TITLE: Investigating Causes for Mortality in Vermont and Adjacent States.

LOCATION: Vermont
DURATION: 3rd year of 3 year project **FUNDING SOURCE:** Base Evaluation Monitoring

PROJECT LEADER: Robert DeGeus, Vermont Dept. of Forests, Parks & Recreation; 802-241-3671; robert.degeus@state.vt.us
COOPERATORS: Randy Morin, USFS; Bob DeGeus, Vt. FPR; Sandy Wilmot, Vt. FPR
FHP SPONSOR/CONTACT: Margaret Miller Weeks, Forest Health Protection, USFS, Durham, NH; 603-868-7712

PROJECT OBJECTIVES:
- Investigate potential causes of tree mortality detected in recent FIA data for Vermont and adjacent states.
- Identify site conditions that contributed to tree decline to support forest management strategies for future forest health.

JUSTIFICATION:
a. **Linkage** to FHM Detection Monitoring. The 2006 Vermont FIA data showed a 56% increase in mortality of growing stock volume since the last inventory. Preliminary investigations of FHM aerial survey and ground plot data also indicate a variety of stress events that have affected different tree species and locations at various times since the last FIA inventory. This project will use our entire suite of aerial detection, ground survey plots and FIA plots to investigate this forest health disruption.
b. **Significance.** Preliminary data analysis within Vermont shows the number of dead trees increased from 25 million to 100 million trees from 1997-2006 (296% increase) statewide. New York, New Hampshire and Maine FIA data show a similar trend since the last inventory. County level data shows that the decline was well distributed.
c. **Biological impact**. While a decrease in growing stock can be a significant economic and ecological problem, there is added importance in knowing whether or not this trend will continue. Information on the cause for this decline gained from this investigation will shed light on the future trend and may alter resource management options. In addition, current efforts toward increasing carbon sequestration and storage in forests will be hindered by increasing trends in mortality.
d. **Scientific Basis/Feasibility.** Vermont has been diligent in collecting an abundance of forest health data for several decades. Data are available and accessible for this project, and key data analysts are participating.
e. **Priority Issues**. This proposal addresses several of the priority issues: tree mortality, tree growth, drought, soil conditions, air pollutants, and climate change.

DESCRIPTION:
a. Background:

In preparation of the 5-year FIA report for Vermont, data analysis of decline and mortality trends showed a startling increase from the last inventory data of 1996-1997. Screening for possible data errors or explanations verified the increase. Existing FHM data sets for each of the years were then used to identify stress events that had occurred since the last inventory. Initially it seemed that the 1998 ice storm may have been responsible for the mortality, but that doesn't seem to be the case since that initial wave of dead trees was counted in the last inventory. FHM

data does show increases in decline associated with drought, insect defoliations, wind storms, and other factors. Recovery may vary with site conditions such as soil fertility, soil depth, species composition, elevation, and others.

This evaluation project will be conducted in two parts: 1. an integration of FIA plot data and spatial data to determine most likely stress events responsible for the decline for each tree species affected; 2. field measurements to verify timing and probable cause, and determine whether site conditions are playing a role in forest decline or recovery.

This project seems like the perfect model of evaluation monitoring: integrating data collected on forest inventory plots with forest health plots, aerial survey, and additional site-related spatial data layers to develop a better understanding of stress-induced decline, and how forest managers may be able to deal with tree health under various site conditions.

b. Methods:

