Remote sensing for agricultural statistics: perspectives with new sensors

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Introduction

Applications of satellite images to agricultural statistics are almost as 'old' as remote sensing (USDA-NASS, 1972…)

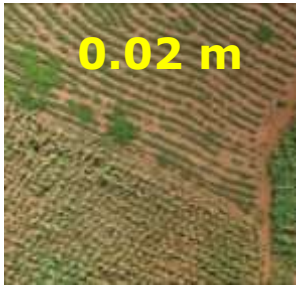
Some image types and their use for agricultural statistics

Rapid Eye

Seldom used

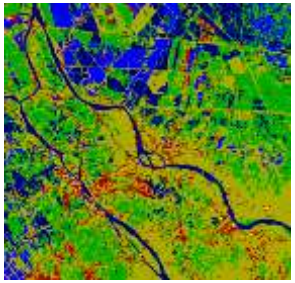
Very high resolution (Google Earth)

Sometimes as ground documents or stratification (points)



Drone

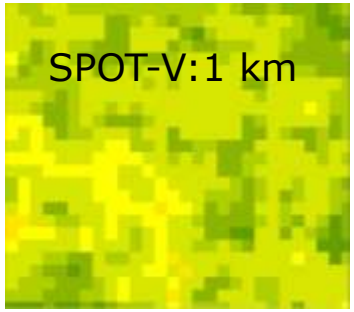
Might substitute field visits in some cases

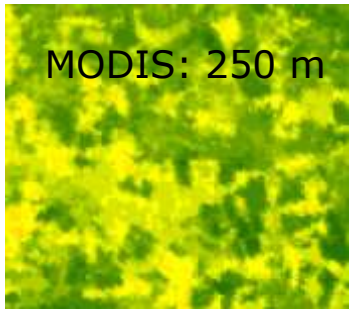


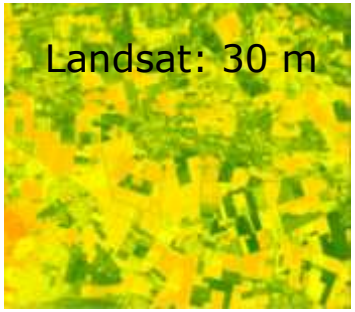
Sentinel 1 (Radar)

Often used for rice monitoring

The most frequently used images







Very often used for yield forecasting, vegetation monitoring and early warning
Sometimes for stratification

Used in different ways for crop area estimation

- **Stratification**
- **As covariates with area frame surveys**

The Past

An old love story
(1972- ?????)

Or better several possible love stories

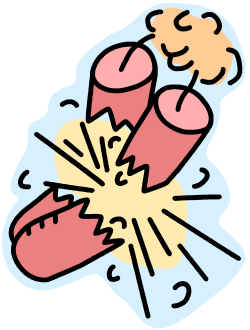
Sometimes a love-hate story

One possible story

I will stand at your side every day of my life and will provide everything you need. Do not worry. I am here.

= I will provide accurate estimates of crop area and yield and you will not need to go to the field to collect data (or very little).

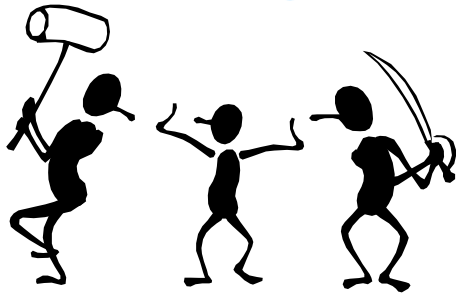
But such intense love often finishes in a violent divorce.



