Key indicators and monitoring techniques for remote sensing-based vegetation degradation analysis

Vegetation Degradation
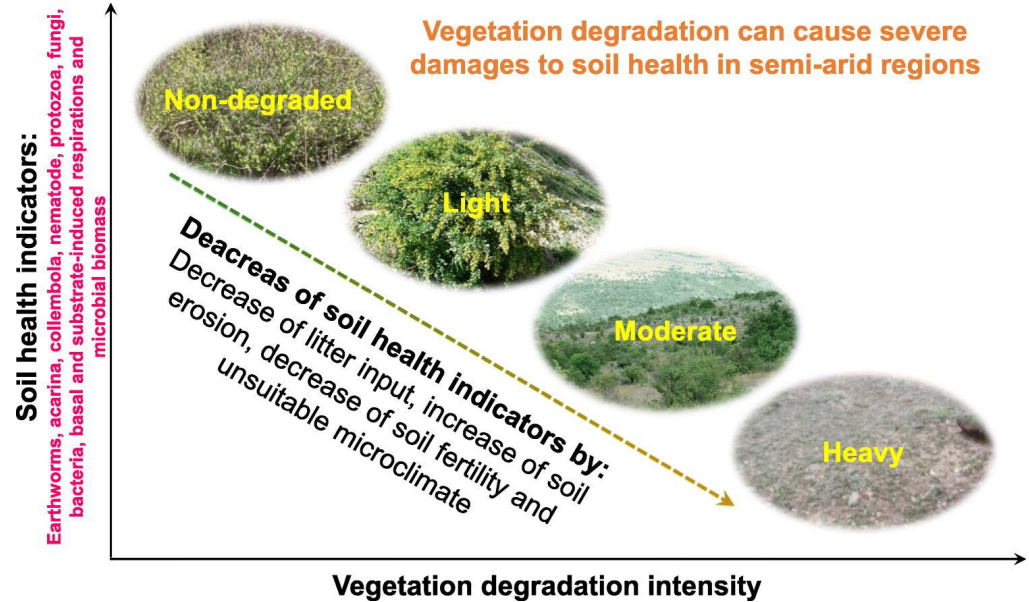
- Decrease in biomass or a change in structure/composition/diversity/carbon stock/functionality/ecosystem process of vegetation

Impacts

- It significantly reduced biomass and soil carbon content

- exacerbating the risk of soil nitrogen loss which decreases the microbial diversity in the soil and the resistance of the soil to environmental stress

Causes

climate change and human activities, such as climate warming, precipitation change, and overgrazing

Soil health indicators:
Earthworms, acarina, collembola, nematode, protozoa, fungi, bacteria, basal and substrate-induced respirations and microbial biomass

Vegetation degradation can cause severe damages to soil health in semi-arid regions

Non-degraded

Light

Moderate

Heavy

Deacreas of soil health indicators by:
Decrease of litter input, increase of soil erosion, decrease of soil fertility and unsuitable microclimate

Vegetation degradation intensity

Classification and change detection techniques for detecting vegetation cover changes

Techniques	Advantages	Disadvantages
Supervised classification	Analyst has control. Images can often be detected and corrected by the operator.	Training data collection is a time-consuming and costly process. A category that is not present in the training data cannot be recognized and represented.
Unsupervised Classification	There are spectrally distinct areas that may not have been noticeab There is no requirement for prior knowledge of the region. Minimizes the possibility of human error.	Analyses may not be able to relate spectral groups to information classes of interest. The analyst has only limited control over the classes.
GEOBIA Classification	A geographic feature in an image is treated as a set of objects rather than as an individual pixel. Generation of vector data.	Analyzing image. Parameters at the analyst's discretion can introduce bias, which directly impacts the segmentation results.
Transform Based Technique	It decreases redundant information between bands.	Limited by the difficulty of labeling the information regarding the changing area.
Geographic Information System (GIS)	Integrates information from multiple sources. Coverage of the study area frequently and the ability to provide a broader view of it.	Affected by the accuracy of information obtained from different sources.
Algebra-Based Technique	Relatively straightforward and easy to implement except for CVA. Reduce the impact from sensors, environment, sun angle, and atmosphere.	Do not provide a complete description of the changes detected. Accurate regression is required for the selected bands.

