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A Successional Dynamics Simulation Model as a Factor for Determining Military Training Land Carrying Capacity

By
Terry McLendon, W. Michael Childress, David Price, and Alan B. Anderson

The U.S. Army is committed to good stewardship of lands within military installations. The Army is also committed to achieving "training to standard" for its forces and therefore is interested in a method of determining optimum levels of training activities such that military preparedness is maximized and ecological impacts and their costs are minimized. A key requirement to the successful implementation of such an optimization is the development of a successional dynamics model that predicts ecological responses to military and non-military stressors.

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Foreword

This study was conducted for the Office of the directorate of Environmental Programs (DAIM), Assistant Chief of Staff (Installation Management) (ACS[IM]) under Project 4A162720A896, Environmental quality Technology; Work Unit EN-TK7, Land-Based Natural Resources Carrying Capacity. The technical monitor was Dr. Victor Diersing, DAIM-ED-N.

The work was performed by the Natural Resources Assessment and Management Division (LL-N) of the Land Management Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (USACERL). This report contains a paper presented at the SCOPE/UNEP Workshop on "The contribution of integrated ecological and economic models to indicators for sustainable development and the roles of stakeholders," Boston, Massachusetts, 30 July to 4 August 1996, proceedings of the session on "Ecological and Planning Perspectives on Land Management Modeling for U.S. Military Installations." The USACERL Principal Investigator was Dr. David L. Price. Dr. William D. Severinghaus is Operations Chief, CECER-LL. The USACERL technical editor was Gloria J. Wienke, Technical Information Team.

Dr. Terry McLendon and Dr. W. Michael Childress are members of the Department of Biological Sciences, University of Texas at El Paso, El Paso, Texas, and performed work on this report under contract with USACERL.

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1 Introduction

Background

Army doctrine states that the basic mission of the U.S. Army is to fight and win in combat (FM 100-5). The training of soldiers is the vital ingredient that assures the readiness of the force to accomplish this mission. An essential ingredient in meeting this training requirement is sufficient land in realistic conditions (TC 25-1). Available training lands have been decreasing as a result of congressionally mandated base closures. In addition, increased public concern about the environment has generated new legal and regulatory restrictions on training land use. Currently, the most difficult problem faced by training land managers is the lack of adequate land to conduct realistic training.

Training can result in significant degradation of installation natural resources (Goran, Radke, and Severinghaus 1983; Johnson 1982; Severinghaus 1984; Severinghaus and Severinghaus 1982; Shaw and Diersing 1990; Trumbull et al. 1994). In particular, training impacts on vegetation integrity, threatened and endangered species habitat, soil stability, and water quality are of concern. The Army must assure that military activities are ecologically compatible with training land and natural resources in order to conduct realistic training with minimum adverse impact on human and natural systems.

The principal program by which the Army manages training lands is the Integrated Training Area Management (ITAM) program (Macia 1996). This program consists of four components. Land Condition Trend Analysis (LCTA) provides a status of the installation's resources and trends in those resources. Training Requirements Integration (TRI) uses LCTA data to optimize use of training lands. Land Rehabilitation and Maintenance (LRAM) provides for the recovery of the land from impacts of Army training. Environmental Awareness (EA) provides information for land users to minimize impacts to the land.

The Office of the Deputy Chief of Staff for Operations and Plans (ODCSOPS), which is currently responsible for ITAM, has initiated actions to improve the day-to-day management of the Army's land assets. These initiatives include a standard method that training and natural resource managers can use to measure and predict the effects of training on land condition, and a means by which to link the cost of training land maintenance to the level of training activity (U.S. Army Concepts Analysis Agency [CAA] 1996). Managers will be able to predict levels of Army training that are supportable by installation lands and the level of investment required to ensure that lands are sustained to support future Army training. These efforts are intended to result in a funding process that directly relates the level and type of training conducted at an installation with the unique environmental conditions of each installation.

The LCTA component of the ITAM program has resulted in the accumulation of large amounts of ecological data for more than 45 installations across the United States. These data provide a significant resource that can be used to evaluate vegetation dynamics over time and thereby indirectly evaluate long-term ecological impacts of training activities at each installation. However, the LCTA data alone does not provide all management tools required to evaluate the impacts and costs of specific training land use scenarios.

Currently available models that allow land managers to predict impacts of land use activities on natural resources suffer from one or more general shortcomings. These models are (1) overly general and of little practical value in evaluation of specific management scenarios, (2) overly specific and therefore limited to only one or a few sites, (3) very complex and require extensive calibration with site-specific data that is not available, and (4) the endpoints they evaluate, such as soil erosion, are important but the endpoint is only one of several important aspects of ecosystem dynamics.

Objectives

The objective of the Land-Based Carrying Capacity research project is to develop simulation models that will provide training land managers with tools that can be used to evaluate potential ecological impacts from various training and non-training scenarios in a more comprehensive way. These tools are being developed in a manner consistent with the objectives and implementation of Army standard programs.

