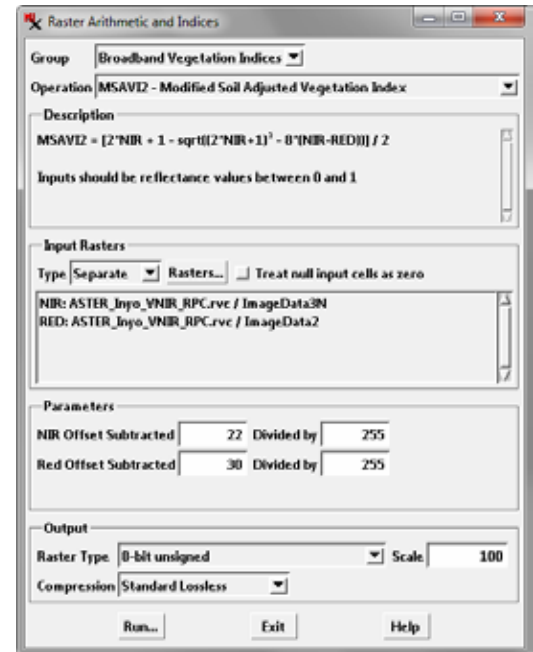


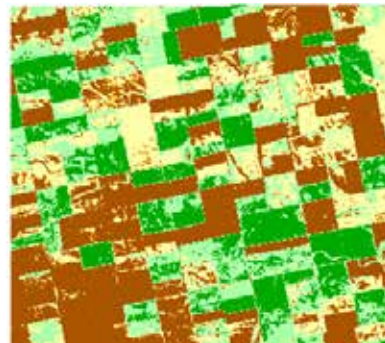
Broadband Vegetation Indices

The Raster Arithmetic and Indices process (Image / Combine / Arithmetic and Indices) in TNTmips allows you to compute a variety of vegetation indices using operations in the Broadband Vegetation Indices group. (See the Technical Guide entitled *Raster & Image Processing: Raster Arithmetic and Indices* for an overview of the process.) The provided index operations perform computations using specific visible and near-infrared bands of multispectral satellite or aerial images.

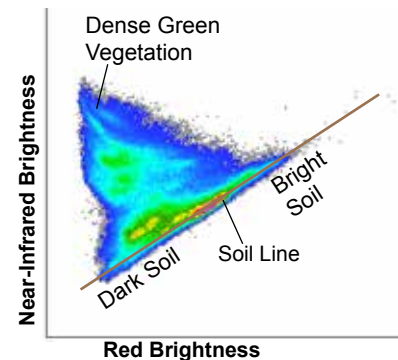
After choosing Broadband Vegetation Indices from the Group menu in the Raster Arithmetic and Indices window (illustrated to the right), use the Operation menu to choose the desired vegetation index. The formula for the selected index is shown in the Description panel. Press the Rasters button in the Input Rasters box to select the input raster(s). Indices computed using only Near-Infrared (NIR) and Red (or Green) bands allow you to use images with separate raster objects for each band or a color-composite image; in the latter case, the red component in the composite image is assumed to be the NIR spectral band and the green component is assumed to be the Red (or green) spectral band. For these indices the Type menu is active, allowing you to choose either Composite or Separate before pressing the Rasters button; the Type setting establishes the filter that is applied in the selection dialog for the input. When using color composites, multiple input images can be processed in one operation.



Color-infrared display (Display Red = NIR, Green = Red, Blue = Green) of agricultural fields with various states of crop cover. Red areas correspond to dense crop cover.



Modified Soil Adjusted Vegetation Index (MSAVI2) result computed in Raster Calculation process. Raster is theme-mapped using 5 classes, with dark green for the highest index values and brown for the lowest values.



Raster correlation scatterplot of near-infrared versus red brightness for the agricultural area in the images to the left.

Background

Vegetation indices are used as measures of biomass, amount of vegetative cover, and vegetation condition. The interaction of incident sunlight with green vegetation is strongly controlled by leaf pigments and leaf structure. Chlorophyll, the dominant leaf pigment, strongly absorbs light in the red and blue portions of the visible spectrum while reflecting green wavelengths, resulting in the green leaf color we see. Near-infrared light penetrates the leaf surface and encounters numerous cell walls and air-water boundaries, resulting in strong upward scattering (diffuse reflection) of this energy.

