Observe Earth from space

Observing the surface from above is well known to give us the possibility of understanding many things that would otherwise be hidden from us by the limited view on the ground.
The possibility of giving this concept a quantitative as well as qualitative aspect derives from a property that belongs to all bodies: the ability to reflect the solar energy that hits them.
The effectiveness of the surface of a body/material in reflecting the solar energy, expressed as the ratio between the incoming light and the reflected light is called reflectance.
This property is closely linked to the electronic structure of the material, and is in general a function of the wavelength, of the solar light, more to the angle of incidence.
All this means that the soil has a very different response curve from that of vegetation or water, forests have a very different curve from crops (for example wheat).
A consequence of this thing that we know very well are the colors of various objects.
Different colors mean different reflectance curve.
Since we know very well that the colors of vegetation, crops and plants can change over time, this means that the reflectance curve changes over time for these which are living organisms and not inanimate ones like rocks. Along is life cycle also snow can change largely reflectance curve.
By measuring the reflectance from space we can therefore not only understand if the surface we are looking is land or water, if it is covered by snow or ice, if there is vegetation and of what type, but we can even understand its state of health, the advancement in growth, abundance, the age of snow cover and more.

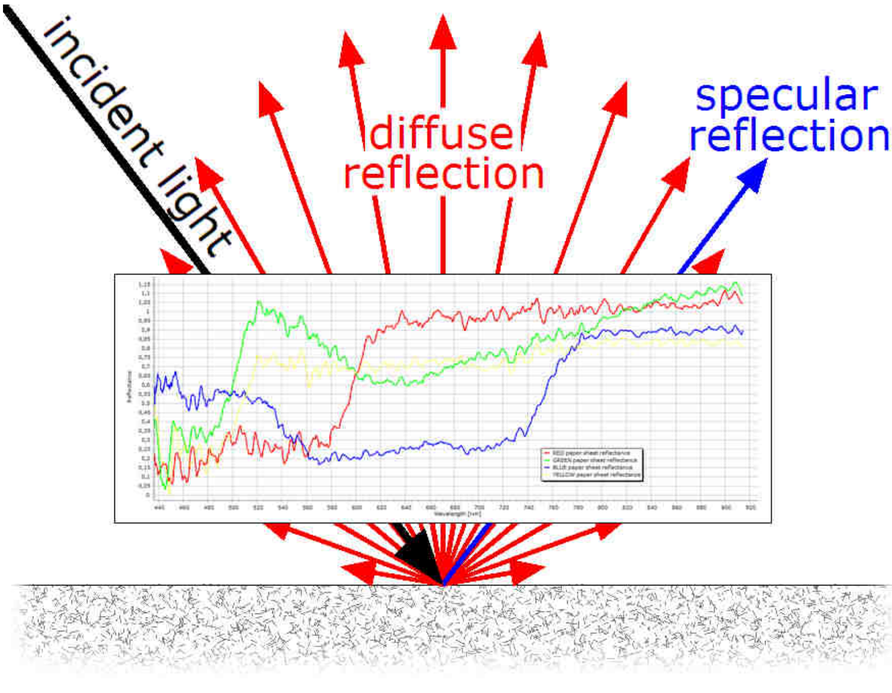


Fig.1 Physical process and the concept of reflectance.
(from https://physicsopenlab.org/2021/07/03/reflectance-spectroscopy-colorimetry/)

Figures below demonstrating very clearly the variety of spectral reflectance curves for surface characteristics coverage. Fig.2 is important to indicate that the same material can also change a lot on the basis of how is composed (density, grain size etc. etc. etc.). This means this property is not intrinsic of the substance, but arise mainly from external factors.

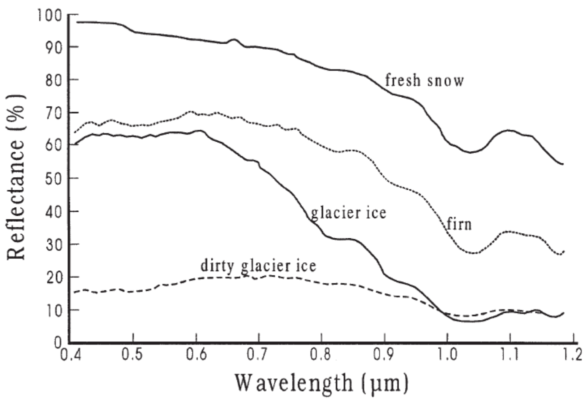


Fig.2 Spectral reflectance curves of different snow and ice cover types in Visible and near infrared spectrum. (From Gao, J. and Liu, Y., 2001. Applications of remote sensing, GIS and GPS in glaciology: a review. Progress in Physical Geography, 25(4), pp.520-540 https://journals.sagepub.com/doi/10.1177/030913330102500404)

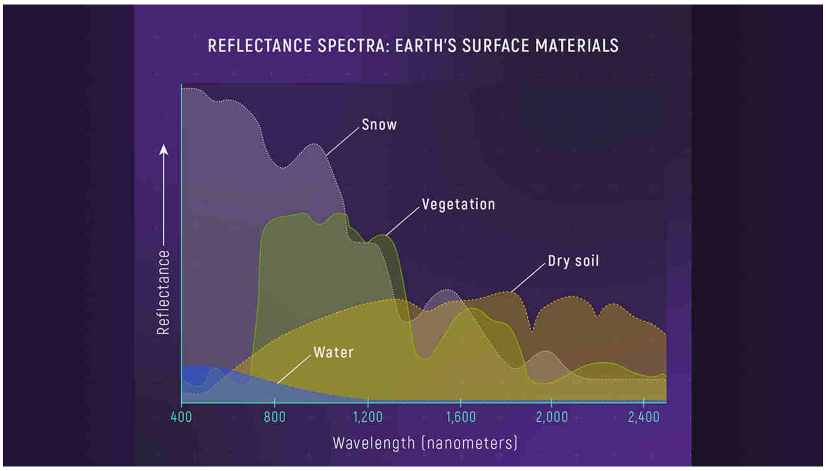


Fig.3 variety of spectral reflectance curves for surface characteristics coverage (from-https://webbtelescope.org/contents/media/images/01F8GFAGTM98YTKDS0FZAAWWV2)

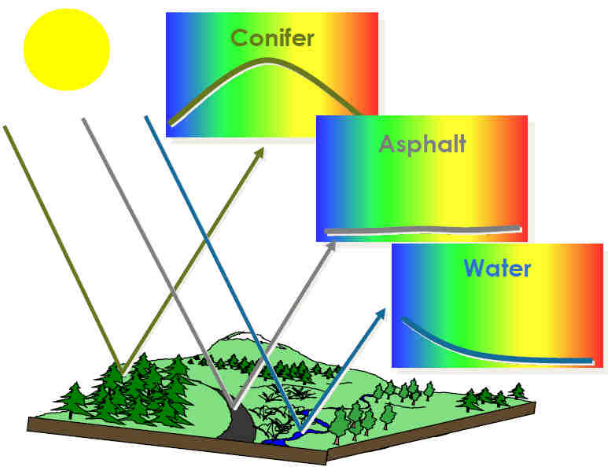


Fig.4 Variety of spectral reflectance curves for surface characteristics coverage (from https://appliedsciences.nasa.gov/get-involved/training/english/arset-techniques-wildfire-detection-and-monitoring)

What we are interested to observe

It is not difficult to understand that the more complicated the feature we want to observe, the more difficult it will be to do so. Identifying a change in the presence or absence of trees (forest change detection) is certainly simpler than noticing a degradation of the forest, whether due to natural causes or man's fault.

