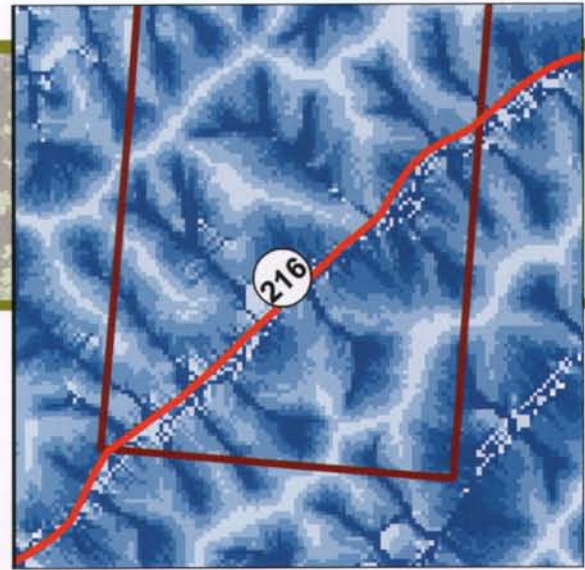# Using an integrated moisture index to assess forest composition and productivity

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The 834,000-acre Wayne National Forest, Ohio's only national forest, lies in the rolling foothills of the Appalachians in the state's southeast. Congress established the forest boundary in 1934 to prioritize land acquisition and ownership of forest lands in need of restoration. The forest is composed of both central hardwoods, primarily oak and hickory, and softwoods, including native pine and hemlock.

To determine long-term soil moisture conditions, a portion of the Wayne National Forest was analyzed to create an integrated moisture index (IMI) map. The IMI was then used to predict forest site productivity and composition. IMI maps are a useful tool for managers and researchers to stratify treatment units so they can understand the effects of prescribed fire and commercial thinning in southern Ohio. When combined with forest inventory and analysis (FIA) data, IMI can provide additional information on site quality and the basal area of various tree species.

The IMI values ranging from wet (green) to dry (brown) are influenced by four layers, including topography, slope, the movement of water, and water supply availability. Using GIS, these layers can be combined and analyzed to predict the forest's productivity and species composition. Topographic maps provide information about the form and elevation of the landscape. Slope maps provide information about the steepness of a landscape, either as a percentage or in degrees. Mapping the movement of water helps to identify both the source and destination of moving water. Finally, available water supply shows the amount of moisture that can be stored in the soil.

The map of IMI is a result of a weighted calculation of the four layers, where each map layer is weighted according to its influence on long-term soil moisture. Flood boundaries are used to mask locations where IMI produces unreliable values because it is difficult for a GIS to correctly determine the direction of water movement across a flat landscape.
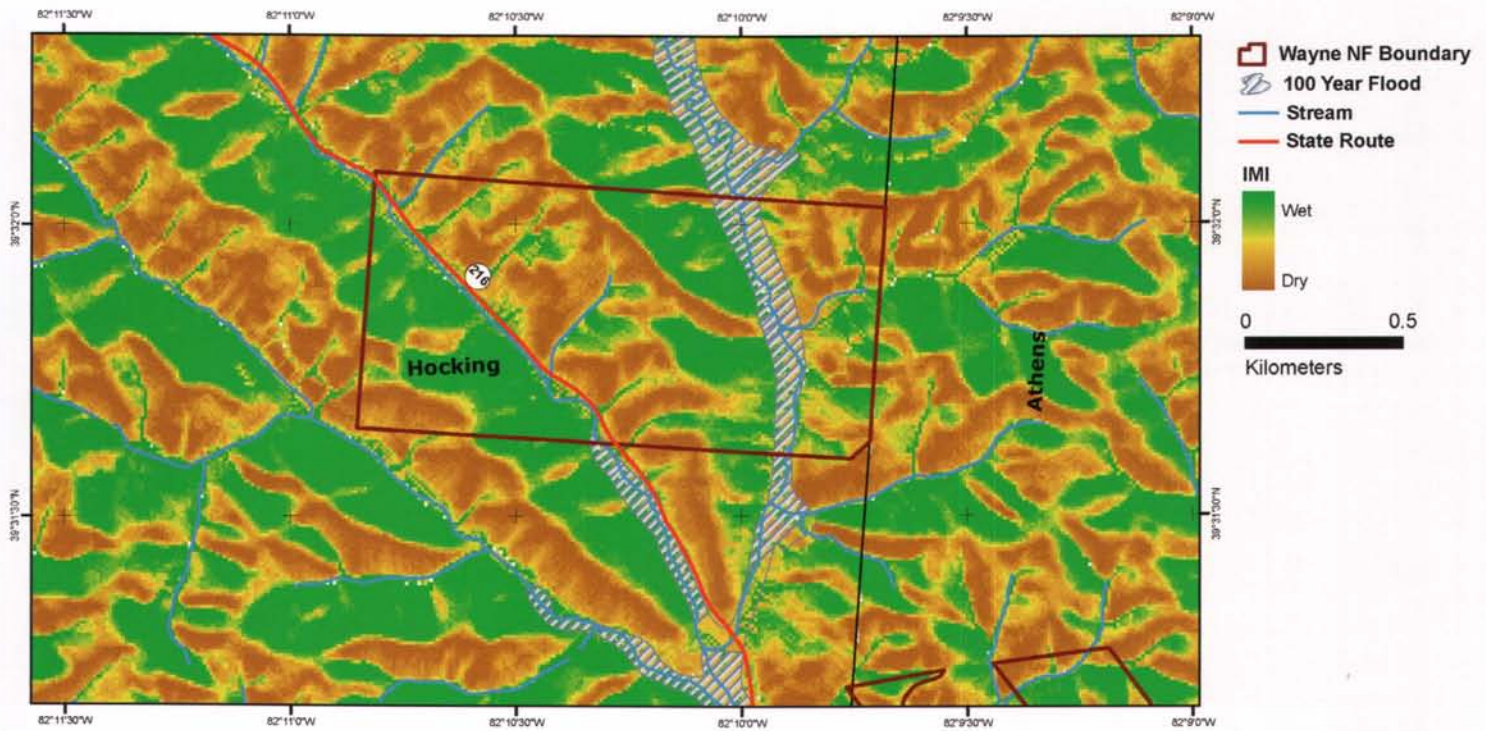
A visual solution

