

# Updating Spatial Datasets Using Geographic Information Systems and Remote Sensing Techniques

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## **Abstract**

*With an increase in the availability and application of remote sensing and Geographic Information Systems (GIS), the development of new methods to accurately and efficiently update spatially derived datasets has become important. Large and small-scaled landcover datasets are costly and time-consuming ventures. Landscape altering events often occur before a mapping project has been completed. Such was the case with the existing vegetation and fire fuel load spatial datasets of Petersburg National Battlefield (PETE) and Shenandoah National Park (SHEN), where Hurricane Isabel and the Rocky Top fire, respectively, caused extensive damage to the natural environment. In both instances a GIS coupled with imagery and Remote Sensing techniques were used to update the pre-existing datasets. An object-oriented classifier; VLS's Feature Analyst was used to map areas of downed trees at PETE. Various classification methods were used to map the Rocky Top fire perimeter and the severity of it upon vegetation. The differenced Normalized Burn Ratio (dNBR) was successful at not only mapping the fire's perimeter but in mapping the different severity levels as well. Validated with field work, the techniques used were able to accurately document and quantify changes that occurred to the natural environment, allowing geospatial datasets to be updated in a time efficient and cost effective manner.*

## **Introduction and Study Areas**

Having recently completed an extensive mapping project for the North East Region of the US National Park Service, North Carolina State University's Center for Earth Observation has begun exploring techniques that will allow small-scaled landcover datasets to be updated in a time efficient and cost effective manner. This is especially important because most parks in the North East Region fall within the Wildland Urban Interface where accurate and current geospatial information is a necessity to effectively implement proper management of available resources. The objective of this research project is to explore several GIS applications to determine which are appropriate and feasible for two types of damage associated with natural resources typically seen in the North Eastern US. Study sites for this project include: Shenandoah National Park (SHEN), where in June of 2002 the Rocky Top Fire burned nearly 1500 acres, and Petersburg National Battlefield (PETE), where in September of 2003 Hurricane Isabel leveled extensive stands of deciduous and coniferous forests.

## **Petersburg National Battlefield**

### **Data and Methods:**

The magnitude of the hurricane damage was immediately realized and park managers decided to document the scope of destruction via aerial or satellite imagery.

Digital aerial photography was chosen because of its ability to capture the area of interest at a small scale (1:6000) and at an affordable cost. True color and Color Infrared (CIR) imagery were captured in October of 2003, processed and delivered to North Carolina State University's Center for Earth Observation in the summer of 2004. Upon initial visual inspection of the imagery, areas of downed woody debris were easily identified. Applying traditional techniques of supervised and unsupervised classification, further areas of forest damage were identified. However, it became apparent that spectral responses alone could not quantify areas of forest damage. Classifying the imagery based on Leaf Area Index was not advised, and the NDVI classification led to similar inconclusive results. The inability to quantify the amount of woody debris present did not satisfy the objectives of the project and required a different approach. Isolating spectral responses, within the areas of forest damage, did not lead to a definitive classification of downed woody debris. These traditional methods rely entirely upon spectral information in an image while neglecting the spatial arrangement of pixels. Literature reviews (O'Brien 2003 and Vanderzanden 2003) led to the use of automated feature extraction or object-oriented classifiers. Descriptions and reviews of VLS Feature Analyst's requirements, methods of object extraction and output into a GIS format, matched the requirements and desired products for the scope of work to be completed at PETE.

The focus of automated feature extraction is the recognition of spatial patterns of pixels in addition to the spectral responses of those pixels. Classification based solely on spectral responses of pixels would not take advantage of the benefit that high resolution imagery provides. For this project, two types of imagery were available; true color and CIR. Determination of the appropriate type of imagery was made first. The true color and CIR imagery taken of Fort Gregg and surrounding area were used to determine Feature Analyst's ability to indicate areas of downed woody debris. Training sites or areas of interest were drawn around areas of downed woody debris and in some instances a single occurrence of a downed tree. Unlike a "wall-to-wall classification" training sites of only downed woody debris were established. Using these areas as training sites, Feature Analyst mapped areas that met similar spectral and spatial pattern responses. As an iterative, or hierarchal process, Feature Analyst outputs are analyzed after each run, with adjustments made to the output shapefile to indicate areas that were identified correctly and areas identified incorrectly. This "on the fly" adjustment allowed the training sites to improve with each iteration. Iterations were performed until the user felt all areas of downed woody debris had been mapped. The same process was used for the CIR imagery as well, applying the same shapefile of training sites, used earlier. The resulting classifications were compared for areas of similarity and differences. After careful examination the true color imagery was chosen based on its ability to discern areas of downed woody debris more accurately, especially in areas of dead herbaceous matter or bare earth. Further, when using the CIR image, Feature Analyst confused roads and portions of homes (both of linear pattern) with downed woody debris more often than when using the true color image. As a result it took more time and iterations to arrive at an acceptable level of classification.

