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EVALUATION OF THE NORMALIZED DIFFERENCE VEGETATION INDEX WITH THEMATIC MAPPER DATA

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ABSTRACT

Remote sensing of the Earth's land surfaces offers potential for improving our understanding of ecological relationships within the terrestrial system and land-climate interactions. At present, the NOAA-6, 7 Advanced Very High Resolution Radiometers (AVHRR) are the only satellite sensors which enable global data collection for land surfaces at a large scale. Spectral data from the AVHRR's first two bands in the red (R) and infrared (IR) portions of the spectrum have been used extensively in the Normalized Difference Vegetation index (NDVI). This is computed as the difference divided by the sum of the relative reflectances in these bands, (IR-R/IR+R). The NDVI has been shown, on the basis of limited agricultural field studies, to be related to green leaf area. It has been used to map large-scale green leaf biomass distributions over regions and continents encompassing both cultural areas and natural vegetation. However, the manner in which a broad range of surface cover types are grouped or segregated by the NDVI has not been investigated. This may be important for interpreting the NDVI.

Based on early results, the Landsat-4 Thematic Mapper (TM) has demonstrated an excellent surface cover mapping capability for interdisciplinary investigations, discriminating among and within a variety of diverse cover types including agriculture, urban areas, forests and wetlands. The additional spectral dimensionality and spatial information of TM data provided an opportunity to compute NDVI values for each pixel of a study area and to associate these with land cover types derived through multi-band spectral clustering analyses. In the process, the distribution of NDVI values among cover types could be determined.

Landsat-4 Thematic Mapper (TM) data for a heterogeneous region in the greater Washington, DC and southern Maryland regions composed of both extensive natural vegetation and culturally altered ares, were analyzed using TM bands 2, 3, 4, 5 and 7 (0.52-0.60, 0.63-0.67, 0.76-0.90, 1.55-1.75, and 2.08-2.35μm). Separate data sets were developed for the same study area for these combinations: a) TM 3 and 4 combined in the NDVI; b) NDVI plus TM 5; c) TM 3, 4 and 5; d) TM 2, 4 and 5; e) TM 3, 4 and 7; and f) TM 2, 3, 4, 5 and 7. These combinations were selected to extract the range of measurements afforded by the middle five of seven TM bands so that 1) spectra for various cover types could be developed and studied; and 2) the advantages/disadvantages of using the spectral regions of TM and AVHRR sensors could be examined. The NDVI was computed for each pixel in data sets 1, 2 and 3; data sets 3-5 were processed by standard spectral clustering and classification analysis, with the cluster labeling process modified to incorporate a third dimension; and 5-band spectral reflectance curves were produced for spectral clusters developed with data set (f). This clustering approach was selected instead of an information reduction approach, such as principle components or greenness-brightness analysis, because it enabled the NDVI computation for each cluster, the extraction of spectra for each cluster, and in general required fewer input bands.

For each of these data sets, the regional distribution patterns, regional acreages, and statistics on spectral data were produced for naturally vegetated (i.e., forests, wetlands) and culturally

altered areas (i.e., urban centers, agriculture). The three-band spectral clusters were assigned to surface cover categories on the basis of x, y, z relative reflectance coordinates and by cross-reference to the multi-band spectra from (f). The TM 2, 4, 5 classification was selected as the reference land cover data set since it produced excellent segregation of urban areas, agriculture, wetlands, and several forest community types. For the NDVI, specific ranges in relative values were identified which roughly correspond to water (very low NDVI), urban/wetlands (low NDVI), deciduous forest (low-moderate NDVI, appropriate for fall date), mixed forest (moderate NDVI), and coniferous forest/agriculture (high NDVI). Within the general categories of natural vegetation and cultural land, an increase in NDVI was found to be associated with an increase in vegetation cover density. However, the same range of NDVI values was associated with ecologically diverse natural and cultural categories. For example, the NDVI were identical for wetlands and urban areas, and for suburban/agricultural areas and natural forests/grassland. Therefore, when surface cover is assumed to be primarily natural vegetation, forests are overestimated and urban/agriculture underestimated with the NDVI. For our study region, in which forests predominate but cultural land use is substantial, forests were overestimated by 44%, urban/agriculture was underestimated by 40%, and most wetlands/grasslands were missed with the NDVI.

This situation was rectified by the addition of a third TM band. When this band was added to the NDVI (bands 3 and 4 combined) as a second band in a clustering and classification procedure, the resulting surface cover representation was much improved. But, a better representation was obtained when the three original bands were input to a clustering and classification procedure. For the fall date studied (11/02/82) either approach with TM5 enabled the NDVI computation for green leaf biomass assessment as well as greatly improved correct designation of natural and cultural cover types. While improved surface cover identification could also be achieved by multi-date NDVI for some cover types (i.e., agriculture), the spectral data indicate that multi-date NDVI would not be helpful for others, such as wetlands and urban areas.

TM 5, for which satellite remotely sensed data have not been available previously, was especially important in the spectral cross-referencing portion of the surface cover association process. The success of TM 5 to improve separability of vegetation classes is speculated to be related to foliar water content of vegetation and surface wetness for other cover types. Consequently, a spectral band similar to TM 5 on future AVHRR satellite sensors would greatly advance global surface cover mapping: with the existing R and near-IR bands it would enable separation of culturally altered land from natural vegetation on a regional basis, along with the NDVI estimates for green leaf biomass. In the meantime, the existing third AVHRR band might be used in a similar way based on satisfactory results achieved with TM 3, 4 and 7.