It is therefore not at all strange that change detection in forest monitoring (deforestation and forest regeneration) already has a long tradition starting with Landsat data in the 1980s and 1990, and yearly deforestation mapping and the derivation of deforestation rates are already operational at global and also at the national level.

While there is still only fragmented information available on the extent and magnitude of forest degradation. However, more high-resolution optical data is now available than ever before. These datasets can be used to build a time series. Tracking areas closely over time allows detecting subtle changes (for both deforestation and forest degradation) and generates the possibility to alert in near real time, when changes are occurring.

A nice compendium of what is possible to observe with satellites can be found at the webpage https://mysustainableforest.com/. Exploring the web site you can see a wide range of products also friendly documented , examples of applications, video, webinars.

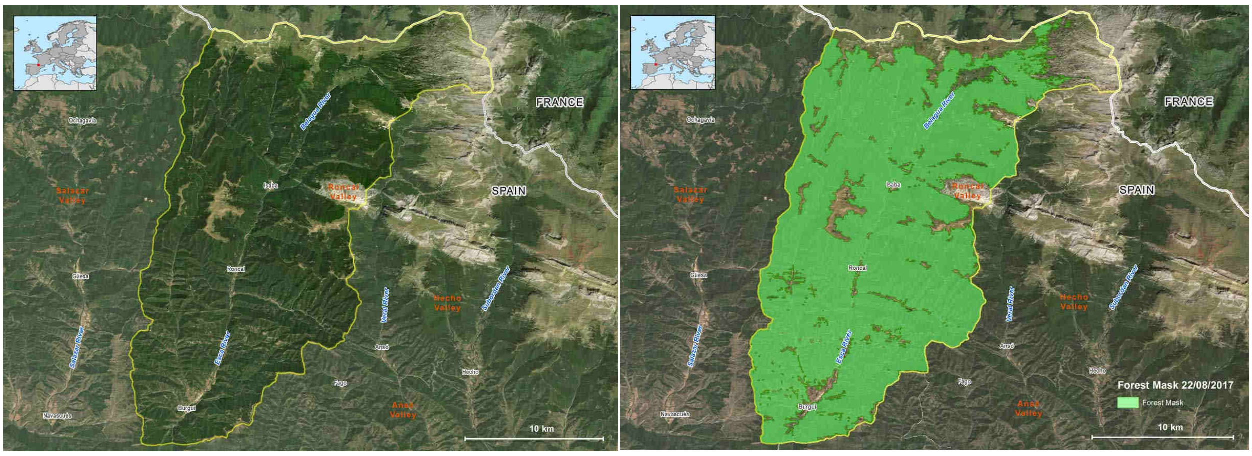


Fig.5 Roncal Valley of the Pyrenees (Navarra, Spain) - The Forest Mask locates the forested area (34.345,00 ha) in the . Automatic product by GMV; validated by FORESNA. (https://mysustainableforest.com/outputs/sample-cases/)

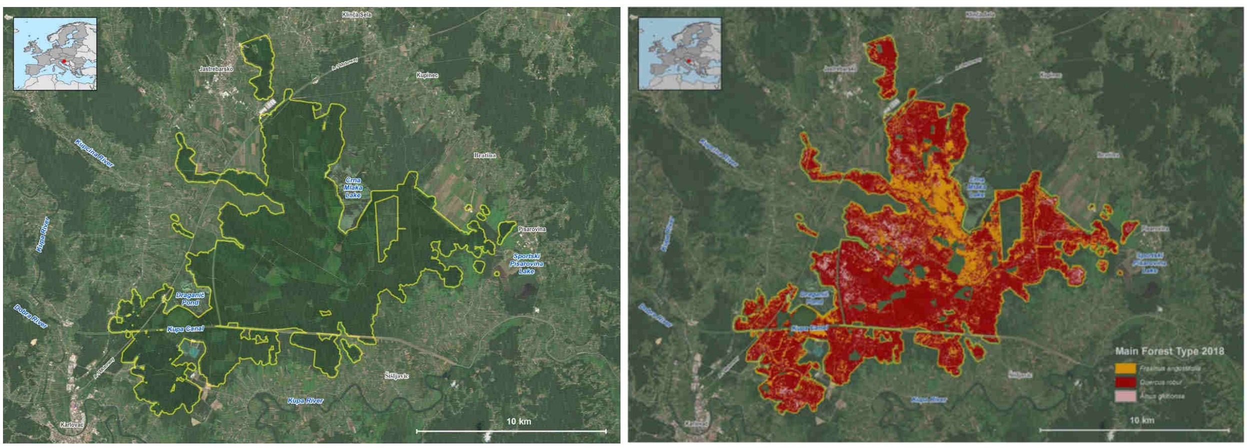


Fig.6 Pokupsko Basin Forest (Croatia) - The Main Forest Type distribution tree species area are shown: these are 71,56 % of European oaks (*Quercus robur*); 22,66% of narrow-leafed ashes (*Fraxinus angustifolia*); and 5,78% of alders (*Alnus glutionsa*). Automatic product by GMV; validated by CFRI.

Disturbance or degradation: what the difference

The term forest disturbance is mostly used for natural causes of crown cover or biomass loss, such as from storm damage, forest fires, drought stress, insect infestations, and disease outbreaks but may also include harvesting operations with a potential negative impact.
The term forest degradation mostly relates to human-induced crown cover or biomass loss.

A further difference between the two terms exists with regard to the temporal impact. A disturbance is usually a single event with a short-term impact and may even be regarded as part of the natural forest dynamics, while degradation has a negative long-term impact that may be a consequence of one or several single disturbances

the Food and Agriculture Organization of the United Nations (FAO) use Forest degradation as an umbrella term for both natural and human-induced forest changes. In fact, FAO defines forest degradation as

> *"changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to supply products and/or services"*

Fig.6 Different types of large-scale forest disturbance: (a) windthrow in a Picea abies stand (photo by Aleksander Marinšek); (b) massive ice storm damage in 2014 (photo by Lado Kutnar); (c) and (d) forest fire in the sub-Mediterranean region of Slovenia (photos by Klemen Eler); (e) dieback of Fraxinus excelsior caused by fungal disease Hymenoscyphus fraxineus (Photo by Janez Kermavnar); (f) forest management after a disturbance -salvage logging (photo by Lado Kutnar). (from https://efi.int/news/increased-forest-disturbances-require-better-reporting-and-data-collection-2023-03-07)

Our eyes: multispectral sensors on satellites

Since the 1980s, with Landsat missions, man has tried to exploit the potential of satellites to monitor surface conditions and their changes.

Sensors capable of measuring surface reflectance in very specific portions (channels) of the electromagnetic spectrum have been designed, built and sent into space.

The choice of channels is a very important and challenging issue, to the point that no two satellites really have the same combination.

The prodigious development of technology, in particular the possibility of being able to create devices capable of measuring at the same time a very large number of wavelengths in increasingly wider spectral channels (hyper-spectral sensors), will quickly make these limitations and challenges a distant memory.

In addition to the portion of the electromagnetic spectrum they are able to measure, a characteristic determining which features the space-borne instrument will be able to observe, a second very important characteristics of the sensors is the ability to observe increasingly smaller portions of the surface (spatial resolution - see a specific sheet on this topic).

Is important in respect spectral resolution find the way to provide the concept that colors in the satellite images are “FAULSE” and derive from a choice of who is analysing. Choice made in general with the aim to emphasise a specific feature (for example the presence of a forest) or a change (put in evidence a burned area).

The work done for satellite images is quite similar to the work to add colors to a black and white photo. For satellite images the process is in an case drived by reflectance values. Make a choice of the color palette (as for example done in word for highlight a text), and which color to start from, each group of values is automatically assigned a very specific color. These digital palettes can have millions of shades and therefore be able to distinguish very small differences in color reflectance. A non-scientific but artistic consequence is that satellite images can usually be of great effect and graphic impact. Several images in this file are a clear example of that.