The Eastern Front, because of its size and extent of damage took the longest to classify. The species makeup of forests of the Eastern Front is different from other areas of the park; in that pine both plantation and naturally occurring are found. Feature Analyst classification outputs were more accurate if training sites were created for each

type of tree, pine or hardwood. (Pine trees are small in size and typically black in color while deciduous trees are larger and either white or brown in color.) When training sites of both tree types were created, the resulting output contained more clutter and took longer to differentiate correct areas from incorrect areas. When training sites of each type were created, the resulting classification was less cluttered and more accurate. This resulted in fewer iterations and the classification of downed woody debris at a faster rate. When clutter, from both output classifications had been effectively removed the outputs were merged, resulting in one layer of mapped downed woody debris. With all occurrences of downed woody debris mapped, quantifying the damage began by creating affected area polygons.

Establishing training sites to enable Feature Analyst to successfully classify an image was a time consuming process. However, this process did not require the knowledge or understanding of spectral characteristics of specific features, such as dead woody material. While successfully applying Feature Analyst required training time, this investment in time was far less than that required to classify an image based solely on spectral responses.

Quantifying areas of damage was accomplished by establishing generalized areas of forest damage then determining the degree or amount of damage per area. Converting a vector image representing downed woody debris to a raster image then reclassifying the raster image into two categories created areas of forest damage. This approach allowed for the capture of fine fuels that are important to fire spread but hard to capture using remote sensing. Using the line density function in ArcMap a buffer determined by the frequency of lines was created. The resulting raster image was classified into two categories, based on a break point set of .01 or 4.4%. This mimicked a minimum density requirement with the raster image indicating the presence or absence of downed woody debris. Other break points were applied, but were either too restrictive, excluding areas of previously mapped downed woody debris, or too general, including areas clearly not damaged. This generalization of forest damage allowed the polygons, representing downed woody debris, to: 1) capture 1- and 10-hour fuels missed by Feature Analyst classifications, and 2) capture the horizontal spatial distribution of downed woody debris across the landscape. These polygons were quantified based on their percent coverage of downed woody debris. The area of each polygon representing an individual occurrence of downed woody debris was calculated, summed, and then divided by the area of the generalized forest damage polygon in which it was located. The integration of GIS with remote sensing techniques, specifically the object oriented classifier Feature Analyst, was invaluable in not only indicating occurrences of downed woody debris in a timely fashion but creating spatial dataset representing generalized areas of forest damage with which a quantifiable map could be made.

### **Field Work:**

Assessing the validity of the Feature Analyst classifications was done according to Brown's Transect guidelines and Burgan Rothermal Protocols. Field work addressed two questions: 1) the ability of Feature Analyst to identify downed woody debris, and 2) determine if the percent coverage classification method accurately represented the actual fuel loads present in the forest damage areas. Using Hawth's Analysis Tools random point generator, points were distributed in areas classified as damaged and outside (but

within PETE boundaries). To assess the validity of the Feature Analyst mapped occurrences of downed woody debris; a predetermined point was navigated to. At the predetermined point any occurrence of downed woody debris within four meters and longer than two meters in length and 12 inches in diameter was recorded as having an occurrence of downed woody debris. The results were incontestable with 100% of points placed in areas called damaged having downed woody debris in them and 90% of points placed in areas called not damaged, actually not having forest damage.<sup>1</sup> With the mapped areas of downed woody debris validated, as indicated by Feature Analyst, the second objective of the field work, fuel load measurements, was begun. Using Hawth's Analysis Tools random point generator, several points were placed in each polygon that met the minimum 0.5-acre mapping unit for this project. These points would serve as possible plot locations. To ensure that an entire plot would fall within the forest damage polygon, a 50-foot buffer was placed around each point to determine the point(s) that would meet the required transect length. If the buffer extended beyond the damage polygon, then the buffer and corresponding point were eliminated as a possible plot location. Once all possible plot locations were determined, they were stratified based on their attributes, percent coverage, pre-hurricane fuel model, and NVCS formation code. While random in their placement, 24 points were selected by the user for field work based on their attributes. This was to ensure collection of field data truly representative of the vegetation communities of PETE.