Approach

This report describes, in general terms, the development of a land management simulation model designed to meet the dual tasks of maintaining necessary levels of training and practicing good land stewardship on military installations. The approach has been to develop a model that is applicable to most terrestrial ecosystems and in which site-specific calibration can be accomplished using literature and currently available field data. Unlike most other successional or vegetation dynamics models, this model is mechanistically based. No assumptions are made as to successional patterns or changes in species composition following impact of stressors such as drought or fire. Instead, we model growth and responses of individual species and ecological processes to stressors; the model determines the patterns over time.

A two-part approach has been used in model development. First, available LCTA data sets are analyzed for a given installation, using multivariate statistical techniques. These analyses provide (1) a quantitative description of the vegetation, including a classification of the plant communities, (2) a description of the species composition of each of the communities, and (3) an analysis of changes in the vegetation over time. Second, the results of these analyses are used to calibrate an ecosystem dynamics simulation model that has been developed. The model can be used for a wide variety of terrestrial ecosystems and has been applied to forest, shrubland, grassland, and desert systems. The LCTA data, along with data from the literature, are used to calibrate the core model for application to specific communities.

The model has been calibrated and applied to multiple plant communities at five installations: Fort Bliss, TX; Fort Carson, CO; Fort Hood, TX; Fort Riley, KS; and Yakima Training Center (TC), WA.

Mode of Technology Transfer

Models described in this report are intended to be incorporated into evolving Army land-based carrying capacity models such as the Army Training and Testing Area Carrying Capacity (ATTACC) model. The models are also being implemented as a stand-alone PC-based program.

2 LCTA Data Analysis

There are three primary objectives for the analysis of LCTA data:

1. to classify the vegetation at each installation
2. to describe the species composition of the vegetation within each classification unit (plant community)
3. analyze changes in the vegetation over time.

The standard LCTA design at an installation consists of approximately 200 permanent 100-m point intercept transects randomly located across an installation. Data on ground and aerial cover are collected every 1 to 5 years (Diersing, Shaw, and Tazik 1992). The relative cover of each species by plot was used in the multivariate analysis to separate and describe the plant communities.

The multivariate analyses of the vegetation was conducted for each installation and for all five installations combined. The results presented below are from the combined analyses.

Multivariate Statistical Procedures

The multivariate classification procedure follows that described by McLendon and Dahl (1983). Principal component analysis (PCA) was used to establish an unbiased initial grouping of the transects. A stepwise discriminant analysis (SDA) was conducted for each installation separately to reduce the initial number of groups. These analyses reduced the number of potential groups from 48 per installation to 15 to 20 statistically different groups per installation (Figure 1). The resulting 88 groups and 922 transects were then entered into a combined SDA, which resulted in a final classification of 68 groups (plant communities) and placement of each of the 922 transects into its respective group.

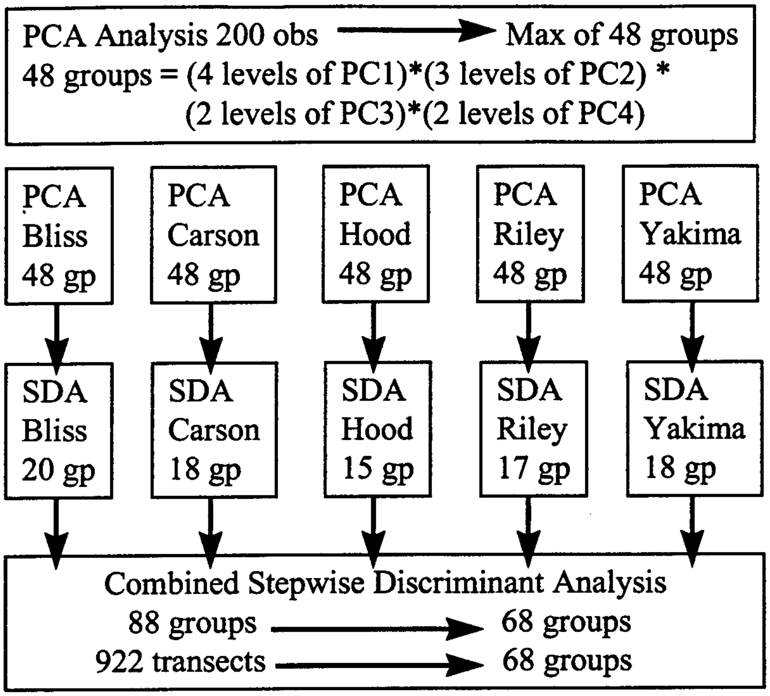

Figure 1. Flowchart of the multivariate statistical analysis of LCTA vegetation data from five installations.

