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Multiband drought index enhances soil and vegetation moisture monitoring

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Satellite multispectral measurements provide accurate images of the intensity of forest fires over time.

Drought, the most complex and least understood of all natural hazards, also affects more people than any other.[1] Traditional drought monitoring is based on observations at specific locations, and thus lacks continuous spatial coverage. Satellite remote sensing offers an effective means to continuously monitor drought across wide areas. Most drought monitoring from space observes vegetation moisture using spectral indices that reflect variations in the spectral signatures caused by water stress. Very few studies focus on equivalent soil-moisture monitoring, however.

Simple spectral indices allow interpretation of changes in vegetation water content using a normalized ratio of a sensitive and an insensitive band. Uncertainties arise because these indices cannot completely remove background soil effects. The reflectance of a canopy is strongly influenced by the background soil reflectance, which is primarily determined by the moistness of the soil surface at a given location. Therefore, soil moisture must be taken into account in drought analysis.

We performed sensitivity studies of three short-wave IR (SWIR) bands of the Moderate Resolution Imaging Spectroradiometer (MODIS) and observed that the reflectance of each SWIR band responds differently to variations in soil and vegetation moisture.[2] We therefore defined the Normalized Multiband Drought Index (NMDI),

$$NMDI = \frac{R_{0.86\mu\mathrm{m}} - (R_{1.64\mu\mathrm{m}} - R_{2.13\mu\mathrm{m}})}{R_{0.86\mu\mathrm{m}} + (R_{1.64\mu\mathrm{m}} - R_{2.13\mu\mathrm{m}})},$$

where R represents the reflectance at the wavelengths denoted by the subscripts.[3] Unlike traditional vegetation indices, which use a single SWIR channel, the NMDI uses the difference between two liquid-water absorption bands (at 1.64 and 2.13μm)

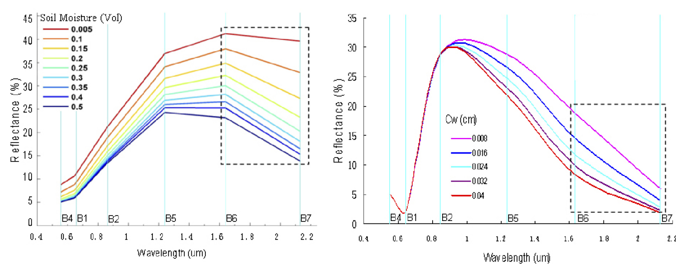

Figure 1. *(left) Model simulated soil spectra at various soil moisture levels. (right) Canopy spectra at different leaf water levels (C_w). Both graphs use Moderate Resolution Imaging Spectroradiometer (MODIS) bands B1-2 and B4-7.*

as a soil and vegetation water-sensitive band. The NMDI is based on the characteristic 'slope variation' in response to different kinds of moisture changes. As shown in Figure 1, the slope between the 1.64 and 2.13μm channels becomes steeper as soil moisture increases, but flatter as leaf water content increases.

To show that the NMDI can be used to monitor both soil and vegetation moisture from space, we investigated its sensitivity to bare soil or weak vegetation as well as to heavy vegetation. For bare soil, higher values of the NMDI indicate increasingly severe soil drought. For heavily vegetated areas, on the other hand, lower NMDI values indicate increasingly severe vegetation drought. The usefulness of NMDI for remote sensing of soil and vegetation moisture has been validated and reinforced using soil spectra and satellite measurements, respectively.[3]

Soil moisture and vegetation water content can influence the occurrence and behavior of wildland fires.[4] Since the NMDI can simultaneously monitor vegetation and soil water content, it should provide valuable information about wildland fire conditions. We used the 2007 wildfires in southern Georgia (USA)

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10.1117/2.1200904.1623 Page 2/2

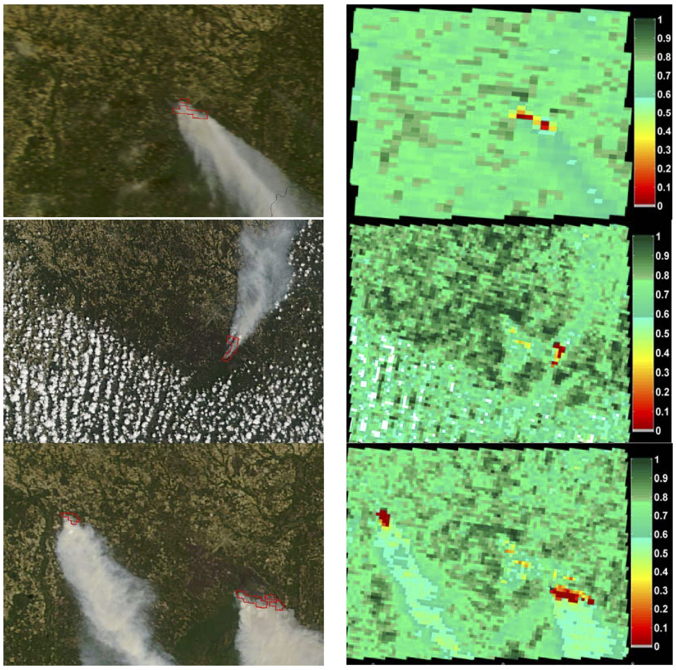

Figure 2. *Three images of the 2007 fire in Georgia (USA). (left) MODIS active fire maps. Active fires are outlined in red. (right) Normalized Multiband Drought Index images with fires denoted by red pixels. The gradient color bar indicates the index value. The white color for clouds appears at the bottom of the scale.*

and southern Greece to investigate the NDMI's ability to detect forest fires.[5]

Compared to the MODIS active fire maps provided by the NASA Rapid Response Project, the NMDI images offered almost the same, similarly accurate depiction of active fire shape, coverage, and location. For each test case, the NMDI exhibits strong signals corresponding to active fires: the NMDI values are much lower for active-fire than non-fire pixels, so the burning spots stand out from neighboring areas (see Figure 2). In addition, the NMDI responds quickly to moisture changes as the fires progress. Performance evaluations using statistical analyses reinforce that active fire detection using the NMDI is quite accurate.[5] Furthermore, the successful application to fire detection in both Georgia and Greece demonstrates that the NMDI is applicable to different areas.

By taking advantage of the information contained in multiple SWIR and near-IR channels, the NMDI has enhanced the sensitivity of spectral detection to drought severity, and is well suited to estimate the water content of both soil and vegetation from space. Future efforts will more fully explore the potential of the NMDI as a drought-monitoring tool, particularly with respect to other vegetation types and geographic areas. If broadly applicable and reliable, the index may provide an opportunity to estimate both soil and vegetation moisture on a regular basis.

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Lingli Wang is a research scientist. Her research interests focus on remote-sensing applications for natural hazards such as droughts, wildland fires, and dust storms. She also works on satellite-instrument calibration and characterization.

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