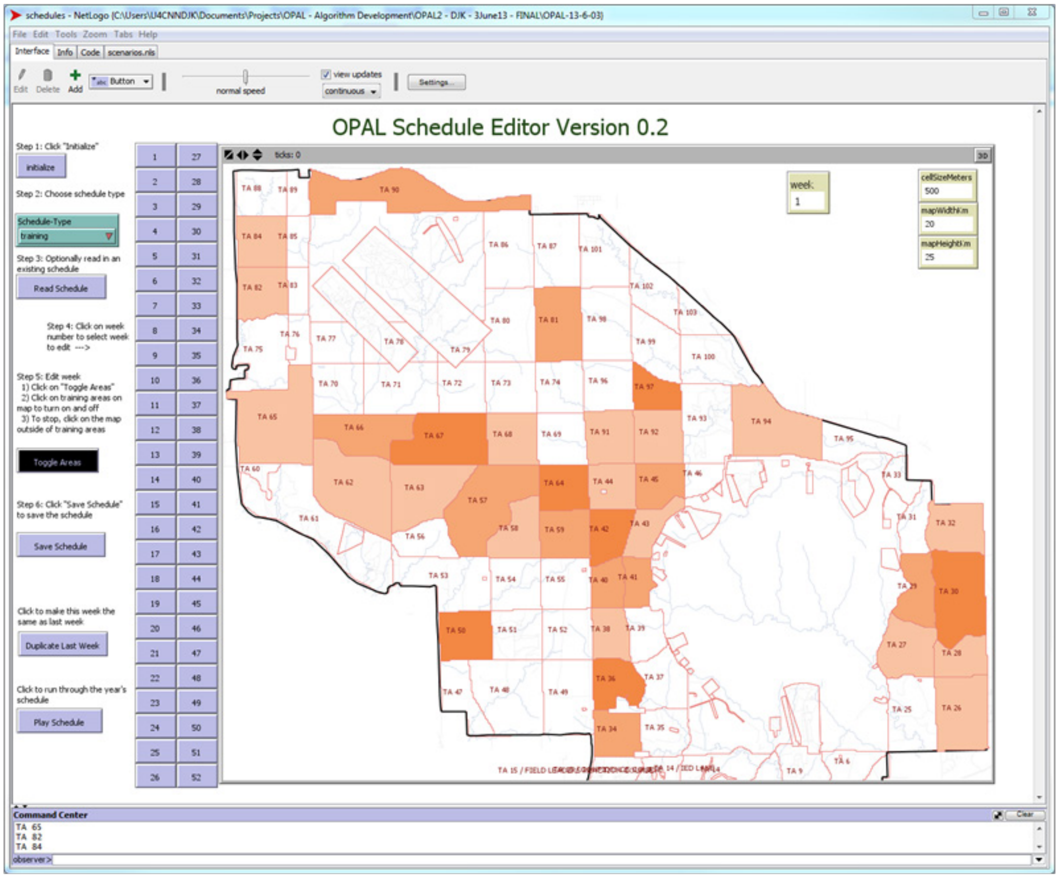


Click on the "Toggle Areas" button to make the map interactive. (When clicked, the button will turn and remain black.) Select (click on) all training areas for which you wish to schedule a treatment for the week selected in Step 4. The selected training area will be highlighted red, yellow, or orange depending on the schedule type (burning = red, haying = yellow, and training = orange).

For burning and haying schedules, a second click on a training area will de-select it so the training area will no longer be scheduled.

For training, each subsequent click will increase the intensity (0->1->2->3); each increase in training intensity will b e indicated by a more intensely colored orange highlight. Clicking on the highest intensity scheduled training area will return to the no scheduled condition (0). Figure 20 illustrates a sample training schedule map for 1 week.

Figure 20. Example of week training schedule. The white training areas are not scheduled to be trained on while the orange highlighted areas will receive light to heavy (1-3) training intensity for the week according to color intensity.



The week reporting box in the upper right hand corner of the map displays the week being scheduled. To stop scheduling training/land management events for the given week, **click on the map outside of the training areas.** The “Toggle Areas” button will turn back to its original color.

Repeat Steps 5-6 until all weeks with training/land management events are scheduled.

To save time, you can replicate the previous week schedule to the current week by clicking the “Duplicate Last Week” button. This must be clicked after the week is selected in Step 5.

