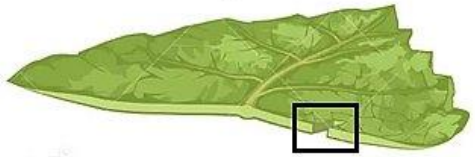
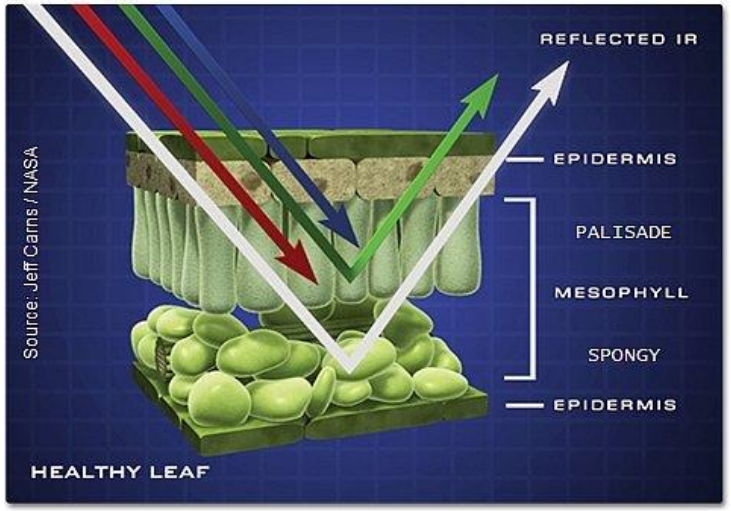
Geospatial indices for semantic understanding

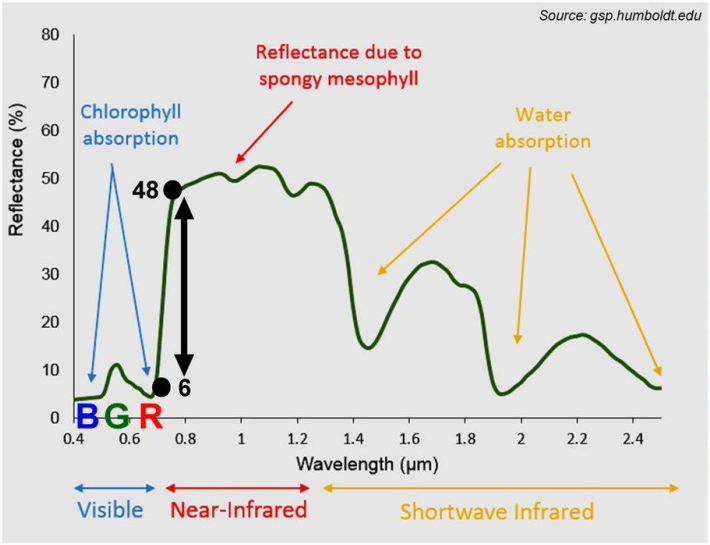
Geospatial Data Science,
Plaksha University,
Mohali

Vegetation Index

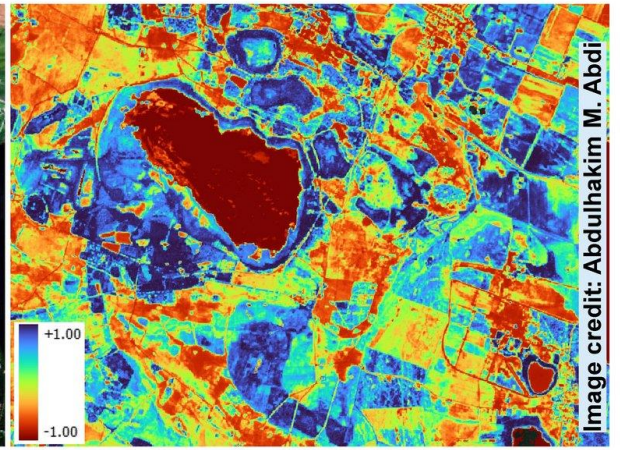




Normalized Difference Vegetation Index (NDVI) $= \frac{NIR-RED}{NIR+RED} = \frac{48-6}{48+6} = 0.77$



