ASSESSMENT OF CUMULATIVE TRAINING IMPACTS FOR SUSTAINABLE MILITARY LAND CARRYING CAPACITY AND ENVIRONMENT: PREDICTION OF ENVIRONMENT QUALITY

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History

- Installation studies accessing environmental factors began with the formation of the US Army Environmental Command in 1972
- Primarily focused on impacts of military training on individual characteristics of land condition, i.e. vegetation, soil
- Land Condition Trend Analysis (LCTA) helped monitor land condition
  - Recently changed to Range and Training Land Assessment (RTLA)

Justification

- U.S. Army owns and cares for more than 12 million hectares (DEPARC, 2007)
- Training activities cause landscape and environmental degradation e.g., landscape fragmentation, soil erosion, etc.
- Degradation restricts military training
- More advanced methods to model and predict land condition for the U.S. Army installations are needed.

Objective

- Develop models to predict military land condition
  - Accounts for:
    - Ground cover
    - Slope
    - Distance to road
    - Landscape fragmentation
    - Landsat TM data
  - Determine significant parameters for further data collection and analysis

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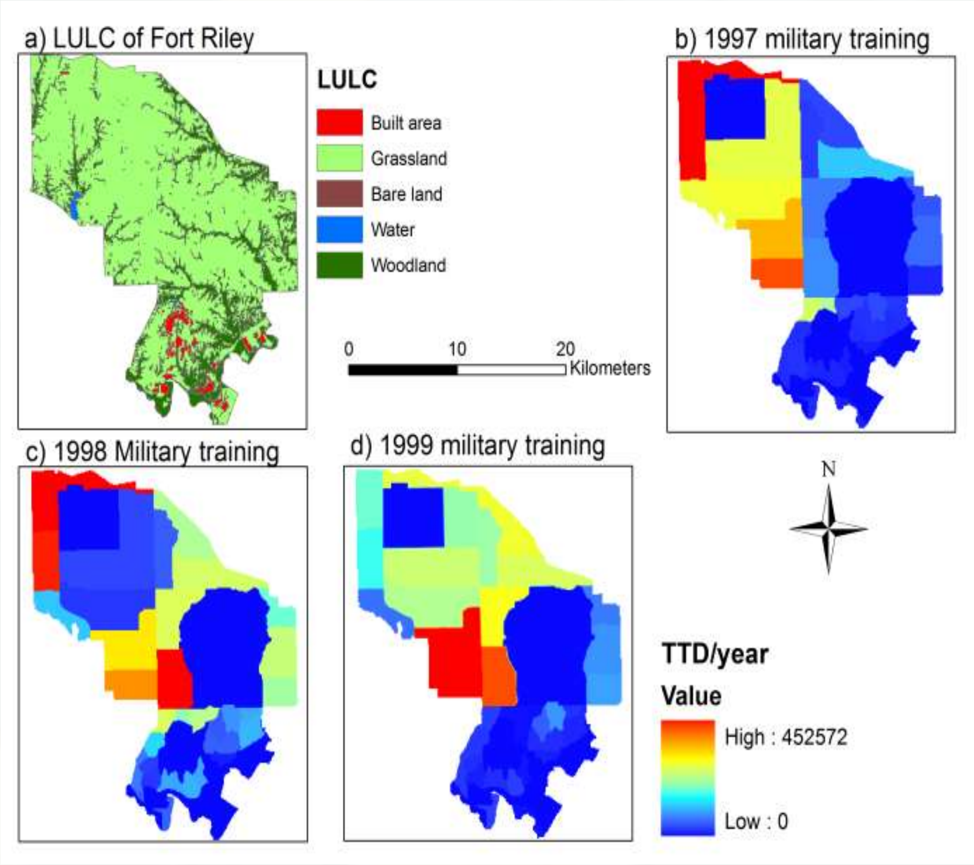
Study addressed the following questions:

