Introduction to ITAM program and ATTACC module

The Department of Defense is responsible for the management of over 25 million acres of land, making it the 5th largest federal land management agency (Mendoza, et al, 2002). The Army's Integrated Training Area Management (ITAM) Program is responsible for the management of training lands and a formal strategy for the sustained use of the Army's training and testing areas. A major objective of the ITAM Program is to develop a method for estimating training land carrying capacity. Training land carrying capacity is defined by ODCSOPS (Office of the Deputy Chief of Staff for Operations and Plans) as the amount of training that a given portion of land can accommodate in a sustainable manner based on a balance of use, condition, and maintenance practices. The ATTACC (Army Training and Testing Area Carrying Capacity) Program, an initiative sponsored by ODCSOPS, is the standard methodology used to estimate the operations and support costs for the use of land on an Army installation for the purpose of training and testing. The ATTACC methodology includes specific processes and algorithms to predict land rehabilitation and maintenance requirements based on the aforementioned training land carrying capacity. These decision support tools include Workplan Analysis Module (WAM), ATTACC Integration Module (AIM), ATTACC functions of the Range Facility Management Support System (RFMSS), and the Land Condition Module (LCM).

The ATTACC methodology consists of three main components: (a) training load characterizations, (b) environmental characterizations and (c) cost analysis. Training loads, quantified in terms of MIMs (Maneuver Impact Miles), are based on mileage projections. All vehicles in every training event have a different impact on the land. To account for these differences, all training events are normalized to a standard unit in a standard event. The cost component characterizes land maintenance and repair practices in terms of type of practice, cost, practice effectiveness and areas affected. Land rehabilitation and maintenance costs are obtained from existing installation records and regional cost estimates. The environmental component currently characterizes land condition in terms of erosion status as a function of training load.

ATTACC Methodology

The ATTACC methodology estimates land condition in terms of the average erosion status for a desired area. The erosion status (ES) is the ratio of the predicted erosion rate to the tolerable erosion rate. ES values less than 1 mean that soil loss is less than what the land can tolerate. It is desired to have ES values to be less than 1.

$$ES = A / T \qquad \text{(Eq. 1)}$$

ES = Erosion Status (dimensionless)
A = soil loss per unit area (tons ac-1 yr-1)
T = soil loss tolerance factor (tons ac-1 yr-1).

The value for ‘A’ is the output for the Revised University Soil Loss Equation (RUSLE). Soil loss can be estimated using the following equation:

$$A = R*K*LS*C*P \qquad \text{(Eq. 1a)}$$

R = rainfall and runoff factor
K = soil erodibility factor
LS = slope length and steepness factor
C = cover and management factor
P = support practice factor

Military training damages soil and vegetation. As a result, soil is more exposed to raindrop impact and surface water runoff resulting in the overall degradation of land condition (Ayers, 1994; Ayers et al, 1990; Braunack, 1986; Burger et al, 1985; Prose, 1985; Shaw & Diersing 1989; Wilson 1988). Loss of vegetation cover results from greater impact on the land. This increased impact further exacerbates the degradation of the land. This balance between training activities and the lands' natural recovery process are incorporated into the model with the following equation.

$$LC_P = LC_C + \Delta LC_T - \Delta LC_R \qquad \text{(Eq. 2)}$$

LC_P = predicted land condition
LC_C = current land condition
ΔLC_T = changes in land condition due to training
ΔLC_R = changes in land condition due to natural recovery

The ATTACC land condition curve is generated by plotting the predicted land condition (Eq. 2) against a range of MIM values. The predicted land condition for a specific training load is compared to a management objective, referred to as a threshold. The difference between the predicted future land condition and management goal is an indictor of the amount of land maintenance required. The graph to the left shows Erosion Status values taken directly from the ATTACC LCM software output. This graph clearly articulates that erosion status will increase as training load increases.