The contrast between strong near-infrared reflectance and low red reflectance of green vegetation is the basis for most vegetation indices. This contrast can also be illustrated by a scatterplot of image cell values with near-infrared brightness plotted against red brightness (see illustration above right) for an area with variable vegetation cover. Near-infrared and red brightness values

of soils and manmade materials (asphalt, concrete) are strongly correlated over a wide range of image brightness, defining a “soil line” trending upward to the right in the diagram. Conversely, healthy green vegetation has high near-infrared brightness and low red brightness, occupying a position at the apex of the scatter of points. Positions between the green vegetation peak and the soil line are mostly image cells that include variable proportions of green leaf cover and soil background.

Many vegetation indices compute some form of ratio of near-infrared to red image band values. This ratio computation tends to remove some of the extraneous variation resulting from topography and differences in the direction of incident sunlight. Other indices perform more complex computations that in some cases include green and blue image bands in addition to near-infrared and red.

(continued)

Vegetation indices are constructed so that higher index values indicate higher amounts/cover of green vegetation. These indices can be described in three categories: General, Atmospherically Resistant, and Soil-Adjusted. The Operation menu lists the vegetation indices in the order shown below but does not indicate their category.

Subtract Offset, Divided by, and Scale Fields

For most vegetation indices the Parameters box includes a pair of numeric fields for each band used in the calculation. The *Subtract Offset* field accepts a positive value that will be subtracted from the raw raster values. The default value is 0. Use the *Divided by* field to enter a value that the offset raster values will be divided by. The default value is 1.

The Output box includes a *Scale* field. Enter a numeric value in this field to rescale the output of the index calculation to the desired range of values. Be sure to choose a scale factor that is appropriate for the choice you have made from the Raster Type menu.

Path Radiance and Reflectance

Dust and gas in the atmosphere may scatter sunlight upward toward the image sensor, where it adds to the brightness signal received from the surface materials. The amount of this atmospheric scattering (sometimes called path radiance) is greatest for blue wavelengths and decreases nonlinearly with increasing wavelength. Thus the path radiance value is different for red and near-infrared image bands, and the path radiance effect does not cancel out in ratio calculations. Vegetation index results can be improved by estimating and subtracting the path radiance values from the image bands before computing the index. You can use the *Subtract Offset* field to enter a path radiance value for raw image bands, or use bands that have already had the path radiance correction applied. A number of techniques for estimating band-dependent path radiance values are described in the remote sensing literature.

Some of the vegetation indices that include additive factors are designed to process image bands that have been converted to apparent surface reflectance values ranging between 0 and 1.0. The Description box for these indices (GEMI, EVI, EVI2, SAVI, OSAVI, and MSAVI2) include the statement that "Inputs should be reflectance values between 0 and 1". You can use the *Subtract Offset* and *Divided by* fields to enter the image-specific corrections needed to convert scaled radiance values to apparent surface reflectance.

General Vegetation Indices

RVI - Ratio Vegetation Index

$$RVI = NIR / RED$$

The RVI captures in simplest form the contrast in near-infrared and red values for areas of healthy green vegetation. For fully vegetated areas the red values may approach zero and the ratio value then increases without bound. The RVI is thus a non-linear measure of vegetation that is very sensitive to variations in areas with high vegetative cover but much less sensitive in areas with sparse cover. Reference:

Birth, G. S., and G. R. McVey, 1968, Measuring color of growing turf with a reflectance spectrophotometer. *Agronomy Journal* 60:640-649.

GRVI - Green Ratio Vegetation Index

$$GRVI = NIR / GREEN$$

The GRVI has the same form as the RVI, but substitutes the green image band for red in the denominator. Because of vegetation's higher reflectance in green wavelengths compared to red, the GRVI is less sensitive to cover variations in high vegetative cover areas than RVI. Reference:

Sripada, R. P., R. W. Heiniger, J. G. White, and A. D. Meijer, 2006, Aerial color infrared photography for determining early-season nitrogen requirements in corn. *Agronomy Journal* 98: 968-977.