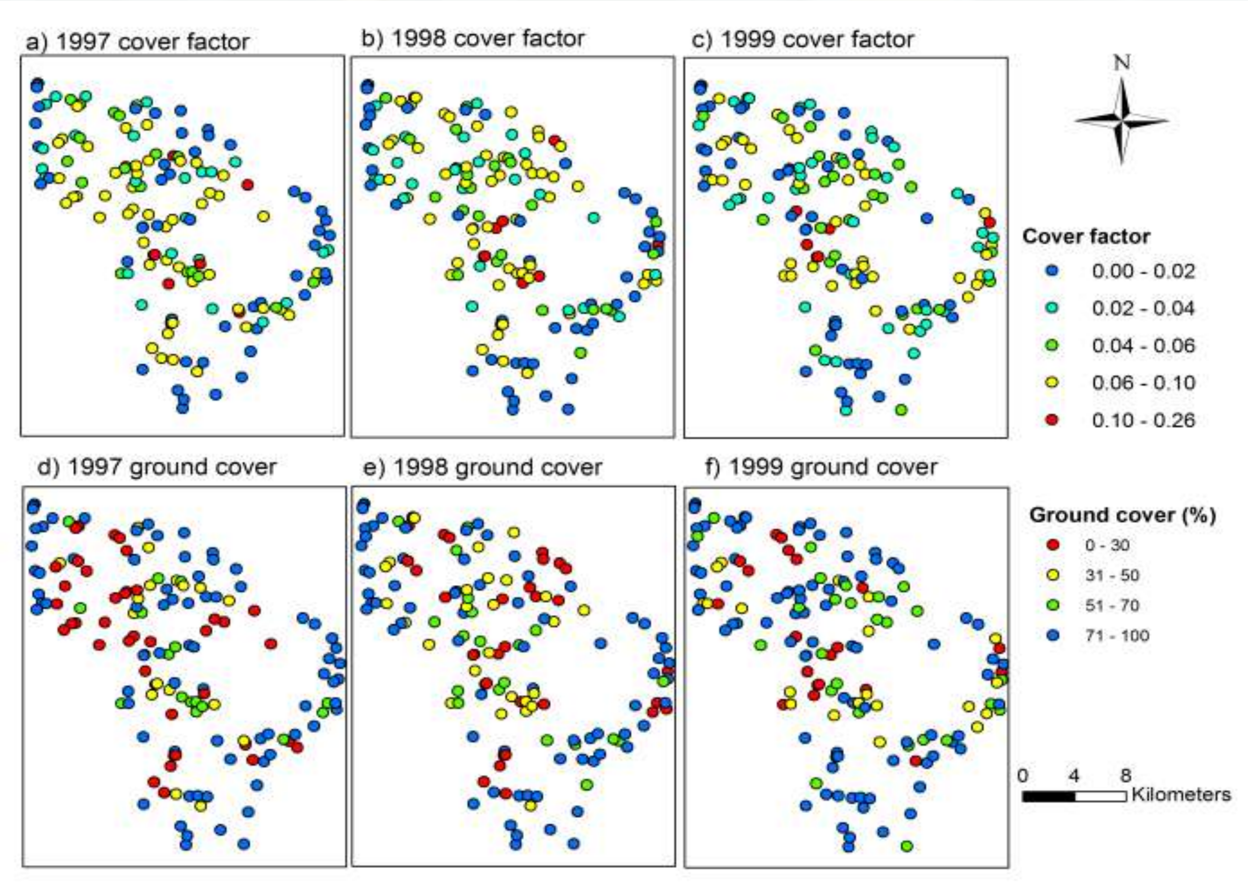
- What are the main factors driving land condition dynamics?
- Whether TM images improve prediction of land condition?
- Does nonlinear regression improve accuracy of land condition prediction compared to linear regression?
- Does historical land condition and military training intensity data increase the accuracy of land condition prediction?

Landuse & Military Training

- Fort Riley 41,154 ha
- Dominated by grasses with shrubs, woodlands
- Training activities began 1940’s



Cover & Ground Factor



154 stratified random plots (RTLA) with ground cover, vegetation cover, and minimum rain drop height measured.

