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Abstract

An accuracy assessment on a 2009 Vegetation Map of Mammoth Cave National Park produced by University of Georgia indicated inadequate reliability. As well, there were significant polygon boundary errors and unclassified polygons left blank on the map. With pressing need for a vegetation map to support the park's Fire Management Plan (FMP), a derivative of the 2008 Landfire map was produced. Specifically, 24 categories were regrouped into 4 vegetation categories useful for the FMP. Barrens and Prairie Plantation categories were added as superimposed polygons, and the same approach was taken for both fire and storm-linked forest canopy gaps. Accuracy assessment data points were sampled on a random basis until the cumulative percent correct stabilized, indicating that the sample size was adequate. The final cumulative average for this map was 66% accurate, which will require enhanced field checking of prescribed fire plots. Funding will be sought for yet a new map.

Introduction

An accuracy assessment by NatureServe (Smart and White 2010) on the 2009 Vegetation Map of Mammoth Cave National Park produced by the University of Georgia (Jordan and Madden 2010) indicated a percent accuracy far below the minimum 80% standard. With the pressing need for a vegetation map to support fire management in the park, a vegetation category consolidation strategy was developed by Olson, who then worked with Scoggins to achieve this in the GIS. Generalizing the map improved the accuracy assessment somewhat, but there were still significant problems. The accuracy assessment was based upon field data taken at random points in the park, which could inform whether the polygon was correct at that point, but which could not evaluate the whole polygon. Therefore, Olson carried out an assessment of polygon boundaries, which determined that there were many significant errors in boundary delineation between vegetation types. As well, it was discovered that there were many polygons never classified and simply left blank. Presentations of the residual errors were given to key park staff, and gradually the scope of the problem was realized. Acting Science and Resources Management Chief Tim Pinion organized a meeting with park and Natchez Trace fire management staff. After extensive discussions, it was accepted that a new map would be needed. There was urgency because revision of the park's Fire Management Plan (FMP) was already under way.

Alternate strategies for deriving a map were pursued. A proposal to acquire and classify multispectral Lansat data was prepared by Toomey and Olson because this approach worked well for a previous vegetation map of the park (Olson et al 2000). However, Burton suggested that the Nature Conservancy's Landfire map (LANDFIRE 1.1.0 Existing Vegetation Type Layer) might be sufficient, and so this was the avenue selected as the way to derive a sufficiently accurate and up to date vegetation map of the park in a compressed time frame, and with no funding.

Burton made the 2005 Landfire map available to Scoggins, who printed it out for review by Olson. Subsequently, we became aware of a more recent version produced in 2008. Scoggins procured the newer Landfire map from their website for use as data upon which to build a map to meet our needs. Based upon Olson's review of the 2005 map, which was very similar, he wrote a three page "Prescription for Altering the 2008 LANDFIRE Vegetation Map for Mammoth Cave National Park's Fire Management Plan".

Methods

Using the prescription as a guide, the following actions were taken to consolidate vegetation types meaningful for fire management planning. Several of the vegetation categories had low pixel counts, and these categories were individually displayed in a bright color to make them easier to find on the computer display. These sets of pixels were compared to adjacent vegetation and also with digital aerial photographs taken along with the LiDAR imaging. For vegetation categories with high pixel counts, we were able to find accuracy assessment points (Smart and White 2010) solidly within that category and look up field data on vegetation composition. With these comparisons as a guide, 24 of the 25 categories designated on the 2008 Landfire map were regrouped into 4 vegetation categories useful for the FMP. One Landfire category, South-Central Interior/Upper Coastal Plain Wet Flatwoods, could not be found and so was not reclassified. Barrens and Prairie Plantation categories were added as superimposed polygons, and the same approach was taken for both fire and storm-linked forest canopy gaps.

