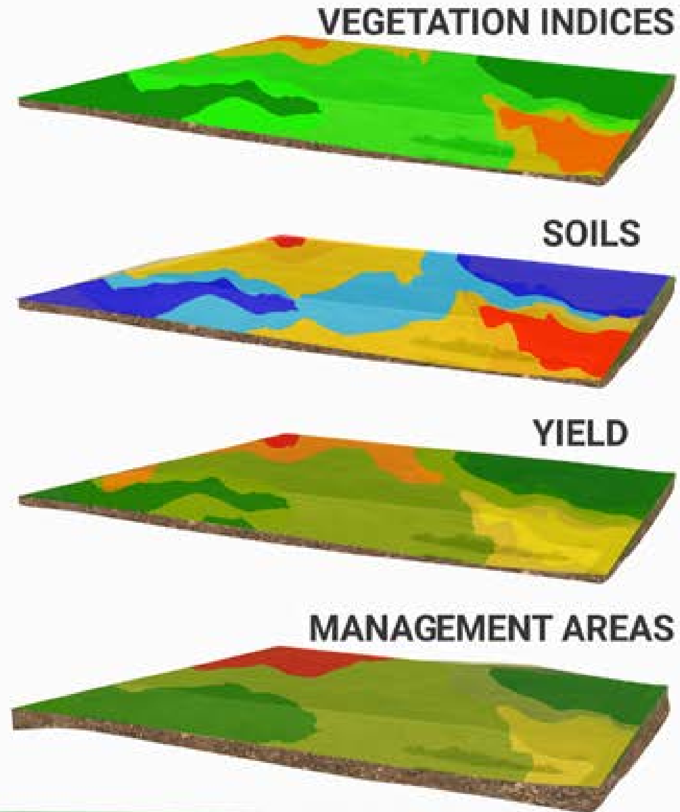
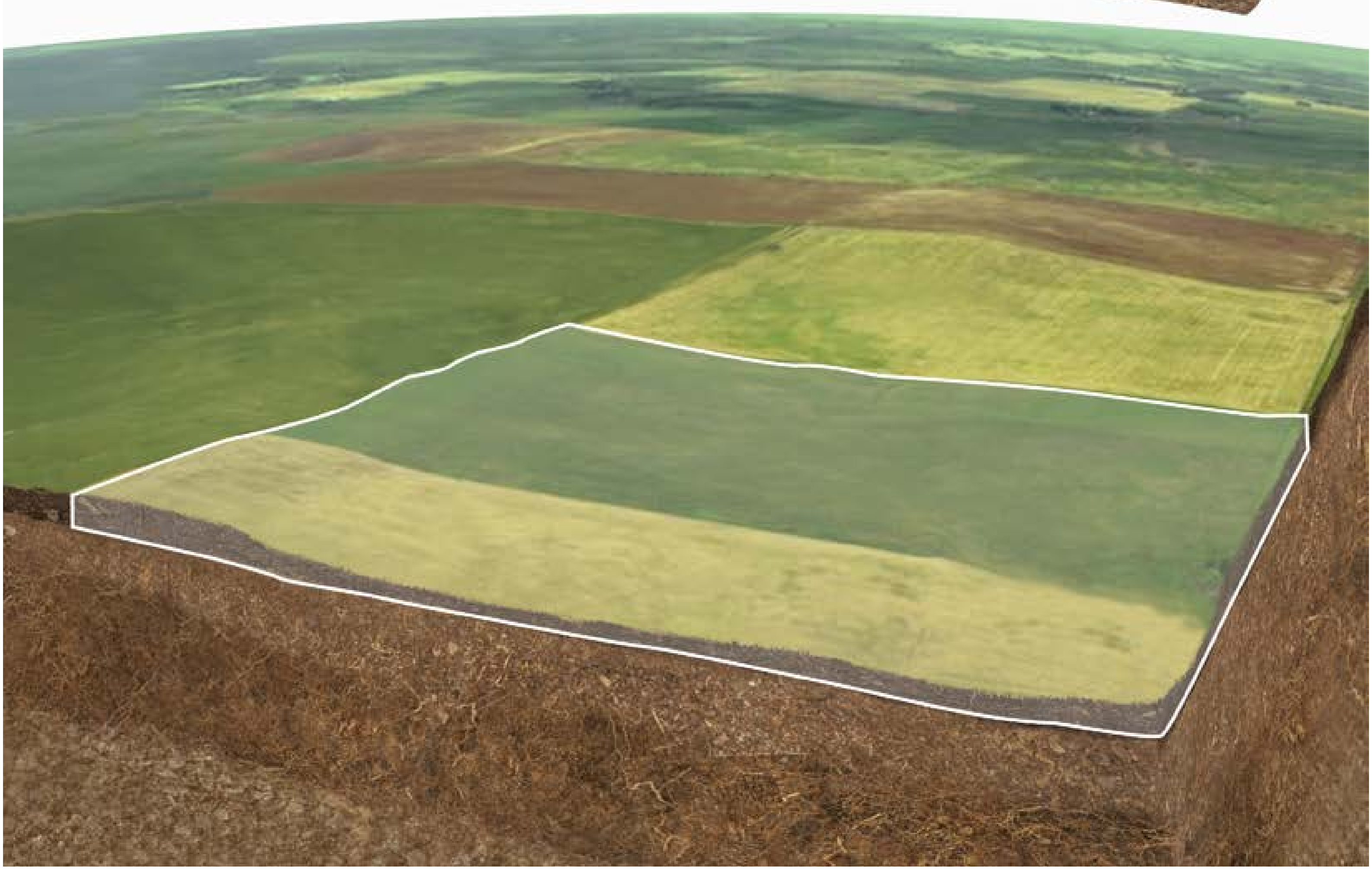
K·STATE Research and Extension