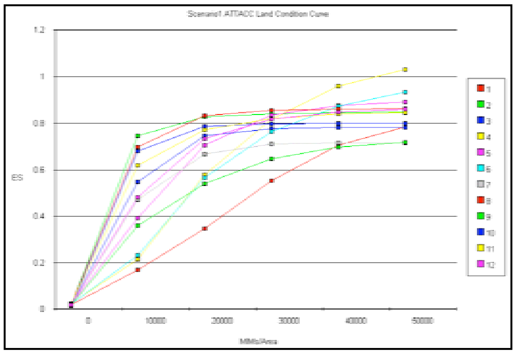


Figure 1: Erosion Status Versus Training Load

Conversely, erosion status and general land condition exhibit an inverse relationship. A high ES value is the result of having a high 'A' value in comparison to the tolerable values from equation 1. This 'A' value is the output from a modified version of the Revised Universal Soil Loss Equation (RUSLE). A higher 'A' value results in a higher erosion status. As the erosion status of the land increases, the land condition of the same area should decrease. The graph to the right should articulate the relationship between land condition and impact and the degradation of the land as the training load increases.

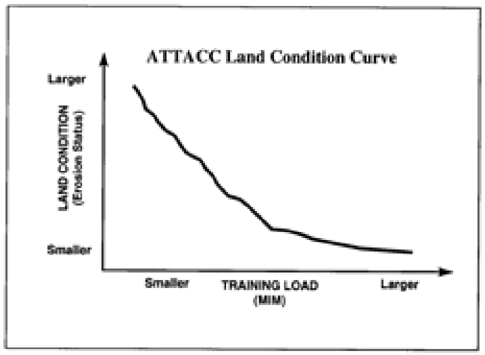


Figure 2: Land Status Versus Training Load

The ATTACC LCM Program

The ATTACC environmental component modeling, the Land Condition Module (LCM), is a GIS based software application that estimates change in land condition associated with mission activity. LCM automates the ATTACC methodology for generating land condition curves. LCM uses natural resource GIS data layers to generate land condition curves.

Land condition is a measure of the ecological state of the land. Various measures of land condition exist, such as vegetation compositions and soil erosion. LCM uses erosion status to represent the current land condition. Soil erosion is a quantifiable variable that is familiar and easily understood by both military trainers and environmental managers. Soil erosion is directly related to the site. Training activities can be linked to soil erosion, thus making it a good general indicator of current condition of the land (US AEC 1999). Most installations have management plans in place with goals to achieve and maintain erosion rates on training lands that allow for the sustainability of the land to support the Army's training mission.

The ATTACC LCM uses a number of basic input variables derived from LCTA, ITAM GIS, or other installation data to determine erosion status. The required inputs depend on the type of erosion model used. The current version of LCM allows for a combination of three erosion models to be used. A modification of the Revised Universal Soil Loss Equation (RUSLE), a modification of the Wind Erosion Equation (WEQ), or a modification of vehicle dust erosion model, or any combination of the three may be selected according to the ecosystem of the installation.

Four basic input layers are required for all erosion models. They are (1) installation boundary, (2) training area designations, (3) the measure of training distribution, and the (4) designation of any areas restricted to training. The installation boundary data layer is a layer that depicts the land areas considered part of the installation. The training areas data layer represents the delineation of land units used for the scheduling and subsequent usage of military training activities. This data layer is required when erosion status is being determined for individual parcels of land. If erosion status is being estimated for the entire installation as a whole, then this layer would be equivalent to the installation boundary layer. The distribution data layer represents the spatial distribution of training intensity across the installation. The distribution layer should reflect the effect of topography, vegetation, and other environmental factors on the distribution of land activities as well as the doctrinal requirements of training and historical land use patterns. The restricted data layer represents areas that are available for training. Areas that are not available for scheduling or training activities or have access restrictions, such as the cantonment area, bodies of water, or impact areas should not be included in the available training lands layer.