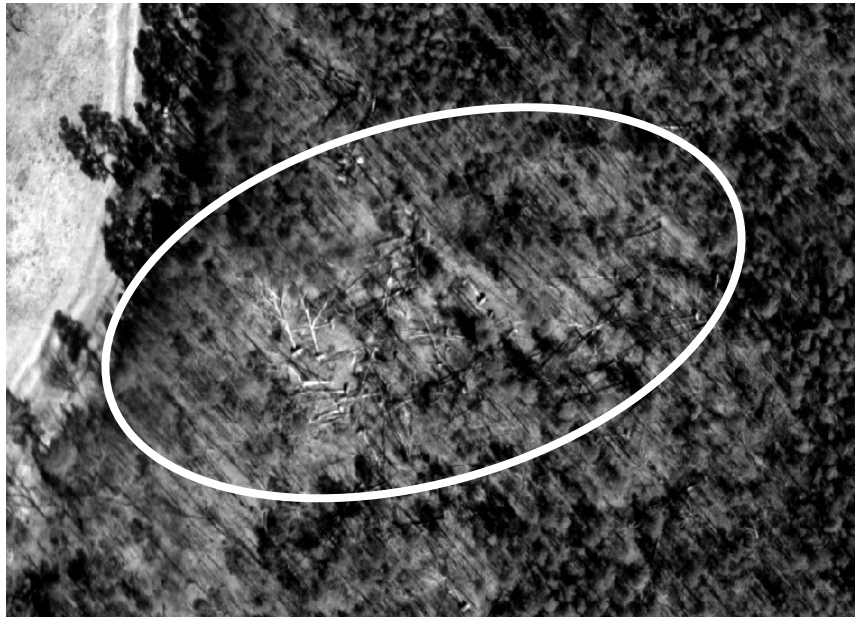


Fig. 2. Area of downed woody debris in PETE.

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<sup>1</sup> These results may be inflated by the copious amounts of downed woody debris due to several ice storms over the past decade, particularly a 1998 event. It is impossible to definitively determine which event, ice storm or hurricane caused the forest damage

## **Shenandoah National Park**

### **Data and Methods:**

Two Landsat 7 TM seams, one pre-fire dated June 30<sup>th</sup>, 2001 and the other a post-fire image dated July 6<sup>th</sup>, 2003, were acquired. Landsat TM data were chosen for this research project because of its temporal availability and the nature of the data that the satellite sensor acquires. With a temporal resolution of eight days (utilizing both Landsat 5 and 7), numerous dates of imagery covering the desired spatial extent were available. A Landsat TM image with seven bands of spectral data can support various data transformations, which were of utmost importance in this research project. The post-fire image, taken a year after the fire, was chosen, because the objectives of this research project were not only to determine the burn perimeter, but also to map the fire impacts upon the vegetation and fuel loads. Imagery taken the following growing season was more likely to record any long term ecological changes caused by the fire. In some herbaceous vegetation communities, an increase in green biomass is seen shortly after a burn. The increase in herbaceous productivity caused by a release of nutrients and an abundance of sunlight would have concealed the true spectral response of the landscape, thus hiding the burn impacts upon the shrub and tree communities. In addition related factors affecting the amount of vegetation and fuel loading such as, seed bank availability, mass wasting, and insect infestation, are more likely to be captured in imagery taken a year later. As updating pre-existing vegetation and fuel load datasets by mapping the long term ecological effects of the fire is the objective of this research, acquiring Landsat TM imagery a year after the fire event was appropriate.

Geometric correction of the two images was not necessary because both image edges matched when comparing the Shenandoah River and numerous agricultural fields. Included in the purchase price of the Landsat data, images are already in reflectance units as well as terrain-corrected, to account for any topographic distortions. The only abnormality was the appearance of diagonal stripes across both images. Using Leica ERDAS Imagine 8.7 software, the radiometric enhancement TM De-striper was used on both images in hopes of reducing the visual and spectral distortion. The De-striper enhancement was successful in reducing the gaps, or areas of no data present in the images' histograms'. While not fully removing the striped appearance in both images, the post-fire image, especially in the burned, area was greatly improved. Because each image's histogram had been altered slightly, the histogram match enhancement was completed. De-striped versions of the pre- and post-fire images were matched, with the post-fire matched to the pre-fire image chosen for further analysis because the striped appearance was diminished further. Atmospheric or transmittance normalization of the Landsat images used was not performed because of the inability to locate areas large enough to collect spectral signatures representing the same object (river, field, road). However this did not cause any variation in the resulting data transformations. In fact the USGS EROS Data Center for National Programs like the National Burn Severity Mapping Project, does not perform atmospheric normalization. The improvements are not worth the time and effort. (Key and Benson 2004)

No spatial enhancements were done to the images primarily due to the desire to preserve the mosaic pattern of burn intensities. Due to Landsat's large spatial resolution and the Rocky Top fire's impact on 1,500 acres, any filter applied caused the image to lose spatial information, aggregating pixels of dissimilar values together. Since the

objective of this research project is to discern not only the burn perimeter but the different fire severities as well, the pixelated appearance of the classifications was not a concern.

Spectral enhancements or data transformations were applied to the images in hopes of elaborating any undetected spectral differences. The two spectral enhancements applied were the Tasseled Cap and the NDVI transformation. While these transformations were not designed with burn detection in mind specifically, they are typically used as surrogates in post-fire analysis, because they discriminate between areas of vegetation change.