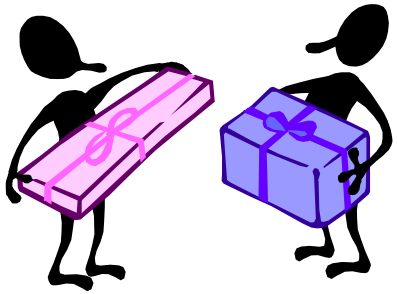
Example in the European Commission (MARS ActivityB: rapid crop area change estimations):

- Good estimates in 1990-1997

➢ Later analysis reveals that there as a ± 20% margin of subjectivity for major crops

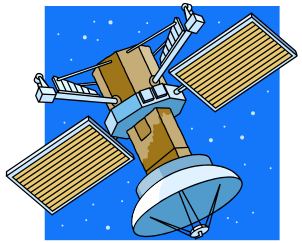


Another story



Let us be friends. You bring your know-how,
I bring my know-how.

= *Ground observations contribute with more reliable data on a sample; remote sensing gives a general view on a larger area*.



Less romantic, but more balanced

- Example: USDA-NASS
- Long-lasting, happy relationship

Current situation

Some available and forthcoming platforms

A lot of existing platforms (available?)

	Nb of satellites in orbit	How many still "alive"
All kinds	3921	1167
Earth Observation	700	192

Source: UNOOSA report 2014

Low resolution platforms, high revisit frequency, available at no cost

Medium-high resolution sensors. Task-programming in some cases to increase revisit frequency. Moderate or no cost

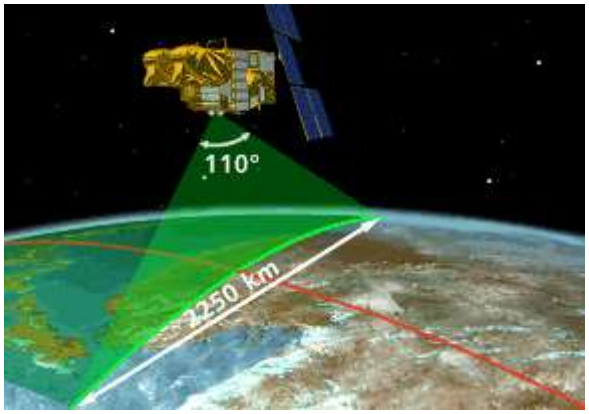
Very high resolution sensors, usually with high costs.

PLATFORM-SENSOR	nr. of satellites	Spatial resolution (m)	Footprint width (km)	Nominal swath (km)	Revisit period (days)	Spectral bands	Price (€/km2)
PROBA-V HTTP://PROBA-V.VGT.VITO.BE/	1	300 (VNIR) 1,000 (SWIR)	2,285	2285	1	3 VNIR+ 1 SWIR	0
SENTINEL 3-OLCI* https://earth.esa.int/web/guest/missions/esa-future-missions/sentinel-3	2	300	1,270	1270	1	21 VNIR	0
TERRA/ACQUA-MODIS HTTP://MODIS.GSFC.NASA.GOV/	2	250, 500, 1,000	2,330	2330	1	36 (VNIR, SWIR,TIR)	0
METOP-AVHRR HTTP://WWW.EUMETSAT.INT/WEBSITE/HOME/SATELLITES/CURRENTSATELLITES/METOP/INDEX.HTML	2	1,000	2,900	2900	1	6 (VNIR, SWIR, TIR)	0
LANDSAT 8-OLI http://landsat.usgs.gov/landsat8.php	1	30	185	185	16	11 (VNIR, SWIR, TIR)	0
SENTINEL 2-MSI* https://earth.esa.int/web/guest/missions/esa-future-missions/sentinel-2	2	10 (VNIR) 20 (NIR-SWIR) 60 (Atm. corr)	290	290	5	13 (VNIR, SWIR)	0
DEIMOS/UK –DMC HTTP://WWW.DEIMOS-IMAGING.COM/	2	22	620	620	1-2	3-VNIR	0.13
SPOT 6/7-NAOMI HTTP://WWW.GEO-AIRBUSDS.COM/EN/147-SPOT-6-7-SATELLITE-IMAGERY	2	6	800	60	1-2	4VNIR	5.7
PLEIADES HTTP://WWW.GEO-AIRBUSDS.COM/EN/52-PLEIADES-VERY-HIGH-RESOLUTION-SATELLITE-IMAGERY	2	2	800	20	1-2	4VNIR	11.5
GEO-EYE HTTP://WWW.SATIMAGINGCORP.COM/SATELLITE-SENSORS/GEOEYE-1/	2	2	780	15	1-2	4VNIR	15.5
WORLDVIEW HTTP://WWW.SATIMAGINGCORP.COM/SATELLITE-SENSORS/WORLDVIEW-1/	3	2	780	16	1	8VNIR	15.5
RAPIDEYE HTTP://BLACKBRIDGE.COM/RAPIDEYE/	5	5	77	77	1	5 VNIR	1.13
UAVs	-	<1	3	0.2	-	Config.	-