A modification of the RUSLE is used to estimate water erosion. For a majority of installations, running water is the primary and significant cause of soil erosion. Input layers for the RUSLE include climatic data, soil erodibility factors, topography and vegetation cover. In dryer climates wind and dust can be significant causes of erosion. A modification of WEQ is used to estimate erosion caused by wind. Input layers required for this model include climatic data, soil erodibility factors, and vegetation cover, structure, and composition. Erosion caused by dust is estimated using a modification of a vehicle dust erosion model, requiring inputs including climatic factors, soil erodablilty factors, and vegetation cover. Some data layers are used by multiple models. All of the erosion models are modified using impact and recovery factors. The impact factor is the impact on vegetation cover due to a standard measure of impact. The recovery factor is an estimate of the amount of time a certain vegetation type requires to recover to its previous unimpacted state. The wind erosion model also has impact and recovery factors associated with the soil erodability index.

The LCM application uses Spatial Analyst operations on raster input resulting in grid and tabular output. Version 1.00 of the LCM application was developed as an ArcView extension through Avenue code. This initial version estimated ES based solely on water erosion. Version 2.00 was released in 2002. This newer version allows the user to estimate current land condition based on any combination of water, wind, or dust erosion estimations.

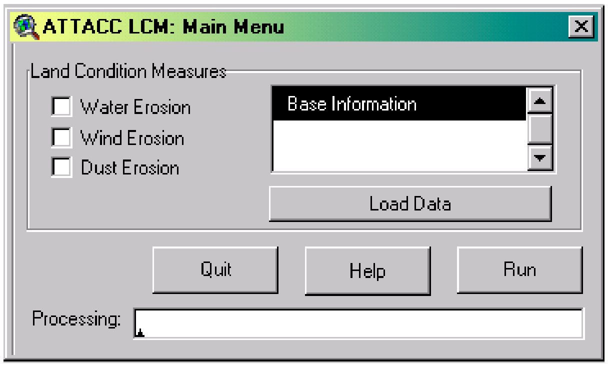
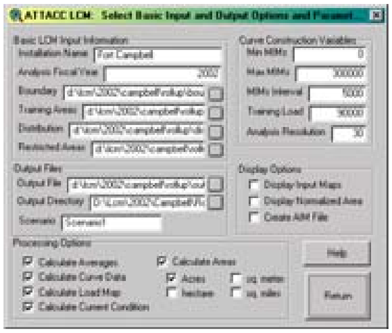


Figure 3: ATTAM LCM Main Menu

The LCM application allows the user to choose a single or combination of models to estimate erosion status. The application requires the name of the raster data layers needed for the chosen erosion models. The ATTACC LCM requires several input data layers and specification of several other processing options regardless of which land condition measures are used in the analysis. Basic input information includes installation name, fiscal year, boundary map name, training area map name, distribution map name, and restricted areas map name.



Basic LCM Input Information
Installation Name: Fort Campbell
Analysis Fiscal Year: 2002
Boundary: d:\lcm\2002\campbell\volkup\bou
Training Areas: d:\lcm\2002\campbell\volkup
Distribution: d:\lcm\2002\campbell\volkup\dis
Restricted Areas: d:\lcm\2002\campbell\vol

Curve Construction Variables
Min MIMs: 0
Max MIMs: 300000
MIMs Interval: 5000
Training Load: 90000
Analysis Resolution: 30

Output Files
Output File: d:\lcm\2002\campbell\volkup\out
Output Directory: D:\Lcm\2002\Campbell\Vc
Scenario: Scenario1

Display Options
☐ Display Input Maps
☐ Display Normalized Area
☐ Create AIM File

Processing Options
☑ Calculate Averages
☑ Calculate Curve Data
☑ Calculate Load Map
☑ Calculate Current Condition
☑ Calculate Areas
☑ Acres
☐ hectare
☐ sq. meter
☐ sq. miles

Figure 4: ATTACC LCM Basic Information Dialog Box

The necessary data required for the application are dependent upon the analysis options selected. The ATTACC LCM disables/enables input and output fields based on the options that the user selects. If required data are not specified or the requested files are missing, the ATTACC LCM will notify the user of the problem. When data are lacking for one of the required input data layers, a map layer with a single installation-wide value can often be substituted until the data layer can be acquired or developed. This will allow the user to use the module as they continue to develop data. The ATTACC LCM Basic Information dialog will save input values between work sessions. The next time the user implements the ATTACC LCM extension, the input values will be restored.