In total, three NDVI images were created: pre-fire, post-fire and differenced NDVI image, with the third image showing different levels of green biomass, gain and loss. This differenced NDVI resulted in a wider range of values when compared to the post-fire image. Darker areas illustrated areas of biomass increase, while white areas illustrated areas that declined in green biomass. Vegetation increase within a burn perimeter is not uncommon; in fact it is often seen. After older forests and accumulated fuels are burned, an increased amount of nutrients coupled with an increase in sunlight, stimulates the fast growing herbaceous community. This change in the type of vegetation growth masks the true spectral response of the landscape. The NDVI transformation delineated the burn perimeter adequately, but was of little assistance when trying to determine the severity of the fire. The southeastern portion of the fire perimeter was not delineated accurately, because of noise created by a cloud and its related shadow. In addition, it was hard to determine if areas showing an increase in green biomass were undergoing periods of brief intensive fire regrowth or just natural forest succession. This inability to further differentiate pixels within the burn perimeter is what led to the next spectral enhancement, the Tasseled Cap.

Wildland forest fires not only alter existing vegetation, but also modify soil properties and change moisture levels within a forested area as well. Three vegetation characteristics are mapped when utilizing the Tasseled Cap data transformation: brightness, greenness, and wetness. These measures can be used to detect a fire's severity not only on vegetation but across the entire landscape too. Tasseled Cap was originally designed for use in agricultural applications but has more recently been used to detect fire-induced changes in moisture contents of soil and vegetation. (Patterson 1997) In addition, detecting levels of brightness in soil is vital as this can be an indicator of fire severity. Soils are typically only blackened during cooler less intense fire, whereas in fires of higher severity, soils are heated so intensely that their color is altered to a lighter color. Tasseled Cap records moisture levels in two fashions measuring the existence of vegetation and recording moisture in the form of humidity. Canopy fires are typically associated with more severe burn events and with the overstory removed humidity once captured by the forest canopy is no longer present. The Tasseled Cap transformation was able to discern spectral differences in the soil and vegetation, as well as differences based on moisture levels. This allowed for a more precise delineation of the burn perimeter, including areas underlying the cloud and its associated shadow. Areas of different spectral responses within the known burn area were noticed, and these were areas that the NDVI transformation had not been able to notice. However, there were still large numbers of pixels within the known burned area that were saturated, meaning of the same value. The Tasseled Cap transformation was successful at highlighting not only the burn

perimeter more effectively, but areas of differing fire severity when compared to the NDVI transformation. There were, however areas within the burn that were still saturated, which is why the Normalized Burn Ratio (NBR) transformation was investigated.

The NBR was developed after compiling large amounts of multi-spectral data on numerous Western US wildfires. After surveying the data, it was found that when comparing pre-fire images to post-fire images, Landsat TM bands 4 and 7 had a profound spectral response, more so than all other bands. When compared to each other, band 4 decreased while band 7 increased from pre-fire to post-fire images. Band 4 records infrared (vegetation) responses and band 7 records characteristics associated with levels of dryness. To start the NBR transformation, a pre-fire image and a post-fire image were created. Using spatial modeler, band 4 was subtracted from band 7 and divided by band 4 plus band 7. This model was applied to both pre-fire and post-fire images. Both images were saved as continuous data with values ranging from -1 to 1. To create a quantitative measure of the burn, a differenced NBR (dNBR) image was created. Again, using spatial modeler the two NBR images were subtracted from each other. The resulting dNBR image expressed the quantified fire severity, with values ranging from -200 to +200.

A response of less than zero represented unburned areas. A score around zero but on the positive side represented areas of vegetation growth caused by a low intensity surface burn and the higher the score the higher the level of fire severity. The fire perimeter was delineated as the dNBR transformation masked any effects caused by clouds and their shadows. More importantly, however, the fire effects (severity) on existing vegetation were delineated.<sup>2</sup> The patchwork landscape within the burn perimeter was delineated and when overlain on the corresponding post-fire Landsat image (viewed in CIR) the two images matched. With the fire perimeter accurately mapped and the burned areas having values, indicating severity, the need to clearly illustrate the data became important.

The results of the dNBR transformation consisted of continuous values that were an indicator of severity. The science of GIS and Remote Sensing had resulted in a classified image; it was time to perform the art of Remote Sensing, by color-coding the results, determined by spatial components such as slope and proximity. After determining the burn perimeter, the pixel values within the burn were scaled. For this study five classes (see Table 1) were used to discriminate the landscape in and near the Rocky Top fire. As values were assigned to a category, they were analyzed on a thematic map at the same time in order to see where the corresponding pixel was in spatial relation to other pixels with similar values. Break points for low severity were established at 27 at the low end and 47 at the high end, the moderate severity break point was determined to be at 68 with higher values consider high severity.

While not an initial objective of this research project, a comparison of dNBR techniques was done to determine which method provided more accurate classifications. VLS's Feature Analyst, with its ability to manipulate individual bands within an image, has the capability to perform the dNBR data transformation.