Study Area Data

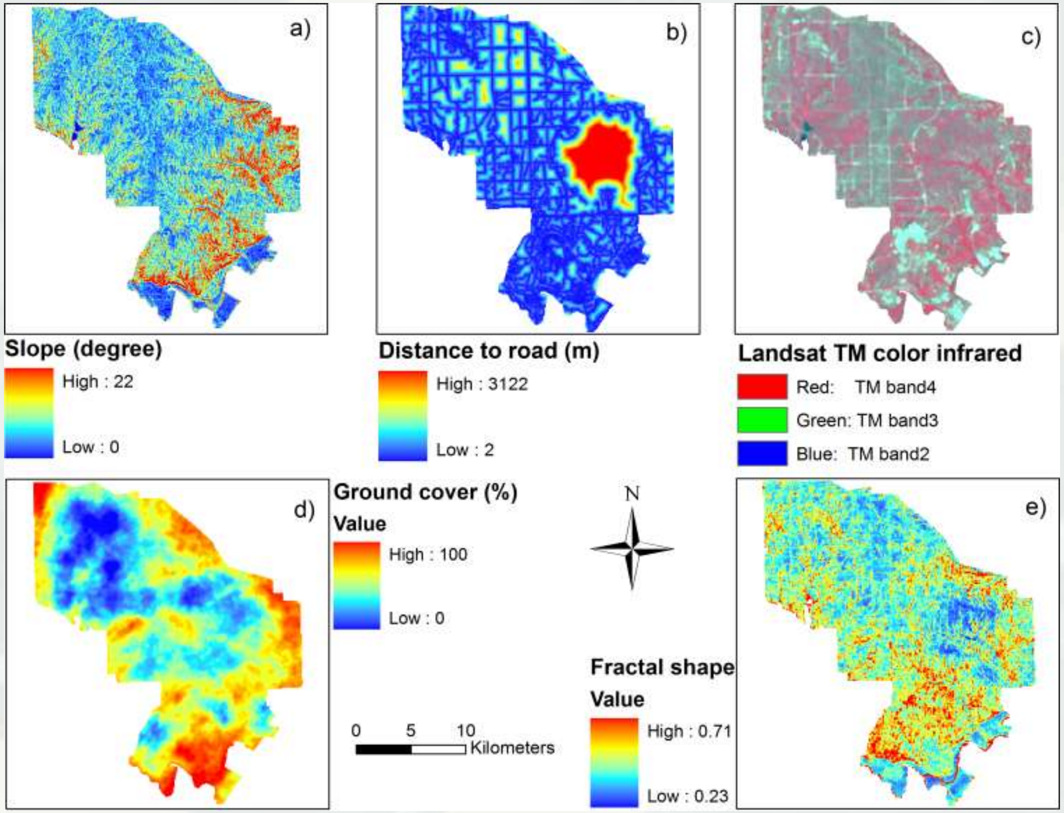
A) Slope

B) Distance to road

C) Landsat TM images

D) Ground cover map created using co-simulation

E) Fractal shape index using image segmentation



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Land Condition

- Dependent variable (Y) – land condition measured using soil erosion relevant ground and cover factor and ranges from 0 to 1
- Independent variables (X_k, k = 1, …, m) - measurable:
  - Military training intensity (TTD / year) TTD=Total Training Days
  - Ground cover (%)
  - Landscape fragmentation (combination of patch perimeter and fractal shape)
  - Distance of a location to road (m)
  - Slope (degree)
  - Landsat TM band 1, band 2, band 3, band 4, band 5, and band 7