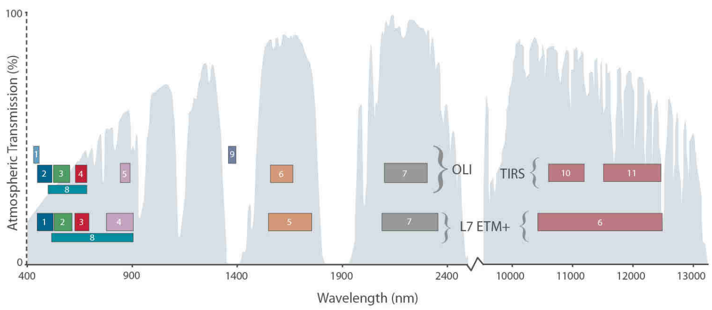


Fig.7 Comparison of Landsat 7 and 8 bands with Sentinel-2
(https://landsat.gsfc.nasa.gov/satellites/landsat-8/)

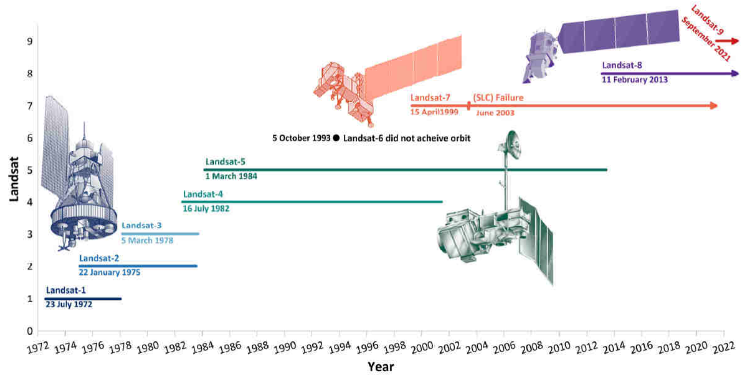


Fig.8 Graphical illustration of Landsat mission’s timeline

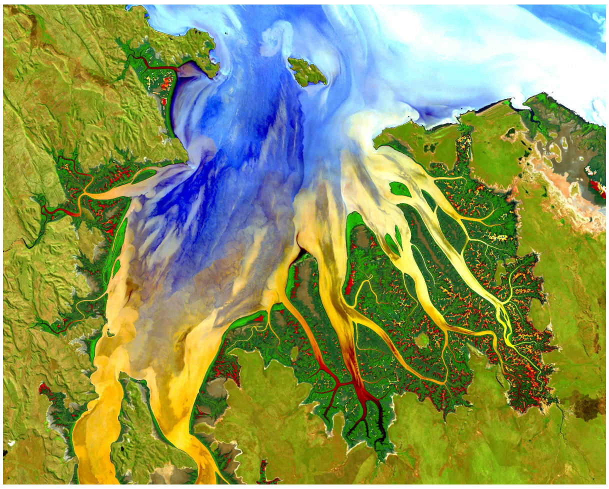


Fig. 9 Image of landsat-8
(https://www.satimagingcorp.com/satellite-sensors/other-satellite-sensors/landsat-8/

Table 1 Active satellite missions overview—optical HR satellites/sensors specifications

Satellite system	Mission start-completion	Spectral characteristics (in µm)		Orbit height	Swath width	Resolution	Repeat cycle	Revisit frequency
FormoSat-2 (ROCSat-2) (NSPO, Taiwan)	2004–*	0.45–0.90 0.45–0.52 0.52–0.60	0.63–0.69 0.76–0.90	888 km	24 km	PAN 2 m Others 8 m	1 day	1 day
Landsat 7 (USGS, USA)	1999–*	0.52–0.90 0.45–0.52 0.53–0.61 0.63–0.69	0.78–0.90 1.55–1.75 2.09–2.35	705 km	185 km	PAN 15 m Others 30 m	16 days	16 days
Landsat 8 (USGS, USA)	2013–*	0.50–0.68 0.433–0.453 0.45–0.515 0.525–0.60 0.63–0.68	0.845–0.885 1.36–1.39 1.56–1.66 2.10–2.30	705 km	185 km	PAN 15 m Others 30 m	16 days	16 days
RapidEye (RapidEye AG, BlackBridge Germany)	2008–*	0.44–0.51 0.52–0.59 0.63–0.685 0.69–0.73 0.76–0.85		630 km	77 km	5 m	5.5 days	1 day
Sentinel-2 (ESA, EU)	2015–* (~ 2027)	center wavelength ; band width – band 0.443; 0.02–1 0.490; 0.065–2 0.560; 0.035–3 0.665; 0.03–4 0.705; 0.015–5	0.740; 0.015–6 0.783; 0.015–7 0.842; 0.115–8 0.865; 0.02 – 8a 0.945; 0.02–9 1.375; 0.03–10 1.610; 0.09–11 2.190; 0.180–12	786 km	290 km	B2, B3, B4, B8 10 m B5, B6, B7, B8a, B11, B12 20 m B1, B9, B10 60 m	10 days (Sentinel-2-A); 5 days (Sentinel-2-A & 2B)	10 days (Sentinel-2-A); 5 days (Sentinel-2-A & 2B)
Spot 6/7 (France)	2012–* (~ 2025)	0.45–0.745 0.45–0.52 0.53–0.59 0.625–0.695 0.76–0.89			60 km	PAN 2.2 m Others 8.8 m	26 days	1–5 days
UK-DMC-1 / 2 (SSTL, UK)	2003–*	0.52–0.62 0.63–0.69 0.76–0.90		686 km	650 km	32 m	14 days	1 day
HJ-1A/1B (China)	2008–*	0.43–0.52 0.52–0.60 0.63–0.69 0.76–0.90		650 km	360 km	30 m	4 days	4 days
CBERS-4 (Ziyuan I-04) (China, Brazil)	2014–*	MUXCam 0.45–0.52 0.52–0.59 0.63–0.69 0.77–0.89	PanMUX 0.51–0.73 (PAN) 0.52–0.59 0.63–0.69 0.77–0.89	748 km	MUXCam 120 km PanMUX 60 km	MUXCam 20 m PanMUX 5 m (PAN), 10 m (Others)	26 days	3–26 days
IRS Series, ResourceSat Series (India)	1988–*	PAN 0.50–0.75 LISS-III 0.52–0.59 0.62–0.68 0.77–0.86	1.55–1.70 LISS-IV 0.52–0.59 0.62–0.68 0.77–0.86	Variable	PAN/LISS-IV 70 km LISS-III 140 km	PAN/LISS-IV 5.8 m LISS-III 23.5 m	22–24 days	5 days
Terra ASTER (USA, Japan)	1999–*	0.52–0.60 0.63–0.69 0.76–0.86 0.76–0.86	1.60–1.70 2.14–2.185 2.185–2.225 2.235–2.285 2.295–2.365 2.360–2.430	705 km	60 km	15 m (VNIR), 30 m (SWIR)	16 days	16 days

Fig. 10 Active satellite missions overview—optical HR satellites/sensors specifications

How deep to observe the surface: the spatial resolution

Observing the surface and being able to notice microscopic details might appear to be the most obvious choice to make, with the only limit being the technological potential.

But in making this reasoning/choice, we must never forget that what we observe must then be analysed, and therefore there is a further limitation in our ability to store and manage data, and process it to obtain the final result.

While very high spatial (VHR) resolution sensors (< 4 m multispectral pixel size) may have better degradation detection capabilities, the image generally has a much smaller footprint compared to a high- or medium-resolution sensor. This means that independent of the repeat cycle and revisit frequency of the satellite, the wall-to-wall coverage using very high-resolution sensors is generally more cost and time consuming and, in the case of larger areas, even impossible.