Satellite Data and Agronomic Decisions

This publication helps producers, crop consultants, and agronomists understand how to use satellite imagery to assist with the on-farm decision-making processes. The following information highlights steps involved in using satellite imagery and its potential applications for farming operations.

1. **Images:** Satellite images from different resources. Historical series.
2. **Analysis:** Development of different vegetation indexes and analysis of the data.
3. **Other information:** Historical data, yield monitors, soil maps, high-resolution soil maps, water content, digital elevation models.
4. **Zone delimitation:** Final result, different potential management areas.





Kansas State University Agricultural Experiment Station and Cooperative Extension Service

Basic Principles

Electromagnetic radiation from the sun drives photosynthesis on Earth. Three things can occur when electromagnetic radiation (irradiance) strikes an object such as a leaf. The irradiance is either reflected (reflectance), is transmitted (transmittance; i.e. passes through the object) or is absorbed (absorbance) by the object (Figure 1).

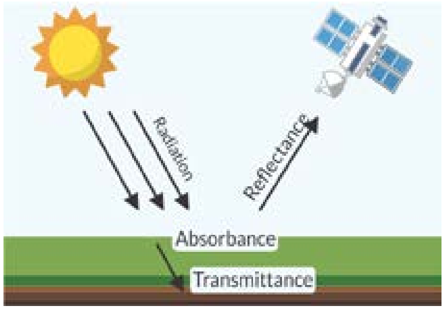


Figure 1. Interaction of the electromagnetic radiation and target: absorbance, transmittance and reflectance.

The proportion for each fraction (reflectance, transmittance, and absorbance) differs depending on the physical and chemical properties of the target object. Plants have a medium, low, and high reflective pattern in the green, red, and near-infrared portions of the electromagnetic spectrum (Figure 2), respectively. A significant portion of visible, blue and red, light is used as energy to trigger important photosynthetic processes in plants.

