

A COMPARISON OF THE INTEGRATED MOISTURE INDEX AND THE TOPOGRAPHIC WETNESS INDEX AS RELATED TO TWO YEARS OF SOIL MOISTURE MONITORING IN ZALESKI STATE FOREST, OHIO

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We collected soil moisture data during the growing seasons of 2001 and 2002 on over 100 points at the Zaleski State Forest in Vinton County, southern Ohio as part of a prescribed fire and thinning study (Iverson and others in press). These data were collected with a portable time domain reflectometry unit (TRIME) which measured volumetric soil water through PVC tubes via an electromagnetic field measurement of the dielectric constant of soil at 0-18, 18-36, and 36-54 cm. Measurements were taken 8 times during the growing season in 2001 and 10 times in 2002. The intention was to sample every two weeks but equipment failure plagued this effort. The PVC tubes were located on a 50 m grid throughout the study area (control and thin + burn treatments), and were accurately located via differentially corrected global positioning.

We developed the Integrated Moisture Index (IMI) some years ago to represent the long-term moisture condition of forested habitats in irregular terrain (Iverson and others 1997). Based on a conceptual model of topographic hillshading, flow accumulation downslope, curvature, and soil water holding capacity, it has been related successfully to vegetation composition (Iverson and others 1996, Hutchinson and others 1999), productivity (Iverson and others 1997), soil characteristics (Boerner and others 2000), and bird distributions (Dettmers and Bart 1999), but hitherto not measured soil moisture. IMI values traditionally have been calculated using ArcInfo Grid from 30 m digital elevation models (DEMs) that were smoothed by bilinearly resampling the 30 m pixels to 7.5 m or even smaller subcells. We modified and improved the traditional IMI algorithm by using the GRASS software function "r.flowmd", which computes flow under an infinite number of aspects, rather than the flowaccumulation function in GRID, which computes flow with only 8 possible aspects. We also acquired LIDAR data which allowed the production of 1, 2, and 4 m DEMs. Through multiple trials, we determined that the 4 m DEM best captured the flowlines downslope, so it was used for all landscape metrics. These data provide a much more detailed DEM, and consequently IMI map, where smaller drainage patterns can be captured as compared to the 30 m data.

Another index of long-term moisture is the topographic wetness index (TWI), or topographic convergence index (TCI) (Bevin and Kirkby 1979), which uses the upslope contributing areas and slope to determine an index of moisture for each cell. It has been used in several hydrological and landscape studies (e.g., Urban et al. 2000). This index was also computed with the 4 m LIDAR DEM for our study area and related to IMI and actual soil moisture values.

Extraction of landscape variables for a 6 m radius around each PVC sampling tube was accomplished via ArcInfo (ESRI 2001). This radius was selected because it roughly matches a 3x3 cell area for the 4 m cells. Average values for the circles were calculated for each of the landscape variables and joined with the moisture data for statistical treatment. Pearson correlations were calculated between landscape variables and soil moisture variables. For this analysis, grand means of soil moisture were calculated for the surface, middle, and deeper horizons (plus all horizons together) for 2001, 2002, and both years together. A subset of seven dates was also selected that had average percentages below 16 percent moisture; these represented 'dry' conditions. Multiple linear regression and stepwise regression were also run to assess the relationship of combinations of landscape variables to moisture.

The relationship between the landscape variables and recorded moisture conditions was explored by date and depth over the two years. Though expected trends of increasing soil water with increasing

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Table 1.—Correlation coefficients of landscape variables with measured soil moisture variables. First column is moisture variables for 2001 (top, middle, and bottom horizons), 2002, average of both years, average for 7 of the 18 dates with average moisture <16 percent, and a single (dry) date in September 2002. Remaining columns pertain to IMI calculated with 30 m DEM and 4 m DEM (with all four variables), the topographic wetness index, and IMI with total available water capacity removed), hillshade, and combinations of hillshade and TWI with 60:40 and 40:60 ratios, respectively. N=98, all values > 0.203 are significant at P<0.05 and values > 0.327 at P<0.001.