1. Initial data analysis to determine FIA/FHM ground plots involved. Identify spatial locations, species, size class involved in mortality trend.
2. Conduct spatial analyses to determine most probable cause for each species/plot. This will include overlaying FIA plots with statewide data layers such as: soil depth, soil dryness index, palmer drought index/precipitation measures, aerial survey data for ice storm, wind storm, defoliation, etc. These data sets have been developed and are available for use.
3. Query foresters for additional insight on probably causes and field measurements that would help discern cause as well as site factors.
4. Field visits to collect supplemental data to assist with verification of possible cause: tree cores for dendrochronology and to discern timing of decline; site and soil characteristics; evidence of disturbance; canopy and understory health.
5. Climate change analysis will involve spatial analysis of spruce/fir forests subject to site conditions that increase risk of decline (soil depth, aspect, elevation, etc).
6. Analysis of air pollution data. Vermont has ozone exposure data from 1989 to present for comparison with FHM ozone bioindicator plant trends. Mortality areas will be compared with Vermont Forest Sensitivity Map to compare to exceedence of critical load for sulfur and nitrogen (buffering capacity). FHM lichen results will also be used.

c. Products:

1. Report of findings to adjacent states and USFS.
2. Poster presentation for the FHM Working Group.
3. Chapter(s) in the 5-yr FIA report that could serve as template for future FIA state, regional, and/or National reports.
4. Website posting for general audience.
5. Presentations to key user groups in Vermont including recommendations for revising forest management guidelines according to results.

d. Schedule of Activities:

Year 1: Preliminary analysis: Analyze available datasets for background information (FIA, FHM, NAMP, HHS, VMC, SCAN (soil climate stations)). Conduct preliminary spatial analysis of FIA plots and selected spatial data layers to assess relationships. Publish FIA report chapter with data summaries and basic results. Selection of sampling locations: Stratify FIA plots based on mortality and standing dead, species abundance, and probable cause. Use this to select areas for additional field measurements, preferably on public land.

Year 2: Field sampling and analysis of samples

Year 3: Data analysis and preparation of products, Distribute products

e. Responsibilities:

Bob DeGeus will serve as project leader, provide input and interpretation of data analysis, serve as liaison with foresters for input on decline observations and field measurements,

assist in planning of field work, and coordinate reporting. **Randy Morin** will be the principal data analyst for plot and spatial analysis, and assist in preparation of products. **Sandy Wilmot** will provide input and interpretation of forest health data, coordinate field data collection and analysis, and assist in product preparation.

f. Budget:

For this third year of funding we are requesting a total of $17,400; $11,000 for the State, and $6,400 for the USFS NRS. These funds will be matched with $17,400 from Vermont and the USFS NRS. For all 3 years our request is a **total of $ 48,000** from the FHM Evaluation Monitoring Program and a total project cost of $96,000.

	Item	Vermont Requested FHM EM Funding	Vermont Matching Funds	Vermont Total Project Cost	USFS Requested FHM EM Funding	USFS Matching Funds	USFS Total Project Cost	Total Requested Funds
YEAR 1								
Administration	Salary	8,840	2,802	11,642		4200	4,200	8,840
	Overhead	360	6,964	7,324	4,000		4,000	4,360
	Travel	400	234	624	200		200	600
Procurements	Equipment	200		200				200
	Supplies	200		200				200
	Y1 TOTAL	**10,000**	**10,000**	**20,000**	**4,200**	**4,200**	**8,400**	**14,200**
YEAR 2								
Administration	Salary	1,602	1,601	1,528		4,400	4,400	1,602
	Overhead	398	399	1,618	4,000		4,000	4,398
	Travel	0	0	0	400		400	400
Procurements	Contracting	10,000	10,000	20,000				10,000
	Y2 TOTAL	**12,000**	**12,000**	**24,000**	**4,400**	**4,400**	**8,800**	**16,400**
YEAR 3								
Administration	Salary	3,605	4,806	8,411		6,400	6,400	3,605
	Overhead	895	1,194	2,089	4,000		4,000	4,895
	Travel	1,500	0	1,500	400		400	1,900
Procurements	Contracting	5,000	5,000	10,000				5,000
	Supplies				2,000		2,000	2,000
	Y3 TOTAL	**11,000**	**11,000**	**22,000**	**6,400**	**6,400**	**12,800**	**17,400**

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Progress Report for 2010 Evaluation Monitoring Funding: Year 2 of 3

This project is progressing according to schedule and without major changes from our original proposal.