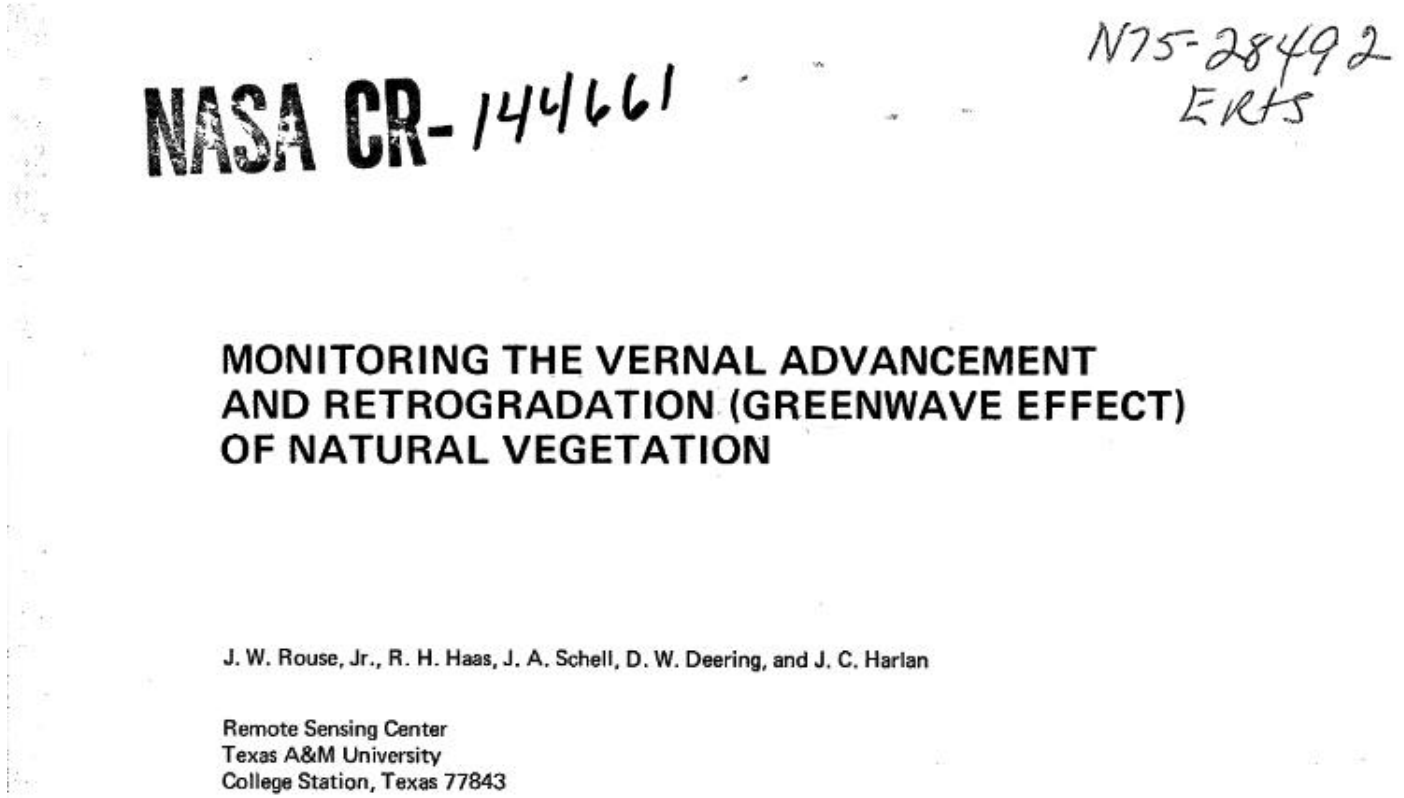
Original RGB Image



NDVI Applied

The original work (1975)

$$NDVI = \frac{NIR - Red}{NIR + Red},$$



NASA CR-144661

N75-28492
ERTS

MONITORING THE VERNAL ADVANCEMENT AND RETROGRADATION (GREENWAVE EFFECT) OF NATURAL VEGETATION

J. W. Rouse, Jr., R. H. Haas, J. A. Schell, D. W. Deering, and J. C. Harlan

Remote Sensing Center
Texas A&M University
College Station, Texas 77843

https://ntrs.nasa.gov/api/citations/19750020419/downloads/19750020419.pdf#page=173.40

