Mapping the Mesic-Frigid Boundary in the Eastern Allegheny Plateau and Mountains (MLRA 127)

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Introduction

Climate is an important soil forming factor in Major Land Resource Area (MLRA) 127, the Eastern Allegheny Plateau and Mountains. An operational rule-of-thumb holds that the mesic-frigid boundary occurs at about 3,000 feet elevation. Previous small scale mapping by Smith (1984), at 1:2,500,000 scale, delineated soil temperature regime boundaries for the northeast U.S. (Fig. 1), but anecdotal evidence indicates that it missed many frigid areas in the mountains and plateaus of MLRA 127 (Fig. 2). The analysis described here will examine three different approaches to map the mesic-frigid boundary and determine the extent of soils with outdated taxonomic temperature regime classifications.

1. Mount (2002) used three years of data collected from sensors above and below ground in seven locations in the central Appalachian mountains to generate a regression function evaluating sensitivity of soil temperature to latitude and elevation. His results produced a means of determining the elevation of the mesic-frigid boundary at latitudes between 35º and 45º north in the Appalachian Mountains.

2. The process presented here (Waltman, unpublished) evaluates the relationships between landscape position (x, y, z, slope gradient, and slope aspect) and soil temperature, similar to the approach used by Miller (Miller, et al. 2006). Thirty-year normals from 147 National Weather Service (NWS) cooperative weather stations in West Virginia, Pennsylvania, and New York were used to calculate climatic parameters. Terrain regression equations were applied to DEMs to generate surfaces for mean annual air temperature (MAAT) and mean annual soil temperature (MAST).

3. The MAST surface was compared with Mount's surface and a rule-of-thumb surface (Craul, unpublished) to determine the extents of soils taxonomically classed as mesic which occur above the mesic-frigid break.

Study Area

MLRA 127, the Eastern Allegheny Plateau and Mountains, comprises 12,049,386 acres in the states of Maryland, New York, Pennsylvania and West Virginia (figure 3). Elevation ranges from 980 feet (300 meters) in the lowest valleys to 1,970 to 2,620 feet (600 to 800 meters) throughout much of the top of the plateau. About three-fourths of the area is in hardwood forests. Most of the forestland is privately owned, although the area has large blocks of State forest and game lands and national forests.

The high elevations of the MLRA 127 produce complex orographic processes as a result of uplift and condensation of continental air masses. Precipitation rapidly decreases at the Allegheny Front, at the eastern edge of MLRA 127, producing rainshadow effects in the Ridge and Valley province. In the highest elevations of the central Appalachian Mountains, temperature and precipitation can vary dramatically in short distances with elevation, local relief, and slope aspect.

Methods

Three methods were used to calculate the mesic-frigid boundary in MLRA 127 from a 30 m DEM.

Mount's terrain regression ($R^2 = 0.99$) predicts the elevation of the mesic-frigid boundary:

Latitude = 46.204504 + (**z***-0.0075558256)
Where z = Elevation (m)

The terrain regression ($R^2 = 0.80$) presented here predicts soil temperature from landscape position parameters:

MAST = 81.9 - (**y***0.000012) - (**x***0.000001) - (**z***0.00890) - (**sa***.22) + (**sg***.0114)
Where MAST = Mean Annual Soil Temperature (ºF), y = Northing (meters, Albers Equal Area, NAD83), x = Easting (meters, Albers Equal Area, NAD83), z = Elevation (m), sa = Slope Aspect Facet (Olivier, 1964), sg = slope gradient (%)

An approach using expert local knowledge calculates the elevation of the mesic-frigid boundary (Craul, unpublished):

M/F = ***f***(Max(**z**), **Latitude**)
Where z = Elevation (m)

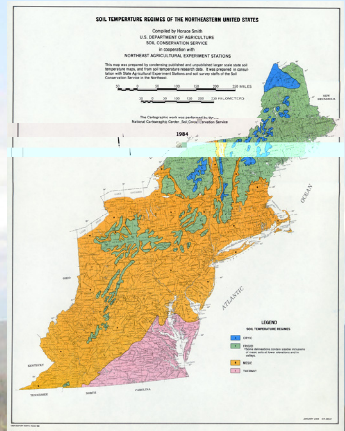

Figure 1. Smith, et al (1984) mapped soil temperature regimes in the Northeast U.S. at a scale 1:2,500,000.

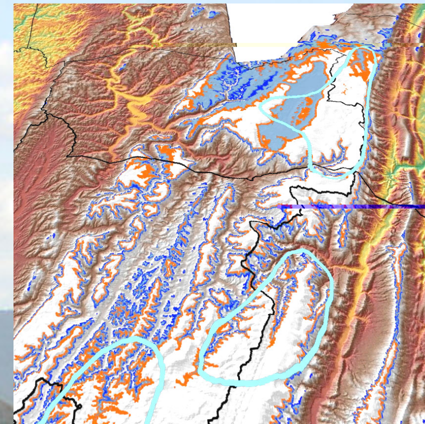

Figure 2. Perspective view of different methods used to delineate the mesic-frigid boundary in Canaan Valley WV. Smith's boundary is light blue, Waltman's is dark blue, Mount's is orange, and white areas are frigid by all methods.

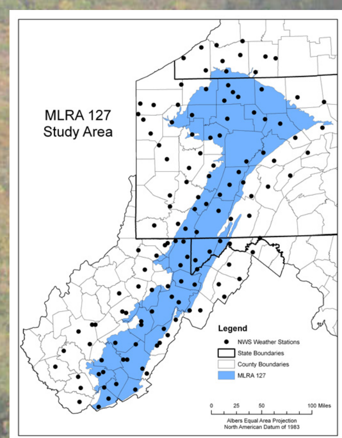

Figure 3. Location of MLRA 127 and NWS weather stations.