Modeling

Linear Model

$$Y = a_0 + \sum_{k=1}^{m} a_k X_k$$

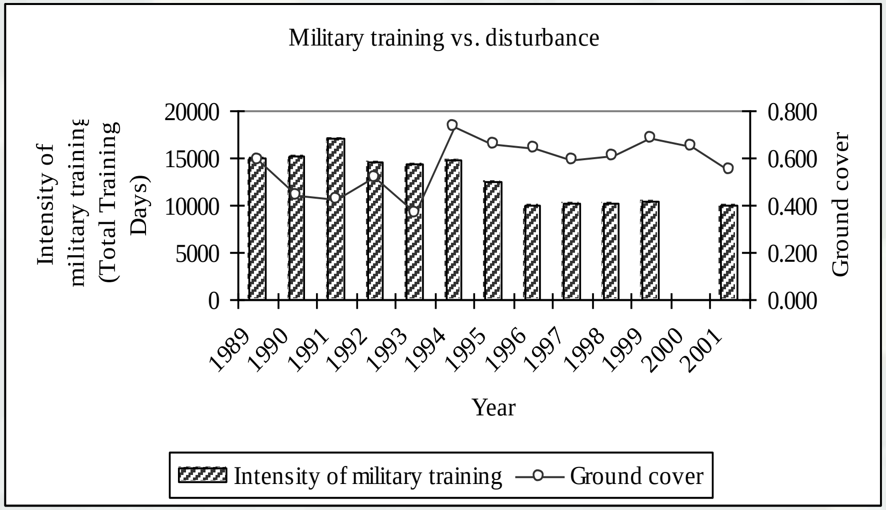
Nonlinear Model

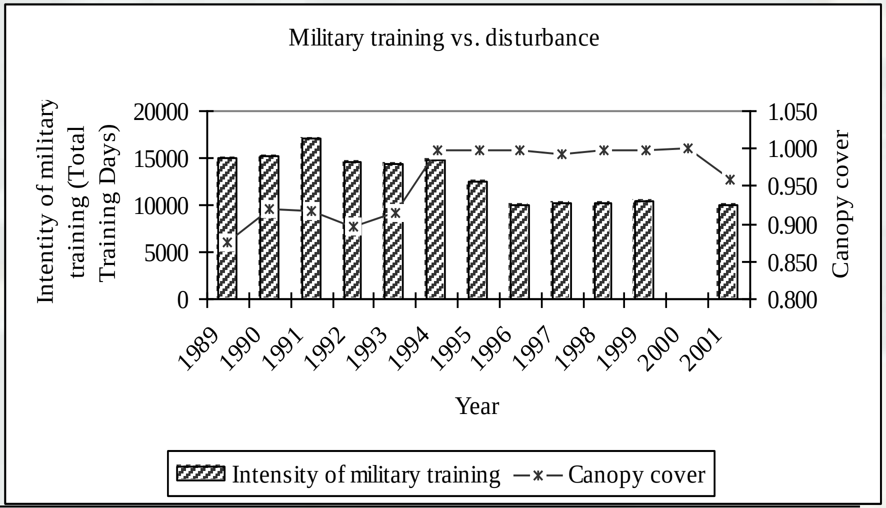
$$Y = \frac{\exp(a_0 + \sum_{k=1}^{m} a_k X_k)}{1 + \exp(a_0 + \sum_{k=1}^{m} a_k X_k)}$$

- Comparisons of model and predicted results were made based on root mean square error and coefficients of determination:
  - with vs. without TM images
  - with vs. without stepwise
  - with vs. without historical land condition variables.