In year 1, we completed an initial period of data analysis, querying of foresters for observations, and spatial data analyses. The methods for spatial analyses proved successful in identifying site relationships contributing to decline.

In year 2, we continued to acquire existing spatial data layers, conducted additional spatial analyses, and selected locations to be evaluated in the summer. Data was collected at 15 plot locations, and samples collected for analysis.

Year 3 will be needed to complete field data collection, process field samples, analyze results, and develop products.

An obstacle was the accessibility of FIA plot location data and a change in FIA coding, but federal partners assisted us in obtaining the necessary information.

Our work is adhering to the budget allocation, and we expect to meet our target deadline for completion.

Objective 1. Investigate potential causes of tree mortality detected in recent FIA data for Vermont and adjacent states.

1. Initial data analysis to determine FIA/FHM ground plots involved. Identify spatial locations, species, size classes involved in decline trend, then identify possible contributors to decline according to species, locations, and size classes affected. **Completed**

Some results from this process:

- Both high elevation forests and timberland are affected by decline, ruling out that the decline is limited to highly stressed forests at upper elevations.
- Northern and southern Vermont are both affected, indicating that the decline distributed statewide rather than in a limited area (Figure 1).
- Although FIA data is not highly accurate at spatial scales less that north and south, there seems to be small differences in the distribution of decline between counties.

- Red maple appears to be the species with the greatest increase in decline since the 1997 inventory. Other species showing increased mortality since last inventory include: red oak, beech, sugar maple, white pine, and spruce.
- The decline does not appear to be due to a high proportion of dense or highly stocked stands.
- Smaller diameter trees may be affected to a greater degree.
- There doesn't seem to be any one cause that would explain the decline across all species and locations.
- The 1998 ice storm did cause an increase in dead and dying trees, but the acute impacts were compensated for in the 1997 FIA data, and monitoring data shows good recovery of most species following the initial impacts with the exception of birch species.
- Other contributing stressors that were identified as possibilities include: droughts in 1999 and 2001/2002, birch decline initiated by ice storm with drought and soil nutrition contributors, spruce winter injury, forest tent caterpillar, beech bark disease, wind storms, critical load exceedence, balsam woolly adelgid, differences in measurement or resiliency of red maple with multiple stems, population genetics change due to high grading.

2. Query foresters for additional insight on probably causes and field measurements that would help discern cause as well as site factors. **Completed**

- The following presentations and interactions were conducted to solicit input: New England Society of American Foresters, Northeast Forest Pest Council, Vermont Forest Health Meeting, Vermont Forest Management Team presentation, Individual discussions with forest professionals statewide, Forest scientists at the University of Vermont and the Burlington Station of the FS NRS
- This has led to several new possible causes or contributing factors, and several new collaborative efforts with forest researchers. For example, we have discussed collaborations with Paul Schaberg at the Burlington FS NRS station to look for calcium depletion as a precursor to stress-induced decline. Several recent research findings point to the role of soil nutrition at a site level contributing to stress recovery.

3. Conduct spatial analyses to determine most probable cause for each species/plot. This will include overlaying FIA plots with statewide data layers to correlate decline with probable causes, and to identify locations for field verifications. **To be completed**

The following spatial analyses were completed by intersecting FIA plots with potential stress factors:

- Aerial survey forest damage data: weather damage, defoliation, dieback & mortality (Figure 2)
- Depth to bedrock (rock outcrop) (Figure 3)
- Soil dryness index (Figure 4)

We are continuing to conduct spatial analyses as new data layers become available, reflecting factors such as air pollution, site, and climate change.

Objective 2. Identify site conditions that contributed to tree decline to support forest management strategies for future forest health.