Medium to coarse resolution sensors (>60 m multispectral pixel size), despite having lower cost/time requirements for wall-to-wall data coverage, are very limited in their ability to detect small area disturbances. High-resolution satellite systems can be considered a good compromise, offering high enough spatial resolution and large enough footprint for cost efficient large-scale degradation monitoring.

Again important to say that tecnological advancemen, in particular AI, could rapidly remove most of computation limitations

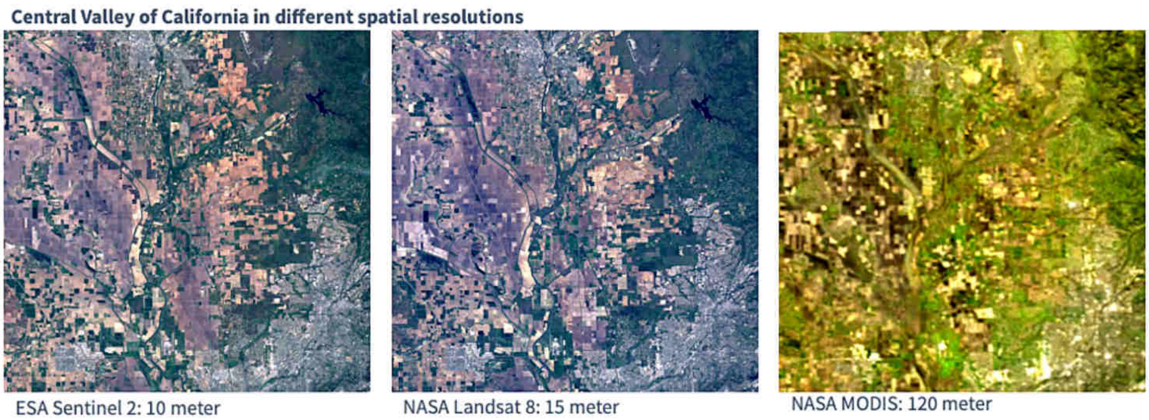


Fig.11 Example of how resolution change your capability to observe the surface

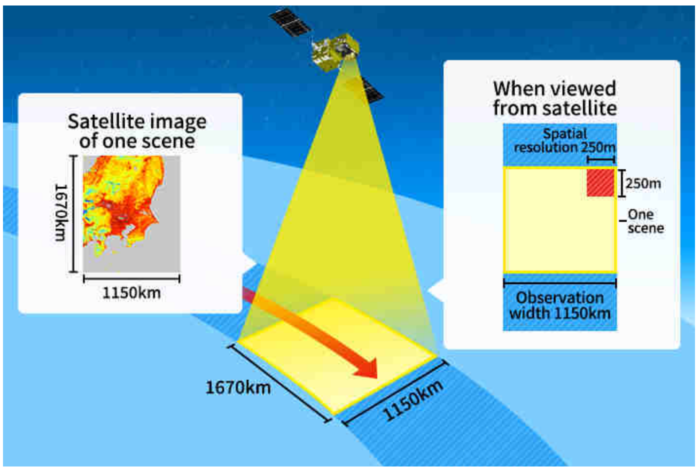


Fig.12 How the satellite work and spatial resolution
(https://earth.jaxa.jp/en/eo-knowledge/eosatellite-type/index.html)

At this link a video illustrating how the satellite observe the earth moving in the space:
https://www.youtube.com/watch?v=ocJVyrklb48

Repeat cycle and revisit time

In the context of satellite remote sensing, the terms "repeat cycle" and "revisit time" are related to how often a satellite passes over the same area on the Earth's surface.

Repeat Cycle: The repeat cycle of a satellite refers to the time it takes for the satellite to complete a full cycle and OBSERVE the same point on the Earth's surface **under the same viewing conditions**. For example, if a satellite has a 16-day repeat cycle, it means that the satellite will pass over the VERTICAL of the same point on the Earth's surface every 16 days.
Repeat cycle is a characteristics of the satellite, the vehicle transporting the instrument. And is determined by the combination of orbital satellite characteristics and Earth rotation.

Revisit Time: Revisit time, on the other hand, refers to the time it takes for a satellite to SEE the same point on the Earth's surface **regardless of the viewing conditions**. It represents how often a satellite can acquire imagery or data for a specific location on the Earth's surface. For instance, if a satellite has a revisit time of 3 days, it means that the satellite will BE ABLE TO SEE the same point on the Earth's surface approximately every 3 days.

Meanwhile the satellite rotate around the planet, a satellite-borne instrument see more that just the vertical, since they have what we call Field of View (FOV). Imagine the satellite's sensor as an high tech paintbrush, weeping across the Earth's surface with each pas. The width of this strocke is called SWATH. The scene is then observed with different angles with respect vertical/nadir. In view of this off-nadir viewing capability of the satellites, revisit time Is usually less than the repeat cycle.

Revisit time represent Temporal resolution of a satellite-borne instrument.

All instrument on board a satellite have the same Repeat cycle, meanwhile can have different revisit time depending from their respective SWATH width