(cont) Classification and change detection techniques for detecting vegetation cover changes
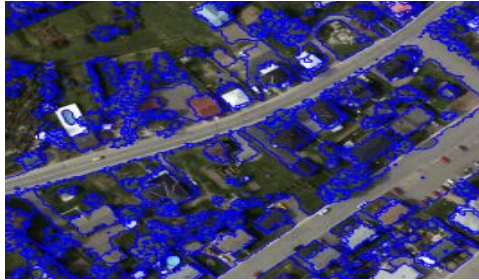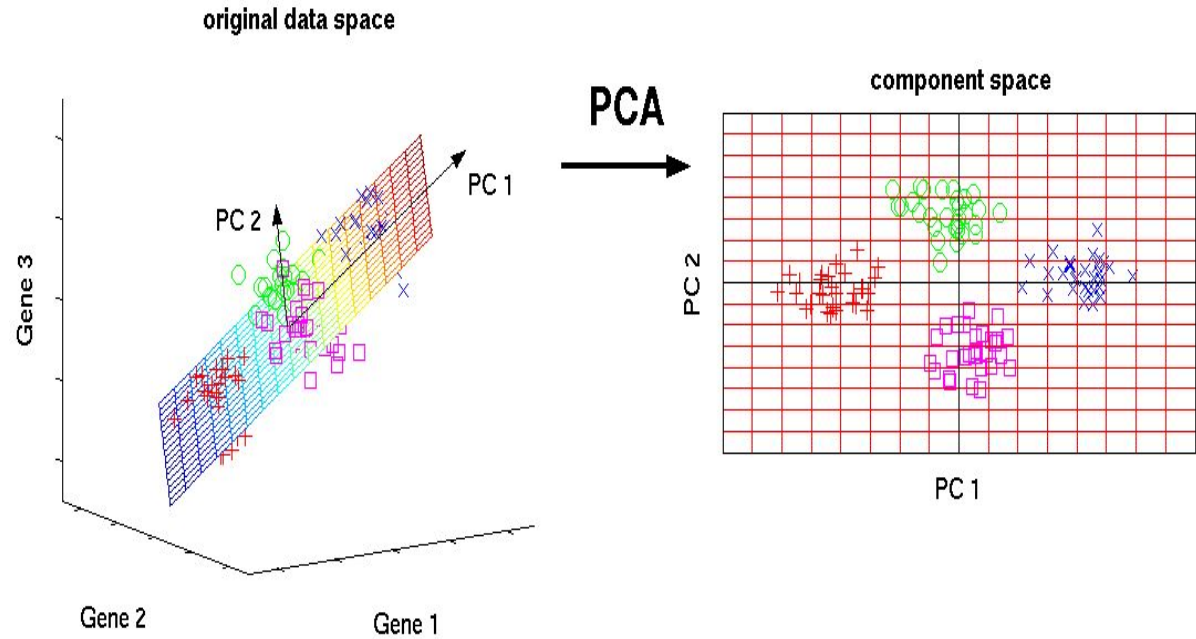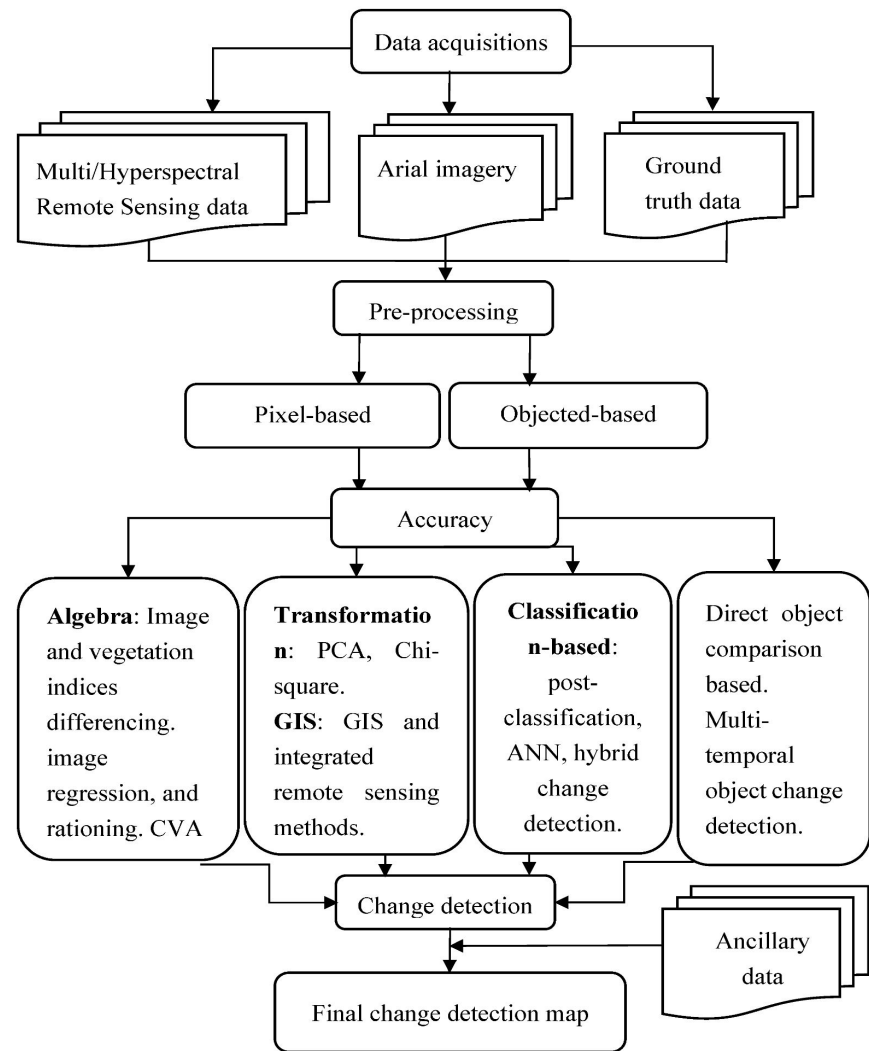