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<sup>2</sup> Fire severity not fire intensity. A fire may be of low intensity (flame height, heat, etc.) but of high severity because all of what little vegetation that did exist was consumed by the fire

Class 1	Unburned areas
Class 2	Surface fire of low intensity showing little if any new growth within the herbaceous plant community. Litter partially consumed by the fire.
Class 3	Low Severity, majority of vegetation alive. No effect to the forest canopy, some shrubs affected. Litter layer partially consumed with a few areas where the duff layer is partially consumed by the fire.
Class 4	Moderate Severity, with greater than 50% vegetation mortality at the time of the fire or within one year. Most if not all litter layer consumed. Duff layers partially consumed by the fire. Effects of erosion seen.
Class 5	High Severity, extreme vegetation mortality at the time of the fire or within one year. All litter and duff layers consumed by the fire. Effects of mass wasting seen throughout.

Table 1 Fire Severity Upon Vegetation Classes

Feature Analyst's dNBR was used in an analysis of before and after Landsat images of the Fort Howes fire in Montana in 2000, and was more accurate in its classification of burn severity than the NDVI classification. (Redmond, 2001) After the completion of the initial dNBR using Leica's ERDAS Imagine software, a second dNBR using Feature Analyst within ESRI's ArcGIS was completed. Using the same break points for classification comparison purposes, the two classifications were similar in mapping the burn perimeter, but varied greatly in portions of the burn perimeter. Due to these differences, field work would concentrate on verifying the accuracy of the two dNBR classifications.

### Field Work

Field work to validate the remote sensing classifications was done in June of 2005. The validity of the dNBR classifications was assessed according to Brown's Transect guidelines and Burgan Rothermel Protocols. Field work addressed two questions: 1) to validate the ability of the dNBR classification to map the differing severity levels of the fire upon existing vegetation and fuel loads and 2) determine which dNBR method better classified the fire's severity. Using Hawth's Random Point Generator, points were distributed in areas where the dNBR classifications did match and did not match. More points were placed in areas that did not have matching dNBR classifications to determine which methodology resulted in a more accurate classification.

Field measurements were taken at 17 points throughout the burn perimeter and covering a variety of burn severities. Of the 17 points only six points fell in areas classified as the same severity level. At each point Brown's Transect and Burgan Rothermel Protocols were taken. Brown's Transects were taken to quantify the fuel load. Fuels represent the dead and alive organic matter available for fire ignition and spread. Fuels are characterized by their load (weight per area), size (1-, 10-, 100- and 1000 hour), and bulk density (weight per volume). Burgan and Rothermel Ocular Estimation Protocols allow for an accurate characterization of the plot's vegetation in terms of a qualitative measure of the litter, grasses, shrubs, and trees present.

### Results

#### Petersburg National Battlefield:

Ground observations and spatial dataset manipulation in a GIS led to a conclusion of no underlying pattern causing the forest damage. Damage incurred was not restricted

to one type of vegetation formation and the type of damage varied widely from complete uprooting and snapping of boles to minor crown damage. The only noticeable pattern was most uprooted trees fell to the ground with their crowns to the west of their associated root ball, as the hurricane winds were from the northeast.

Feature Analyst excelled in its ability to map areas of downed woody debris. Classified areas of downed woody debris were more accurate in hardwood canopy cover than in mixed or coniferous cover. However quantifying the areas of woody debris proved more difficult. While plot points were partially determined on their percent coverage, this had no bearing upon the assigned fuel model. Fuel loads (and thus fuel models) were determined from plot measurement calculations coupled with comparing written descriptions of fuel models to observations made.

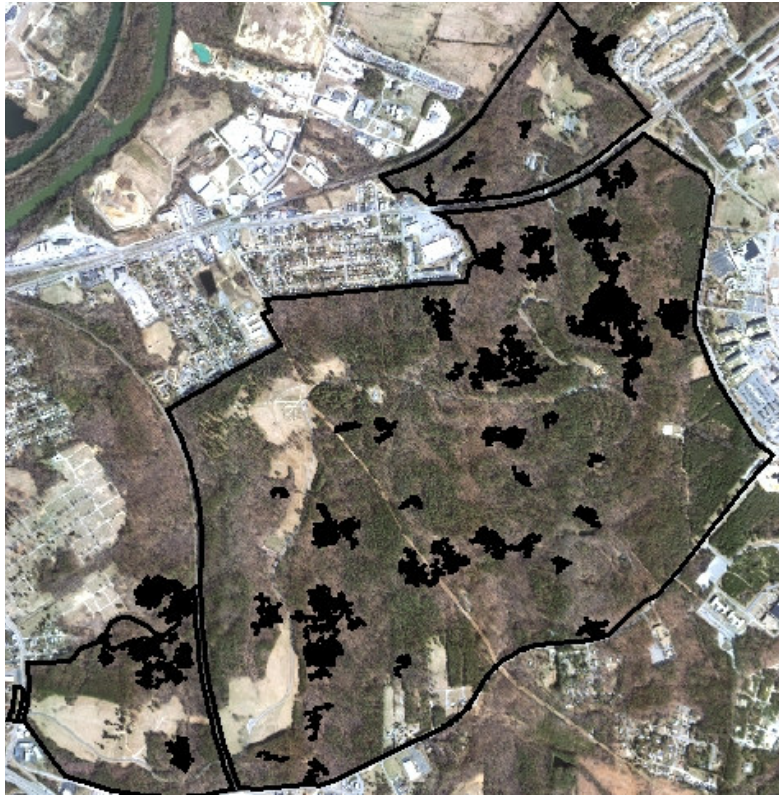


Fig. 3. Feature Analyst mapped areas of downed woody debris in the Eastern Front of PETE.

