Assessing Forest Cover and Change across Massachusetts using Satellite Images

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Abstract

The Massachusetts Forest Monitoring Project (MAFoMP) uses remote sensing data in conjunction with environmental GIS variables to detect changes in forest cover throughout Massachusetts. We acquire, process, and classify Landsat satellite imagery over three-year intervals from 1973 to the present. In doing so, we study landscape change, assess state-of-the-art image processing techniques, and provide a prototype for a large-area operational monitoring program.

Introduction & Background

The goal of the MaFomp is to establish a retrospective, long term, forest monitoring project for Massachusetts that examines change in forest condition and abundance from 1973-present. Non-parametric decision tree classification techniques are employed to map land-cover at multiple hierarchical levels, with an emphasis on forest cover. This process relies on extant spectral and environmental data.

Pre-1850, Massachusetts had < 30% percent forest cover. Today the state is 70 – 80% covered in forest. Sixty-two hardwoods make up 70% of total cover. Twelve conifers make up 30% of total cover. Small scale selective timber harvesting and peri-urban expansion are currently reversing the ongoing trends of state-wide aforestation. Despite the current levels of forest cover, the extent of timber harvest (private) is unknown.

The MaFoMP is currently conducting a pilot study which aims to acquire, atmospherically correct, georectify, classify, and calculate change between two Landsat images (*see figure 2*). The study focuses on two dates of Landsat (E)TM imagery for one WRS path/row. The end goal of the pilot study is to establish the methodology that will subsequently be applied to the rest of the state. Conducting the pilot study illuminates recurring issues with establishing a long term, large scale forest mapping project. Major issues faced in developing the large area mapping project have been acquisition of spectral data from disparate sources and sensors and preprocessing complexities associated with georegistration.

Using Environmental GIS Variables

Traditionally, the detection and identification of land-cover change has relied on variables derived from spectral imagery alone. Non-spectral spatial data (environmental GIS variables, *figure 3*) can provide useful information for digital image processing, classification, and change identification. While climate, geology, and complex topographic variables have proven useful in predictive vegetation mapping (Franklin 1995), a relatively small number of remote sensing forest change mapping studies have utilized ancillary GIS data beyond the traditional topographic variables of DEM, slope and aspect (sensu. Rogan and Miller 2005 In press).

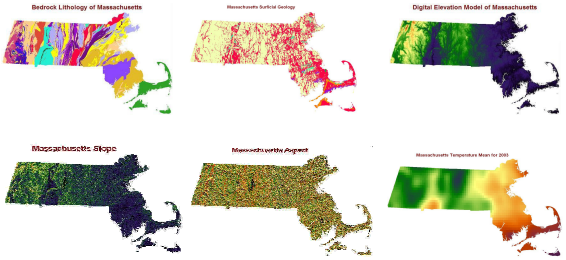
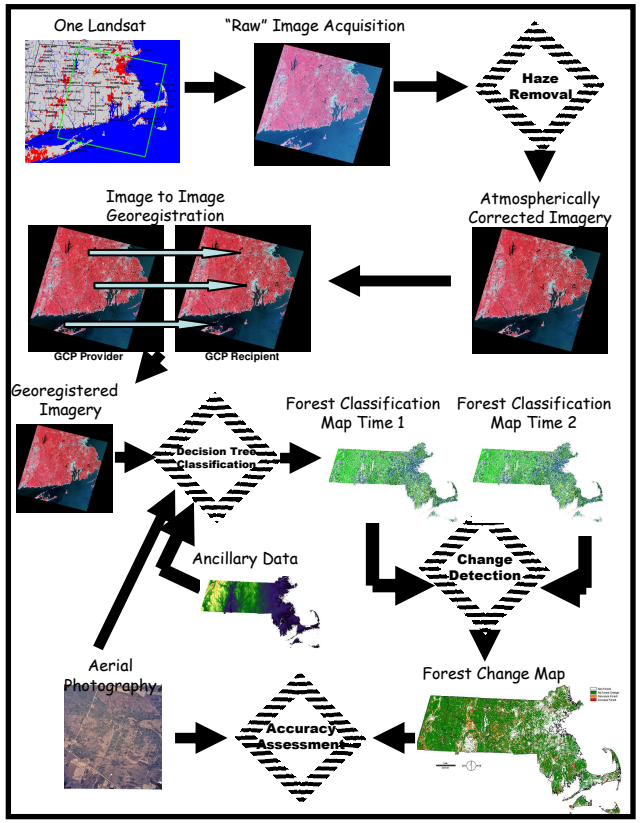


Figure 1. Environmental GIS variables used in conjunction with remote sensing data.

Figure 2. Image Processing & Classification Pilot Study Flow.



Sponsors:

Results

Initial Classification and analysis of the 2000 data has been performed. Input variables into the Classification Tree included 6 leaf-on spectral bands, 6 leaf-off spectral bands, and 7 environmental GIS variables.