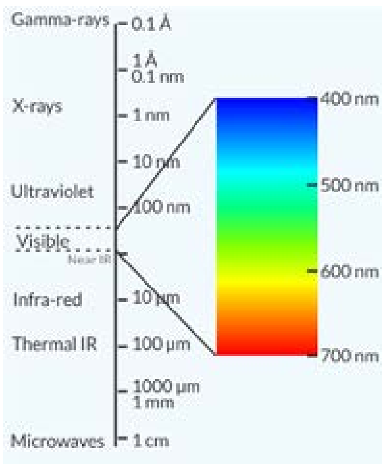


Figure 2. The electromagnetic radiation spectrum.

The term "band" identifies wavelength regions of electromagnetic spectrum where a satellite is sensitive to the reflected signal from the ground. Vegetation indices (VIs) relates to different bands or regions and are used to derive biophysical information important to monitor the status of the crops. Multispectral onboard sensors retrieve data from the visible part of the spectrum (520 to 600 nanometers = green, 630 to 680 nanometers = red, and 450 to 520 nanometers = blue), infrared (IR), and microwaves. The IR band, depending on the characteristics of the satellite sensor, also can be divided into close IR or near IR (NIR = 760 to 900 nanometers), medium IR (MIR) and far IR (FIR), or thermal. As an example, the chlorophyll in the leaves absorbs more blue and red (630 to 680 nanometers) and less green (520 to 600 nanometers) electromagnetic radiation. Plants appear green because more green radiation is reflected to our eyes (Figure 3).

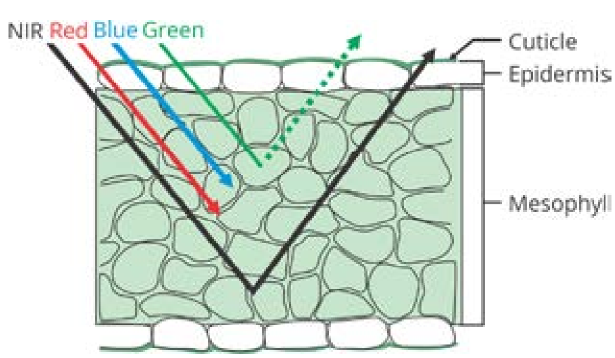


Figure 3. Interaction between radiation and mesophyll.

Satellite Basics

Many of the satellites orbiting Earth were designed to monitor changes in land cover. The main characteristics of the satellites for agricultural application are:

1. **Temporal resolution:** The frequency (time interval) for obtaining imagery data from the same point on the surface.
2. **Spatial resolution:** The level of detail visible in an image (pixel dimensions). The smaller the area represented by each pixel in a digital image, the greater the details.
3. **Spectral resolution:** The width of the spectral bands recorded by a sensor. The narrower these bands, the higher the spectral resolution.
4. **Radiometric resolution:** The sensitivity of the sensor to capture change on signal from the ground, ranges from 8-bit to 16-bit, and so on.

The most commonly used sensors for agricultural applications are (Figure 4):

- **MODIS** (Moderate Resolution Imaging Spectroradiometer) is a sensor on the Terra and Aqua satellites with a high temporal resolution (daily) but low spatial resolution. The minimum pixel size is 250 meters, ideal for large-scale or regional work, for example county-level data. MODIS has a total of 36 bands.
- **Landsa**t, with different missions (Landsats 5, 7, and 8), have a finer spatial resolution (30 meters), but with a lower temporal resolution than MODIS. The number of bands is 11.
- **Sentinel 2 A** and **Sentinel 2 B**, from the European Space Agency (twin satellites), these sensors allow more detailed spatial resolution (10 meter) and weekly imagery data when both are functional. The number of bands is 13.
- **Rapid Eye**, is a constellation of five satellites, and each satellite has a spatial resolution of five meters per pixel and daily frequency. The number of bands is five.