The integrated moisture index analysis can predict a forest's site composition when species-specific site conditions are related to index values. One would expect to find species known to perform well on dry sites to be present where IMI values are low and species that prefer moist sites where values are high. With this information, strategic plans can be developed to conserve individual species or groups of species that require specific site conditions. Mapping IMI also gives forest managers a visual assessment of the flow and storage of water across the landscape in the form of a map.
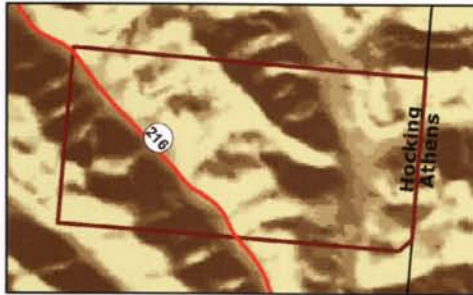
Developing an integrated moisture index map requires extensive use of raster-based analysis. Raster data consists of rows and columns of cells. Each cell stores a single value such as percent slope, aspect, elevation, direction of flow, to name a few. Cells are the smallest individual unit of a raster layer, and the resolution of a raster layer is dependent on the ground scale that a single cell measures, usually calculated in meters. GIS analysts performed raster analysis using the ArcGIS Spatial Analyst extension to generate the IMI model. Specific GIS functions used include hillshade, curvature, and flow accumulation.

Researchers also used IMI to stratify the landscape of four treatment units in a study of oak regeneration using prescribed fire and mechanical thinning. Locations where IMI indicated dry soils had more intense fires, greater canopy openness, and increased oak and hickory regeneration over a seven-year period.
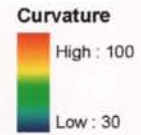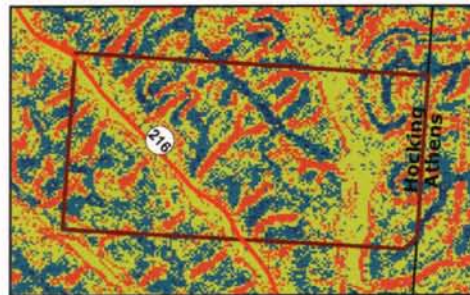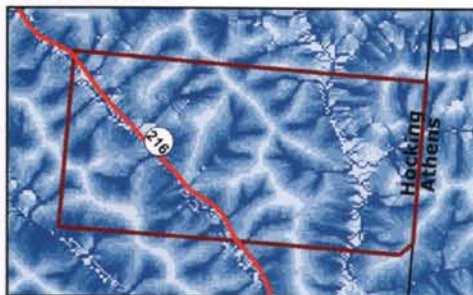
Integrated Moisture Index: Wayne National Forest