To provide a further validation of the Feature Analyst classification, the perimeter of an affected area was measured and compared to that of the area indicated by Feature Analyst and the generalization method. The goal was to gauge the effectiveness of the generalization method used to capture missed areas, consisting of one and ten hour fuels. The accuracy of Feature Analyst classified areas was directly related to canopy type. Perimeters of forest damage were captured more accurately in areas of hardwood canopy dominance than in areas of mixed or coniferous cover. This lower accuracy in coniferous formations is related to Feature Analyst's inability to locate woody debris occurring under the canopy. Where canopy gaps occurred in these formations, downed woody debris was

mapped. Leaf-off photography was imperative for this project, as it allowed for the capture of downed woody debris, which would have been obscured if leaf-on photography had been used.

While mapping the occurrences and the spatial distribution of downed woody debris was successful, quantifying those areas was not. Fuel load calculations were made using Brown's Transect Guidelines. These calculations, in combination with professional opinion (Klein, 2005), and written descriptions of the Anderson fuel models, were used to assign new fuel models to the affected areas. Taking into account the entire landscape where forest damage occurred, (i.e., pockets of severe fuel loading found in an area of otherwise uniform fuel load) the fuel model 10 was assigned to all affected areas, except in an area of younger homogenous pine, where "red slash" and grasses were documented. This area was assigned to fuel model 11.

The inability to quantify the downed woody debris should not overshadow the time and money saved by using a GIS and the remote sensing technique Feature Analyst. Time required to complete field work to determine appropriate fuel loads, was reduced from months to a week. By focusing attention to specific areas of PETE, field work was done in areas that were known to have an increase in fuel loads. As part of the Wildland Urban Interface, this quick assessment and inventory of the available fuel is a useful hazard identification tool for local land managers. Incorporating GIS and remote sensing techniques, specifically object-oriented classifiers, to map areas of downed woody debris in larger and more remote settings would significantly reduce the time and money needed to update various geospatial datasets, not just fuel load datasets.

### **Shenandoah National Park:**

Preliminary results indicate that both dNBR classifications did a superior job at delineating the burn perimeter, despite the interference from a cloud's shadow. In comparing the mapped levels of severity, the Feature Analyst dNBR classification tended to exaggerate the fire's severity, especially in Classes 2 and 3. Fuel load measurements were consistent across all plots done in different areas of burn severity. Mapping vegetation regrowth using the dNBR classes proved more difficult, as differences in pre-existing vegetation and environmental gradients like elevation and aspect caused differences within similarly classified areas.

More plots need to be visited before a definitive recommendation can be made, but early results show that plots classified as moderate burns (Class 3) by Feature Analyst, were associated more with fuel load measurements and ocular estimations seen in areas classified by Leica ERDAS Imagine's version as less severe (Class 2.) Likewise areas classified as Class 2 by Feature Analyst correlated more with measurements associated with ERDAS's version which was classified Class 1. An appropriate way to classify fuel loads, after a burn is to distinguish between areas experiencing high and low burn severity. (Redmond, 2001) These areas will exhibit different fuel loadings as a result of the reduction of fuels being consumed by the fire. Accurately mapping these areas will result in a more precise representation of future fuel loads as well. Acting like a data patch, these classifications can be used to update outdated existing spatial datasets. Consistent fuel load measurements amongst similar severity classes of different spatial locations offers promising results for mapping the available fuel loads using remote sensing techniques, specifically the dNBR data transformation. Fuel loads are decreased