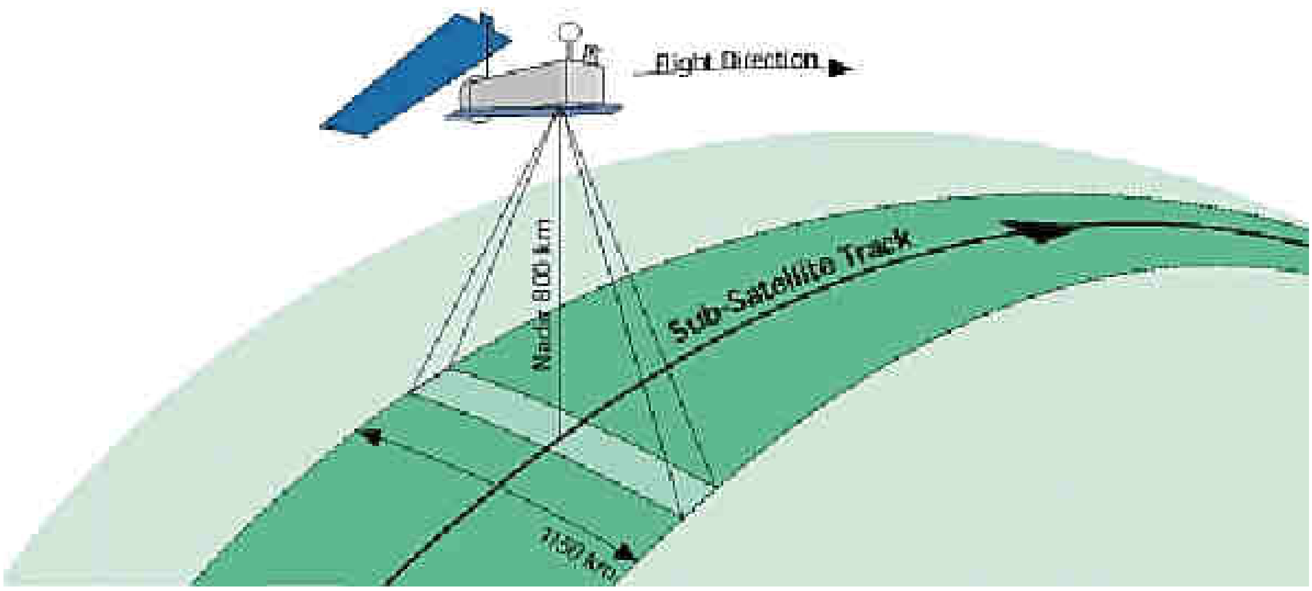
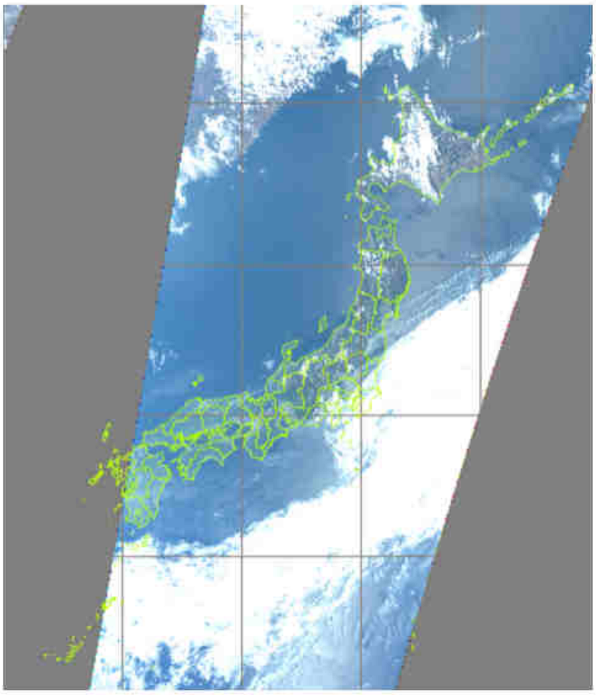
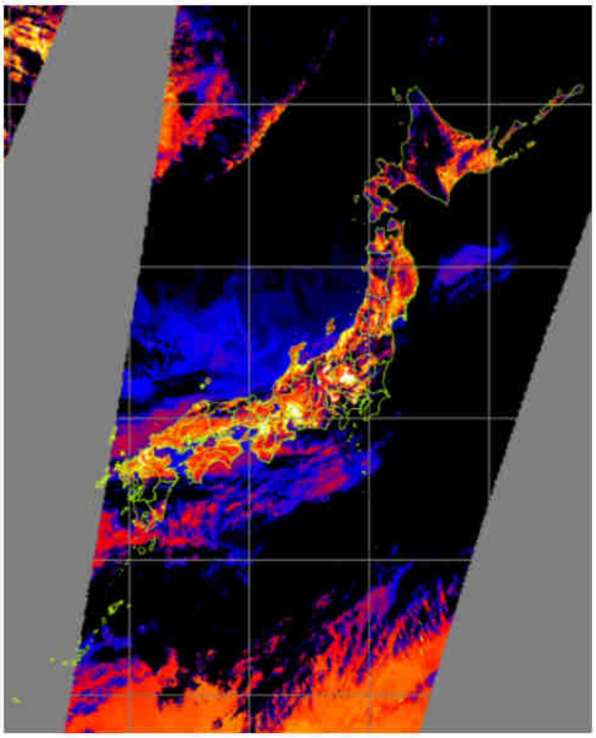


Fig.13 Track of satellite and SWATH
(https://www.scitepress.org/Link.aspx?doi=10.5220/0006655003120319)



Visible image
Satellite/Sensor：GCOM-C/SGLI-VNR
Swath：1150km



Thermal infrared image
Satellite/Sensor：GCOM-C/SGLI-IRS
Swath：1400km

Fig.14 Difference of swath by the sensor onboard GCOM-C satellite
(https://earth.jaxa.jp/en/eo-knowledge/eosatellite-type/index.html)

Methods for Forest Degradation Mapping

The methods for forest degradation mapping from optical image data can be subdivided in two broad categories depending from the type and number of datasets/images used:

1. - Image-to-image change detection;
2. - Time series analysis-based change detection.

We focus in this card on the first category, dedicating a specific card to the second one.

Image-to-image change detection

At least one image acquired before and one after a degradation event is required, of which the first must be from the start of a monitoring period and the second at the end.

Image-to-image change detection is currently the most commonly used method for mapping forest degradation. It makes use of the change of the spectral signatures of the land surface between the images taken at two different dates in time in order to assess changes that occurred between these two dates.

For image-to-image change detection, a forest mask is necessary in order to focus on changes in those forest areas only, since other major land cover categories, especially agricultural areas, can change significantly over the course of one vegetation period and would lead to false results. Such forest masks must be as up-to-date as possible and can be either derived from the EO data used for change detection or from other sources.

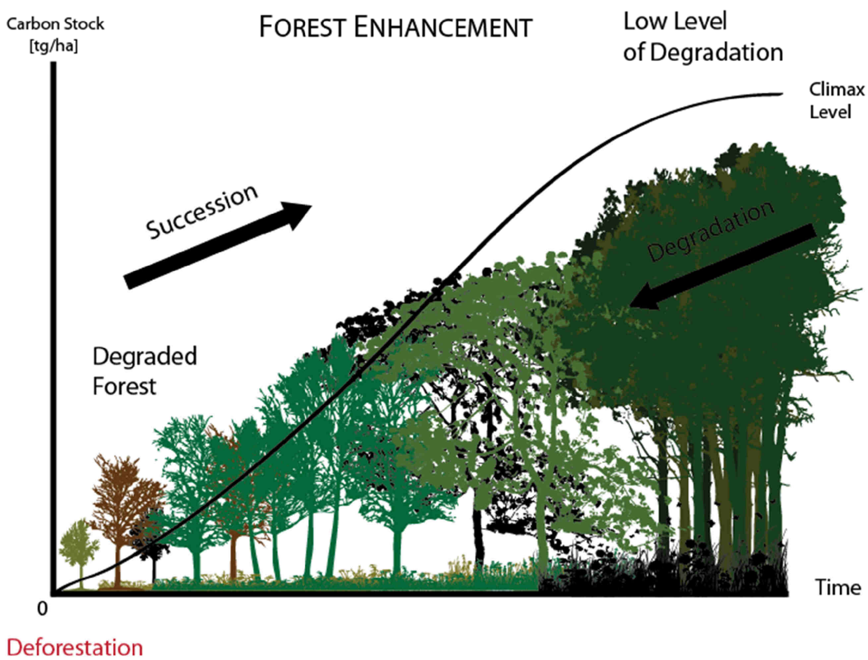


Fig.15 Forest succession curve (From Morales-Barquero, L.; Skutsch, M.; Jardel-Peláez, E.J.; Ghilardi, A.; Kleinn, C.; Healey, J.R. Operationalizing the Definition of Forest Degradation for REDD+, with Application to Mexico. Forests 2014, 5, 1653-1681. https://doi.org/10.3390/f5071653)

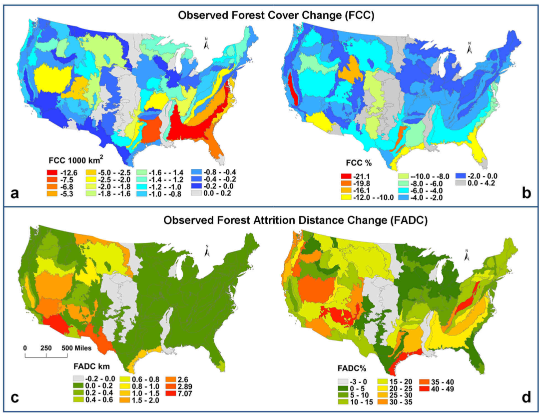


Fig.16 Forest cover change (FCC) and forest attrition distance change (FADC) by area (in km) and by percentage. Forest cover change (FCC) is calculated by subtracting the amount of forest in 1992 from the amount of forest in 2001 (from Yang S, Mountrakis G (2017) Forest dynamics in the U.S. indicate disproportionate attrition in western forests, rural areas and public lands. PLoS ONE 12(2): e0171383. https://doi.org/10.1371/journal.pone.0171383 ,Figure 2)