Analyses can be preformed at the installation level or at a larger scale, such as individual training areas. A boundary map, delineating the land areas considered part of the installation, is required when estimating land condition for the installation as a whole. The boundary map should include all lands that are applicable to the ITAM program. A training area map is a map delineating land units used for scheduling and conducting military training. The ATTACC LCM will generate a land condition curve for each training area identified in the training areas map. To generate a single land condition curve for the installation to use in HQDA analyses, provide a boundary map of the installation for the training area data layer input request (Figure 4). To generate a land condition curve for a single training area, the extent of the training area should also double as the installation boundary area.

An important aspect to adequately model the impacts of training and testing activities revolves around the spatial distribution of land use activities. Land use activities are not distributed uniformly across the installation. The training distribution map should reflect the effects of topography, vegetation, and other environmental influences on the distribution of land uses. It should also reflect the doctrinal requirements of training and historic land use patterns. In ATTACC, the methodology to create this data layer is flexible, but the land use patterns estimated should reflect actual land use. Evidence of historic disturbance can be used as a surrogate measure of future training use distribution. To spatially extrapolate historic data, measures of disturbance from field plots are statistically related to spatial data. The statistical techniques that relate point and spatial data can vary greatly in complexity.

There are various processing operations that can be preformed using the ATTACC LCM extension (Figure 4). If no processing options are selected, all other input fields will be inactive and grayed out. As options are selected, the required input fields will be activated. The user can select to calculate the average, minimum, and maximum values for each input data layer. Summary data are stored to a table in the ArcView project. This summary is provided to help the user confirm the input data. The option to calculate curve data will generate the tabular data necessary to estimate the ATTACC Land Condition Curve. The output will be saved to a table in the ArcView project. The 'Calculate Load Map' option on the form will estimate the land condition for the projected training load set in the curve construction variables section of the input dialog window. The projected training load map can be used to look at the spatial distribution of land condition measures for a specified training load. This output map can be useful for assessing the quality of land condition curves.

The application has the option to calculate the current land condition. The current condition map can be used to look at the current spatial distribution of land condition measures. This output map can be useful for assessing the quality of land condition curves generated with a given set of input data. Area sizes for installation and training areas can be calculated in one or more selected measurement units. This summary is provided to help the user evaluate the quality of ATTACC LCM data inputs.

If curves for individual training areas are being developed, the land condition curves will be generated for each training area. An example of these curves can be seen in Figure 1 on Page 2. As such, the curves are not directly comparable because each training area differs in size. To compare land condition curves on an equal area basis select the ‘Display Normalized Area’ button. The user has the option to display the land condition data and curve on a normalized 10,000 acre basis. Otherwise the land condition data and curve is displayed on an areal basis. The normalization process assumes that the distribution of mission activities and natural resource characteristics are the same for the normalized area and the actual area. Normalized curves allow the user to compare land condition curves without concern for differences in size of training areas. Differences in normalized curves reflect only differences in data layer inputs. As such, this option allows the user to evaluate land condition curves more easily. Normalized land condition curves should not be used in AIM and other ATTACC applications. This option is only provided to help in the ATTACC data development and evaluation process.

The application allows the user to define the parameters for the land condition curve. The land condition curve data will be estimated for training loads over the range defined by the curve construction variables ‘Minimum MIMs’, ‘Maximum MIMs’, and ‘MIMs Intervals’. The minimum MIMs value is used to determine the minimum training load value to use in developing the land condition curve. This value defines the minimum X axis value on the ATTACC land condition curve. This value is normally left at zero. The maximum MIMs value is used to determine the maximum training load to use in developing the land condition curve. This value defines the maximum X axis value on the ATTACC land condition curve. A reasonable value will depend on the size of the installation and installation specific input maps. The value should cover the range of MIMs values required for the ATTACC land condition curve to reach a threshold.