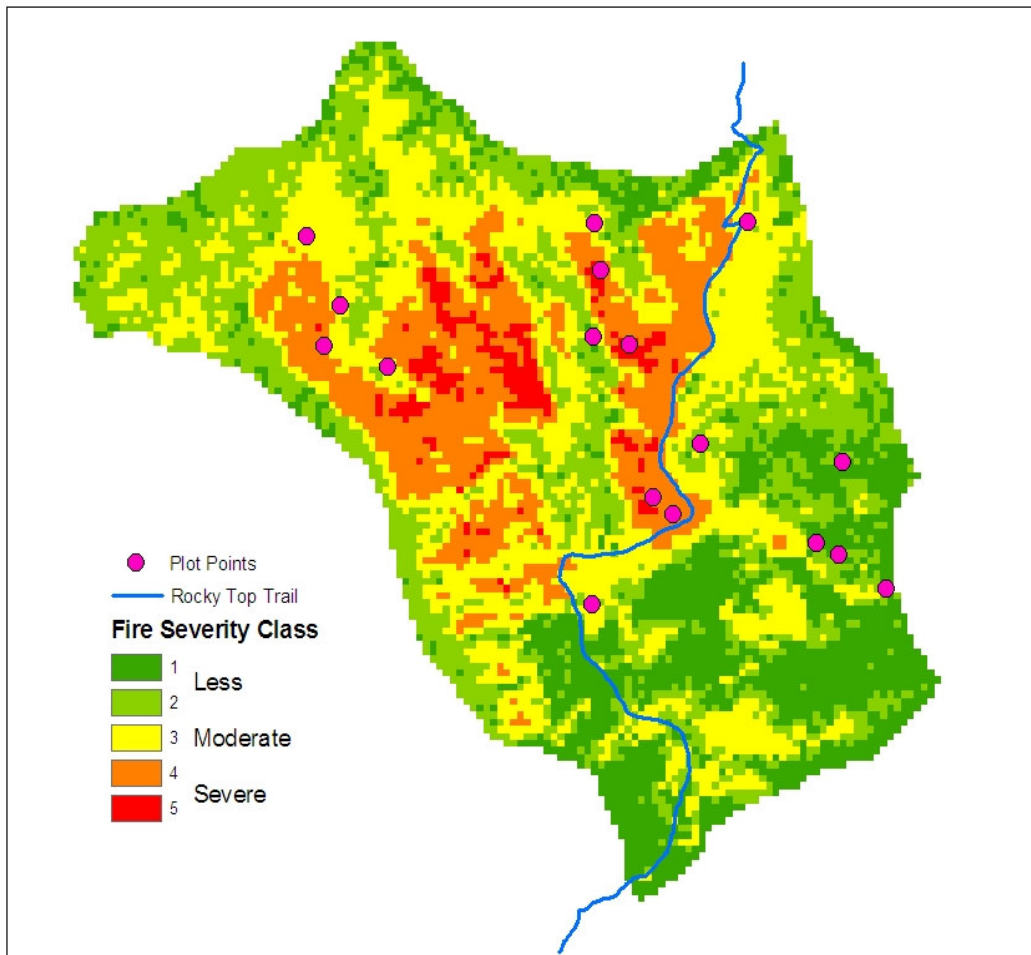


Fig. 4. dNBR classification of the burn severity of the Rocky Top Fire in Shenandoah National Park

in areas experiencing a Class 3, 4 or 5 level of severity. Areas where a severity of Class 1 occurred show no change in fuel loads. Areas where a severity of Class 2 has occurred actually show a slight increase in fuel loads. While fuels, in the form of leaf litter, and 1- and 10-hour fuels are consumed in a Class 2 fire, portions of shrubs that are defoliated and killed, but not consumed by the fire, add available fuels, which in some cases slightly increase the fuel load, specifically in the 1-hour fuel category. In severity classes two through five, the ability to start or spread a fire either natural or prescribed, is greatly diminished, because of the decrease in leaf litter and 1-hour fuels.

While associating future fuel loads with fire severity offers promising results, mapping future vegetation based on fire severity is less reliable, as other environmental gradients affect vegetation regrowth. Regardless of differences in slope, exposure, elevation, and aspect all areas classified as Class 4 or 5 severities are reset to early successional stages. Vegetation regrowth is by those species that were there before the fire, either by re-sprouting from stumps or from seed germination. Elevation and aspect have effects on the regeneration rates of vegetation. Areas of lower elevation and southern aspect had more vegetation than did areas of similar fire severity at higher elevation and northern aspect. Slope affects Class 4 and 5 areas in that mass wasting is

more predominate. Areas of higher slope are subjected to extensive erosion because of the lack of fuels (leaves, roots, logs) to anchor soil in place, removing what little litter or duff that was not consumed by the fire. This is reflected by the areas inability to regenerate vegetation of any type.

The change between pre and post fire Landsat imagery may be greatly affected by not only the amount of vegetation change, but the type of vegetation change as well. Mountain laurel may have a profound effect on the dNBR classification, possibly because of the dark green color of Mountain laurel. Several plots where Mountain laurel were documented were associated with areas of high severity, despite seeing a wide variety of vegetation regrowth. This relationship will have to be explored more, but it should be noted that dNBR method was developed using Western US vegetation and forest fire data. Forests of the Western US seldom have an understory like that seen in Eastern Forests. While no doubt affecting the spectral responses of Landsat imagery, the lack of an understory may cause dNBR classifications to over emphasis a fire event. This however does not diminish the credibility of the dNBR data transformation to delineate the burn perimeter and quantify the severity within the burn perimeter, especially when compared to the Tasseled Cap and NDVI transformations.