Results of Multivariate Analysis

Analysis of the 1989 LCTA vegetation data sets combined for the five installations resulted in the separation of 68 statistically distinct communities, including 14 woodland, 9 shrubland, 38 grassland, and 7 early-seral communities. On an intra-installation basis, Fort Bliss had the most heterogeneous and Fort Hood the most homogeneous vegetation (Table 1). The earlier installation-only SDA had identified 20 communities at Fort Bliss (Figure 1). However, when placed in the combined SDA, five of these communities were not statistically different from other communities at Fort Bliss, therefore the 20 groups were reduced to 15 in the combined SDA (Table 1). At the same time, the vegetation along some transects at Fort Bliss was more similar to that in Fort Carson (5) and Fort Hood (1) communities than any of the 15 remaining Fort Bliss communities (Table 1).

Stepwise discriminant analysis also provides a measure of the statistical difference among the groups. By averaging these difference values, weighted by number of transects per group, an average difference value can be calculated that compares differences within and between installations (Table 2). Although Fort Hood had the most homogenous vegetation based on number of communities, Yakima TC had the most homogenous vegetation based on statistical differences among its communities (diagonal values, Table 2). Fort

Table 1. Summary of the results of the multivariate analysis of 1989 LCTA vegetation data combined for all five installations.

Installation	Installation Of Origin For Communities					Total
	Bliss	Carson	Hood	Riley	Yakima	
Fort Bliss, TX	15*	5	1	0	0	21
Fort Carson, CO	2	14	0	3	0	19
Fort Hood, TX	0	1	11	0	0	12
Fort Riley, KS	0	0	2	14	0	16
Yakima TC, WA	0	0	0	0	14	14

TOTAL (diagonal) = 68 = 14 woodland, 9 shrubland, 38 grassland, 7 disturbance.

*Values are number of communities classified at each installation.

Riley had the statistically more diverse vegetation (average F-ratio of 150, Table 2), perhaps reflecting the strong ecological differences between the woodlands and grasslands there.

Differences in vegetation among installations overall was greatest for Yakima TC (highest off-diagonal values, Table 2). Yakima is located farthest away from the other four installations and its vegetation is dominated by cold desert species. The vegetation of Forts Bliss, Carson, and Hood are approximately equal in similarity. These three installations are in semiarid regions and share a number of the same species.

This multivariate analysis provides an excellent method for comparing vegetation across broad geographical and ecological scales. But it also allows for detailed comparisons at the landscape scale within an installation. Table 3 represents relative cover of the major species of 14 plant communities, 5 woodland and 9 grassland, at Fort Riley, KS.

Table 2. Average F-ratio values testing significance of statistical differences in vegetation within (diagonal) and between (off-diagonal) installations.*

	Bliss	Carson	Hood	Riley	Yakima
Fort Bliss, TX	67.00	68.89	74.80	131.85	469.54
Fort Carson, CO	68.89	55.70	65.47	132.82	525.33
Fort Hood, TX	74.80	65.47	45.83	126.09	578.96
Fort Riley, KS	131.85	132.82	126.09	150.88	512.82
Yakima TC, WA	469.54	525.33	578.96	512.82	41.26

*Results are taken from the stepwise discriminant analysis of the 1989 LCTA data set combined for all five installations.

Table 3. Relative cover values (%) of the major species within each of the 14 Fort Riley plant communities, as identified by multivariate analysis of the 1989 LCTA data.

Community	Species and Relative Cover					
W1 Mapo/Ceoc-Elvi*	Ceoc 33		Mapo 52			
W2 Ceoc-Ulru/Juni	Ceoc 31	Juni 14	Mapo 01	Qumu 03	Ulam 10	Ulru 23
W3 Qumu-Ceoc-Ulru	Ceoc 20	Juni 13	Mapo 01	Qumu 26	Ulam 10	Ulru 14
W4 Qumu-Ulam/Juni	Ceoc 09	Juni 20		Qumu 31	Ulam 28	Ulru 03
W5 Juvi-Qumu-Ulru	Ceoc 09	Juni 01	Juvi 26	Qumu 21	Ulam 09	Ulru 13
G1 Ange/Sonu-Bocu	Ange 49	Bocu 09	Pavi 01	Scsc 03	Sonu 11	Spas 01
G2 Ange/Sonu-Spas	Ange 42	Bocu 07	Pavi 05	Scsc 06	Sonu 25	Spas 08
G3 Spas-Sonu/Ange	Ange 14	Bocu 06	Pavi 07	Scsc 11	Sonu 21	Spas 26
G4 Sonu-Scsc/Ange	Ange 18	Bocu 08	Pavi 02	Scsc 26	Sonu 31	Spas 10
G5 Sonu-Spas/Pavi	Ange 03	Brin 02	Pavi 05	Scsc 03	Sonu 37	Spas 33
G6 Sonu-Spas-Brin	Ange 05	Brin 21	Pavi 04	Scsc 04	Sonu 29	Spas 24
G7 Brin/Sonu-Spas	Ange xx	Brin 37	Pavi 01	Scsc 00	Sonu 12	Spas 13
G8 Brin/Spas-Popr	Ange 03	Brin 72	Pavi 01	Scsc 00	Sonu 03	Spas 10
G9 Brja-Ange-Spas	Ange 19	Brin 04	Brja 29	Scsc 01	Sonu 02	Spas 12