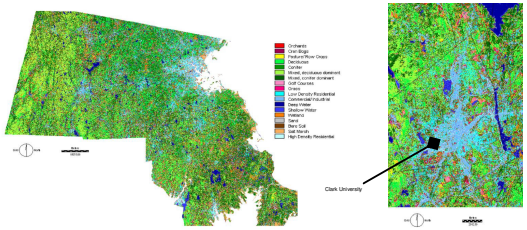


Figure 3. Classification results using 2000 data; Full pilot study extent and Worcester area

Using independent validation data, an error/ confusion matrix was calculated to determine the accuracy of the classification and identify where misclassification occurs:

The classification algorithm seemed to have the most trouble discriminating between the mixed forest classes, however the confusion in the two mixed classes was predominantly with each other. Additionally, the classification algorithm had trouble accurately mapping grassland, confusing it with the pasture/ agriculture. For the most part, the errors in the classification make intuitive sense (e.g., forest classes with other forest classes; grassland with pasture/agriculture; residential built with commercial built).

Inclusion of Leaf-off spectral data boosted overall map accuracy by 4%, particularly aiding in the classification of the mixed forest classes. The use of ancillary GIS variables was shown to boost overall accuracy by more than 8%.

kappa		evergreen	hwood	agriculture	deciduous	conifer	shrub/ med	shrub/ dec	grf/ coniferous	grass	lo res	coniferous	deciduous	pasture	wetland	sand	bare soil	urb/ mixed	high resid	total	Producers	User's
0.618	evergreen	40	9	4	0	0	2	3	4	2	1	0	0	0	2	0	0	0	0	67	63.49	59.7
0.798	hwood	0	87	0	0	0	2	1	0	0	1	0	0	0	1	0	0	0	0	72	79.76	93.1
0.634	agriculture	10	0	60	1	0	1	0	12	18	0	0	0	0	1	0	3	0	0	105	65.93	56.6
0.764	deciduous	2	0	2	77	1	5	2	0	0	0	0	0	0	1	0	0	0	0	90	77.78	85.6
0.741	conifers	0	2	0	0	74	0	6	0	0	0	0	0	0	0	0	0	0	0	82	75.51	90.2
0.615	shrub/ med	0	0	1	20	2	53	12	0	0	1	0	0	0	2	0	0	0	0	91	53.96	58.2
0.566	shrub/ dec	0	5	0	1	21	19	33	0	0	0	0	0	0	1	0	0	0	0	80	57.89	41.3
0.542	grf/coniferous	4	0	3	0	0	0	0	44	12	0	0	0	0	0	0	0	0	0	63	65.67	69.8
0.548	grass	5	0	15	0	0	0	0	7	56	1	1	0	0	1	0	1	0	0	89	57.43	65.2
0.719	lo res	0	0	1	0	0	0	0	0	0	61	7	0	0	2	0	5	0	9	85	73.49	71.8
0.664	coniferous	0	0	0	0	0	0	0	0	4	73	0	0	0	2	5	7	0	8	105	68.7	75.2
0.898	deciduous	0	0	0	0	0	0	0	0	0	0	94	7	0	0	0	0	0	0	101	89.62	93.1
0.886	pasture	0	0	0	0	0	0	0	0	0	1	11	75	2	0	0	1	0	0	90	89.29	83.3
0.809	wetland	2	1	0	0	0	1	0	0	5	4	2	0	2	79	1	5	4	1	107	82.29	73.8
0.864	sand	0	0	0	0	0	0	0	0	1	7	0	0	0	0	75	3	0	2	88	87.21	95.2
0.614	bare soil	0	0	5	0	0	0	0	0	6	2	7	0	0	2	4	41	0	0	67	63.08	56.8
0.928	urb/mixed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	68	1	69	93.15	98.6
0.659	high resid	0	0	0	0	0	0	0	0	0	7	11	0	0	0	1	0	0	43	62	67.19	69.4
	total	63	94	91	99	98	83	57	57	101	83	115	105	84	96	86	65	73	64	1514		
	omission error	36.51	20.2	34.07	22.22	24.49	36.14	42.11	34.39	42.57	26.5	31.3	10	10.71	17.71	13	36.92	6.85	32.81			
	comm error error	40.03	6.94	43.4	14.44	9.76	41.76	58.75	30.16	34.88	28.2	24.76	6.9	16.67	26.17	15	38.81	1.45	30.65			
	overall accuracy %	74.04																				
	overall kappa	0.72																				
	mean kappa	72.00																				

Table 1. Error Matrix of the Classified 2000 image

Conclusions & Future Work

Since June 2004, the Massachusetts Forest Monitoring Program (MaFoMP) has been developing the necessary foundations for a workable methodology to map forest cover changes in Massachusetts over three-year intervals from 1973 to the present. The completion of this long-term project will give both researchers and policy-makers invaluable insights into the patterns and processes of selective timber harvesting, fragmentation due to land development and forest growth in Massachusetts, something unachievable before the advent of remote sensing data and techniques. The next steps for the program in the coming 2006-'07 academic year are in two directions: 1) Completion of the pilot study through classification of the 1987 image and change detection from '87 to 2000; and 2) Expansion of the 2000 classification to cover the entire state of Massachusetts.

References

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