EVI
Enhanced vegetation index

$$\mathrm{EVI} = G\frac{\rho_{\mathrm{NIR}} - \rho_{\mathrm{red}}}{\rho_{\mathrm{NIR}} + C_1 \times \rho_{\mathrm{red}} - C_2 \times \rho_{\mathrm{blue}} + L}$$

where ρ are atmospherically corrected or partially atmosphere corrected (Rayleigh and ozone absorption) surface reflectances, L is the canopy background adjustment that addresses nonlinear, differential NIR and red radiant transfer through a canopy, and C_1, C_2 are the coefficients of the aerosol resistance term, which uses the blue band to correct for aerosol influences in the red band. The coefficients

Targeted to improve sensitivity in high biomass regions and reduce atmospheric and soil background noise

More useful in denser areas

More robust in atmospherically turbulent areas (for example, higher pollution)

Huete, Alfredo, Kamel Didan, Tomoaki Miura, E. Patricia Rodriguez, Xiang Gao, and Laerte G. Ferreira. "Overview of the radiometric and biophysical performance of the MODIS vegetation indices." *Remote sensing of environment* 83, no. 1-2 (2002): 195-213.

Water Index

The use of the Normalized Difference Water Index (NDWI) in the delineation of open water features

S. K. McFEETERS

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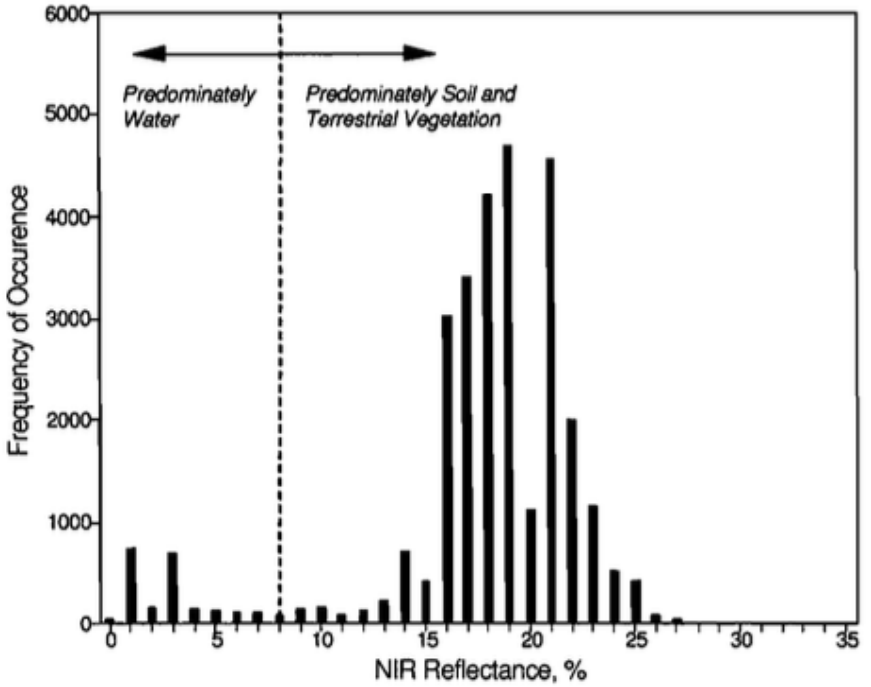
To link to this article: https://doi.org/10.1080/01431169608948714



$$\frac{(\mathrm{GREEN} - \mathrm{NIR})}{(\mathrm{GREEN} + \mathrm{NIR})}$$

Building index

Use of normalized difference built-up index in automatically mapping urban areas from TM imagery