*All codes are from the U.S. Department of Agriculture *National List of Scientific Plant Names, Volume 1, List of Plant Names.*

Discriminant analysis can also be used to evaluate temporal changes in vegetation. The LCTA data sets are especially useful in this task. To conduct this analysis, we entered data from the same transects but from different years. An analysis for Fort Riley was conducted using 1989 and 1994 data. The Ange/Sonu-Bocu community (G1) in 1994 was statistically different from what it was in 1989. This was largely the result of an increase in tall dropseed (Spas) and decreases in big bluestem (Ange) and sideoats grama (Bocu) from 1989 to 1994 (Table 4). At the same time, there was a shift in the Ange/Sonu-Spas (G2) community toward the Ange/Sonu-Bocu (G1) community. This was the result of decreases in big bluestem (Ange), Indiangrass (Sonu), and sideoats grama (Bocu) during the 5 years (Table 4).

Table 4. Changes in species composition (% relative cover) in the grassland communities at Fort Riley 1989 and 1994.

Community	Ange		Sonu		Spas		Scsc		Bocu		Brin		Pavi	
	89	94	89	94	89	94	89	94	89	94	89	94	89	94
G1 Ange/Sonu-Bocu*	49	43	11	13	6	11	3	4	9	1	1	2	6	10
G2 Ange/Sonu-Spas	41	40	25	20	8	6	6	6	7	2	1	1	5	10
G3 Spas-Sonu/Ange	14	35	21	16	26	16	11	10	6	4	0	0	7	2
G4 Sonu-Scsc/Ange	18	23	31	18	10	9	26	15	8	2	1	0	2	7
G5 Sonu-Spas/Pavi	3	7	34	19	33	24	3	3	0	0	2	5	5	5
G6 Sonu-Spas/Brin	5	8	24	16	26	18	4	2	1	0	22	19	4	4
G7 Brin/Sonu-Spas	0	1	12	21	13	11	0	0	0	0	37	52	1	1
G8 Brin/Spas-Popr	3	2	3	3	6	6	3	0	0	0	70	54	1	2
G9 Brja-Ange-Spas	19	2	2	1	11	7	1	1	3	0	4	20	1	0

* All codes are from the U.S. Department of Agriculture *National List of Scientific Plant Names, Volume 1, List of Plant Names.*

Plans for Statistical Development

We plan to continue the analyses of LCTA data sets in four primary task areas. First, we plan to conduct more detailed analyses of spatial patterns at each of the five installations. In particular, we are interested in analyzing for patchiness within individual transects, and using this information in the development of the spatial module of our simulation model. Second, we plan to conduct further analyses of the temporal aspects of the vegetation comparing changes over time across the broad geographical and ecological scales encompassed by these LCTA data. We would also like to continue the temporal analyses at each installation as LCTA data become available for more years. Third, we would like to test the accuracy of existing vegetation maps at each of the installations by use of LCTA data. If the accuracy of the current vegetation maps is found to be unacceptable, we would like to develop new maps based, in part, on our analyses of LCTA data. Fourth, we would like to expand the analysis of LCTA data to other installations.

3 Development Of The Simulation Model

Analysis of the LCTA data provides a large body of useful information. However, it cannot provide: (1) predicted ecological responses to natural and anthropogenic stressors or (2) the "turn key" decision-making tool required by trainers and managers. The data provided by LCTA are descriptive, and statistical inference can be made. The data are very useful in documenting what is there and what happens to it over time. But to meet the objective of supplying the Army with a training and environmental decision-making tool, we need more than descriptive data and statistical inference. We need a method for predicting ecological responses before they occur. This requires a mechanistic, rather than statistical or descriptive, model. Such a model, if adequately developed, would also become a central component of the decision-making tool used to translate ecological responses into management objectives and restrictions.

Therefore, there are two parts to this modeling effort. One is to produce a simulation model that can adequately predict ecological responses to various stressors at site, landscape, and installation levels. This model must supply site-specific information at an acceptable level of accuracy, but also must be robust enough to be used at any Army installation with a minimum amount of calibration. The second part of the task is to combine this ecological dynamics model with a decision-making model so the resulting alternative management decisions can be predicted and evaluated.

To date, we have concentrated on the first task, the development of the ecological dynamics model, because the first step is required before the second can be taken. We present an overview of its structure and an example of some of its results in the following sections. We have completed the conceptual design of the decision-making module and have started development of its software.

Prototype Ecological Dynamics Model

A primary requirement of the model is that it be able to model ecological dynamics on a mechanistic basis. The approach is to model how ecosystems function and what they consist of at some starting point. The model then produces the patterns that we recognize as disturbance and succession. The measure of success then becomes how well the predicted patterns match the actual patterns.

The current version of the model consists of four modules (climate, soil, plant, and animal), five stressors (water, nitrogen, fire, herbivory, and trampling), and three ecological processes (decomposition/mineralization, succession, and competition). Spatial and erosion components are being added to the next version of the model, and contaminants can be added now, if desired (Figure 2).