4. Field Verification will be done during the 2011 field season to verify probable cause using ground plot data such as: cores to determining timing of decline and growth effects, evidence of disturbance, site nutrition especially calcium and nitrogen status, contribution of red maple decline due to multiple stems, incidence of Armillaria (esp. ash) as a potential contributor

following the ice storm, crown condition, current dead trees, canopy closure, and others. **To be completed**

Field methods were developed in conjunction with a University of Vermont review committee. A graduate student was hired to conduct field surveys, and collect samples for analysis. Potential field sites were visited in spring and early summer 2011 to determine their suitability for the project.

Six sites with red maple, four with white ash, three with balsam fir, and two with beech decline were sampled in summer 2011. Data was data taken on tree crowns, site factors, and damaging agents. Increment cores were collected from target species over a range of condition classes. Soil samples were collected from each study site.

We are continuing to conduct site evaluations. Our target is two additional red maple sites, and 3-5 additional balsam fir sites. Although no additional white ash sites will be visited, some summer 2011 plots will be sampled for ash yellows. No additional beech mortality sites will be visited because the cause of mortality is known to be beech bark disease.

Field data sheets that were used are in Appendix 1.

5. Outcomes and products will be completed in 2012, and will include: A report of findings distributed to adjacent states and USFS; poster presentation for the FHM Working Group; Chapter(s) in the 5-yr FIA report that could serve as template for future FIA state, regional, and/or National reports; website posting for general audience; presentations to key user groups in Vermont including recommendations for revising forest management guidelines according to results. **To be completed**

In year 3, increment cores and soil samples will be processed. All field data will be analyzed. Findings will be reported as above.

Figures

Figure 1. Spatial pattern of decline based on Forest Inventory and Analysis (FIA) plots.

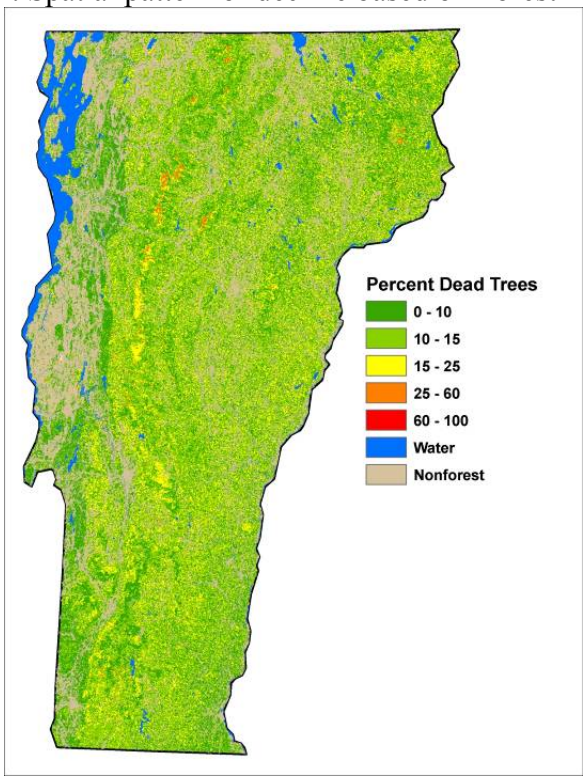
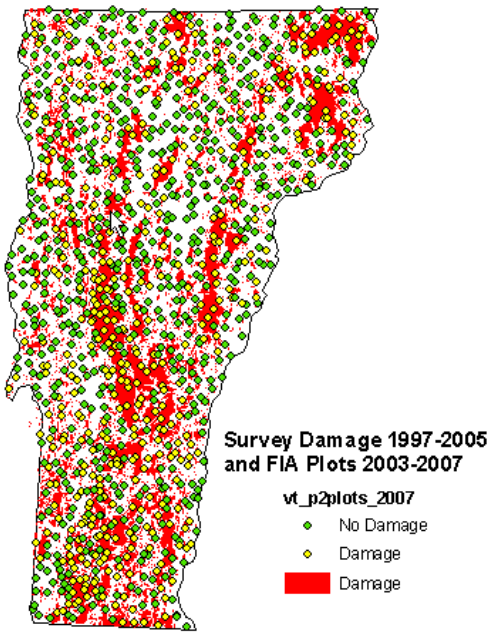
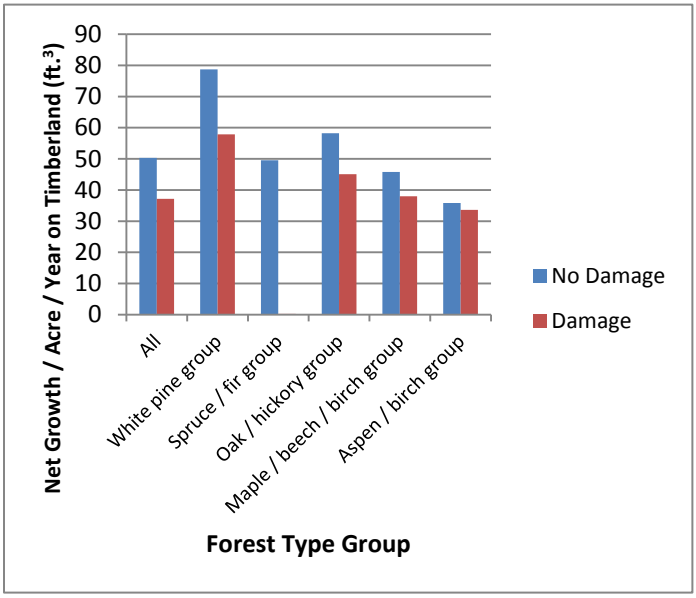