The MIMs interval value is used to determine how many data points should be used to develop the land condition curve. Smaller intervals capture the shape of the curve better but require more processing time. Larger intervals may be useful when developing and evaluating new data layers. The training load is the expected training load in MIMs. This value is used to estimate the land condition of a specific training load. The value is typically the expected MIMs load for an area of interest and is obtained from the RFMSS or AIM program. The analysis resolution specifies the resolution of analysis for all calculations. The Analysis Resolution should be set to the resolution of the lowest resolution map. Lower resolution values (larger numbers) are often used when first running the ATTACC LCM program. Lower resolution values allow the program to run faster.

Version Three Advancements

The most recent version of the ATTACC LCM, Version 3.00, was released in 2003. It has a number of additions from previous versions.

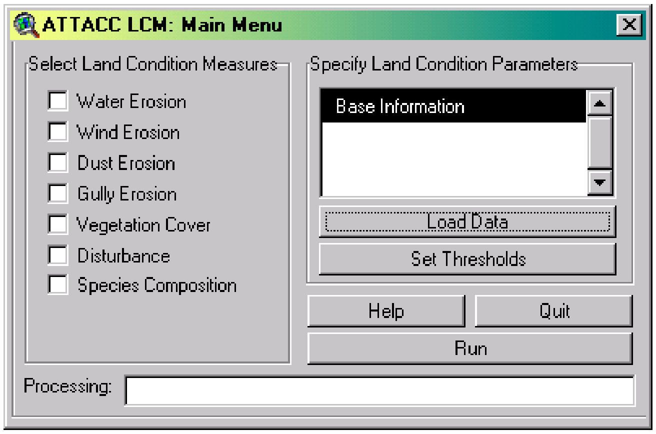


Figure 3: Opening Screen of LCM Version 3.00

In Version 3.00, the C and P factors used to estimate the vegetation cover and mitigations practice activities for the RUSLE erosion estimates are broken into two separate input layers. This version has an additional option for an estimate of gully erosion to be used in the calculation for erosion status. One of the most significant improvements in the 2003 LCM application is the ability to perform multi-criteria analysis.

Previous methodology assessed land condition based only on one factor, erosion status. While this may be adequate for some military installations, it is more meaningful to expand the definition of land condition beyond erosion status to include other factors. With these additional factors, evaluating land condition requires a multi-criteria analysis procedure. When using a multi-criteria analysis procedure, it is best to express land condition as an index as shown in equation 3.

$$LCI = \_\ (w_j LC_j) \qquad \text{(Eq. 3)}$$

LCI = Land Condition Index
LC_j = Land Condition based on factor j
w_j = relative weight of the factor j such that the sum of all j equals 1

This linear additive model (Eq. 3) reflects a composite land condition involving multiple factors. Individual factors are weighted to reflect their relative importance with respect to the overall land condition. Hence, factors that are deemed more significant indicators of land condition for a given location can be assigned higher weights, giving them greater importance in the estimation of the land condition index (LCI). The additive model also allows estimation of the impact of each factor separately. The model offers a simple way to estimate a composite land condition index that can be viewed as a summation of these different impacts. The relative weights (w_j) are central to the multi-criteria method. If the factors are sufficiently known and supported with adequate data and the interactions among the factors are also sufficiently understood, then the weights may be estimated using sophisticated methodologies that take into account the dynamic processes that link the various factors. For most military installations, this level of information is not readily available. However, there are procedures that allow estimation of these weights using qualitative and quantitative measures that do not rely heavily on 'hard' data, but can use mixed data sources, including expert opinions (Mendoza, 2000).

Often times, the factors affecting land condition are of different scales and their values are of different magnitudes. For example, vegetative cover and range condition are expressed in terms of percent with values ranging from 0 to 100. Erosion status is expressed as a ratio with dimensionless values greater than 0. In order to make these factors comparable and additive for the land condition index, they must to be scaled. The scaling procedure should be a tool for standardizing the factors so that:

1) the values are comparable
2) the scaling limits are also comparable, and
3) the scaled values have real meanings with respect to how far they are from the 'target' or ideal values which also must serve as the scaling limit.

