EMPOWERING WOMEN IN GEOSPATIAL INFORMATION TECHNOLOGY

Remote sensing indices and their applications

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Electromagnetic spectrum (EMR)

From very short Gamma rays to very long radio waves



Blue (400 – 500), Green (500 – 600) and Red (600 – 700nm) bands

Features in Sentinel-2A satellite bands

			2	Store Look	Spectral /wavelength	Martin Rock	Spatial
Kabul region of Afghanistan			77. 4	Band	range (nm)	Objective	range (m)
	<u>g.e</u> e		B1	Coastal aerosol	433-453	Aerosol correction	60
		The start				Aerosol correction,	
THANK &			B2	Blue	458-523	land measurement	10
C. Mark	S. M. S.		B3	Green	543-578	Land measurement	10
Stranger 1			B4	Red	650-680	Land measurement	10
			B5	Red edge1 (RE1)	698-713	Land measurement	20
Google Earth	B2 (Blue)	B3 (Green)	B6	Red edge2 (RE2)	733-748	Land measurement	20
			B7	Red edge3 (RE3)	773-793	Land measurement	20
1 the W						Water vapour correction.	
2. Or K			B8	Near infra red	785-900	Land measurement	10
						Water vapour correction.	
			B8a	Near infrared narrow	855-875	Land measurement	20
	in the part of a	the test which is the	B9	Water vapour	935-955	Water vapour correction	60
B4 (Red)	B6 (NIR)	B9 (SWIR)	B10	Shortwave infrared	1360-1390	Cirrus detection	60
			B11	Shortwave infrared 1	1565-1655	Land measurement	20
						Aerosol correction,	
			B12	Shortwave infrared 2	2100-2280	land measurement	20

Features in Landsat satellite bands

K		Spectral		Spatial
ST B	Band	range (nm)	Objective	range (m)
B1	New deep blue	433-453	Aerosol/coastal zone	30
B2	Blue	450-515	Pigments/coastal/scatter	30
B3	Green	525-600	Pigments/coastal	30
B4	Red	630-680	Pigments/coastal	30
B5	Near infra red	845-885	Foliage/coastal	30
B6	Shortwave infrared 2	1560-1660	Foliage	30
B7	Shortwave infrared 3	2100-2300	Mineral/litter/no scatter	30
B8	Panchromatic	500-680	Image sharpening	15
B9	Shortwave infrared	1360-1390	Cirrus cloud detection	30

<u>https://www.sentinel-hub.com/develop/documentation/eo_products/Sentinel2EOproducts</u>
 <u>https://modis.gsfc.nasa.gov/about/specifications.php</u>
 <u>https://gisgeography.com/landsat-8-bands-combinations/</u>

Difference between Landsat and Sentinel data

	Landsat-8-OLI	Sentinel-2A
Bands	9	13
Spectral range (µm)	0.435-1.384	0.44-2.22
Spatial resolution (m)	30	10,20,60
Temporal resolution	16 days	10 days
	Operational Land	Multi-Spectral
Sensor	Imager (OLI)	Instrument (MSI)
Туре	Multi-spectral	Multi-spectral
Satellite	Landsat-8	Sentinel-2A
	U.S. Geological	European Space
Operator	Survey (USGS)	Agency (ESA)





- Undesirable effects on recorded radiances (e.g. variable illumination) caused by variation in topography
- Differences in brightness values from identical surface material or vice versa are caused by topographic slope and aspect, shadows or seasonal changes
- These hamper the ability of interpreter to correctly identify surface material in image
- Ratio transformation can be used to reduce the effects of such environmental conditions



Spectral response and reflectance is similar from two different objects in RED band of Sentinel-2A

Google Earth



Google Earth



NIR band



Spectral signature of two different objects are mixed in NEAR-INFRA RED band of Sentinel

Google Earth



NIR band



Spectral signature of two different objects are mixed in NEAR-INFRA RED band

- Specific target has an individual and characteristic manner of interacting with incident radiation
- >Interaction are described by
 - the **spectral response** of the target in a particular wavelength of EMR



Spectral curves for various natural features

Differences between histogram

of Red and near-infrared Histogram reflectance representing more pixel frequency at higher reflectance in NIR of Sentinel-2A data



GEE

B4 (Red)



Spectral indices

- 1. Spectral indices help in modelling, predicting, or infer surface processes
- 2. Developed to assess and monitor several land change processes
- 3. Computed from multiband images by adding and subtracting bands thereby making various band ratio
- 4. Emphasizes a specific phenomenon that is present, while mitigating other factors
- Vegetation health and status
- Burned area
- Fire severity etc.