Figure 2. Forest damage polygons from FHM aerial survey data are overlaid with FIA plots to determine biotic or abiotic forest damage, or no damage on plots for the years preceeding the FIA inventory. Approximately 45% of VT's forest land received 'damage' between 1997 and 2005. The damaged plots in all forest type groups had smaller growth per acre per year than the undamaged plots, and the spruce/fir, oak/hickory and aspen/birch groups had more standing dead trees than the undamaged plots.





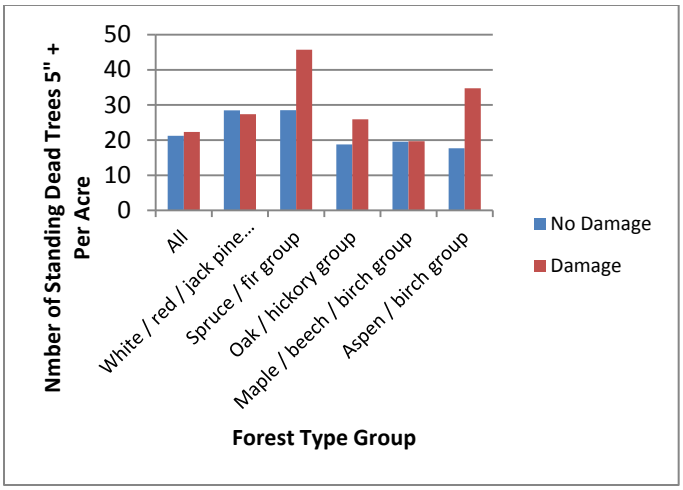
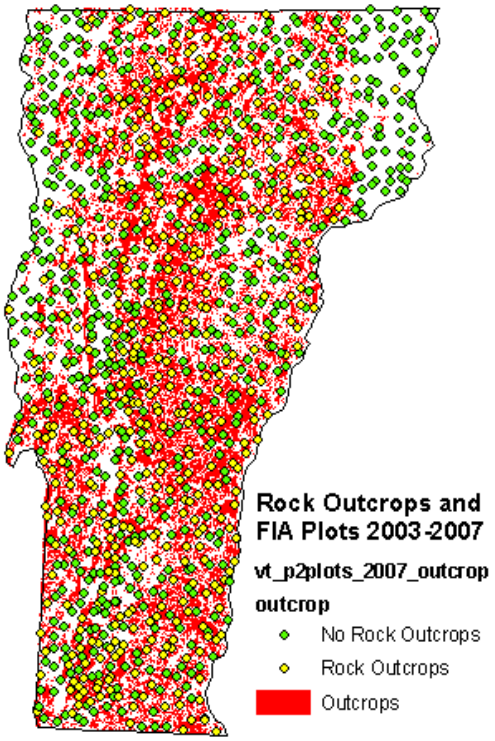
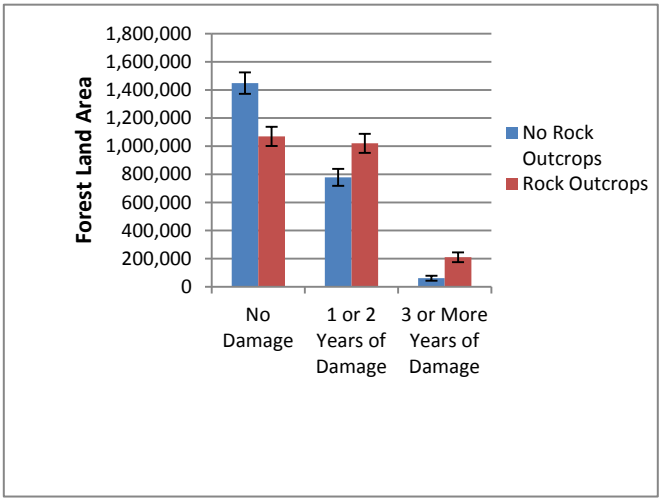