These four are the most common, but there are several satellites with different spatial, temporal, and spectral resolution, and different costs. Examples of these are: Proba-V, Sky-Sat, Planet constellation, WorldView constellation, Aster, GeoEye, QuickBird, and Spot.

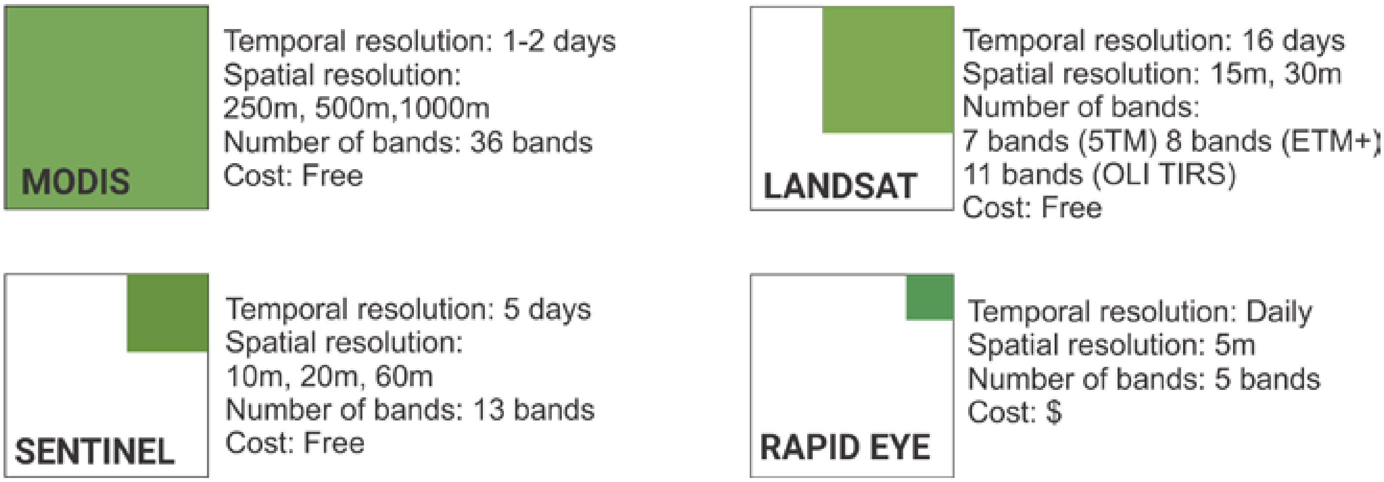


Figure 4. Different satellites and characterization for Spatial, Temporal, and Spectral resolution

The Importance of the Resolution

Satellite choice and sensor to use depends on several factors such as budget, field size of interest, required accuracy/precision, threshold in decision making, size of land-cover/land-use change patches, scale of variations, presence of important features or management practices, and the frequency of data updates for the study.

Spatial resolution is an important consideration when choosing the correct satellite, and the choice usually depends on the level of spatial detail required. For example, Figure 5 shows the increasing level of detail. In Figure 5 (a) we can observe 30-meter resolution, for Landsat, (b) is an example of 10-meter, Sentinel, and c) shows 5-meter resolution with Rapid Eye constellation, and d) shows 10-meter resolution, Google.

Vegetation Indices (VIs)

Vegetation indices (VIs) are mathematical combinations of certain spectral bands, which allow us to monitor changes in vegetation. Examples of some of the most commonly used indices are: normalized difference