Development of spectral indices

- 1. Initially intrinsic indices were developed from simple band ratios, which highlighted the spectral properties of vegetation at different stages of growth and senescence.
- 2. To compensate for background effects such as that caused in areas in which the soil response dominates over the vegetation.
- 3. To compensate for the effects of atmospheric distortion.
- 4. Development of new spectral indices to applications other than vegetation health. These include indices for burned area assessment and fire severity etc.

The criterion of a spectral index

- Maximize the sensitivity of certain surface feature (e.g. plant biophysical properties). Ideally, such responses should change linearly to allow both ease of scaling and use over a wide range of surface conditions.
- Normalize or reduce effects due to sun angle, viewing angle, the atmosphere, topography, instrument noise, etc., to allow consistent spatial and temporal comparisons
- Be linked to specific and measurable **surface processes** (e.g. biophysical parameter such as leaf area index (LAI), biomass, absorbed photosynthetically active radiation (APAR, etc.)) i.e. be related to a measurable parameter or process
- Source: Jenson (RSE Book, 2000)

Use of ratio to reduce topographic effects

Example 1



Figure 7.25 Reduction of scene illumination effects through spectral ratioing. (Adapted from Sabins, 1997.)

NB. The objective is to map 2 classes –coniferous and deciduous forest

0.96

Use of indices to reduce topographic effects

Example 2 from Kabul

False color composite (FCC)



Normalized difference vegetation indices (NDVI)



Sunlit: 0.36 Shaded:0.359

R and NIR represents the reflectance in red and near infra-red band of Sentinel for SUNLIT and SHADED region and their respective ratio in NDVI image

- Enhances green vegetation so that plants appear distinct from other image features
- Reflectance of light spectra from plants changes with plant type, water content within tissues, and other intrinsic factors
- Vegetation reflectance is determined by chemical and morphological characteristics of the surface of organs or leaves e.g. leaf structure, leaf pigments etc.



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Simple Difference Vegetation Index

DVI = NIR-R (Richardson et al., 1977)

- Distinguishes between **soil** and **vegetation**
- Does Not deal with the atmospheric effects

Ratio-based Vegetation Index

RVI = R/NIR (Jordan 1969)

- Reduces the effects of atmosphere and topography
- Low for soil, ice, water, etc.



- Normalized Difference Vegetation HEALTHY Index
- Standard method for comparing the vegetation greenness from satellite
- > NDVI = (NIR)-(RED)/ (NIR)+ (RED)
- Explains density of vegetation
- The NDVI values tentatively ranges between -1 to +1, the values close to +1 denotes the good health of vegetation



NDVI is sensitive to the effects of soil and atmosphere and saturates at high density of vegetation



NDVI



Negative values correspond to areas with water surfaces, manmade structures, rocks, clouds, snow;

> Plants will always have positive values between 0.2 and 1.

Soil Adjusted Vegetation Index

- The concept of distinction of vegetation from the soil background was proposed by Richardson and Wiegand., 1977
- Soil background conditions exert considerable influence on partial canopy spectra and the calculated vegetation indices

SAVI = ((NIR - Red) / (NIR + Red + L)) x (1 + L) Huete, 1988

- Minimizes soil brightness influence
- L is a variable ranges within -1 to 1, depending on the amount of green vegetation present in the area
- To run the remote sensing analysis of areas with high green vegetation, L is set to be zero (in which case SAVI index data will be equal to NDVI); whereas low green vegetation regions require L=1

- Atmospherically Resistant Vegetation Index (ARVI; Kaufman and Tanré, 1992)
- > Relatively prone to atmospheric factors (such as aerosol)
- > Atmosphere affects significantly **Red** region compared to the **NIR**
- Corrected for atmospheric scattering effects in the red reflectance spectrum by using the measurements in blue wavelengths.