The climate module includes precipitation, season, evaporation, and light; temperature will be added at a later date. For now, the seasonal variable is adequate to account for temperature responses. The soil module divides a site-specific profile into a series of layers, each layer corresponding to a soil horizon or sub-horizon (Figure 3). Each layer has a characteristic available water holding capacity (WHC) and initial available nitrogen (N), total N, and organic matter (OM) level. The plant module, which can consider multiple plant species per community, consists of structural characteristics (including root architecture), potential growth rate, seasonal growth rate (including flowering), growth allocation factor, and water- and N-use efficiencies for each major species in the community. The animal module currently consists only of a herbivory factor. Number, biomass, and growth rate for each major animal species, along with the respective food webs, are being added.

Ecosystem Dynamics	
Climate Module:	precipitation, season, evaporation, temperature, light
Soil Module:	horizons, moisture, nutrients, contaminants
Plant Module:	roots, aboveground, biomass, nitrogen
Animal Module:	number, biomass, food webs
Process Module:	decomposition, succession, competition
Stressor Module:	herbivory, fire, drought, trampling
Spatial Module:	height, area, multiple scales
Landscape Module:	slope, erosion, ecosystem linkages

Figure 2. Modules and variables in, or being added to, the community dynamics simulation model.

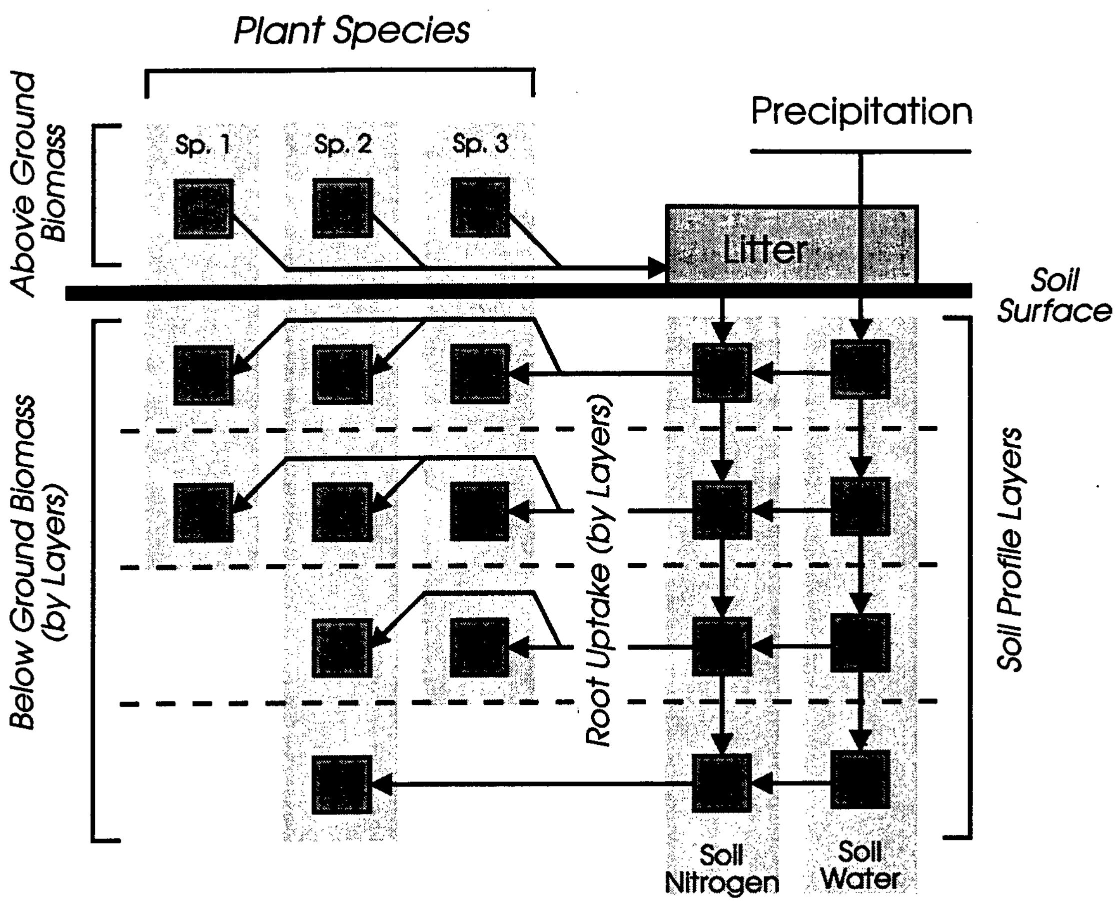

Figure 3. Schematic illustrating the structural organization of the soil and plant modules of the community dynamics simulation model.