Figure 3. Overlay of shallow depth to bedrock (rock outcrops) with FIA plots to determine the relationship between locations more susceptible to drought and decline (standing dead trees). Aerial survey data was supplemented to relate forest damage and shallow soils. FIA plots were more likely to have one or more years of damage if the site had shallow soil. The aspen/birch forest type group had the largest relationship between sites with shallow soils and standing dead trees per acre.





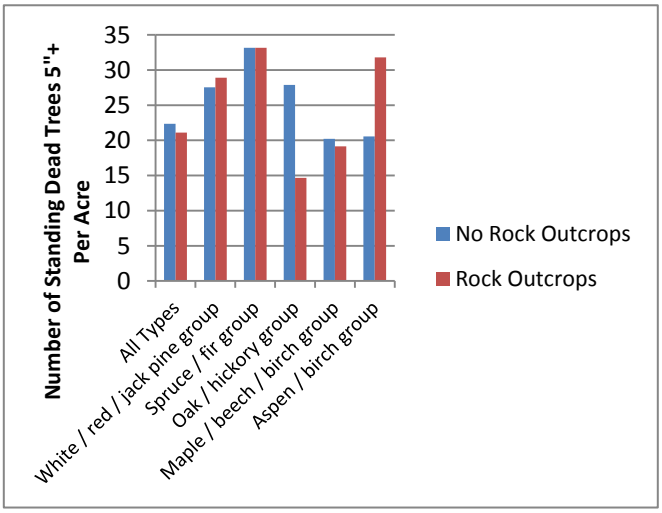
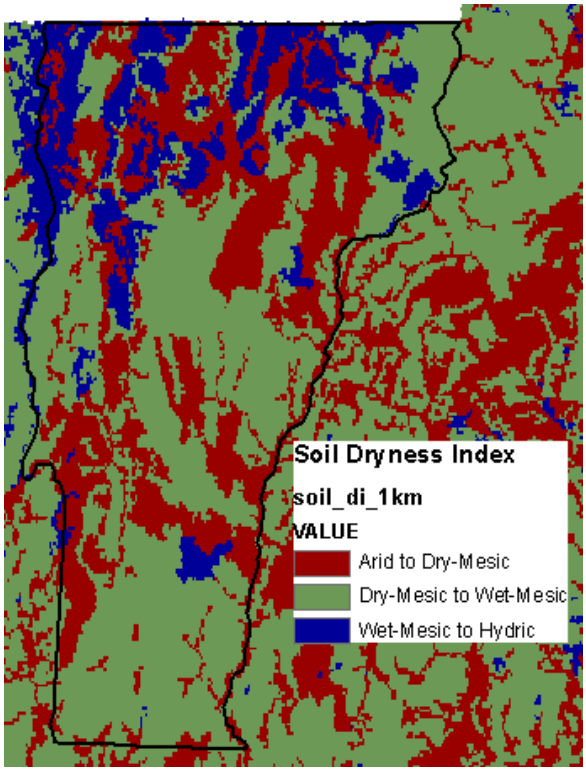
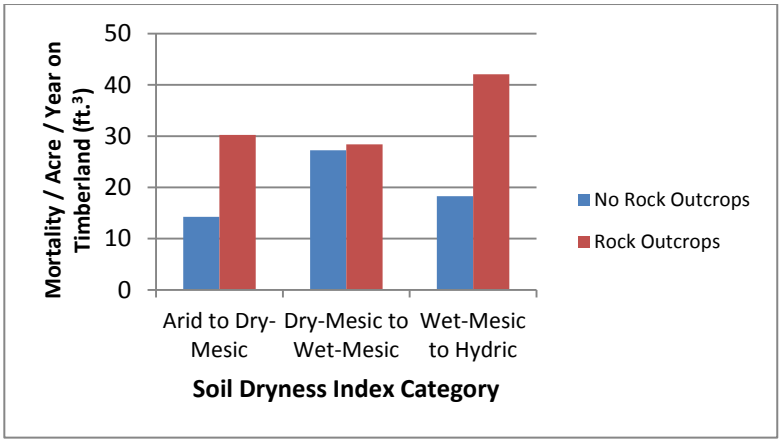
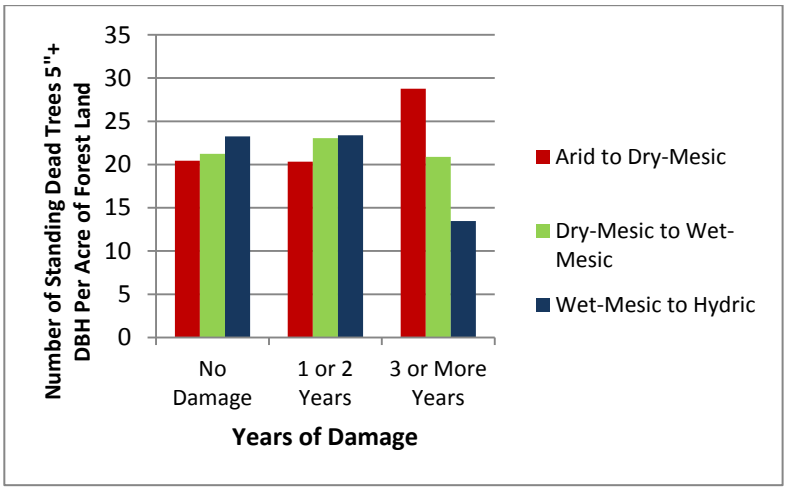


Figure 4. Overlay of soil dryness index with FIA plots to determine the relationship between decline and locations with soils more susceptible to drought. The soil dryness index did not appear to relate to the number of standing dead trees nor mortality of different forest types. However if soil depth was combined with soil dryness index, the soil dryness index was related to plots with higher mortality and better growth on shallow soils (rock outcrops). Also, declining FIA plots with Arid to Dry-Mesic soil dryness index were related to areas with three or more years of damage as mapped during aerial survey flights.