ARVI = (NIR - (2 * Red) + Blue) / (NIR + (2 * Red) + Blue)

- Eliminates the effect of atmospheric aerosols
- Monitoring tool for tropical mountainous regions often polluted by soot coming from slash-and-burn agriculture

Land Surface Water Index (LSWI)

NIR-SWIR/NIR+SWIR

- LSWI is sensitive to changes in vegetation canopy water content and indicates the water stress
- Vegetation Condition Index (VCI)
 (NDVI-NDVI_{min}/NDVI_{max}- NDVI_{min})*100
 Lower and higher values indicate bad and good vegetation state conditions



Water indices

- > Used to highlight the water bodies while suppressing the other land cover
- Water absorbs more energy (low reflectance) in NIR and SWIR wavelengths
- > Have the greatest reflectance in the blue portion of the visible spectrum
- Clear water has high absorption and virtually no reflectance in near infrared wavelengths range and beyond

Factors affecting water

- > Algae: Water with higher algal density reflect more in green bands
- Turbidity: Turbid water has a higher reflectance in the visible region than clear water. This is also true for waters containing high chlorophyll concentrations

Water indices



Reflectance response of water with different levels of turbidity

Snow indices

Ice and snow generally have high
 reflectance across all visible
 wavelengths, thus bright white
 appearance

 The low reflection of ice and snow in the SWIR is related to their microscopic liquid water
 content

Blue

Green

Red



NIR







Snow indices



Spectral reflectance curves of bare glacier ice, coarse-grained snow, and fine-grained snow. Spectral bands of selected sensor on Earth-orbiting satellites are shown in gray. The numbers in the gray boxes refer to the associated band numbers of each sensor

Water and snow indices

Indices

Formula

Normalized Difference Water Index (NDWI)	GREEN-NIR/GREEN+NIR
Modified Normalized Difference Water Index (MNDWI)	GREEN-SWIR/GREEN+SWIR
Normalized Difference Pond Index (NDPI)	MIR-GREEN/MIR+GREEN
Water Ration Index (WRI)	GREEN+RED/NIR+SWIR
Normalized Difference Turbidity Index (NDTI)	RED-GREEN/RED+GREEN
Automated Water Extraction Index (AWEI)	4*(GREEN-SWIR2- 0.25*NIR+2.75*SWIR1
Normalized Difference Snow Index (NDSI)	GREEN-SWIR/GREEN+SWIR
Normalized Difference Snow and Ice Index (NDSII-1)	RED-SWIR/RED+SWIR
	GREEN (NIR-SWIR)/
Snow Water Index (SWI)	(GREEN+NIR)(NIR+SWIR)

Applications

- Vegetation mapping and monitoring
- Biodiversity assessment
- Estimation of biophysical parameters (LAI, fPAR)
- Phenological assessment
- Vegetation health/stress
- Forest degradation
- Biomass mapping and modelling
- Productivity and carbon assessment
- Crop condition monitoring and predicting crop yield

Index	Wavebands	Application		
Ratio	R_{NIR}/R_{red}	Biomass, LAI, cover		
Normalized D	ifference Vegetative Indices	12A		
Red NDVI	$(R_{NIR} - R_{red})/(R_{NIR} + R_{red})$	LAI, Intercepted PAR		
Green NDVI	$(R_{NIR} - R_{green})/(R_{NIR} + R_{green})$	LAI, Intercepted PAR		
Red Edge	$(R_{NIR} - R_{red edge})/(R_{NIR} + R_{red edge})$	LAI, Intercepted PAR		
NDVI	\$2			
Soil Adjusted	Vegetation Index			
SAVI	$(R_{\rm NIR} - R_{\rm red})(1 + L)/(R_{\rm NIR} + R_{\rm red} + L)$	LAI		
Enhanced Veg	etation Index			
EVI	$2.5(R_{NIR} - R_{red})/(R_{NIR} + 6R_{red} - 7.5R_{blue} + 1)$	LAI		
Normalized Pi	gment Chlorophyll Ratio Index	80		
NPCI	$(\text{Red}_{660} - \text{Blue}_{460})/(\text{Red}_{660} + \text{Blue}_{460})$	Leaf chlorophyll		
Chlorophyll In	ndices			
CIgreen	$(R_{NIR}/R_{green}) - 1$	Leaf chlorophyll		
CI _{red edge}	$(R_{\rm NIR}/R_{\rm red\ edge}) = 1$	Leaf chlorophyll		
Plant Senescen	nce Reflectance Index	6- 74 W 50		
PSRI	(Red ₆₆₀ - Green ₅₁₀)/NIR ₇₆₀	Plant senescence		