Each variable in the model is initially calibrated based on the best site-specific data available. Precipitation is based on historical data (daily), but can also be modeled stochastically. Daily rainfall enters the profile and is distributed downward among the layers based on WHC (Figure 3). Daily evaporation can remove soil water from the upper layer. Plant roots remove soil water on a daily basis, based on potential growth rate, water-use efficiency, season, and competition with other species. Growth is also constrained by N availability and presence of contaminants. Decomposition, by layer, supplies the available N pool and is dependent on available water and organic matter.

Plants produce new growth based on maximum potential growth rate (adjusted monthly), amount of aboveground biomass (or seed biomass in the seedbank), and availability of water and N. New growth (biomass) is allocated to the respective plant parts (roots, trunk, stems, leaves, flowers/seeds) based on species-specific allocation factors. Aboveground biomass can also be removed by herbivory, fire, and senescence. Aboveground and belowground biomass can be removed by moisture stress and maintenance respiration.

Belowground competition is modeled on the basis of proportional root biomass within a soil layer and absorption efficiency of roots (species-specific). Aboveground competition is modeled on the basis of effect of shading. Once the spatial component is added, available surface space will also influence competition.

In the model, fire affects plants by removal of aboveground biomass (total in the case of a crown fire, partial in the case of a surface fire) and nutrient release. Plant response following fire is species specific (e.g., resprout, regrowth only from seeds). The fire regime can be set by month, annual frequency, and intensity. Herbivory is modeled as monthly removal of designated plant parts (e.g., leaves, leaves and stems). The herbivory rate can be altered. Trampling is modeled in a manner similar to herbivory and fire (amount and type of tissue removed).

The model provides a series of printouts giving monthly plant biomass and production (by species and by plant part), N dynamics (by soil layer, plant species, and plant part), and water dynamics (by layer). These printouts can be easily loaded into a spreadsheet for graphical displays. The spatially-explicit version of the model will display spatial patterns of species, communities, and soil variables at multiple spatial scales during the simulation runs.

Plans for Model Development

Calibration of the model is currently based on LCTA and literature data. We have recently completed several greenhouse and field experiments that will supply data on the effects of moisture, nitrogen, and competition on growth and development of nine of the major species used in the model. As soon as these data are analyzed, the results will be incorporated into the model to increase its accuracy.

Field plots are being established at some of the installations and at three supporting sites. These plots will serve two purposes. First, baseline data taken at the beginning of the experiments will allow for more accurate calibration of the model for the respective communities. Second, they will be used as validation plots. Data collected from the plots over time will be used to test the accuracy of the model predictions in relation to actual field data.

We are in the process of adding the complete animal module to the model. This will allow modeling of animal population dynamics and will provide for a more realistic modeling of animal impacts on vegetation.

The current version of the model bases all dynamics on an average square meter, and does not represent the spatial heterogeneity at the multiple scales characteristic of real ecosystems. We are working on a major revision that incorporates spatial aspects of the communities and will allow for modeling of landscape-level dynamics. An early prototype version of the spatial component can scale ecosystem dynamics from 1x1 m to 100x100 m (Figure 4). Our approach is to represent multiple scales simultaneously. Most herbaceous species will be modeled on the 1x1 m scale. Shrubs and small-scale ecological processes (e.g., decomposition and mineralization; bunchgrass patchiness) will be modeled on a slightly larger scale (2x2 m), in which four replicates of the 1x1 m scale are represented. Trees will be modeled on a 10x10 m scale, with 25 replicates of the 4x4 m scale added. The 100x100 m scale will be the basic scale for simulating community-wide processes and ecotones. Larger scales, such as 1x1 km and 10x10 km, will be used to model landscape, training area, and installation-wide characteristics. In each case, aggregates of the smaller scales will be used to define the larger scales.

We have also begun developing the decision-making module to interface with the ecological model (Figure 5). When completed, this will provide trainers and managers with a PC-based tool they can use to translate ecological impacts into training and management allocation decisions (Figure 6).