Appendix 1: Field Data Sheets
Vermont Department of Forests, Parks, and Recreation- 2011 Tree Mortality Study

Date: _____ Site name: _____ Crew:_____

Subplot : _____ Center Location (NAD83 decimal degrees):

_____

Slope: _____ Aspect: _____ Elevation: _____ Terrain: Flat / Hilly / Mountainous

Forest Type : _____ Crown structure: Single story / Two-story / Multistory

Roads Yes / No _____ **Water** Yes / No

_____

Disturbance:

_____

__

Soil series (from NRCS maps):_____

□ Soil samples collected Soil depth to bedrock: 1-____ 2-_____ 3-_____ 4-_____

Drainage: Excessive / Well / Poor

Rockiness: _____ (1- Not more than one protruding large rock (usually more than 2' diameter), no exposed bedrock, 2- two to ten large rocks, no exposed bedrock, 3- ten or more large rocks or bedrock showing)

Canopy Closure: 1- <15% / 15-30% / 31-70% / >70% **2-** <15% / 15-30% / 31-70% / >70%

Notes and general description of plot and surrounding area:

Ground Cover (% over entire subplot)	
Moss	
Fern	
Herb	
Shrub	
Seedlings	
Bare Soil	
Duff	
Grass/sedge	
Rock	

Seedlings, saplings, shrubs (density within subplot)			
Species	**Density**	**Species**	**Density**

Density: 1- infrequent, one to a few; 2- sparsely throughout; 3- localized patches, several together in a few locations; 4- frequent and common throughout or densely in a few locations; 5- densely throughout

Indicator species and herbaceous plants			
Species	**Density**	**Species**	**Density**

Indicator species: 1- Blue Cohosh, 2- Wild Ginger, 3- Wild Leek, 4- Maidenhair Fern, 5- Wild Sarsaparilla, 6- Wild Lily of the Valley, 7- Staghorn Clubmoss, 8- Bracken Fern, 9- Wintergreen, 10- Starflower, 11- Meadow-rue, 12, False Hellebore, 13- Ostrich Fern, 14- Interrupted Fern, 15- Cinnamon Fern, 16- Royal Fern, 17- Jewelweed

Density: 1- infrequent, one to a few; 2- sparsely throughout; 3- localized patches, several together in a few locations; 4- frequent and common throughout or densely in a few locations; 5- densely throughout

Invasive/exotic species			
Species	**Density**	**Species**	**Density**

Invasive/exotic species: 1- Barberry, 2- Buckthorn, 3- Bittersweet, 4- Honeysuckle, 5- Multiflora rose, 6- Norway maple, 7- Autumn olive, 8- Japanese knotweed, 9- Garlic mustard, 10- Privet, 11- Tree of heaven, 12- Wild chervil, 13- Burning bush, 14- Goutweed, 15- Oriental bittersweet, 99- Other, specify

Density: 1- infrequent, one to a few; 2- sparsely throughout; 3- localized patches, several together in a few locations; 4- frequent and common throughout or densely in a few locations; 5- densely throughout

Vermont Department of Forests, Parks, and Recreation-
2011 Tree Mortality Study

Date: _____ Site name: _____ Crew: _____

Subplot: _____

TREE DATA

ID#	Species	Status	DBH	Height	Crown Class	Dieback	Transparency	Vigor	Seed abundance	Damages	Decay class	Cored	Notes

Species: Two-letter common name abbreviation; **Status:** 1- Alive, 2- Dead**; Crown Class:** 1- Dominant/co-dominant, 2- Intermediate, 3- Overtopped/suppressed; **Dieback:** %; **Transparency:** %, **Vigor:** 1- Healthy, 2- Light Decline, 3- Moderate decline, 4- Severe decline (% affected in notes), 5- Dead, natural, 6- Dead, human-caused, tree removed, 7- dead, other; **Seed abundance:** 0- None present, 1- Light to moderate, 2- Heavy, 3- Seeds dropped/dispersed; **Bole damage:** use special damage codes; **Decay class (dead trees only):** 1- Limbs, branches, bark present, 2- Limbs and branches present, no fine twigs, 3- Limbs, stubs only, 4- No branches or stubs, bole soft but holds shape, 5- No stubs, bole soft, does not hold shape