Segmentation

Classification

GEOBIA

original data space

PCA

component space
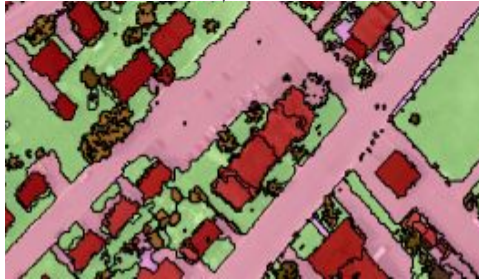
Transform Based: PCA

(cont) Classification and change detection
techniques for detecting vegetation cover changes

Multi-Temporal analysis

- sequentially in time

- Useful to identify disturbances
- Using satellite imagery or aerial photography, to monitor the long term trend in vegetation cover and growth status.
- Near-infrared reflectance (NIR) band is sensitive to the vegetation type, health, and density.
- When plants are unhealthy, they have a lower level of photosynthetic activity and thus exhibit an increased amount of visible reflectance as well as a reduced amount of NIR

The derived remote sensing based vegetation indices can be used as proxy to the vegetation health and monitoring status.

Common Vegetation Indices are:

- normalized differential vegetation index (NDVI)
- atmospherically resistant vegetation index (ARVI)
- enhanced vegetation index (EVI)
- soil adjusted vegetation index (SAVI)
- leaf area index (LAI)

