


Modeling Vegetation Dynamics using Neural Networks

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Outline

- Motivation
- Vegetation Measurements
- Linear Regression
- Multilayer Perceptron
- Supervised Learning and Bootstrap
- Inputs and Results
- Improvements and Stability
- Discussion

Motivation

- Water and Energy Exchange Process
- Part of Terrestrial Ecosystem
- Explain the Past
- Predict the Future
- Environmental Changes
- Agriculture and Conservation

Vegetation Measurements 1/2

- Multispectral Remote Sensing
- Past Climate Data
 - Recorded History
 - Carbon Dating and Core Samples
- Soil Samples
- Flora and Fauna Frequencies
- Classification Features

Vegetation Measurements 2/2



Table 2
 Vegetation classes used in the analysis, abbreviations used, the corresponding type in the Forest and Wetland classification, and the percent of the total forested area in each class. Detailed description of individual classes can be found in Forest 2002P.

Abbrev.	Abbreviation	Forest and Wetland Code	Percent of study area	Description
1	SWP	1 and 2	25.7%	Wooded Wet Forests – swamps, stream, high density of water, shallow and – swamp
2	SWP	3	6.1%	Wooded Wet Forests with trees – swamp
3	SWP	4	6.7%	Wooded Wet Forests with trees – swamp
4	SWP	5a	3.0%	Wooded Wet Forests with trees – swamp
5	SWP	5b	3.0%	Wooded Wet Forests with trees – swamp
6	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
7	SWP	6, 6, 6, 6	62.6%	Wooded Wet Forests with trees – swamp
8	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
9	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
10	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
11	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
12	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
13	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
14	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
15	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
16	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
17	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
18	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
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23	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
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25	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
26	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
27	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
28	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
29	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
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76	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
77	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
78	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
79	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
80	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
81	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
82	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
83	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
84	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
85	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
86	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
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88	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
89	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
90	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
91	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
92	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
93	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
94	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
95	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
96	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
97	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
98	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
99	SWP	6	6.2%	Wooded Wet Forests with trees – swamp
100	SWP	6	6.2%	Wooded Wet Forests with trees – swamp

Linear Regression

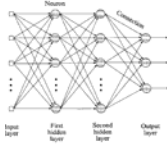
- Simplest Linear Network (Pattern Associator)
- Iterative Version of Regression

$$y(t) = \sum_{j=1}^p w_j(t) x_j(t)$$

$$w_j(t+1) = w_j(t) + \eta e_j(t) x_j(t)$$

Multilayer Perceptron

- Layered Feedforward Network
- Nonlinear Neuron Outputs
- Error Back-Propagation Algorithm



$$y'_j(t) = f(u'_j(t))$$

$$u'_j(t) = \sum_{i=0}^k w'_{ji}(t) y_i^{t-1}(t)$$

$$w'_{ji}(t+1) = w'_{ji}(t) + \alpha [w'_{ji}(t) - w'_{ji}(t-1)] + \eta e'_j(t) y_i^{t-1}(t)$$

Inputs and Results 1/3

- Landsat TM (30x30m)
 - Band 3 (Red)
 - Band 4 (NIR)
 - Band 5 (MIR)
- Standard Statistics
 - Vegetation Index (VI)
 - Normalized Difference Vegetation Index (NDVI)
- Field Surveyed Attributes
 - Loblolly Pine Age

Table 2. Error distribution and calculation percentage of models with $n=2$ years for each method for pine age modeling with training data.

Model type	Absolute age error (years)					
	0	1	2	3	4	5 or 2 (%)
Distance linear regression	14	24	24	11	4	22.1
Multiple linear regression	14	24	24	11	4	22.1
Multiple regression of log-transform	14	24	24	11	4	22.1
Polynomial regression (2 nd)	14	24	24	11	4	22.1
Back propagation (1981)	14	24	24	11	4	22.1
Back propagation (1971)	14	24	24	11	4	22.1
Back propagation (1972)	14	24	24	11	4	22.1
Back propagation (1982)	14	24	24	11	4	22.1
Back propagation (1983)	14	24	24	11	4	22.1
Back propagation (1984)	14	24	24	11	4	22.1
Back propagation (1985)	14	24	24	11	4	22.1
Back propagation (1986)	14	24	24	11	4	22.1

$$age = 58.74 - 1.023B_4$$

Supervised Learning and Bootstrap

- Data Divided into
 - Training Set
 - Testing Set
- Iterate Over Multiple Epochs
 - Adaptive Learning and Momentum Rates
- Possible Bootstrapping at Each Epoch
 - Resampling of Training Set

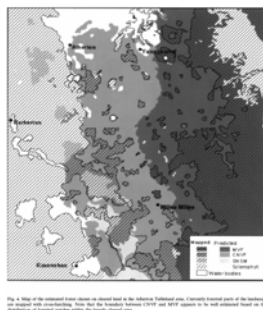
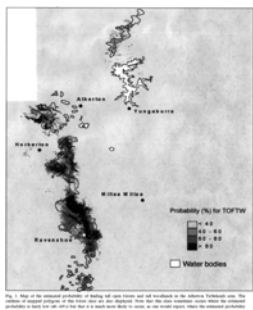
Inputs and Results 2/3

- Sampled at 1 Hectare
- Vegetation Classes
- Climate Variables
- Digital Elevation Model

Table 2. Inputs to the model and their range in the total spatial data set

Input variable	Minimum	Maximum
Annual mean temperature (°C)	14.1	25.7
Min. Temperature of coldest period (°C)	5.1	19.4
Max. Temperature of warmest period (°C)	20.9	27.9
Annual Precipitation (mm)	770	1966
Precipitation of warmest quarter (mm)	152	371
Precipitation of coldest quarter (mm)	0	913
Slope (°)	0	41.7
Soil water index (logarithmic scale)	-9.7	26.4
Aspect (°)	-9.2	36.4
Aspect EW	-30.4	30.2
Distance to nearest drainage (m)	0	1613
Distance to nearest permanent stream (m)	0	3076
Distance to coastline (m)	0	8392

Inputs and Results 3/3



Improvements and Stability

- Exclude Distance to Coastline
- Input Climate Data for
 - 16000 BC
 - 7000 BC
 - 5000 BC
 - Present
- Analyze Stability
- Use Neighborhoods

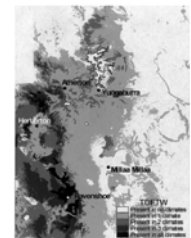


Fig. 4. Map estimating the long-term stability of locations on the Adirondack Tableland for the presence of tall open forests and tall woodlands (TQFTW) based on the map in Fig. 3. Locations that remain appropriate for TQFTW in all five climates can be interpreted as stable for the forest type.

Discussion

- Different Scales of
 - Spatial Resolution
 - Temporal Resolution
 - Continuity of Values
- Validity of Ground Truth
 - Accuracy of Field Surveys
- Explaining MLP-model