Y. ZHA
College of Geographical Sciences, Nanjing Normal University, Nanjing 210097, China; e-mail: yzha@njnu.edu.cn

J. GAO*
School of Geography and Environmental Science, University of Auckland, Private Bag 92019, Auckland, New Zealand; e-mail: jg.gao@auckland.ac.nz

and S. NI
College of Geographical Sciences, Nanjing Normal University, Nanjing 210097

(*Received 23 January 2001; in final form 3 October 2001*)

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR}$$

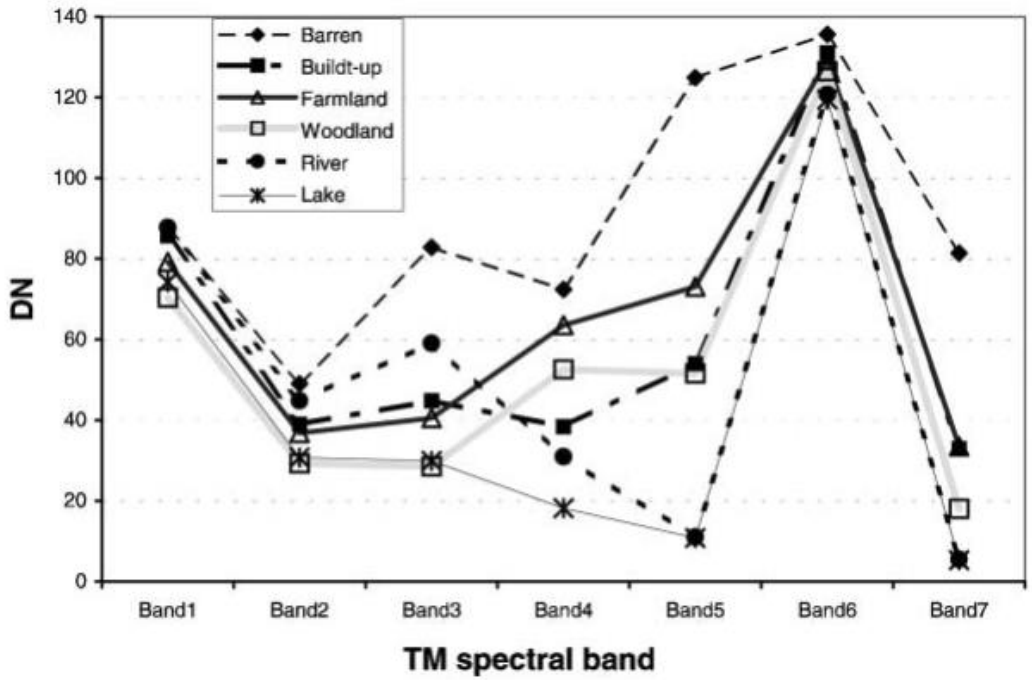


Figure 3. Spectral profiles of six typical land covers in the study area.

https://www.tandfonline.com/doi/epdf/10.1080/01431160304987?needAccess=true

Match my vibe?

Wavelength Range	Sensor Type	Satellite Examples	Agency	Data Availability	Common Applications
Visible (400–700 nm)	Optical (Multispectral)	Landsat-8/9 (OLI), Sentinel-2 (MSI)	NASA/USGS, ESA	Free via USGS Earth Explorer, Copernicus Hub	Land cover classification, urban growth monitoring, disaster response .
Near-Infrared (NIR)	Multispectral/Hyperspectral	EO-1 (Hyperion), PRISMA	NASA, Italian Space Agency	Free (Hyperion), limited (PRISMA)	Vegetation health analysis (NDVI), precision agriculture .
Shortwave Infrared (SWIR)	SWIR Sensors	Landsat-8/9, Sentinel-2	NASA/USGS, ESA	Free via USGS Earth Explorer	Mineral exploration, soil moisture assessment .
Thermal Infrared (8–14 µm)	Thermal (TIRS)	Landsat-8/9, Aqua (MODIS)	NASA/USGS, NOAA	Free via NASA Earth Data	Wildfire detection, volcanic activity monitoring, urban heat island mapping .
Microwave (1 mm–1 m)	Radar (SAR)	Sentinel-1, RADARSAT Constellation	ESA, Canadian Space Agency	Free (Sentinel-1), restricted (RADARSAT)	All-weather imaging, ground deformation monitoring, flood mapping .
LiDAR (Visible/NIR)	Laser Altimetry	ICESat-2, GEDI (on ISS)	NASA	Free via NASA Earthdata	Ice sheet elevation tracking, forest canopy height measurement .