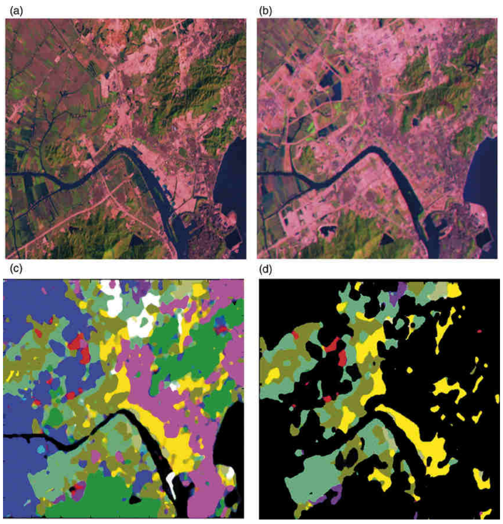


Fig.17 Change detection result and changed area: (a) Imagery taken in 1992, (b) imagery taken in 1996, (c) change detection results and (d) changed area masking (in black) areas they can't be changed for sure (like the river)
(From Deren Li (2010) Remotely sensed images and GIS data fusion for automatic change detection, International Journal of Image and Data Fusion, 1:1, 99-108, https://doi: 10.1080/19479830903562074 , Figure 3)

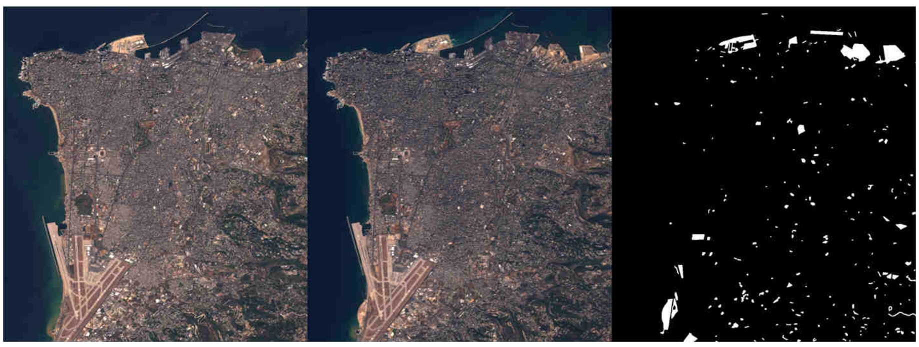


Fig.18 Two pair of multispectral images taken from Sentinel-2 included in the The Onera Satellite Change Detection dataset (https://rcdaudt.github.io/oscd/), Images refers to Beirut area, and are used to detect urban changes, such as new buildings or new roads.

Identify changes

Despite the method adopted at the and we have in our hands imagines captured in different spectral channel. In order to identify changes of the features we are interested (for example burned areas) we need to decide if to map them DIRECTLY, comparing surface reflectance values observed in different portion of the electromagnetic spectrum, or INDIRECTLY through indices.
Use of the indices can have the great advantage to emphasize changes combining and integrating what occurring in different spectral bands. In general changes in surface characteristics affect spectral reflectance curve differently along the spectrum.
What presented for different snow types in the observe from space card is an example of that.
Meanwhile modification of reflectance values is very high in some channels, this can be very low or almost zero in other channels.

A fantastic and very successful example of the powerfulness to use indices based on channel combination as indicator of changes is the Normalized Difference Vegetation Index (NDVI), an index widely-used for quantifying the health and density of vegetation using satellite sensor data. It is calculated from spectrometric data at two specific bands: red and near-infrared.
In general, if there is much more reflected radiation in near-infrared wavelengths than in visible wavelengths, then the vegetation in that pixel is likely to be dense and may contain some type of forest. Subsequent work has shown that the NDVI is directly related to the photosynthetic capacity and hence energy absorption of plant canopies.
In addition to the simplicity of the algorithm and its capacity to broadly distinguish vegetated areas from other surface types, the NDVI also has the advantage of using only two broad spectral channels, and compressing the size of the data to be manipulated by a factor 2 (or more), since it replaces the two spectral bands by a single new field. Also thanks to these features, NDVI have been developed and used since 70s for a huge amount of different scopes.

Focusing on detecting changes and degradation on vegetation and forest, other commonly used indices are normalized burnt ratio (NBR), enhanced vegetation index (EVI), and the soil-adjusted vegetation index (SAVI).
Way to identify the change is in general strictly related to the feature to which we are interested. For different features there are different optimal indicator that is better to use (cfr. the challenge of attribution card).

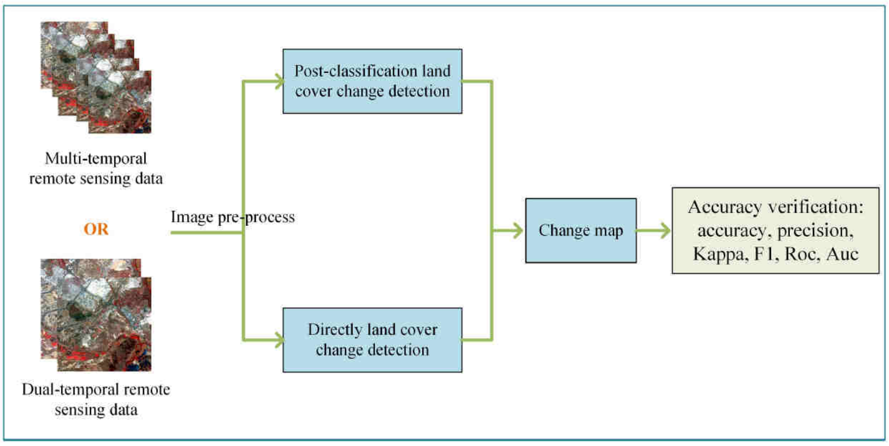


Fig.19 The process of change detection using satellite remote sensing data.
(From Gu, Z.; Zeng, M. The Use of Artificial Intelligence and Satellite Remote Sensing in Land Cover Change Detection: Review and Perspectives. Sustainability 2024, 16, 274. https://doi.org/10.3390/su16010274)

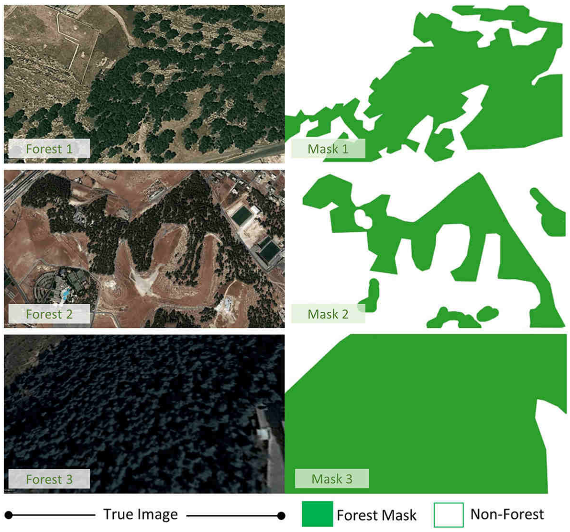


Fig.20 The original true images (left) and the corresponding ground-truth masks (right)