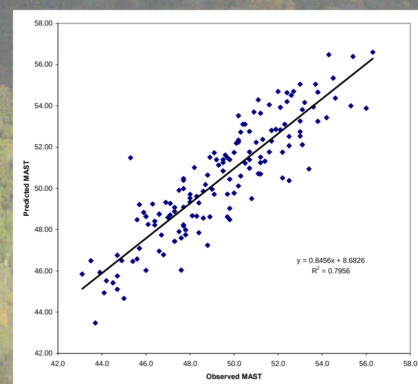

Figure 4. Scatter plot of predicted vs. observed MAST calculated by Waltman at NWS weather stations.

Results

A total of 101 unique map units with mesic major components occur above the mesic-frigid boundary calculated with these three methods (table 1).

Benchmark mesic soils with extents greater than 1,000 acres above the mesic-frigid

		Computed Acreages		
Benchmark Soil Series	***Taxonomic Subgroup***	***Waltman***	***Mount***	***Craul***
Hazleton	MESIC TYPIC DYSTRUDEPTS	759161	353276	79673
Cookport	MESIC AQUIC FRAGIUDULTS	491681	237645	76390
Hartleton	MESIC TYPIC HAPLUDULTS	413339	310042	19395
Dekalb	MESIC TYPIC DYSTRUDEPTS	293963	230558	65418
Leck Kill	MESIC TYPIC HAPLUDULTS	249441	163371	14964
Gilpin	MESIC TYPIC HAPLUDULTS	235997	140747	23834
Buchanan	MESIC AQUIC FRAGIUDULTS	215657	116978	21390
Laidig	MESIC TYPIC FRAGIUDULTS	168419	94071	3775
Clymer	MESIC TYPIC HAPLUDULTS	147396	59043	20844
Ernest	MESIC AQUIC FRAGIUDULTS	141686	63439	19760
Calvin	MESIC TYPIC DYSTRUDEPTS	104573	83193	23881
Wharton	MESIC AQUIC HAPLUDULTS	89205	27192	13670
Cavode	MESIC AERIC ENDOAQUULTS	72620	23498	13053
Brinkerton	MESIC TYPIC FRAGIAQUALFS	52733	21511	14055
Rayne	MESIC TYPIC HAPLUDULTS	50785	23332	2868
Albrights	MESIC AQUIC FRAGIUDALFS	48549	19710	2719
Leetonia	MESIC ENTIC HAPLORTHODS	47956	32988	13967
Berks	MESIC TYPIC DYSTRUDEPTS	40076	20278	5163
Lehew	MESIC TYPIC DYSTRUDEPTS	35700	26894	2360
Hustontown*	—	30515	20231	8305
Meckesville	MESIC TYPIC FRAGIUDULTS	29504	14919	1635
Ungers	MESIC TYPIC HAPLUDULTS	28566	592	257
Cateache	MESIC ULTIC HAPLUDALFS	25624	24144	6293
Nolo	MESIC TYPIC FRAGIAQUULTS	22278	9623	3618
Shouns	MESIC TYPIC HAPLUDULTS	19916	15959	6144
Portville	MESIC AERIC FRAGIAQUALFS	15952	6592	4
Philo	MESIC FLUVAQUENTIC DYSTRUDEPTS	15273	641	—
Rock outcrop*	—	15256	14159	3629
Atkins	MESIC FLUVAQUENTIC ENDOAQUEPTS	12288	1209	694
Macove	MESIC TYPIC HAPLUDULTS	10329	8921	310
Belmont	MESIC TYPIC HAPLUDALFS	8687	7578	3247
Basher	MESIC FLUVAQUENTIC DYSTRUDEPTS	6148	1344	87
Very stony land*	—	4594	4PU2215(07)TJT*-0.0232 Tc0.0696	
ville599.2(M)14.1(E)12.4(S)27.7(55.7(C)42.7(L)29.2(55879 I)8381H2ICDCS 3				
Pope	MESIC FLUVENTIC DYSTRUDEPTS	2116	100	139
Barbour	MESIC FLUVENTIC DYSTRUDEPTS	1650	187	38
Braceville	MESIC TYPIC FRAGIUDEPTS	1398	56	6
Craigsville	MESIC FLUVENTIC DYSTRUDEPTS	1389	—	—
Andover	MESIC TYPIC FRAGIAQUULTS	1304	109	25
Totals		3924580	2181175	473741

* Not benchmark soils, but significant in acreage

Discussion

This analysis only considered SSURGO map units and components with taxonomic temperature class set to mesic. Acreages were calculated for benchmark soil map units and components that did not use taxonomic temperature class or were set to NULL. Map units occurring in amounts of less than 1,000 acres in frigid areas were not listed in the table above.

Waltman's MAST surface yielded nearly 4 million acres that can be considered frigid in MLRA 127, while Mount's terrain regression outlined an area of about 2.2 million acres, and Craul's approximation showed about .5 million acres.

For the analysis presented here, the mean annual air temperature (MAAT) was calculated at each weather station for the period 1971-2000. Mean annual soil temperature (MAST) was calculated with the lag function of 1.2º F described by Carter and Ciolkosz (1982). The terrain regression was applied to each cell of the DEM. Predicted MAST values at each station correlated closely with observed values (Fig. 4).

As the National Cooperative Soil Survey progresses toward physiographically based correlation and mapping, these techniques will be valuable in identifying components, map units, and series that need investigation. Landscape visualization techniques, as in figure 2, are valuable in guiding placement of on-site soil temperature monitors. Since 2006, more than a dozen HOBO Pro Data Loggers (from Onset Corporation) have been installed in soil profiles targeted by the methods described here. The data collected in these areas will help to refine the models, and will guide correlation decisions.

References

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