Modeling the Death of Sugar Maple as a Function of Soil/Site Characteristics

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Introduction

The decline of sugar maple continues to cause concern. Several studies of sugar maple mortality exist (Horsley et al. 2000; Long et al. 2009), but most evaluations focus on an area of known decline from Pennsylvania to New Hampshire. Our study was designed to span the range of the sugar maple across the northern region, including plots on a wide variety of soils and sites.

Methods

Phase 2 and 3 plots in the NRS were joined and extracted from the Forest Inventory Analysis Database (FIADB) (USDA Forest Service 2009). These data were collected between 2000 and 2006. Plots were included in the analysis if at least three sugar maple trees (d.b.h. > 1 inch) were measured on the plot.

Statistical analyses were conducted in three phases: 1) ordinary linear regression on all plots, 2) logistic regression on the presence and absence of dead sugar maple, and 3) ordinary linear regression of those plots with dead sugar maple. These analyses were completed in using stepwise techniques R (R Development Core Team 2008).

Results and Discussion (Phase 1)

A total of 219 plots were selected that met the defined criteria of more then 3 maple trees and the collection of soil chemistry data. Many predictors were available to the model (Table 1).

Our first effort was directed at **modeling the fraction of dead sugar maple** trees as the response in a multiple regression model. The inverse of this fraction was suggested by Box-Cox analyses. If successful, this would be a simple and complete model of sugar maple mortality.

This investigation collapsed because of **too many plots without dead sugar maple** (Fig. 1).

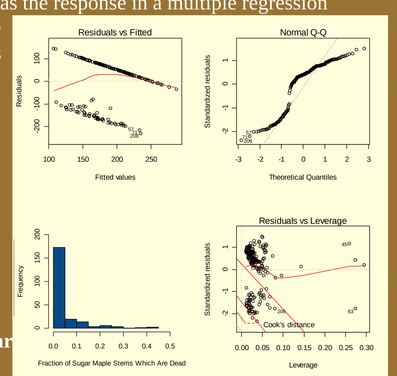

Figure 1.—Diagnostic plots for phase 1 analyses.

Objective

In this study, we are modeled both the presence of dead sugar maple and the amount of sugar maple mortality in the forests of the northern region as a function of soil and site charateristics measured by the Forest Inventory and Analysis program.

Results and Discussion (Phase 2)

Given our trouble with modeling the fraction of dead sugar maple on FIA plots, we attempted to **model the presence or absence** of dead sugar maple using logistic regression. This was accomplished using the `binomial` family of `glm()`.

As before, 219 plots were used to parameterize the model, and a number of terms were available as predictors (Table 1).

Models were built using two starting points: 1) intercept only and 2) a full model. Stepwise regression found the best model using AIC as the selection criteria. Similar models were selected from different starting points

d ~ log(Mg:Mn) + geo — *AIC=240.62*[(1)]

d ~ log(Mg:Mn) + geo + BA + log(ekp) + √(ECEC) + pH + slope — *AIC=229.92*[(2)]

d ~ log(Mg:Mn) + geo + BA + log(ekp) + √(ECEC) + pH — *AIC=228.85*[(2)]

d ~ log(Mg:Mn) + geo + BA + log(ekp) + √(ECEC) — *AIC=228.81*[(2)]

d ~ log(Mg:Mn) + geo + BA + log(ekp) — *AIC=228.65*[(2)]

d ~ log(Mg:Mn) + geo + BA — *AIC=228.39*[(2)]

Table 1. Parameters available for modeling sugar maple mortality.

Site characteristics	Soil characteristics	
Latitude	pH	
Longitude	ECEC (square root transform)	
Drought index	Ca:Al ratio	
Ecoprovince	Mg:Al ratio	
Forest type group	Mg:Mn ratio	
Basal area	Exchg. K percentage	(ekp)
Stand age	Exchg. Na percentage	(esp)
Stand size class	Exchg. Ca percentage	(ecp)
Site class	Exchg. Mg percentage	(emp)
Slope	Exchg. Al percentage	(eap)
Aspect		
Disturbance		
Geology		

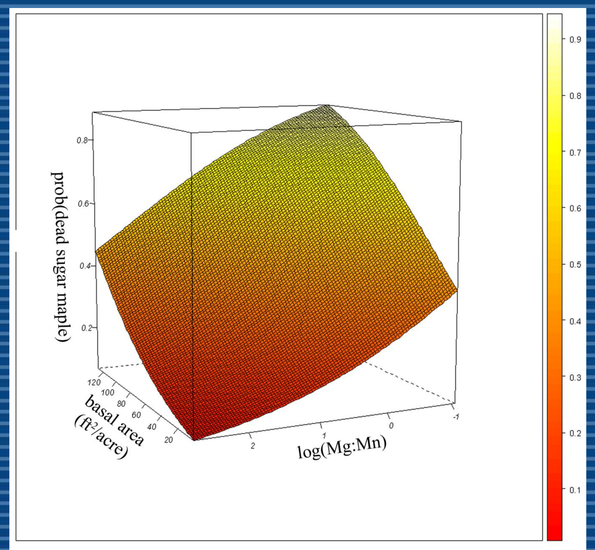

Figure 2.—Response surface for the best phase-2 model, conditioned on geology. Details on the effects of each predictor (including geology) are described using odds below.