Technical requirements for remote sensing platforms

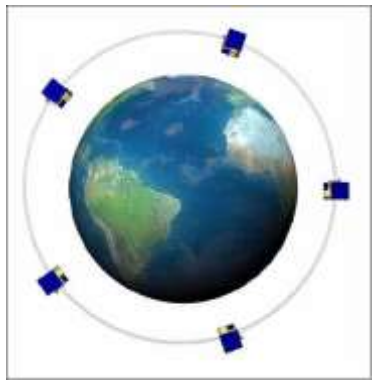
1) Revisiting period and swath (image width)

- Full coverage needed for most agricultural statistics applications
  - Sampling images is generally very cost-inefficient
  - Mosaicking small images is long and expensive
- Strictly linked to the instrument field of view that determines swath



SPOT-VEGETATION (CNES)

- Critical for yield and vegetation monitoring
- Less critical, but important, for area estimation
- Can be improved by constellations of similar satellites



Technical requirements for remote sensing platforms

2) Spatial resolution

- Essential for area estimation
  - Pixel size should be well below the typical size of agricultural plots
  - In the US, Russia, Australia, 30-60 m is ok
  - In western Europe, 10-30 m is a good compromise
  - In (semi-)survival agriculture, 5 m might be suitable
- Important for crop-specific yield monitoring

Technical requirements for remote sensing platforms

3) Spectral resolution Number of bands and spectral width of them

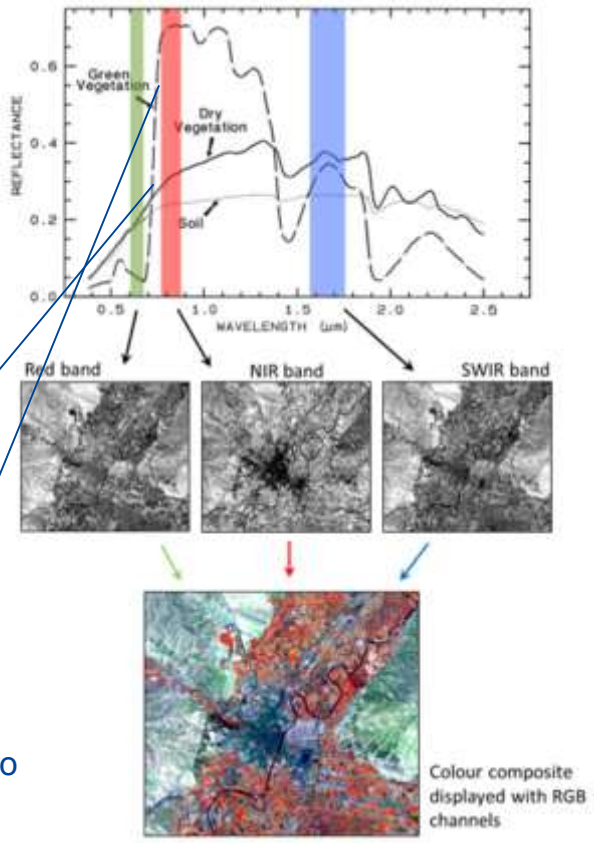
Most of the applications are based on on visible (0.4-0.7 µm) and near-infrared (NIR) channels (0.75-0.9 µm)