Spectral Region	Satellite/Constellation	Sensor Type	Agency/Company	Data Availability	Key Applications
Visible (400–700 nm)	PlanetScope	Multispectral (8 bands)	Planet Labs	Commercial (subscription), limited free samples via ESA	Daily land monitoring, deforestation detection, urban growth tracking .
NIR & SWIR	Pixxel Firefly	Hyperspectral (300 bands)	Pixxel	Commercial licensing	Crop health analysis, mineral exploration, pollution monitoring .
Thermal Infrared	Landsat-9 (TIRS-2)	Thermal	NASA/USGS	Free via USGS Earth Explorer	Wildfire detection, surface temperature mapping .
Microwave	Sentinel-1 (SAR)	C-band SAR	ESA	Free via Copernicus Hub	Ground deformation, flood mapping, maritime surveillance .

Hyperspectral images

https://cdn.prod.website-files.com/602ca6bcbe64eee6c15a1b47%2F6673f03223a6ed74c1059967_pixxel-video-transcode.mp4

5 m resolution

250+ bands

Try out interesting use cases

While NDVI and NDWI are typically associated with agriculture and hydrology, researchers have uncovered some unconventional applications:

1. Archaeological Site Detection
Using NDWI to identify buried structures by detecting subtle moisture differences in vegetation above ancient ruins. Dry-soil crop marks over buried walls show distinct NDWI signatures compared to surrounding areas.

2. Urban Heat Island Mitigation
Scientists combined NDVI with thermal data to identify "micro-oasis" trees in cities that reduce temperatures more effectively than other vegetation. Some tree species showed 5°C cooling anomalies per 0.1 NDVI increase.

3. Glacial Methane Tracking
Modified NDWI detected methane bubble columns under Arctic ice by analyzing spectral distortions in meltwater patterns. This helped map subglacial methane vents previously undetectable.

4. Illegal Cannabis Farm Detection
Law enforcement used anomalous NDVI patterns (persistent high values under artificial lighting) to identify hidden indoor plantations through roof-mounted vegetation signatures.

5. Antarctic Penguin Census
Researchers developed a "Guano Index" using NDWI variations to count penguin colonies. Penguin excrement alters snow reflectance properties, creating unique spectral fingerprints visible in winter imagery.

These unconventional uses demonstrate how spectral indices can reveal hidden patterns when combined with domain-specific knowledge. The key lies in interpreting index anomalies through non-traditional lenses.

Let’s try more use cases

https://courses.spatialthoughts.com/end-to-end-gee.html

Normalized burn ratio (NBR)

$$NBR = \frac{R_{NIR} - R_{SWIR}}{R_{NIR} + R_{SWIR}}.$$

Used for detecting burnt areas/wildfires

Key, C. H., and N. C. Benson (1999), Measuring and remote sensing of burn severity, in Proceedings Joint Fire Science Conference and Workshop, vol. II, edited by L. F. Neuenschwander and K. C. Ryan, p. 284, Univ. of Idaho, Moscow, Idaho.

Why normalized differences?