Results (Phase 2, continued)

The coefficients of the best phase 2 model are included below.

	Est.	Std.Error	Z	Pr(>|z|)
BA	0.0197	0.0057	3.47	0.0005
Log(Mg:Mn)	-0.5959	0.2198	-2.71	0.0067
Geo:glacial	-0.3715	0.5001	-0.74	0.4576
Geo:till	-1.0628	0.3698	-2.87	0.0041
Geo:non-glacial	-2.5894	0.5593	-4.63	3.67e-06

Because we used logistic regression, the interpretation of the intercepts is done using log-odds.

- Each unit **increase in basal area increases** the odds of dead basal area by a factor of 1.02. ↑
- Each 10x **increase in Mg:Mn reduces** the odds of dead basal area to 55% of that for the original landscape. ↓
- A **till landscape reduces** the odds of dead basal area to 50% of that for other glacial landscapes. ↓
- A **non-glacial landscape reduces** the odds of dead basal area to 10% of that for a glacial (non-till) landscape. ↓

Results and Discussion (Phase 3)

Logistic regression and log(odds) can be difficult to interpret. **What can we learn by modeling the amount of dead sugar maple found on those plots that have dead sugar maple?** We focused on the 58 points where dead sugar maple was observed (Fig. 3), only 26% of the population of plots with sugar maple. Three models were indistinguishable, but the parameters from the "best" one are included below:

```
sdead ~ lat + secec + lca.al + lmg.mn + lesp
      + lemp + forest + age + size + site.class
      + disturb + geo + ba
```

	Est.	Std.Error	t value	Pr(>|t|)
Intercept[(1)]	-0.675	0.587	-1.150	0.257
lat	0.018	0.014	1.334	0.190
secec	**0.077**	**0.031**	**2.473**	**0.018**
lca.al	**0.027**	**0.013**	**2.066**	**0.046**
lmg.mn	*-0.018*	*0.011*	*-1.636*	*0.110*
lesp	**0.080**	**0.022**	**3.674**	**0.001**
lemp	**-0.078**	**0.033**	**-2.362**	**0.023**
forest (MBB)	-0.110	0.077	-1.428	0.162
forest (OH)	**0.213**	**0.085**	**2.501**	**0.017**
forest (Other)	-0.140	0.104	-1.340	0.188
age	0.002	0.001	1.660	0.105
size (Medium)	0.055	0.042	1.318	0.196
size (Small)	0.157	0.115	1.366	0.180
site.class (4)	0.025	0.103	0.244	0.808
site.class (5)	0.187	0.107	1.743	0.089
site.class (6)	0.111	0.111	1.004	0.322
disturb	0.065	0.056	1.164	0.252
geo (nonglacial)	*0.045*	*0.098*	*0.455*	*0.652*
geo (till)	***0.089***	***0.039***	***2.245***	***0.031***
ba	***-0.001***	***0.001***	***-2.543***	***0.016***

[(1)]The intercept includes forest (AB), size (Large), site (3), and geo (glacial, not till).

Multiple R-squared: 0.6118, Adjusted R-squared: 0.4177

F-statistic: 3.152 on 19 and 38 DF, p-value: 0.001269

We prefer the phase 2 models from a theoretical perspective because they include our complete dataset.

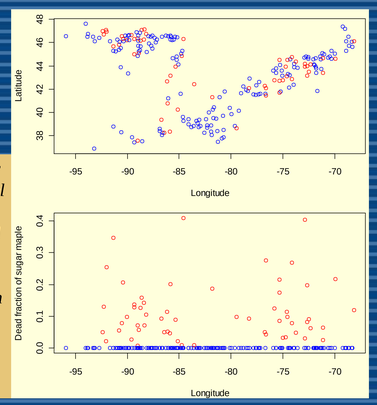

Figure 3.—Plots selected for the phase 3 model included only those where dead sugar maple was observed (red). The dead fraction of sugar maple ranges from a high of 41% to a low of zero.