$y = 0.01x - 19.75$
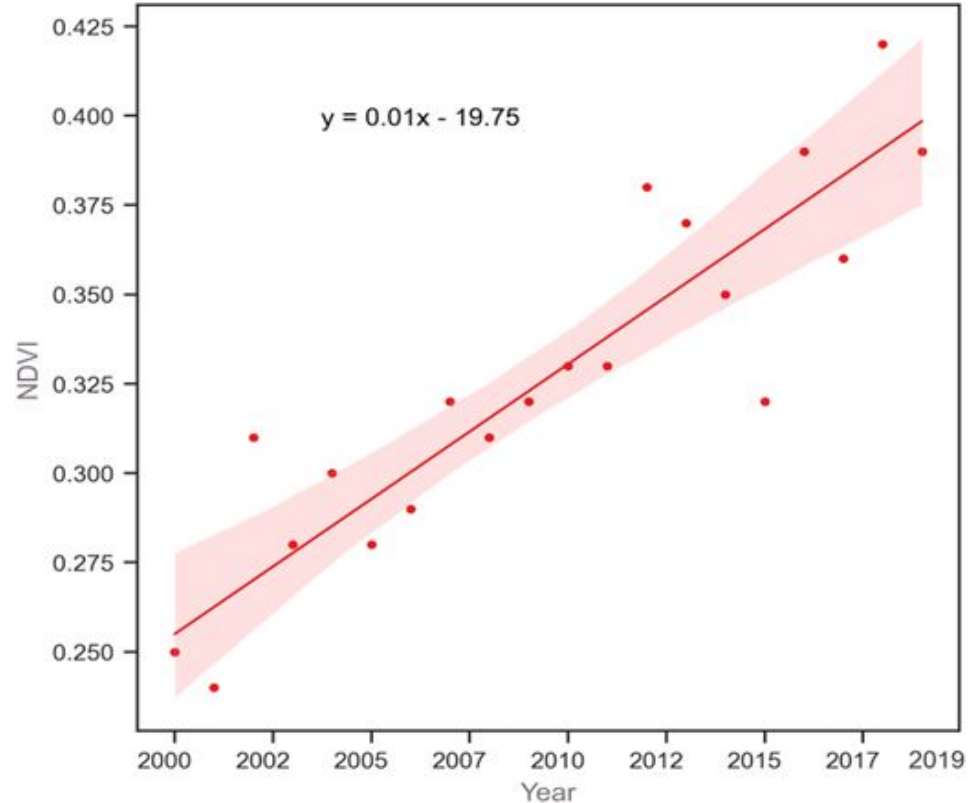
Components of Time-Series Analysis

Trend: shows the long term condition of the vegetation (stable, increasing, decreasing)

Seasonality: the repetitive seasonal change that relates to wet and dry seasons

Residual: remains after the trend and seasonal components are removed from the time series, and can represent short term fluctuations from e.g. disturbances or could be noise
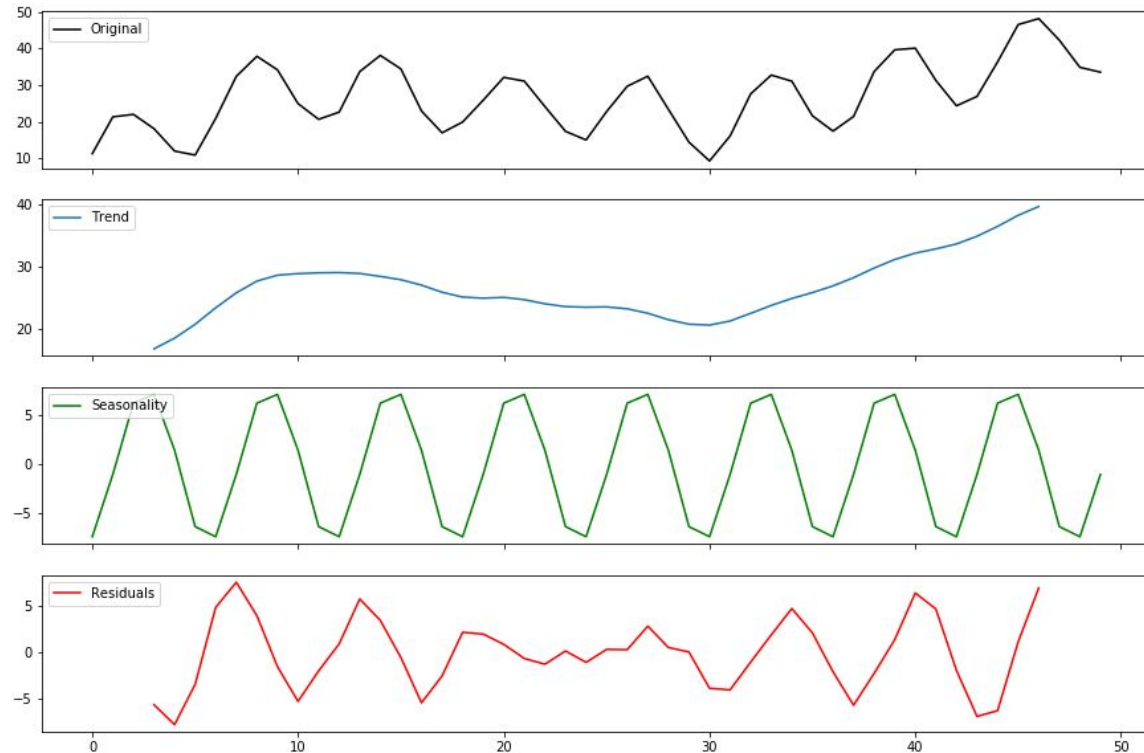
Components of Time-Series Analysis