- Highlights difference in spectral response
  - More reliable indicator than the absolute value

AOD – Aerosol Optical Depth

- Measures diffusion of light by the vertical column of atmosphere
  - 0 on clear sky
  - 1 on heavy pollution
- Uses spectral reflectance and a radiative transfer model
  - A physics based algorithms which models the effect of clouds, atmospheric absorption, gases, aerosols, etc.
- Can be used to approximate PM data
  - Van Donkelaar, Aaron, Randall V. Martin, Michael Brauer, Ralph Kahn, Robert Levy, Carolyn Verduzco, and Paul J. Villeneuve. "Global estimates of ambient fine particulate matter concentrations from satellite-based aerosol optical depth: development and application." *Environmental health perspectives* 118, no. 6 (2010): 847-855.

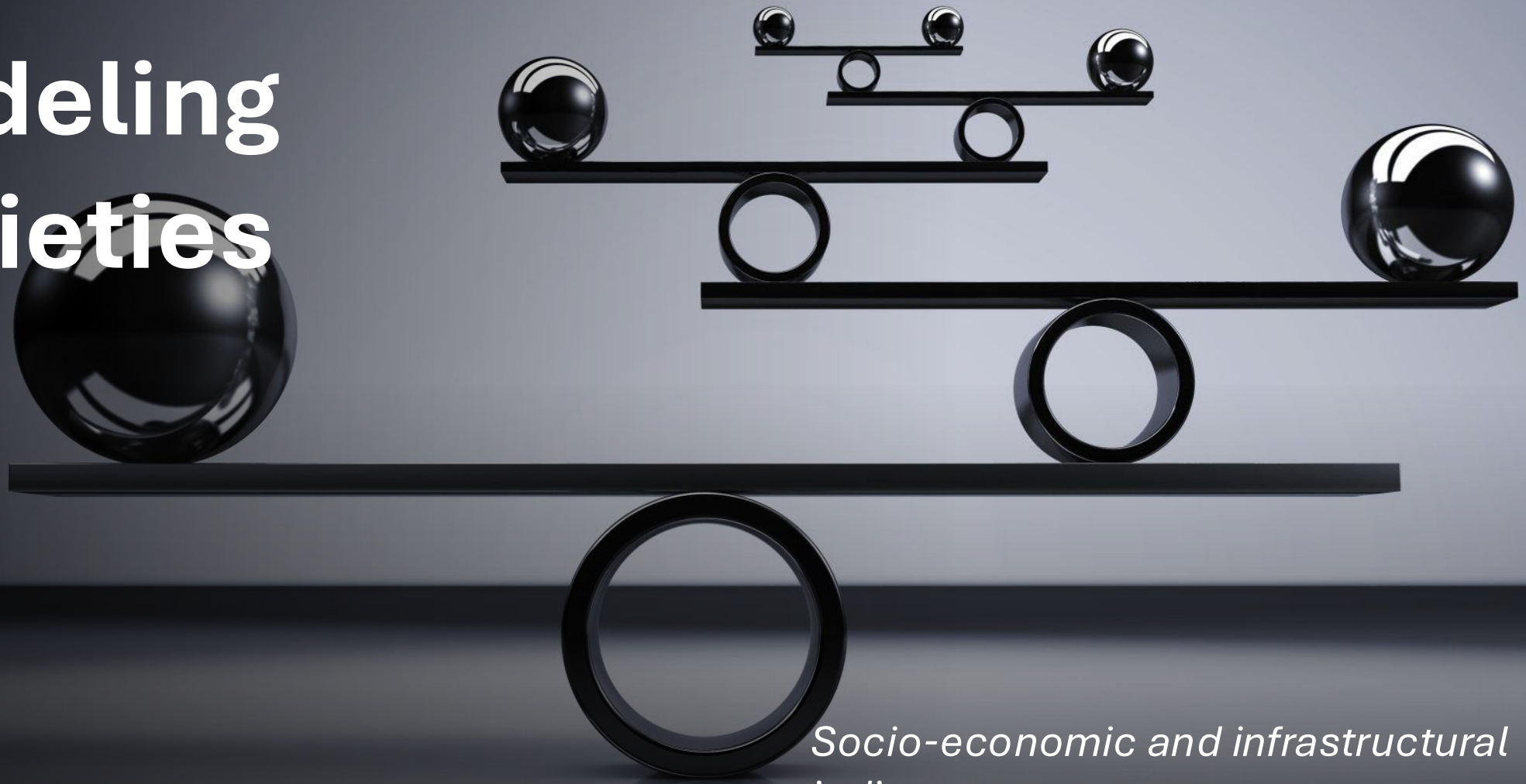
Land Surface Temperature

- Derived from thermal infrared bad using Planck's Radiation Law
  - Corrections for surface emissivity and atmospheric absorption
- Captures the geophysical phenomenon of energy/water exchange between land and atmosphere
- Used for agricultural drought/urban heat island studies

More

- Total precipitable water index
- Chlorophyll index (algal blooms)
- Snow index
- Albedo

Modeling societies



Socio-economic and infrastructural indicators

How are social indices calculated?

- Census data
- Land use
- OpenStreetMap data (roads, places, building areas)

$$\text{Walkability} = z(\text{residential density}) + z(\text{street connectivity}) + z(\text{land use mix}) + z(\text{retail floor area ratio})$$

Socioeconomic deprivation index

A combination of

- unemployment rate,
- non-car ownership,
- non-home ownership (renting), and
- household overcrowding

Some Indian Surveys:

- **Periodic Labour Force Survey (PLFS) - NSSO**
  Collects data on employment, unemployment, and labor market conditions in India, including workforce participation, job status, and housing conditions.
- **National Family Health Survey (NFHS) - MoHFW**
  Primarily focused on health and demographic indicators but also includes household characteristics such as asset ownership (cars, houses) and living conditions.