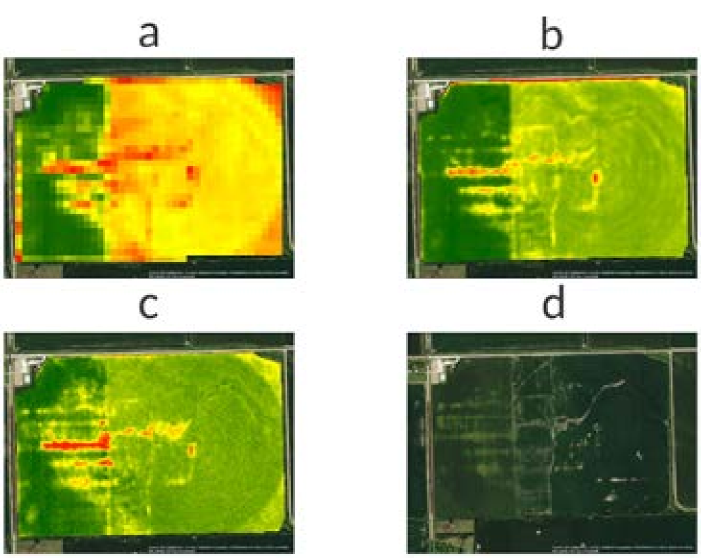


Figure 5. Comparison of spatial resolution, between satellites NDVI a) Landsat 8, 30 meters, NDVI b) Sentinel 2 A, 10 meters, NDVI c) Rapid Eye, 5 meters, NDVI d) Google, 10 meters, color.

Index	Acronym	Equation	Reference
Normalized Difference Vegetation Index	NDVI	(NIR-RED)/ (NIR + RED)	Rouse et al. (1974)
Enhance Vegetation Index	EVI	2.5* (NIR-RED)/ (NIR+6* Red 7.5*Blue+1)	Huete and Lui (1997)
Normalized Difference Water Index	NDWI	(Green-NIR)/ (Green+NIR)	Gao (1996)
Green Normalized Difference Vegetation Index	NDVIG	(RNIR-Rgreen)/ (RNIR+Rgreen)	Gitelson et al. (1996)
Red-edge Normalized Difference Vegetation Index	NDVIre	(RNIR-REDedge)/ (RNIR+REDedge)	Gitelson and Merzliak (1994)
Red-edge Simple Radio	SRre	RNIR/REDedge	Jordan (1967)

Table 1. Description, acronym, equations, and references for all vegetation indices (Vis)

vegetation index (NDVI), enhance vegetation index (EVI), normalized difference water index (NDWI), red edge NDVI (NDVIre), red edge simple ratio (SRre), and green NDVI (gNDVI).

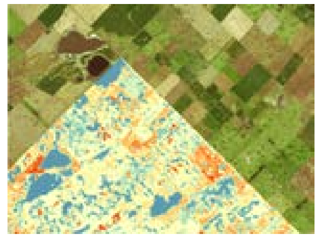
The NDVI is universally used as an index for measuring temporal and spatial differences in overall plant health. For agricultural purposes, NDVI values ranges from 0 to 1, with values ranging from 0.1 to 0.2 for soil surfaces and 0.3 to 1.0 for crop canopies. Canopy NDVI values have been shown to be positively related to crop vigor and yield potential. Important VIs with their respective equations are shown in Table 1.

Some Applications

Help when crop scouting and sampling according to the field dimensions.

Forecasting crop yields at different scales: county, district, regional, state, and national levels.

Site-specific management (SSM), imagery-derived prescription maps for variable rate seeding and fertilization, which vary as a function of yield potential with the field.



In-seasonal (within a season) and temporal (across seasons) monitoring of crop vegetation (diagnosis of potential stress factors such as drought, nutrient deficiencies, diseases, and insects).

Future

- New public satellites allowing a finer time resolution (e.g. Sentinel-3), reducing problems with cloud interference.
- Higher spectral resolution satellites that will benefit a more intensive monitoring of functional crop growth parameters (e.g., ESA FLEX mission - planned launch date is 2022).
- More studies to focus on how to integrate information from different satellites while taking advantage of the different features from each.
- Development of remote sensing end-to-end solutions by agricultural providers for farmers (integration with ground sensors, mobile apps, etc.).

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Satellite Data Available at:

earth.esa.int/web/sentinel
landsat.usgs.gov
modis.gsfc.nasa.gov
www.planet.com

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