A review of agriculture applications of earth observation satellites.

1959-2018
Agriculture forecast and nowcasting

• A story beginning before the space age: Pharaoh (Sesostris?) and his intelligent minister Joseph stored $\frac{1}{5}$ of the wheat harvest during 7 abundant years and used their stock to centralize power in Egypt during 7 following lean years.

Map originating most probably from Google maps (Landsat 8?)
1959-1962: discovery of the earth from space.

Explorer 4: 1959

TIROS: 1960

Florida image by John Glenn, 1962, manned space demonstrated the capabilities of resolving details from space.

Civilian use is only possible now because of progressive declassification.
Progress between 1962 and 1970

Essentially a development of meteorological imagery in the TIROS programme and ESSA operational satellites.

Military reconnaissance satellites both in the United States and Soviet Union.

Probably an advance in digital imaging on the Soviet side but no intent of civilian use, most of the data acquired is probably lost.

1964: start of the NIMBUS series

Advanced Very High Resolution Radiometer (AVHRR): an instrument which beside meteorology found rapidly land and sea applications. AVHRR flew and flies on various NASA, NOAA, ESA and EUMETSAT METOP satellites. The SEVIRI instrument on METEOSAT has commonalities in objectives with AVHRR.
The first success case: LANDSAT: thematic mappers.

- Began as an experimental technology earth digital observation programme in 1972
- Now, LANDSAT is a prime source for the study of global change on the earth and since 2013 operates its eighth version: the LANDSAT continuity mission with joint data management by NASA and the USGS (US Geological Service). One of its satellite (LANDSAT 5) holds the record of the longest operating earth observation satellite, launched in 1984 and decommissioned in 2013.

LANDSAT image of the Etna 2001 eruption,
The wavelength ranges used by Landsat are these: deep blue, blue, green, red, four near and shortwave infrared bands, a panchromatic (grayscale) band, and two thermal Infrared bands.
Landsat became fundamental for agriculture applications.

- Monitoring agriculture from space.
- Estimating crop production
- Monitoring consumptive water use.

- Field level management tools leading to increase yields.
A British Landsat companion: DMC

- DMC (Disaster Monitoring Constellation) has been deliberately designed to be compatible with LANDSAT
- DMC is coordinated by Surrey Satellite Technology

Volcanoes of central Java, high repeat rate is important for agriculture and thus DMC is used by USDA as a complement to LANDSAT.
DMC-2 imaging, deforestation of Amazonia

Biomass burning in Namibia
LANDSAT operates in conjunction with other present satellite data systems.

**NASA**
- MERIS
- Several NASA or commercial imaging satellites.

**ESA and other European ventures**
- MODIS
- DMC
- SPOT 4- SPOT 5
- **Off course: COPERNICUS and the SENTINEL satellites.**
- New addition: SMOS

Data exploitation requires the definition of indexes common to all platforms: NDVI.
NDVI = \( \frac{(\text{NIR} - \text{red})}{(\text{NIR} + \text{red})} \)

**Seasonal variations: June and October**

**Danger of reducing to a single index**
- NDVI means Normalized difference vegetation index.
- It is not crop specific, each crop has a specific index varying with the plant cycle.
- Big Data means that the entire spectral and spatial data are used.
An example from DronesImaging company

The 5 cm resolution of the image corresponds to an imaging by drones.

NDVI from MODIS (NASA)
June 2017, soil moisture in the Netherlands: SMOS
Models deduce locusts from SMOS and MODIS
French FARMSTAR agriculture assistance company: based on ASTRIUM images: SPOT, PLEIADES and DMC.
2017: FARMSTAR uses the new VENUS satellite

VENUS is a Franco-Israeli satellite launched in 2017 and allows a good monitoring of irrigated agriculture. As LANDSAT and SENTINEL 2, it uses validation sites.
GREEN SPIN: a service for forecasting crops, based on SENTINEL and LANDSAT 8: support of DLR, ESA, COPERNICUS and Spin-Off of Würzburg University.

Cotton yields in Khorezm, a central Asian oasis region.
**Düngesplanungen**

<table>
<thead>
<tr>
<th>Name</th>
<th>Nummer</th>
<th>Strategie</th>
<th>Planungsgrundlage</th>
<th>Düngermenge</th>
<th>Stickstoffmenge</th>
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</thead>
<tbody>
<tr>
<td>Edererhof</td>
<td>04-3</td>
<td>homogenisieren</td>
<td>60 kg/ha</td>
<td>90 kg</td>
<td>60 kg</td>
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<tr>
<td>Fuchsthal</td>
<td>04-4</td>
<td>homogenisieren</td>
<td>50 kg/ha</td>
<td>80 kg</td>
<td>50 kg</td>
</tr>
<tr>
<td>Heidenplatz</td>
<td>04-8</td>
<td>homogenisieren</td>
<td>50 kg/ha</td>
<td>80 kg</td>
<td>50 kg</td>
</tr>
</tbody>
</table>

**Koppeleide**

<table>
<thead>
<tr>
<th>Planungsdetails</th>
<th>Zonen</th>
<th>Ihre Angaben</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schlag: Koppeleide (66-8)</td>
<td>Düngermenge in kg/ha</td>
<td>Strategie: diversifizieren</td>
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<tr>
<td>Jahr: 2016</td>
<td></td>
<td>Mittlerer Ertrag: 80 dt/ha</td>
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<tr>
<td>Gabe: 1</td>
<td></td>
<td>Planungsgrundlage N/ha: 50 kg/ha</td>
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<tr>
<td>Gesamtfläche: 9,1 ha</td>
<td></td>
<td>Intensität: stark</td>
</tr>
<tr>
<td>Gesamt-Düngemenge: 1,085 kg</td>
<td></td>
<td>Stickstoffgehalt: 23 %</td>
</tr>
<tr>
<td>Gesamstickstoff: 307 kg</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some reflexions on this short survey.

- The described satellites and the few presented applications cover essentially the 30 m. scale.
- Real high spatial resolution as used now in military reconnaissance is rare in current applications.
- Repeat rate has become so important that the large satellites are seconded by a zoo of intelligent mini-satellites, sometime managed by private companies or small countries.
- Clouds will always be present and thus will limit the capability of satellite measurements.
- **Full use of the data is still to come**
The future: precision agriculture

• Only real time present action: **irrigation management**.
• Generalisation: go to high spatial resolution and the individual plant.
• **High resolution hyperspectral: really big data.**
• Real time operation of farm machines.
• Maybe, the age of local drones coordinating GPS driven machines and modulating harvest and phytopharmacy.