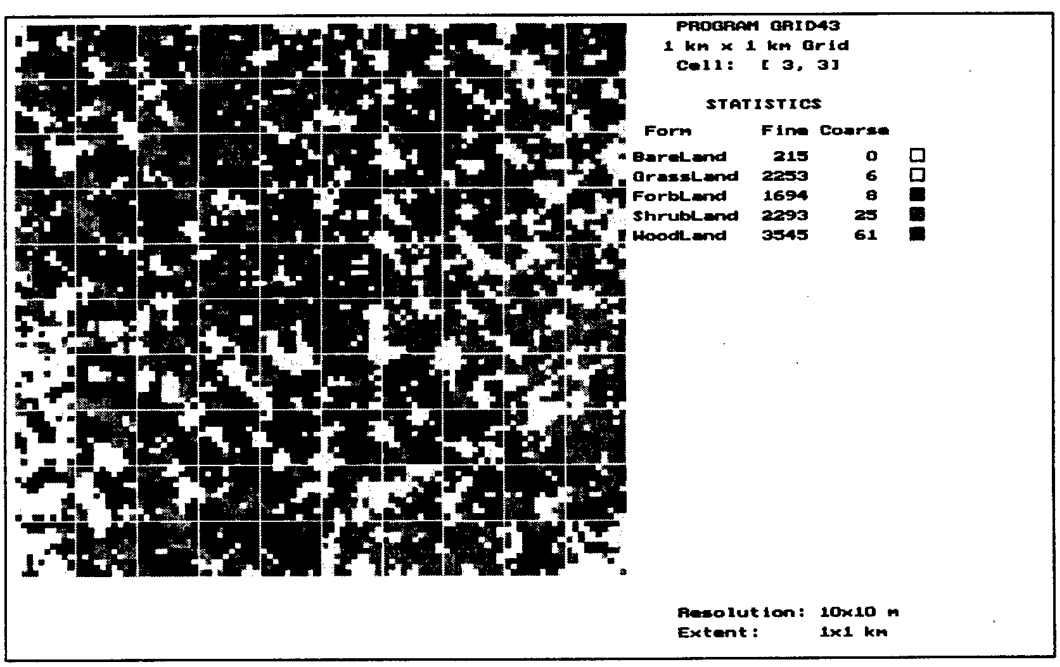

Figure 4. Sample output from the prototype spatial module of the community dynamics simulation model.

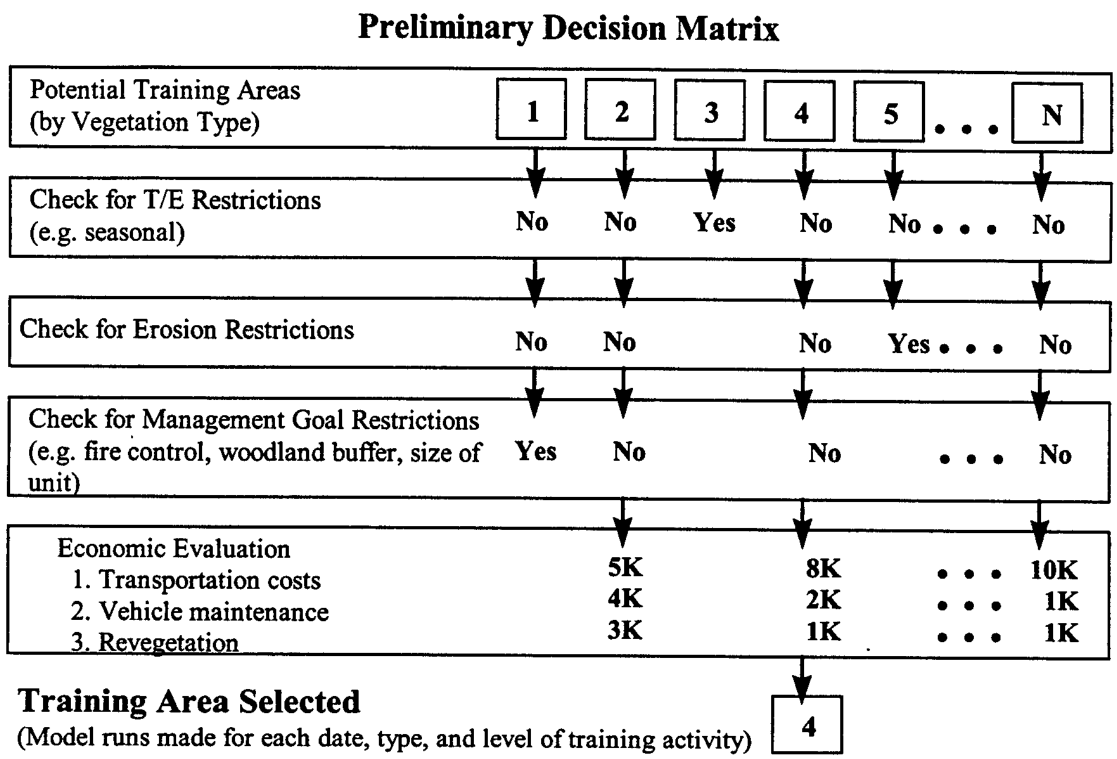

Figure 5. Conceptual overview of the prototype decision-making module for the community dynamics simulation model.