Moisture	IMI_30m	IMI_4var	TWI	IMI_3var	HILL	HILL60TWI	HILL40TWI
G01.top	0.211	0.256	0.174	0.263	0.260	0.278	0.279
G01.mid	0.085	0.132	0.262	0.167	0.241	0.241	0.273
G01.bot	0.123	0.186	0.314	0.205	0.238	0.251	0.279
G01.all	0.141	0.199	0.292	0.223	0.267	0.278	0.304
G02.top	0.269	0.285	0.173	0.306	0.302	0.310	0.319
G02.mid	0.085	0.107	0.223	0.156	0.229	0.221	0.256
G02.bot	0.051	0.248	0.216	0.241	0.225	0.270	0.251
G02.all	0.150	0.205	0.247	0.234	0.271	0.277	0.300
2yr.top	0.249	0.280	0.179	0.294	0.290	0.304	0.309
2yr.mid	0.086	0.121	0.245	0.164	0.238	0.233	0.268
2yr.bot	0.090	0.223	0.274	0.230	0.239	0.269	0.274
2yr.all	0.146	0.204	0.272	0.230	0.271	0.279	0.304
dry2y.top	0.276	0.292	0.205	0.330	0.312	0.327	0.334
dry2y.all	0.174	0.202	0.233	0.245	0.290	0.296	0.317
Sep02.top	0.300	0.330	0.170	0.360	0.360	0.380	0.380
Average	0.162	0.218	0.232	0.243	0.269	0.281	0.297

TWI or IMI were apparent, the correlations were low (table 1). Regression analysis revealed that a combination of hillshade and TWI provided slightly more explanatory power than any single index, so it too was included here. The table lists the variables in increasing overall relationship with the 15 soil moisture variables. Even with the high resolution DEM and the precise spatial location of the moisture tubes, the relationships account for little variance, though the correlations are mostly significant (P<0.05). All IMI and hillshade values tend to have relatively higher correlations with the surface moisture, whereas TWI correlates relatively higher with deeper soil moistures. As expected, the 4 m DEM is better than the 30 m DEM for this purpose, although the coarser data also do allow general mapping of stress zones over broader areas during drought periods (as evidenced by a relatively high correlation on the dry September 2002 sampling date). Curvature, total water holding capacity, and flow accumulation, three components of the 4-variable IMI, were not independently correlated to soil moisture. Hillshade, the largest component of IMI (40 percent for the 4-variable IMI and 50 percent for the 3-variable IMI), overall rated higher than IMI, but IMI_3var correlated slightly higher at the surface horizon. The combination of hillshade and TWI had the best correlations, regardless of moisture variables. TWI weighted 60 percent and hillshade at 40 percent was slightly better than the reverse weightings (table 1). TWI is not correlated with hillshade or IMI.

We believe that micro-scale phenomena near the PVC tubes and poor contact between tube and soil may be responsible for a large part of the unaccounted for variance in the relationships. The TRIME technology only measures soil moisture in a ~25 cm radius of the tube, and needs good contact (no air space) between tube and soil. Any air space would curtail the dielectric constant and underestimate the water contact. Tree roots near the tube can quickly dry out the soil moisture in the vicinity regardless of landscape position. In any case, the TRIME is not a fully dependable technology at this point. On the other hand, small depressions or rills, even if only several cm in size near the tubes, can collect and hold moisture even if the overall landscape is prone to dryness. Variability in the amount of litter, duff, and soil organic matter can also account for variation in either direction, as can variation in soil texture or coarse fragments. Finally, there may still a spatial mismatch between tube and the landscape variables being tested.

We have shown that some landscape variables do have weak, but significant, relationships to actual measured soil moisture for this one site in southern Ohio. The IMI, previously shown to relate well to many soil and vegetation characteristics, relates weakly to surface soil moistures. We intend to determine if these relationships hold on another site, and will explore whether a combination metric of hillshade and TWI relates well to vegetation and soil patterns.

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