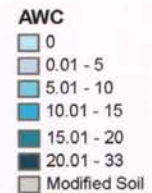**Legend (IMI map):**
- Wayne NF Boundary
- 100 Year Flood
- Stream
- State Route

IMI
Wet — Dry

0 — 0.5 Kilometers

Hocking

Athens

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Hillshade

Hillshade
High : 100
Low : 0

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Hocking / Athens

Curvature

Curvature
High : 100
Low : 30

216

Hocking / Athens

Flow Accumulation

Flow Accumulation
High : 100
Low : 0

216

Hocking / Athens

Available Water Holding Capacity

AWC
- 0
- 0.01 - 5
- 5.01 - 10
- 10.01 - 15
- 15.01 - 20
- 20.01 - 33
- Modified Soil

216

Hocking / Athens

Resource tables

Data dictionary

General data description	Data sources
10m DEM of Ohio	Ohio Department of Natural Resources.
County soil surveys	USDA Natural Resource Conservation Service.
Wayne National Forest polygons	Ohio Department of Natural Resources.
FEMA 100-year flood polygons	Ohio Department of Natural Resources.
State routes	Ohio Department of Transportation.
Streams	Ohio Department of Natural Resources.

Software dictionary

Software	Description
ESRI ArcGIS Desktop	Cartographic production, data management and analysis.
ArcGIS Spatial Analyst extension	Raster analysis.
ArcGIS Maplex extension	Provides advanced label placement for ArcView.
Soil Data Viewer 5.2	ArcGIS extension that maps soil attributes.
TauDEM	ArcGIS extension that provides advanced analysis tools for processing a digital elevation model (DEM).
Hawth's Tools	ArcGIS extension that provides various tools for ecological research.

Recipe for map-building success

The integrated moisture index can be created from a digital elevation model (DEM) and county soil survey data. A DEM represents the surface topography of the earth to help define both the form and elevation of the terrain. The quality of the output is determined by the resolution of the DEM and algorithm used to calculate flow accumulation. Our model uses TauDEM's D-infinity algorithm to calculate flow direction and flow accumulation from a ten-meter DEM. We used the USDA Natural Resources Conservation Service's Soil Data Viewer to calculate the soil component of the IMI model. Once the area had been selected and the data acquired, we followed these steps:

Step 1: Apply the Fill tool to reduce errors

From the Spatial Analyst toolbox, we ran the Fill tool on the DEM to reduce errors in the model input files.

Step 2: Calculate hillshade

We calculated hillshade and curvature from the filled DEM using tools in the Spatial Analyst toolbox.

Step 3: Standardize hillshade output

We used the raster calculator to standardize the output of hillshade and curvature from 0 to 100.

Step 4: Calculate flow direction and slope

We used TauDEM to calculate D-infinity flow direction and slope. The output was in radians.

Step 5: Determine contributing area

With the flow direction, we used TauDEM to calculate the D-infinity contributing area with a slope weighting.

Step 6: Calculate flow accumulation

We standardized the output of contributing area (flow accumulation) from 0 to 100 using the raster calculator.

Step 7: Map available water supply

Using the Soil Data Viewer extension, we mapped the total available water supply, 0 to 100 cm.

We then converted the available water supply vector file to a raster grid.

Step 8: Calculate integrated moisture index

We used the raster calculator to calculate IMI with the following formula: [(hillshade x 0.4) + (curvature x 0.1) + (flow accumulation x 0.3) + (available water supply x 0.2)].

Step 9: Mask flat areas

We overlaid flood data to mask areas of unreliable values due to flat topography.

Step 10: Label features

We labeled features using the Maplex extension, which provides increased label control over placements.

Conclusion

Stratifying a landscape with the integrated moisture index can help with sample design and provide information related to soil moisture. The IMI is algorithmically simple to produce, requires no field data, and is reliable for areas with moderate topography. It is not appropriate for flat or mountainous areas where elevation is a prime driver of vegetation. The resulting model is not time-specific and is consistent among locations. Using the D-infinity algorithm produces a more representative pattern of water movement through the landscape. The model can be calibrated to the landscape influences specific to your area by modifying the IMI formula weights.