When all events are scheduled, select the “Save Schedule” button to bring up the schedule naming dialog. The model will automatically save the schedule to the appropriate file according to the schedule type selected.

The model has the capability to incorporate any schedule being edited by selecting the “Play Schedule” button. The map will cycle through each week and display the training area scheduled to be treated each week.

4.5 Hints on using program

To create multiple year schedules, create schedules for individual years first with the OPAL Schedule Editor. Then open the individual year’s CSV files in a spreadsheet program and sort them by training area. Sorting by training area is necessary because the Schedule Editor does not create the same training area order for each schedule. Begin with the first year and copy the 52 columns with schedule data from the 2nd year to the first. Then append the data from the next year to the appended dataset until all years’ data is in a single file. Resave this file as a new CSV file (with a different name) to create a multiyear schedule.

5 OPAL Programmer Information

The information in this chapter is intended to assist anyone interested in modifying the OPAL model.

5.1 Software environment

The software environment chosen for OPAL development is NetLogo, an open-source, freely distributable environment that is very easy to learn, but also very powerful and extensible. Netlogo is a Java-based program, which allows the OPAL model to run on virtually any system that supports Java. Netlogo remains under continuous development and maintenance, the current version being 5.0.

Before beginning tp program the OPAL model directly, a person new to NetLogo is encouraged to learn about the modeling environment by reviewing the many sample models included with each NetLogo installation. Netlogo is also supported by an extensive and complete user manual that can be accessed via web browser and in an Adobe Portable Document Format (PDF) form, through the NetLogo interface.

Netlogo is designed to be an agent-based modeling system that supports two basic types of agents: landscape patches and mobile objects. OPAL makes use of both types, but primarily focuses on the dynamic behavior of landscape patches.

5.2 Directories and files

The data in Table 1 (p 6) outline the high-level organization of OPAL model files. All of the files associated with the OPAL program code are under the “model” directory, which contains the main programs (opal.nlogo and schedule-editor.nlogo), supporting model program files in the “nls” directory, supporting images in the “images” directory, and a NetLogo extension package in the “pathdir” directory, which supports the management of files and directories. Here is a short description of these files:

- **opal.nlogo**. This is the main NetLogo instruction file for the OPAL program. Although a text file, it should be opened and edited with the NetLogo program. It uses the NetLogo “_ _includes” command to include the *.nls files listed below. The commands in these files are broken out from the main OPAL instructions to help with the logical organization of files.

- **schedule-editor.nlogo**. The is the main NetLogo instruction file for the OPAL Schedule Editor. It uses some of the *.nls files below.
- **nls/weather.nls**. These procedures read the user-selected weather file, which contains daily weather data, and process that daily information into weekly information, which is held in a list. As the simulation progresses over time, that weather information is then provided as needed.
- **nls/biomass.nls**. The biomass procedures provide the equations and logic that support biomass growth and destruction dynamics.
- **nls/soil.nls**. This module contains the soil moisture dynamics, which are primarily based on weather. Many of the soil-based parameters that drive biomass production are read from the soils vector map, with several of the values cached as faster-read raster maps. During simulation runs, soil moisture is updated.
- **nls/training.nls**. These procedures read the user-selected military training schedule, store the results, and then provide training intensity over time by training area during simulation runs.
- **nls/management.nls**. These procedures read the user-selected haying and burning schedules, store the results, and then provide the management information over time by training area during simulation runs.
- **nls/maps-vector.nls**. This supports various required vector GIS maps and coordinate transformation between GIS and NetLogo space.
- **nls/maps-raster.nls**. This file supports required raster GIS maps.
- **nls/scenarios.nls**. This file is for managing scenario files, including selecting, creating, deleting, and reading and writing.
- **nls/reports.nls**. This file is for saving information in files.
- **nls/graphics.nls**. This file contains procedures for displaying the requested background map with vector map overlays during simulation runs, plotting graphs on the map area, and starting and stopping movie production.
- **nls/on-screen-plot.nls**. This file contains the low-level procedures for plotting graphics on-screen.
- **nls/utilities.nls**. This file contains low-level procedures.
- **pathdir/**. This NetLogo extension package supports the creation and destruction of file system files and directories.
- **images/**. This directory simply holds several images that are displayed under the OPAL program's "info" tab as part of the text that provides internal model documentation.