NDVI - Normalized Difference Vegetation Index

$$NDVI = (NIR - RED) / (NIR + RED)$$

NDVI is the most widely-used vegetation index. By computing the ratio of the difference and sum of the near-infrared and red bands, NDVI produces a linear index that is more sensitive in areas of sparse vegetation than RVI. However, it tends to saturate in areas of high biomass, becoming insensitive to cover variations in these areas. It is also sensitive to variations in soil background brightness and moisture conditions, especially in areas of low vegetation cover, and is also sensitive to atmospheric effects of aerosols. Areas of little to no vegetative cover have positive or negative values near zero; when you choose an unsigned integer output raster type, negative values are output as 0. Reference:

Rouse, J. W., R. H. Haas, J. A. Schell, and D. W. Deering, 1973, Monitoring vegetation systems in the Great Plains with ERTS. *Proceedings, Third ERTS Symposium*, NASA SP-351, 1:309-317.

IPVI - Infrared Percentage Vegetation Index

$$IPVI = NIR / (NIR + RED)$$

Crippen (1990) argued that subtracting red from near-infrared in the NDVI numerator is unnecessary. He proposed that the IPVI is functionally equivalent to NDVI, is never negative, and is faster to compute. Reference:

Crippen, R. E., 1990, Calculating the vegetation index faster. *Remote Sensing of Environment* 34:71-73.

TVI - Transformed Vegetation Index

$$TVI = \sqrt{(NIR - RED) / (NIR + RED) + 0.5}$$

TVI modifies NDVI by adding a constant (0.5) to all values and taking the square root of the result. These changes were designed to eliminate negative values and to produce a normal distribution of values. Reference:

Deering, D. W., J. W. Rouse, R. H. Haas, and J. A. Schell, 1975, Measuring forage production of grazing units from Landsat MSS data. *Proceedings, 10th International Symposium on Remote Sensing of Environment* 2:1169-1178.

Atmospherically Resistant Vegetation Indices

Indices in this category attempt to minimize atmospheric effects that may vary within and between scenes.

ARVI - Atmospherically Resistant Vegetation Index

$$ARVI = (NIR - 2 * RED - BLUE) / (NIR + 2 * RED - BLUE)$$

This index can be used with imagery that incorporates a blue spectral band, which is the visible band most sensitive to atmo-

(continued)

spheric effects. ARVI is a modified form of NDVI that attempts to minimize atmospheric effects on the red band by using the blue band to correct the red values. References:

Kaufman, Y. J. and D. Tanre, 1992, Atmospherically resistant vegetation index (ARVI) for EOS-MODIS. *IEEE Transactions on Geoscience and Remote Sensing* 30:261-270.

Kaufman, Y. J. and D. Tanre, 1996, Strategy for direct and indirect methods for correcting the aerosol effect on remote sensing: from AVHRR to EOS-MODIS. *Remote Sensing of Environment* 55:65-79.

GEMI - Global Environmental Monitoring Index

$$\text{GEMI} = \text{eta} * (1 - 0.25 * \text{eta}) - (\text{RED} - 0.125) / (1 - \text{RED})$$

where

$$\text{eta} = [2 * (\text{NIR}^2 - \text{RED}^2) + 1.5 * \text{NIR} + 0.5 * \text{RED}] / (\text{NIR} + \text{RED} + 0.5)$$

GEMI is a non-linear index that applies a standardized atmospheric correction to near-infrared and red values that have been converted to reflectance (values between 0 and 1). Comparative studies have shown it to be very sensitive to soil background variations in areas of low vegetation cover. Reference:

Pinty, B. and M. M. Verstraete, 1991, GEMI: a non-linear index to monitor global vegetation from satellites. *Vegetatio* 101:15-20.

Soil Adjusted Vegetation Indices

Indices in this category attempt to compensate for variations in the amount and condition of soil background (brightness and moisture content).

EVI - Enhanced Vegetation Index

$$\text{EVI} = 2.5 * (\text{NIR} - \text{RED}) / (\text{NIR} + 6 * \text{RED} - 7.5 * \text{BLUE} + 1)$$

EVI was developed as a standard vegetation index product for the MODIS sensor to provide improved sensitivity in high-biomass areas and to provide corrections for soil background effects and atmospheric aerosol effects. Inputs should have reflectance values between 0 and 1. Reference:

Liu, H. Q., and A. Huete, 1995, A feedback based modification of the NDVI to minimize canopy background and atmospheric noise. *IEEE Transactions on Geoscience and Remote Sensing* 33:457-465.