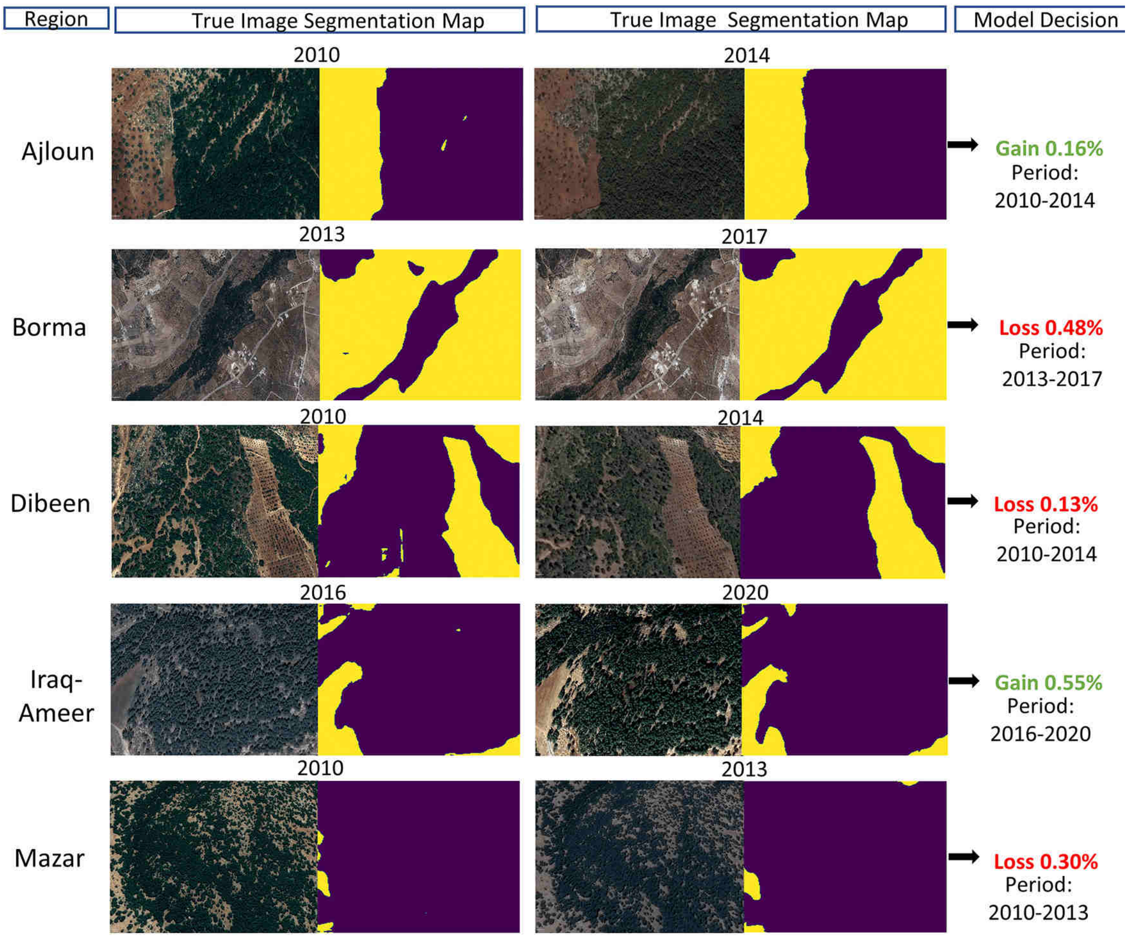


Fig.21 Sample results of deforestation monitoring in five forest regions

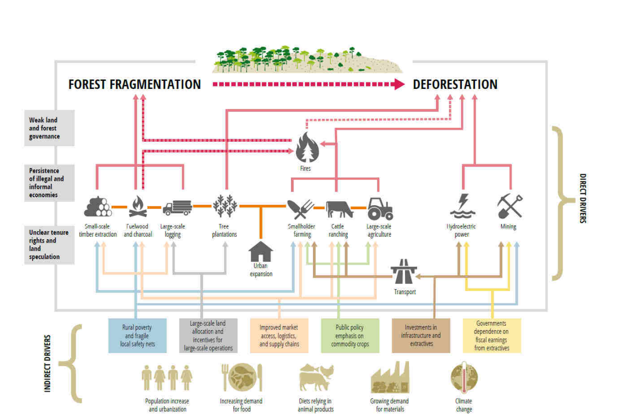
(Ahmad Alzu'bi, Lujain Alsmadi, Monitoring deforestation in Jordan using deep semantic segmentation with satellite imagery, Ecological Informatics 70 (2022) 101745 Ecological Informatics 70 (2022) 101745 https://doi.org/10.1016/j.ecoinf.2022.101745)

A big challenge: attribute an origin/cause to changes

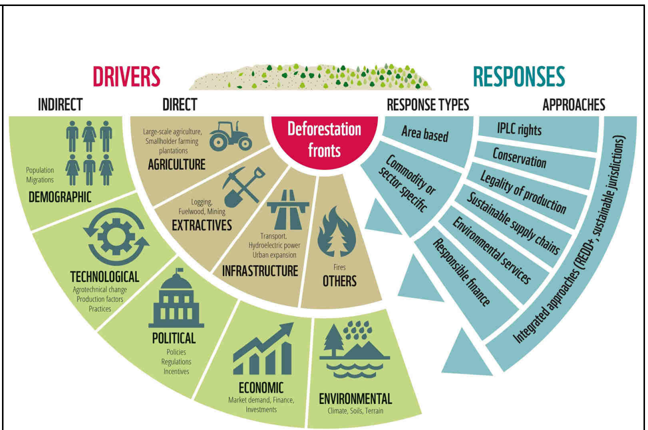
Our eyes from the satellite can only tell us that something has changed, but this change in the reflectance of the surface does not automatically bring with it the reason for what happened.
Attributing the right cause to the change implies knowing quite well how this cause can modify the spectral reflectance curve of the surface

Changes are classified based on the change of indicators between the two dates, using indicators such as the NDVI or the NBR. Numerous approaches to identify an optimal indicator for the detection both on the basis of our knowledge of the process as well as results of testing.
These indicators can be used in detection algorithms in two modality
(i) as a threshold. In this case results of detection algorithms when displayed as a composite image, show changes in unique colours
(ii) to define a more standard classification procedure.

The type of method implemented can profoundly affect the qualitative and quantitative estimates of the disturbance. Even in the same environment, different approaches may yield different change maps. The selection of the appropriate method therefore takes on considerable significance.
A wide assortment of alternatives exist and that all have varying degrees of flexibility and availability. To give an idea, for the image-to-image change detection method, several review identify up to 10 different categories for detection algorithms developed in the last 50 years.



Main interactions among drivers of deforestation and forest fragmentation



Analytical framework linking drivers of and responses to deforestation

Fig.22

Toward a Near-time monitoring of degradation/disturbances

An alternative to *image-to-image change detection* method is represented by *Time series analysis-based change detection,* requiring a series of images taken continuously over a period of time. Thus for this method there is a need for substantially more and regular image acquisitions over the area of interest.

With respect to the first method category, in this case we need to pay a lot of attention to the time evolution of the images.

A typical remote sensing time series consists of three components: (A) a long-term directional trend component, (B) a seasonal component, and (C) a residual component.

Depending on the research focus, either one or all of these components, are of special interest.

With respect the first category of methods preprocessing steps need to include mathematical tools for separating components and smoothing the time series.

With regard to forest degradation monitoring, the residual component is of high interest and has to be differentiated from residual noise. Depending on the forest ecosystem region, also the seasonal component plays an important role in the characterization of the forest disturbances.