1. **Image Differencing:**
   - directly subtracting the pixel values of two images taken at different times (e.g., images from two different dates) to highlight areas of change
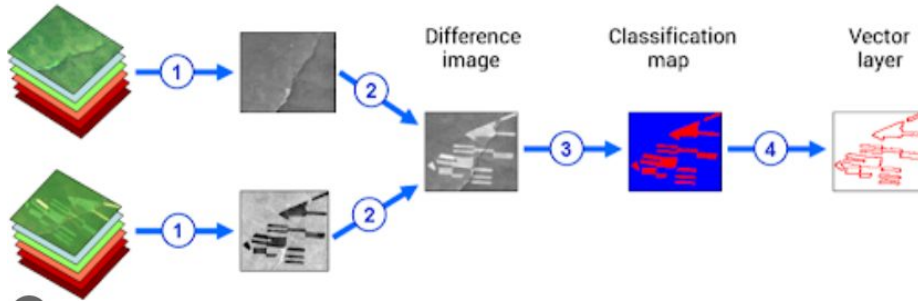2. **Classification-Based:**
   - classifying each pixel in two or more images into land cover or land use categories and then comparing the resulting classification maps to identify changes.
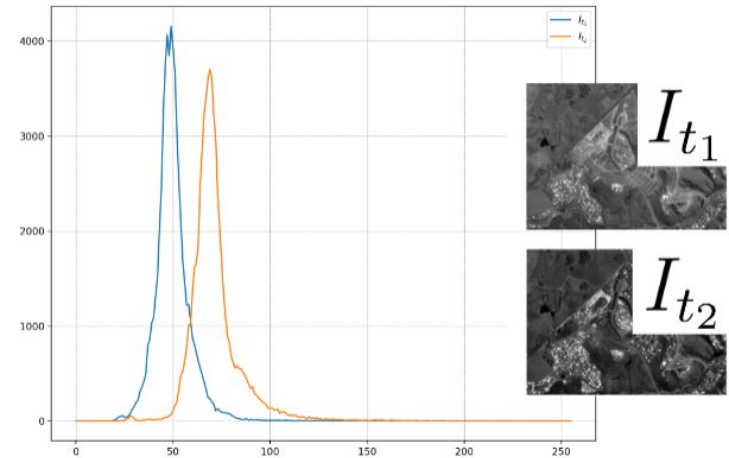3. **Indices-Based:**

Example:
NDTS (Normalized Difference of Time Series) which is basically:
NDTS = (It2 - It1)/(It2 + It1)

Figr: Image Differencing

Figr: Indices based

Challenges of Remote Sensing methods

- the spatial, spectral and temporal resolution of RS sensors may be insufficient to accurately detect degradation
- Increased Spatial and Temporal Coverage and Resolution of Satellite Observations could imply higher cost and processing time
- Vegetation phenology (cyclic biological events in vegetation)
- Continuity of sensor, data interoperability, etc.
- Other inherent challenges of remote sensing

Commonly used multispectral satellite sensors for vegetation studies

Satellite Imagery	Bands	Temporal Resolution (Days)	Spatial Resolution (m)	Period
Landsat MSS	4	180	80	1972–1992
TM Landsat	7	16	30, 120	1982–present
ETM+ Landsat	8	16	30, 15, 60	2003–present
Landsat OLI	11	16	30, 15	2013–present
Sentinel-1	C-band	12	5	2014–present 1A 2016–present 1B
Sentinel-2	13	5	60, 10, 20	2015–present 2A 2017–present 2B
MODIS	36	1–2	250, 500, 1000	2000–present Terra 2002–present Aqua
AVHRR	5	1	1100–5000	1980–present
IKONOS	5	1–2	4	1999–2015
MERIS	15	3	300	2002–2012
QuickBird	5	1–3.5	2.4	2001–present
Rapid Eye	5	5.5	5	2008–2020
SPOT	4	26	10, 20	1986–2013
Worldview-2	8	1	<1	2014–present

References

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