Training vs. Ground Cover

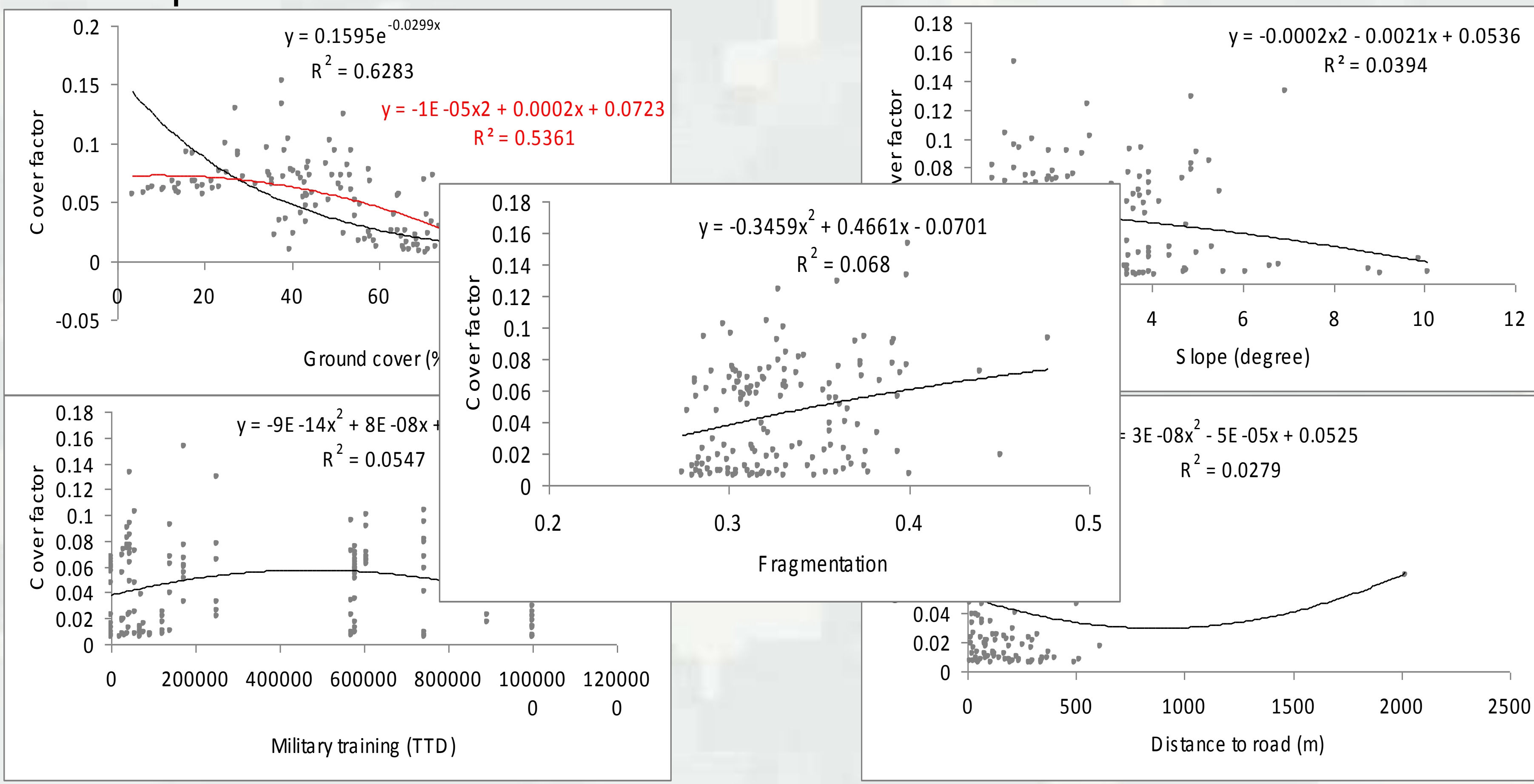
- Training disturbed ground cover as expected
  - Led to landscape degradation
- Earlier years higher intensity, less cover
- Later years lower intensity, more cover, and became more steady





Cover Factor

The variables were significantly correlated with C factor for years 1997, 1998, and 1999 (significant R2 = 0.0253 at a risk level of 5%). Ground cover, landscape fragmentation, military training had higher correlation. Examples for 1997.



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1997 Review

	R square	Error %	R square	Error %
	Linear 1997 without TM		Linear 1997 with TM	
All variables	0.539	50.89	0.615	55.86
Stepwise	0.532	50.55	0.602	48.43
	Nonlinear 1997 without TM		Nonlinear 1997 with TM	
All variables	0.491	51.19	0.576	46.96
Stepwise	0.476	51.96	0.548	48.41

Stepwise regression included:

- Ground cover
- Fragmentation
- TM 1 & TM 7

1998 Review

	R square	Error %	R square	Error %
	Linear 1998 without TM		Linear 1998 with TM	
All variables	0.466	49.88	0.540	123.16
Stepwise	0.420	51.79	0.521	61.62
	Nonlinear 1998 without TM		Nonlinear 1998 with TM	
All variables	0.498	48.06	0.578	47.68
Stepwise	0.435	50.97	0.558	67.15

Stepwise regression included:

- Ground cover
- Military training intensity
- Fragmentation
- TM 2, TM 5 & TM 7

1999 Review

	R square	Error %	R square	Error %
	Linear 1999 without TM		Linear 1999 with TM	
All variables	0.543	68.27	0.564	189.46
Stepwise	0.537	67.30	0.552	75.60
	Nonlinear 1999 without TM		Nonlinear 1999 with TM	
All variables	0.565	53.74	0.625	49.90
Stepwise	0.561	53.98	0.588	52.31

Stepwise regression included:

- Ground cover
- Military training intensity
- Distance to road
- TM 4

All Years

- Nonlinear regression was much better than linear
- Adding the historical land conditions could increase the accuracy of prediction
- Historical military training intensity was excluded in the stepwise regression
- Current and historical ground cover, historical cover factor, current year TM2, TM4, TM5, and TM7 were involved in stepwise regression

	Use of historical data			
	1998: 1998+1997		1999: 1999+1998+1997	
	R square	Error %	R square	Error %
Linear & Stepwise	0.640	48.58	0.573	86.70
Nonlinear	0.653	39.31	0.571	52.01