### **Discussion:**

As high resolution imagery becomes readily available, the future role of GIS integration with Remote Sensing techniques, especially automated feature extraction, will enable researchers to reliably delineate features on the ground, and thus increase the range of remote sensing applications within the natural resource community. Additionally the utility of software programs like VLS's Feature Analyst will allow those users not familiar with Remote Sensing spectral responses to accurately delineate desired real world features. Subsequent projects will explore mapping canopy gaps as a surrogate for forest damage that appear after a hurricane or other wind-driven events. This will be of particularly interest in areas dominated by a coniferous canopy, and especially since hurricanes strike the Southern US during the summer and fall months or during leaf-on conditions. Incorporating high resolution satellite imagery, e.g. Quickbird, with automated feature extraction may automate vegetation formation delineation.

Forest structure may affect dNBR's ability to discern fire severity upon Eastern US forests. While the dNBR technique is currently better suited for mapping fire severity than NDVI or Tasseled Cap, more studies need to be completed until a definitive statement can be made about its abilities to map a fire's severity.

### **Conclusions:**

Integrating GIS and remote sensing capabilities is appropriate for addressing a wide variety of situations, from preventing wildfires to improving 911 responses in rural areas. Presented in this research project are just two aspects of how a GIS is utilized in a natural resource setting. Remote Sensing techniques, specifically automated feature extraction offers limitless possibilities. The research presented here explores several GIS applications in hopes of determining which are more applicable or feasible for two types of damage associated with natural resources typically seen in the Eastern US. Accurate and current data are vital to communities along the Wildland Urban Interface. Given

scarce funds and resources, employing Remote Sensing techniques coupled with a GIS allowed for the quick and accurate classification of areas of woody debris after Hurricane Isabel. Quantifying these areas of woody debris remains a laborious and time-consuming process, but with the help of Feature Analyst the areas where increased fuel loading occurred were delineated quicker. Combining Remote Sensing techniques and a GIS allowed for not only the delineation of the Rocky Top fire but the fire's severity upon existing vegetation and fuel loads as well. Both methods of the dNBR technique accurately mapped the burn perimeter, but the Feature Analyst version of the dNBR tended to exaggerate the fire's severity level, especially in Classes 2 and 3. The dNBR classification allowed for the quick and accurate delineation of future fuel loads. The dNBR classification alone cannot be used to update vegetation datasets as additional environmental gradients like elevation and aspect greatly affect the rate of vegetation regeneration. Both research projects covered in this paper illustrate the capabilities of a GIS when it is integrated with various Remote Sensing techniques.

## REFERNECES

- Anderson, H.E. 1982. Aids to Determining Fuel Loads for Estimating Fire Behavior. USDA Forest Service GTR-INT-122. Intermountain Forest and Range Experiment Station, Ogden UT.
- Brown, J.K. 1974. Handbook for Inventorying Downed Woody Material. USDA Forest Service, GRTE-INT-16., Ogden, UT.
- Burgan, R.E. Rothermel, R.C. 1984. Behave: fire behavior prediction and fuel modeling system-FUEL subsystem. USDA Forest Service GTR-INT-167., Intermountain Research Station. Ogden, UT.
- Greenberg, C.H., and W.H. McNab. 1998, Forest disturbance in hurricane-related downbursts in the Appalachian mountains of North Carolina: Forest Ecology and Management. 104 170-191.
- Key, C.h. & Benson, N.C. (2002). Remote sensing measure of severity, the normalized burn ratio. Fire effects monitoring and inventory protocol, Landscape Assessment. Rocky Mountain Research Station, <http://www.fire.org/firemon/lc.html>
- Klein, Robert. Fire Ecologist, Great Smoky Mountains National Park, email. April 15, 2005.
- O'Brien, M.A., 2003. Feature Extraction with the VLS Feature Analyst System, Proceedings of the American Society for Photogrammetry and Remote Sensing. NIMA/IDR, Reston, VA.
- Patterson, M. W., & Yool, S.R. (1998). Mapping fire-induced vegetation mortality using Landsat Thematic Mapper data; A comparison of linear transformation techniques. *Remote Sensing of Environment*, 65, 132-142.
- Redmond, Roland L. Classifying and Mapping Wildlife Severity. Imaging Notes, Sept/Oct 2001.
- Vanderzanden, D. and M. Morrison, 2003. High Resolution Image Classification: A Forest Service Test of Visual Learning System's Feature Analyst. Remote Sensing Applications Center, Salt Lake City, UT.
- Viedma, O., Melia, J., Segarra, D., & Garcia-Haro, J., (1997). Modeling Rates of Ecosystem Recovery after fires by using Landsat TM data. *Remote Sensing of Environment* 61 383-398.
- Whigham, D, I. Olmstead, E.Cano, and M. Harmon. 1991. The impact of Hurricane Gilbert on trees, litterfall, and woody debris in a dry tropical forest in Northeastern Yucatan Peninsula. *Biotropica* 23:434-441.