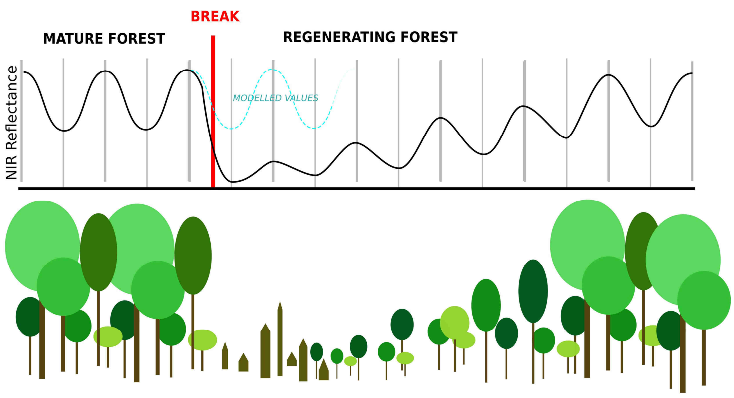


Fig.23 Near-real time disturbance detection using time series looks for breaks from modelled seasons patterns in forest reflectance
(source: https://forest.jrc.ec.europa.eu/en/activities/forest-disturbances/ © European Union, 2022; Jonas Viehweger).

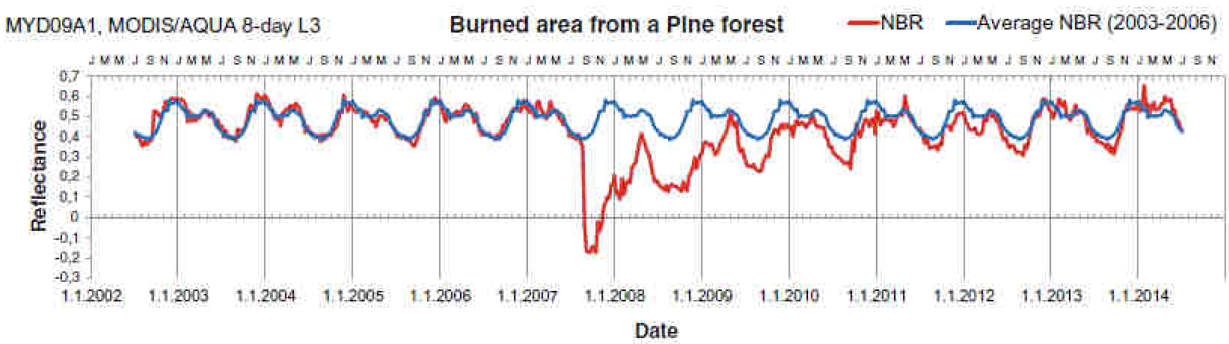


Fig.24 Time series from MODIS data showing a forest fire and the vegetation recovery (Greece) (from Hirschmugl et al., 2017, Methods for Mapping Forest Disturbance and Degradation from Optical Earth Observation Data: a Review, Current Forestry Report, 3, pp. 32–45, DOI 10.1007/s40725-017-0047-2)

Identify Burned Areas

Let's now try to apply the things we have learned to the concrete case of areas burned by fires.
As mentioned, everything starts from understanding what happens to surface reflectance when a healthy and thriving vegetation/forest is crossed by fire.
Lush vegetation has a strong reflectance in the visible wavelengths, and this is reflected in a color that favors shades of green. What remains after a fire is strongly characterized by a brown/black color, indicating that the reflectance is greatly diminished and almost close to zero. In any case, the greatest variation occurs in areas of the spectrum that our eye cannot see. The important thing is that this variation is very large and that it depends on how strong/intense the fire was (severity)
If we consider these characteristics, it seems obvious to think that we can obtain a good indicator to identify whether an area has been crossed by a fire or not, by comparing the reflectance measured in the visible region (the one that our eyes can appreciate - 400 - 700 nm) with that measured in the immediately following region, that of the near infrared (700-2500 nm) which our eye does not see but satellites do.
The two indices NDVI and NBR that are usually used to identify areas burned by fires are obtained in this way (see figure). An obvious way to increase the precision of these indices is to then introduce a comparison with detected fires into the analysis algorithm. Because it is clear that if in an area that I say has burned before I have not always detected a fire from satellite, I have to ask myself some questions. And vice versa obviously. A fire is normally detected because it emits upward radiation which the satellite interprets as a ground temperature that is very/too high to be normal.
Disturbance maps you are using are produces mostly by procedures (algorithms) base on above considerations and approaches.

Fig.25 Photo of a burned area

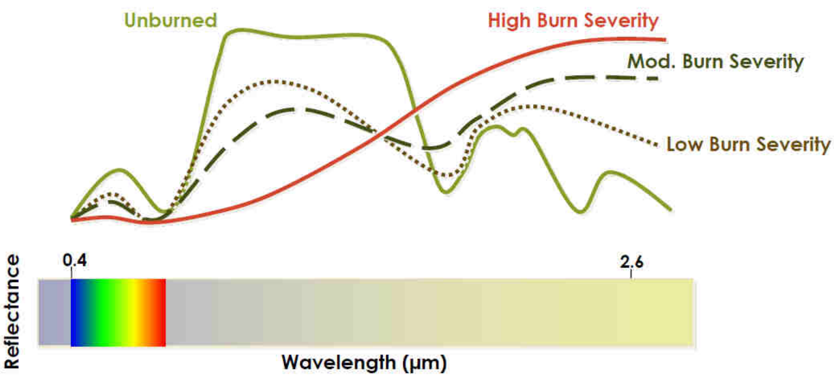


Fig.26 Healthy Vegetation vs. Burned Areas
(https://appliedsciences.nasa.gov/get-involved/training/english/arset-techniques-wildfire-detection-and-monitoring)

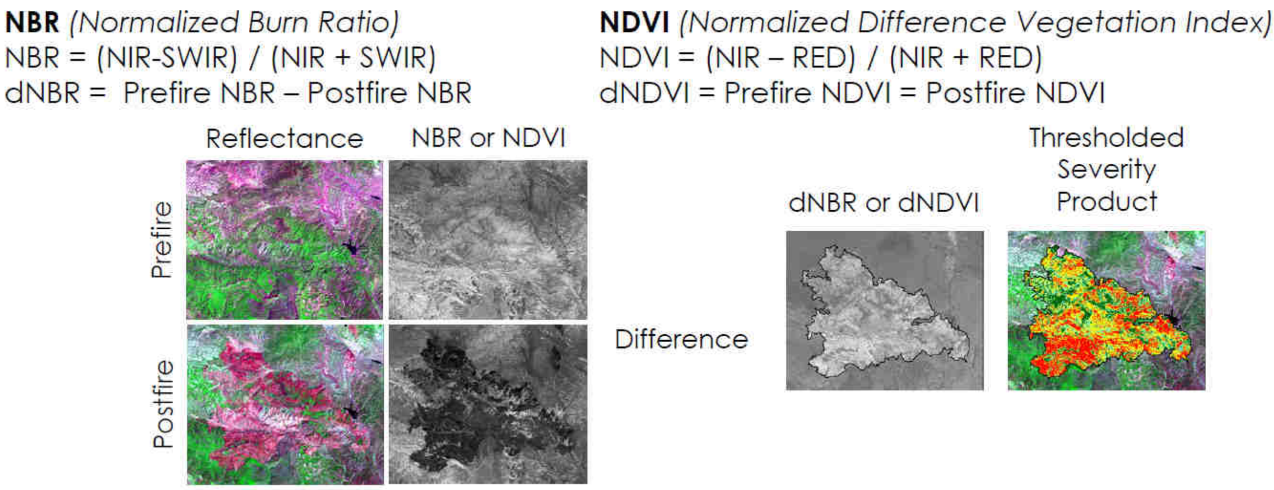


Fig.27 NBR and NDVI
(https://appliedsciences.nasa.gov/get-involved/training/english/arset-techniques-wildfire-detection-and-monitoring)

CREDITS

in preparing these information sheets we have made extensive use of the material and ideas presented in the work of Hirschmugl et al., 2017, *Methods for Mapping Forest Disturbance and Degradation from Optical Earth Observation Data: a Review, Current Forestry Report, 3, pp. 32–45, DOI 10.1007/s40725-017-0047-2*

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