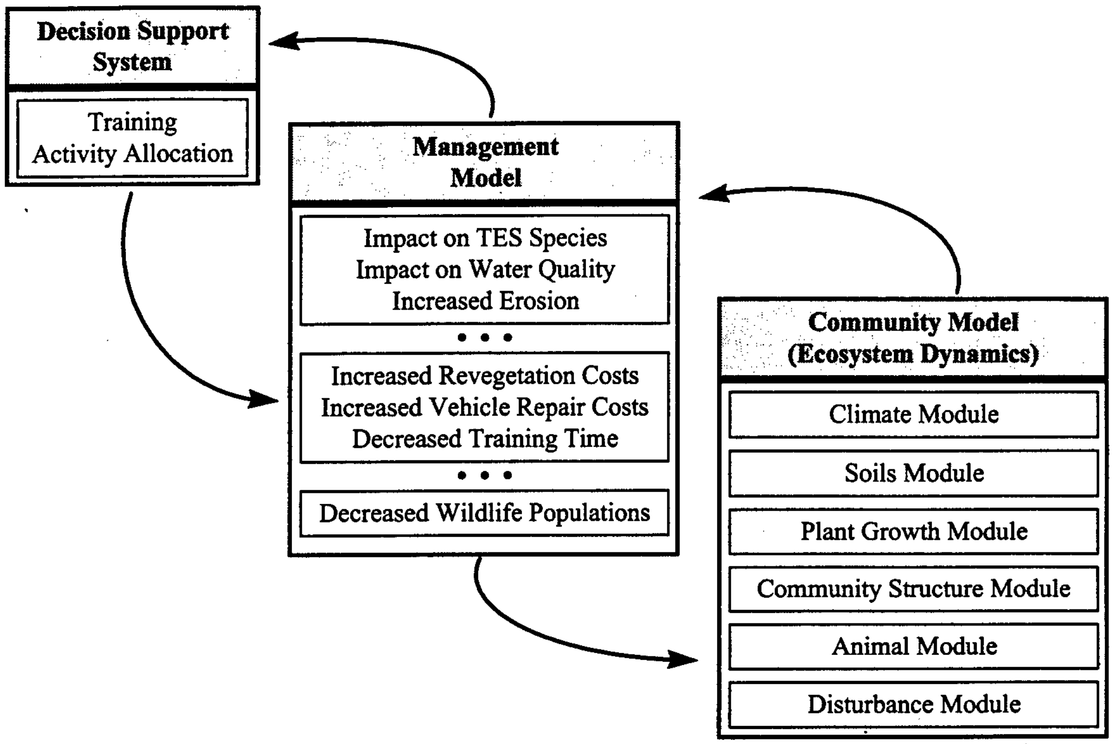

Figure 6. Schematic illustrating the conceptual linkages among the ecological, management, and decision-making modules of the community dynamics simulation model.

In summary, we are developing a simulation model that can accurately predict

1. responses of ecological communities to disturbance and ecological stress
2. responses of disturbed communities to remediation/restoration efforts
3. maximum sustainable use under various scenarios and ecological conditions.

We believe this is possible because we

1. base the model on ecological mechanisms controlling ecosystem dynamics
2. calibrate a general core model to site-specific conditions for each community
3. test the model with field validation experiments
4. will adapt the model to sufficiently large scales to accommodate realistic training activity scales.

References

Diersing, V.E., R.B. Shaw, and D.J. Tazik, "The U.S. Army Land Condition-Trend Analysis Program," *Environmental Management*, 16(3):405-414, 1992.

Field Manual (FM) 100-5, *Operations*, Headquarters, Department of the Army (HQDA), 14 June 1993.

Goran, W.D., L.L. Radke, and W.D. Severinghaus, *An Overview of the Ecological Effects of Tracked Vehicles on Major U.S. Army Installations*, 75 pp, USACERL Technical Report N-142/ADA126694 February 1983.

Johnson, F.L., "Effects of Tank Training Activities on Botanical Features at Fort Hood, Texas," *The Southwestern Naturalist*, 27(3):309-314, 1982.

Macia, T.E., "Army Reinvents Training Land Protection Operators Take the Lead." in: *Proceedings of the 22nd Environmental Symposium and Exhibition of the American Defense Preparedness Association*, Orlando, Florida, 1996.

McLendon, T., and B.E. Dahl, "A method for mapping vegetation utilizing multivariate statistical techniques," *Journal of Range Management*, 36:457-462, 1983.

Severinghaus, W.D., *Effects of Tracked Vehicle Activity on Higher Vertebrate Populations at Army Installations*, USACERL Technical Report N177/ ADA142653, April 1984.

Severinghaus, W.D., and M.C. Severinghaus, "Effects of Tracked Vehicle Activity on Bird Populations," *Environmental Management*, 6(2):163-169, 1982.

Shaw, R.B., and V.E. Diersing, "Tracked vehicle impacts on vegetation at the Pinon Canyon Maneuver Site, Colorado," *Journal of Environmental Quality*, 19(2):234-243, 1990.

Training Circular (TC) 25-1, *Training Land*, U.S. Army Training Support Center (USATSC), 31 September 1991.

Trumbull, V.L., P.C. Dubois, R. Brozka, and R. Guette, "Military Camping Impacts on the Ozark Plateau," *Journal of Environmental Management*, 40:329 – 339, 1994.

U.S. Army Concepts Analysis Agency, *Evaluation of Land Values Study*, USACAA Technical Report CAA-SR-96-5, 1996.

U.S. Department of Agriculture, National List of Scientific Plant Names, Volume 1, *List of Plant Names*, SCS-TP-159 (Soil Conservation Service, U.S. Department of Agriculture, Government Printing Office, Washington, DC, January 1982).

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