Different spectral response of leaf tissues: absorption in VIS and scattering in NIR, permitting to monitor crop photosynthetic activity

Recently there are new applications based on high spectral reoslution, targeting specific narrow bands related to:

- Chlorophyll content (red edge)
- Canopy fluorescence (absorption O_2 lines)

Succesful at field scale, but still not mature enough to monitor large areas with low resolution sensors



Technical requirements for remote sensing platforms

4) Consistent time series

- Essential for yield forecasting
- A typical situation
  - Until 2000, NOAA 6 – NOAA 15 AVHRR images
    - Heterogeneous characteristics
  - 2000-2014 SPOT-Vegetation
  - 2014-2016 Proba-V
  - 2016-…. Sentinel 3
- Intercalibration is a nightmare and even with the best efforts, the impact of heterogeneous sensors remains unknown.

Policy requirements for satellite images

5) Price

- In many cases RS is in competition with traditional approaches
  - It becomes operational only if the cost/efficiency is better
    - Very few operational applications for area estimation in developing countries
    - Only for building area frames or for support to field surveys
- Very high resolution images are unlikely to be useful for agricultural statistics.

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GEO-EYE HTTP://WWW.SATIMAGINGCORP.COM/SATELLITE-SENSORS/GEOEYE-1/	2	2	780	15	1-2	4VNIR	15.5
WORLDVIEW HTTP://WWW.SATIMAGINGCORP.COM/SATELLITE-SENSORS/WORLDVIEW-1/	3	2	780	16	1	8VNIR	15.5
RAPIDEYE HTTP://BLACKBRIDGE.COM/RAPIDEYE/	5	5	77	77	1	5 VNIR	1.13

Because of spatial auto-correlation, and assuming that the accuracy of crop identification is similar to field survey (unlikely), the value of a VHR image is equivalent to 5-20 unclustered points

- **The cost per image, including processing, should be < 500 €**

Can drones substitute field surveys in frame area surveys?

Peas under Maize (Malawi 2015)

Some major crops, such as maize, can be easily identified on drone-acquired images (2-3 cm resolution), but

- **In mixed crops, the second crop cannot be identified**
- **Crops with similar leaves and phenological cycle (ground nuts, soya, potatoes) are difficult to discriminate**

Feasible for surveys with a limited target (staple food)

Sampling transects of 20 km x 100 m may be efficient if regulations allow such flights

Small traditional aircrafts might be a better alternative, even if less trendy.

Area estimation and yield forecasting

On **area estimation**, only images of the current year are used (inmost cases)

Images used to assess spatial variability between sampling units

On **crop yield forecasting**, models look mainly at inter-annual varibility

if statistics are biased, so will be the forecasts

time series are averaged per region, fine spatial distribution is seldom considered

OR

Area forecasting and yield estimation ?

For **area forecasting**, the limiting factor is the need of very quick collection and processing of field data **AND** images

Easier with farm survey

A possible application of **crop yield estimation** would use crop cutting surveys

A empirical model would be established relating seasonal remote sensing indicators with observed yield in sampling points

That requires high frequency images in which fields can be identified.

It may become feasible combining Landsat TM with Sentinel 2.

Not sufficiently explored in scientific litterature, sometimes confounded with forecasting applications

Main factors for the near future

Coarse spatial resolution:

- Continuity of long-term archives
- Accuracy improvement at long term

Medium/high resolution (10-30 m)

- Free access policy
- Wider swath and better resolution of Sentinel 2 compared to previous sensors
- To be assessed: yield estimation combining Sentinel 2 and Landsat 8

Very high resolution: the segment that concentrates most investments.

- Not much to be expected at short term for agricultural statistics

SAR (Synthetic Aperture Radar)

- Sentinel 1 seems to have a better signal/noise ratio compared to previous instruments, but the practical impact still needs to be assessed
- More difficult to analyze than optical images

Drones

- Promising for specific applications, but limitations due to flight regulations
- Small aircrafts (with pilot) might be more useful