- **Consumption Expenditure Survey (CES) - NSSO** *(latest round awaited)*
  Provides insights into household income, expenditure, and asset ownership, including vehicle ownership and housing tenure (owned vs. rented).
- **Census of India** *(last conducted in 2011, next planned in 2025)*
  A decadal survey collecting comprehensive demographic, housing, and socio-economic data, including household size, home ownership, and living conditions.
- **Socio-Economic and Caste Census (SECC) - 2011**
  Captures socio-economic conditions at a granular level, including asset ownership (cars, houses) and indicators related to poverty and living standards.
- **Consumer Pyramids Household Survey (CPHS) - CMIE**
  A high-frequency panel survey covering employment, income, expenditure, housing tenure, and asset ownership, offering more recent and frequent data compared to government surveys.

Urban accessibility indices

- Transit accessibility index
  - Measures public transport coverage
- Street intersection density
  - A proxy for connectivity
- Green Space index
  - Parks per capita/NDVI within urban bounds

Liveability indices

- Environment quality
  - Normalized difference pollution index (NDPI)
- Jobs
- Number of relationships you value in that city?
  - *Personalized indices*

Driving action

- Finding areas where stricter regulations/interventions are required
- Globally consistent drought indices for severity assessment
- Zoning decisions
- Urban disaster management planning
- Vaccination planning
  - COVID-19

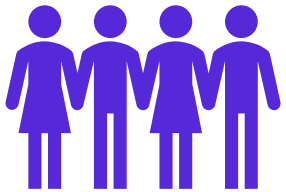
Machine learning based indices

- Poverty and economic indicators
  - Night time lights
  - Poverty indices through street view assessments
- Street view perception
  - Safety
  - Accessibility
  - Green view index
- NDVI from smartphone RGB images
- Crop yield and food security indices

The future of indices

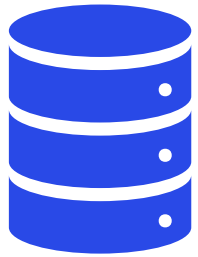
- From pixels to patterns
- Data fusion, not just with satellite data but with ground data and digital data,
  - Twitter
  - Maps, etc.

Things to remember while you invent the future



Explanability and standardization are important

You are impacting lives at scale



Capture systemic complexities