Source: Hatfield and Prueger (2010)



Source: Tripathi et al., 2014



Monthly pattern (January- December) of leaf area index (LAI) derived from NDVI (exponential relationship)

Biomass estimation

	AGB (t/ha)	CC (%)
AGB (t/ha)	1	
CC (%)	0.83	1
NDVI	0.85	0.95
EVI	0.75	0.91
SR	0.86	0.96
SAVI	0.70	0.84

Correlation between above ground biomass and vegetation indices for *Quercus rotundifolia*

Source: Macedo et al., 2018, southern Portugal



Drought Assessment

TABLE 1.

Remote sensing data, indices and thresholds relevant to drought assessment used in the study.

Drought index		Band or index used to compute the index		Range	Normal condition	Severe drought	Healthy vegetation
		AVHRR	MODIS				
1.	Normalized difference vegetation index	Band 1 (0.58-0.68µm)	Band 1 (0.62-0.67µm)	-1 to +1	Depends on the location	-1	+1
	(NDVI)	Band 2 (0.73-1.10µm)	Band 2 (0.84-0.87µm)				
2.	Drought severity index (DEV _{NDVI})	NDVI NDVI long-term mean	NDVI NDVI long-term mean	-1 to +1	0	-1	+1
3.	Vegetation condition index (VCI)	NDVI NDVI long-term minimum	NDVI NDVI long-term minimum	0 to 100 %	50 %	0%	100%
		NDVI long-term maximum	NDVI long-term maximum		Source:	Thenkabai	l and Gamage, 2004

Southwest Asia NDVI deviation

A monthly NDVI time series [] 0.25
 for a drought year (1987)
 and a wet year (1993) 0.2
 compared to the NDVI long term mean 0.15



Source: Thenkabail and Gamage, 2004



Monthly median of drought condition in Herat province during vegetation seasons of 2003-2014 based on VCI

Source: Mohammad Ehsan Razipoor, 2019

http://www.fao.org/giews/earthobservation/asis/index_2.jsp?lang=en

Application of water and snow indices

- Water Mapping and monitoring
- Change detection
- Water quality assessment
- Flood monitoring and damage assessment
- > Algae assessment
- Snow and Ice mapping and monitoring



(a) Reference water cover map (b) Automated Water Extraction Index (AWEI), (c) Modified Normalized Difference Water Index (MNDWI), (d) Normalized Difference Water Index (NDWI), (e) Superfine Water Index (SWI)



Water mapping and change dynamics

Simple water index (SWI)



Source: Acharya et al., 2019

Water inundation mapping

 Minimum and maximum inundation areas and their distributions during each climatological month between
 2000 and 2010 for Poyang Lake, China

Source: Feng et al. (2012)



Water quality assessment

Table 3. Correlation coefficient analyses between water quality and spectral indices

Parameter	EC	pH	Nitrate	Nitrite	Silicate	Phosphate	O.M	NDSI	NDVI	NDBI	N/P ratio
EC	1										14110
pH	0.192	1									
Nitrate	0.106	0.173	1								
Nitrite	0.2.92	0.144	0.806	1							
Silicate	0.827	0.229	0.46	0.721	1						
Phosphate	-0.016	-0.353	-0.28	-0.069	-0.002	1					
O.M	-0.02	-0.339	-0.086	-0.185	-0.044	-0.03	1				
NDSI	-0.273	0.033	-0.416	-0.517	-0.272	-0.085	0.246	1			
NDVI	0.273	-0.033	0.416	0.517	0.272	0.085	-0.246	-1	1		
NDBI	-0.355	-0.006	-0.332	-0.516	-0.392	0.032	0.488	0.744	-0.744	1	
N/P ratio	-0.221	0.329	0.897	0.738	0.334	-0.171	-0.096	-0.345	0.345	-0.135	1.000

Source: Ahmed M. El-Zeiny, 2018

Flood hotspot analysis

International Water Management Institute project



Source: Matheswaran et al, 2018



Application of snow indices



Source: Bajracharya et al., 2015

Thank You

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