Nonlinear Equations

Three best stepwise nonlinear regression models:

$$\hat{CF}_{97} = \frac{Exp\{-0.992 + 3.812\,Frag - 0.017\,GC - 0.046\,TM1 + 0.036\,TM7\}}{1 + Exp\{-0.992 + 3.812\,Frag - 0.017\,GC - 0.046\,TM1 + 0.036\,TM7\}}$$

$$\hat{CF}_{98} = \frac{Exp\{-4.585 + 8.3CF_{97} + 0.010GC_{97} - 0.025GC_{98} + +0.132TM2_{98} - 0.039TM5_{98} + 0.045TM7_{98}\}}{1 + Exp\{-4.585 + 8.3CF_{97} + 0.010GC_{97} - 0.025GC_{98} + +0.132TM2_{98} - 0.039TM5_{98} + 0.045TM7_{98}\}}$$

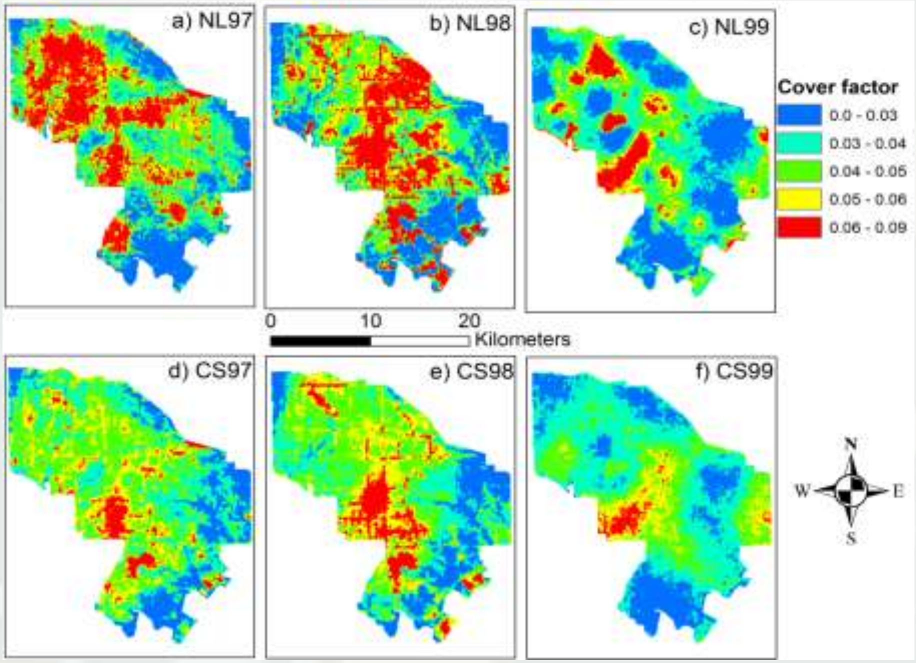
$$\hat{CF}_{99} = \frac{Exp\{0.281 + 5.573CF_{98} - 0.033GC_{99} - 0.017TM4_{99}\}}{1 + Exp\{0.281 + 5.573CF_{98} - 0.033GC_{99} - 0.017TM4_{99}\}}$$

Mapping Results

Comparison of maps from nonlinear (NL) regression with the maps by co-simulation (CS) (Wang et al., 2007).

All the averages fell within the confidence intervals except for 1998's regression and 1999's co-simulation.

Spatial patterns were similar, but the regression models led to greater map averages.



Conclusions

- Ground cover, cover factor, and Landsat TM variables were most often used in stepwise regression.
  - ► Ground cover and military training intensity had the highest correlation with cover factor.
  - ► Historical military training intensity was excluded in the stepwise regression because the historical cover factor and ground cover explained the cumulative impacts of military training.
  - ► Adding historical land condition variables increases the accuracy of prediction.
  - ► Adding TM images may slightly improve land condition predictions.

Conclusions

- Stepwise regression greatly reduced number of the independent variables without significant loss of accuracy.

- Nonlinear regression modeling predictions were more accurate than linear regression modeling predictions.

- The coefficients of determination for all the models varied from 0.42 to 0.70.

Acknowledgements

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