EVI2 - Enhanced Vegetation Index (2-band)

$$\text{EVI2} = 2.5 * (\text{NIR} - \text{RED}) / (\text{NIR} + 2.5 * \text{RED} + 1)$$

This index is a version of EVI for use with images from sensors that lack a blue band, calibrated to give similar results to EVI. Inputs should have reflectance values between 0 and 1. Reference:

Jiang, Z., A. Huete, K. Didan, and T. Miura, 2008, Development of a two-band enhanced vegetation index without a blue band. *Remote Sensing of Environment* 112:3833-3845.

SAVI - Soil Adjusted Vegetation Index

$$\text{SAVI} = (1 + L) * (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED} + L)$$

SAVI is a modified form of NDVI that includes a soil-adjustment factor L to account for effects from a variable soil background. In a near-infrared versus red scatterplot, the L factor shifts the origin of the plot so that the soil line and all lines of equal index value pass through the origin. The L factor can be specified as an estimate of the percentage of bare soil in the scene. Use the *Bare Soil %* parameter field to set this value. The default value is 50%. Inputs should have reflectance values between 0 and 1. Reference:

Huete, A. R., 1988, A soil-adjusted vegetation index (SAVI). *Remote Sensing of Environment* 25:295-309.

OSAVI - Optimized Soil Adjusted Vegetation Index

$$\text{OSAVI} = (1 + L) * (\text{NIR} - \text{RED}) / (\text{NIR} + \text{RED} + L)$$

where L = 0.16

OSAVI has the same formula as SAVI but has a fixed L factor value of 0.16. Inputs should have reflectance values between 0 and 1. Reference:

Rondeaux, G., M. Steven, and F. Baret, 1996, Optimization of soil-adjusted vegetation indices. *Remote Sensing of Environment* 55:95-107.

MSAVI2 - Modified Soil Adjusted Vegetation Index

$$\text{MSAVI2} = [2 * \text{NIR} + 1 - \text{sqrt}((2 * \text{NIR} + 1)^2 - 8 * (\text{NIR} - \text{RED}))] / 2$$

This is a modified version of SAVI with parameter values derived by iterative analysis of images over a range of L factor values and soil line slopes/intercepts in near-infrared versus red scatterplots. In comparison to SAVI and TSAVI (below), the resulting equation does not require an estimate of soil cover percentage or a determination of the soil line slope and intercept values. Inputs should have reflectance values between 0 and 1. Reference:

Qi, J., A. Chehbouni, A. R. Huete, and Y. H. Kerr, 1994, A modified soil adjusted vegetation index. *Remote Sensing of Environment* 48:119-126.

TSAVI - Transformed Soil Adjusted Vegetation Index

$$\text{TSAVI} = s * (\text{NIR} - s * \text{RED} - a) / [a * \text{NIR} + \text{RED} - a * s + X * (1 + s^2)]$$

where

a = soil line y-intercept in NIR vs RED scatterplot
s = soil line slope
X = 0.8 (adjustment factor to minimize soil noise)

TSAVI uses soil-line slope and intercept values determined by the operator from a near-infrared versus red scatterplot in place of the L factor in SAVI. These values must be entered in the Soil Line Slope and Soil Line Intercept fields in the Parameters box. Reference:

Baret, F., and G. Guyot, 1991, Potentials and limits of vegetation indices for LAI and APAR assessment. *Remote Sensing of Environment* 35:161-173.

Gram-Schmidt Greenness / Soil Brightness Indices

To understand the Gram-Schmidt operation, consider each band of a multispectral image as one orthogonal axis of a multidimensional spectral space and the image cell values as points within this space. The plot of near-infrared versus red values shown on the first page of this TechGuide is a projection of image values into one plane through this spectral space. The Gram-Schmidt operation reprojects the image cell values to a new set of orthogonal coordinate axes such that one axis is parallel to the soil line (soil brightness) and a second perpendicular axis expresses the amount of green vegetation (greenness). This method requires selection of at least two bands, red and near-infrared (selected in that order), but other bands can be selected to help constrain the computation. Use the fields in the Parameters box to enter red and near-infrared values for dark soil, bright soil, and green vegetation (obtained from the image scatterplot). Reference:

Kauth, R. J., and G. S. Thomas, 1976, The Tasseled Cap - a graphical description of the spectral temporal development of agricultural crops as seen by Landsat. *Proceedings of the Symposium on Machine Processing of Remotely Sensed Data*, Purdue University, West Lafayette, Indiana, 41-51.