Results and Discussion

Four Landfire categories were consolidated into Xeric-Mesic Oak Forest/Woodland, which were: Southern Interior Low Plateau Dry-Mesic Oak Forest, South-Central Interior/Upper Coastal Plain Flatwoods, Central Interior Highlands Dry Acidic Glade and Barrens, and Central Interior Highlands Calcareous Glade and Barrens. These last two categories sounded promising, but turned out to be pixels scattered along roads and other apparently random locations. Representative species of the Xeric-Mesic Oak Forest/Woodland group are shown in red in Table 1 because this is a fire-adapted or fire tolerant community. It should be noted that the park does have dry limestone outcrop communities that have never been differentiated by any remote sensing mapping effort or by aerial photo interpretation. These communities, which have been called Cedar-Oak Glades and Cedar-Blue Ash Woodlands by different botanists, are very special communities. Several have been mapped by GPS circumnavigation, and that or high resolution habitat modeling will likely be needed to get these communities mapped in. We know where they are in each burn unit and can take their low fire intensity and frequency into consideration during the planning process.

Five Landfire map categories were consolidated into Mesic Hollow/Floodplain Forest, which were: South-Central Interior Mesophytic Forest, Central Interior and Appalachian Floodplain Systems, Central Interior and Appalachian Riparian Systems, Gulf and Atlantic Coastal Plain Floodplain Systems, and Central Interior and Appalachian Swamp Systems. Representative species of the Mesic Hollow/Floodplain Forest are shown in blue in Table 1 because this is a not a fire-adapted or fire tolerant community.

Two Landfire map categories were consolidated into Coniferous/Deciduous Successional Forest, which were: Ruderal Forest-Northern and Central Hardwood and Conifer, plus Southern Appalachian Low-Elevation Pine Forest. Based upon a vegetation map by Ivan Ellsworth (1936), a significant portion of the park was open or recently abandoned fields and pastures during the period of land acquisition for park establishment. On limestone substrate, these open areas tended to be dominated by Eastern red cedar, and on sandstone the old fields tended to be dominated by Virginia pine. With time, deciduous trees have become established too, but many of these species are not fire adapted and so great care must be taken if prescribed fire is used in these community types. Representative species are shown in green in Table 1 because few are fire-adapted or fire tolerant.

Thirteen Landfire map categories were consolidated into Disturbed Lands, which were: Developed-Open Space, Developed-Low Intensity, Developed-Medium Intensity, Developed-High Intensity, Barren, Agriculture-Pasture and Hay, Agriculture-Cultivated Crops and Irrigated Agriculture, Introduced Upland Vegetation-Treed, Managed Tree Plantation-Southeast Conifer and Hardwood Plantation Group, Managed Tree Plantation-Northern and Central Hardwood and Conifer Plantation Group, Ruderal Forest-Southeast Hardwood and Conifer, Bluegrass Savanna and Woodland, and Pennyroyal Karst Plain Prairie and Barrens. This last category was intriguing, but it consisted of a scattering of 18 pixels that were found to fall on open fields. Fire is not welcome in developed areas or farm fields, and so the vegetation examples are shown in green in Table 1.

The park does have Barrens or prairie community types on the Pennyroyal Karst Plain and equivalent karst valley habitat that was either present at the time of acquisition, such as Wondering Woods north of Chaumont, or which was released by deliberate removal of

Table 1: Community vegetation types, representative species, and coverage in the park. Due to the low precision inherent in mapping large areas with complex vegetation, acreages /percentages have been rounded. Red and bold indicates fire adapted vegetation, blue and underlined indicates non-fire adapted vegetation, and green in italics indicates where fire is not welcome such as developed areas, or where caution must be exercised in determining if fire can help move successional vegetation toward desired future conditions.

Vegetation Type	Typical Species	Acres/Percent of Park
Xeric-Mesic Oak Forest Woodland	**Chestnut, post, chinquapin, blackjack, black, and white oak**	22,300 acres / 42%
Barrens	**Prairie grasses, forbs, plus shingle, post, and blackjack oak**	120 acres / 0.2%
Prairie Plantation	**Prairie grasses and forbs**	110 acres / 0.2%
Mesic Hollow/Floodplain Forest	Sugar maple, beech, tulip poplar, box elder, sycamore	17,100 acres / 32%
Coniferous/deciduous successional forest	*Eastern red cedar , Virginia pine, red maple, tulip poplar, dogwood, sweetgum*	8130 acres / 15%
Disturbed lands	*Developed areas in fescue, road sides*	150 acres / 0.3%
Forest canopy gap – storm linked	*Downed pines, early successional and invasive plants.*	800 acres / 2%
Forest canopy gap – fire linked	*Downed and standing dead pines, successional and invasive plants.*	4120 acres / 8%