5.3 Programming conventions

A key goal in model development was to leave coding instructions that could be readily read and interpreted months or years later. Some of the programming conventions that were used to fulfill this goal are:

- Variable and procedure names tend to be spelled out to provide contextual meaning to the programmer. They can take any, or a mix, of several forms. Often the first letter in a string of words is capitalized as in *potEvapoRateCmPerWk*. Sometimes words are separated by dashes, as in *parse-CSV-line-into-list*, which is the NetLogo language standard approach. Many of the OPAL procedures use underscores instead of dashes to separate the words, as in *Set_Check_Input_Files*.
- Many of the variable names have their units built in, such as *potEvapoRateCmPerWk*, which should read "potential evaporation rate in centimeters per week."
- In keeping with NetLogo conventions, variables that are given true or false values terminate in a question mark, as in *movieMap?*
- A substantial amount of commented-out documentation is included in the model code. Much of the code was originally described with equations and logical statements that were later translated into NetLogo code. During that initial description of logic and algorithms, references were identified that supported the modeling decisions. That information has been left in the code to help later programmers to understand where the model details came from.
- When procedure names are organized into separate supporting *.nls files, it can be challenging to find a procedure. To assist, many of the OPAL procedure names in these supporting files start with the nls file name. For example, the *Training_Conduct_Simple* procedure can be found in the *training.nls* portion of the code.

5.4 Technical support

For technical support please contact either:

Dr. James Westervelt
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6 Conclusion

The OPAL project developed approaches to estimate cumulative land disturbance on military training lands through above- and below-ground biomass responses by merging current biomass disturbance methods/models with OPAL field data to capture disturbance regimes for military land managers. This phase of work has provided a step-by-step guide to install the OPAL software and to run the model.

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Acronyms and Abbreviations

Term	Spellout
°C	Degrees Celsius
ACIS	Applied Climate Information System
ANSI	American National Standards Institute
AR	Army Regulation
ASAALT	Assistant Secretary of the Army for Acquisition, Logistics, and Technology
ASCII	American Standard Code for Information Interchange
ATTACC	US Army Training and Testing Area Carrying Capacity
CD	Compact Disk
CEERD	US Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
cm	Centimeter
CSV	Comma Separated Values
DVD	Digital Video Disk
e.g.	exempli gratia ("for example")
ERDC	Engineer Research and Development Center
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESA	Endangered Species Act
g	Grams
GUI	Graphical User Interface
HQDA	Headquarters, Department of the Army
hr	Hour
i.e.	id est ("that is")
ID	identification
ITAM	Integrated Training Area Management
m	meter
MIM	Maneuver Impact Mile
NATO NRMM	North Atlantic Treaty Organization Reference Mobility Model
NREL	National Resource Ecology Laboratory
NSN	National Supply Number
NT	No Training
OMB	Office of Management and Budget
OPAL	Optimal Allocation of Land for Training and Non-training Uses
OSX	(Apple Macintosh) Operating System X
PDF	Portable Document Format
PET	Potential Evapotranspiration
RFMSS	Range Facility Management Support System

Term	Spellout
SAR	Same as Report
SCL	Sandy Clay Loam
SF	Standard Form
SICL	Silty Clay Loam
SRP	Sustainable Range Program
SSURGO	(USDA-NRCS) Soil Survey Geographical Database
TA	Training Area
TEPC	Threatened, Endangered, Proposed, and Candidate
TES	threatened and endangered species
TR	Technical Report
URL	Universal Resource Locator
USACE	US Army Corps of Engineers
USAEC	US Army Environmental Command
USCS	Unified Soils Classification System
USDA-NRCS	US Department of Agriculture– Natural Resources Conservation Service
USHCN	US Historical Climatology Network
VCF	Vehicle Conversion Factor
VSF	Vehicle Severity Factor
WT	With Training
WWW	World Wide Web

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14. ABSTRACT
This report provides user and programmer information supporting the Optimal Programming of Army Lands (OPAL) model, which was designed for use by trainers, Integrated Training Area Management (ITAM) coordinators, and land rehabilitation offices. The model provides an environment for testing how different combinations of training schedules, haying and burning schedules, and weather affects the quality of the lands vegetation, which provides training realism and erosion protection.

15. SUBJECT TERMS
ITAM, OPAL, land management, military training, simulation modeling

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