In view of the above, the proposed scaling procedure should be as follows:

$$X_i = (R_i - R_{min})*(X_{max} - X_{min}) /(R_{max} - R_{min}) + X_{min} \qquad \text{(Eq. 4)}$$

X_i = scaled value of the factor i
R_i = raw value of factor i
R_{min} = minimum raw value of factor i
R_{max} = maximum raw value of factor i

Scaling has minimal effect on factors like vegetative cover and range condition factors because their values are already between 0 to 1 (0 to 100 percent), their maximum and minimum values serve as the scaling limits (i.e. minimum is 0 percent for the worst condition, and the maximum is 100 per cent for the best or 'ideal' value), and the raw values themselves are already relative values with respect to the scaling limits of 0 and 100. Scaling is essential for factors like erosion status factor because its values are not directly comparable to factors like vegetative cover and range condition. In scaling the ES factor, two things need to be established: the scaling limits to define the range of scaled values, and the minimum (worse) and maximum (better) values for the factor. The scaling limits must also be comparable with the other land condition factors, namely the vegetative cover and range condition factors. Both factors have 0 and 100 as their scaling limits; hence, the ES factor should also adopt these as scaling limits.

The ideal value is obvious; that is 0 for no erosion at all. However, the worst is not easy to determine because it is the maximum amount of erosion and is dependent on the amount and intensity of training. After examining the data, a reasonable range of ES values can be determined and the worst-case scenario can be established. It is clear from equation 1 that an ES value of 1 implies that the amount of erosion is equal to the tolerance limit T. It should also be pointed out that for the two other factors, land condition is negatively correlated with the amount of training load. That is, percent vegetative cover and range condition decreases as the amount of training load (i.e. the magnitude of MIM's) increases. Moreover, it is clear that higher values of the percent cover and range condition factors are preferable. The opposite is true for erosion status; ES increases as training load increases. Hence, the scaling process must also transform the scaled values so that higher values are preferable because they imply less negative impact. Finally, in scaling the ES factor, the original values must be reclassified so that all ES values greater than 2 will be classified as having values of 2. Then, the second stage scaling process will transform the re-classed data so that 2 is standardized to the scaling limit of 100, and finally, the other values are transformed using the model in equation 4 where X_{max} , X_{min}, R_{max}, and R_{min} are set at 100,0, 2, and 0 respectively.

Land based ecosystems are generally flexible and capable of absorbing stresses caused by various forms of disturbance, including damages from military training exercises. Most terrestrial ecosystems are able to maintain their functions despite heavy loads of disturbance as long as the intensity of disturbance is within an acceptable range denoted by the threshold values. Besides defining acceptable levels of disturbance, threshold values may also serve as guides in identifying areas in need of restoration. Hence, thresholds are essentially reference values that define acceptable levels of disturbance both from the standpoint of restoration as well as the expected costs of land maintenance and improvement.

Thresholds have meaning at the individual factor level and also at the composite land condition index level. At the individual factor level (e.g. erosion status), thresholds are useful guides in determining the maximum amount of training load an area can support without compromising its ability to recover from training damages to the soil. Composite thresholds may also be specified for the purpose of establishing limits where all of the factors are considered critical. These limits may be useful in determining and prioritizing critical areas that are in need of restoration. Moreover, these thresholds may also serve as the bases for estimating land maintenance and improvement costs. It is conceivable that in some areas, land condition is already at the threshold based on one factor; however, this may not necessarily be the case for other factors. In such a case, the composite threshold helps identify these areas. Resources available for restoration can then be allocated to those areas whose land condition index is closest to the composite threshold value.

Version 3.00 of the ATTACC LCM application is currently being developed for ArcMap Desktop. This will have the same capabilities as the version currently developed for ArcView. This application will load as an ArcMap template, adding a toolbar to the interface. The remainder of the interface is equivalent to the ArcView version. Raster and tabular data are readily visible within the application so that further GIS analyses can be performed if the user desires to do so.