coniferous vegetation thickets so the seeds already in the soil could germinate, as on the Barrens south of Chaumont. None of the Landfire categories corresponded to these grasslands, and so polygons of actual Barrens communities were superimposed upon the map. The park also has three locations where prairie grasses and forbs have been planted in disturbed areas. These plantations show no evidence of having been natural prairie or barrens, and simply serve as refuges for marginalized species. The Prairie Plantation polygons can be found at the former Job Corps Center on Flint Ridge, the current Job Corps Center (called Eagle Prairie), and at the site of the former Great Onyx Hotel (called Onyx Meadows). Both restored and installed grasslands require frequent fire for maintenance, and so the characteristic vegetation is shown in red in Table 1.

Two classes of forest canopy gaps were mapped using different data sets. Storm-linked canopy gaps were mapped using a GIS layer created by Toomey using a portion of LiDAR data on forest structure. These gaps are based upon vegetation 2 meters or shorter, and are mostly found in Virginia pine stands damaged by an ice storm in January 2009, plus other less catastrophic storms. Fire-linked canopy gaps were based upon fire effects team field observations for development of composite burn index (CBI) data. This groundwork was used in conjunction with remote sensed data to generate burn severity maps. These maps are provided with the caveat that they are intended for use on a broad scale. However, the two burn severity pixel categories indicating the hottest areas were highly correlated to canopy gaps shown with Toomey's LiDAR layer, indicating high spatial accuracy. We know that these areas with high burn severity have standing dead Virginia pines and Eastern red cedar killed by fire. This makes these canopy gaps quite different from the gaps caused by storm damage only. Both types of canopy gaps can be virtually visited via Google Earth aerial photographs of the park where downed and standing dead trees can be seen. Field observations will be needed to determine current vegetation and if, when, and how prescribed fire may be useful in moving these gaps toward desired future conditions.

Accuracy Assessment

In late March of 2012, Scoggins set up Olson on the GIS over a period of four days to do an accuracy assessment of this vegetation map derived from the 2008 Landfire Map and also the 1999 Satellite Vegetation Map based upon 1995 Landsat multispectral imaging. Both maps are based upon Landsat imagery.

Based upon blocks of 50 accuracy assessment points chosen by a Stat Trek random numbers table from the NatureServe data set, the percentages of points correct for the derivative Landfire map were 64%, 54%, 78%, and 70% with cumulative accuracies coming in at 59%, 65% and finally 66% with all 200 points. This does not meet the national standard of 80% minimum correct, but given that we desperately need a vegetation map for the prescribed fire program, we can still use it by doing more field checking in burn units, especially for developing ignition maps.

The 1999 Satellite Vegetation Map map did not fare quite so well. Again, based upon the same blocks of 50 accuracy assessment points chosen by the Stat Trek random numbers table from the NatureServe data set, the percents correct for this map were 50%, 44%, 66%, and 46% with cumulative accuracies coming in at 47%, 53% and finally 52% with all 200 points. This map is old and it also has more vegetation categories, which increases the chance of being wrong.

Thankfully, in both cases the cumulative percentages stabilized within one percentage point, indicating that the sample of 200 was adequate.

Conclusion

There are aspects of this map that offer more information than the 2000 vegetation map of the park. For instance, canopy gaps caused by storms or fire are delineated, and these will be useful for fuels classification and for determining some nodes of exotic plant invasions. On the other hand, successional vegetation is lumped into one category in the current map, and this precludes learning anything about spatial changes in successional status. The 2000 map has three categories of successional vegetation, which can inform the trajectory at different sites. For this reason alone, it is worth acquiring Landsat data in the future and classifying it as we did for the 2000 map so that we can compare "apples to apples" with approximately two decades between Landsat datasets.

There are exciting possibilities for the future. Toomey has indicated that it should be possible to derive a DEM of the vegetation surface and then drape the classification on top of that surface, which could really help us better understand vegetation structure. As well, Burton pointed out that Cecil Frost's studies on pre-settlement vegetation will help inform us in determining desired future conditions in different habitat types in the park, and that these data can be used in future vegetation mapping efforts.

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