Overview of the role of remote sensing in crop monitoring and yield forecasting

Allard de Wit
How do we forecast crop yield

Winter-wheat - Spain

Sugar beet - Germany
Forecast example: Winter-wheat (Spain)
<table>
<thead>
<tr>
<th>Fundamental observations and requirements</th>
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<tbody>
<tr>
<td>■ Our systems generally do not predict yield</td>
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<td>■ Historic archive is crucial:</td>
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<td>● Regression or scenario analysis between system output and regional statistics</td>
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<td>● Needed to cover the range of climatic conditions</td>
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<td>● Continuity and consistency of system output over time</td>
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<td>■ Large area coverage (continental/global scale)</td>
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<td>■ High temporal coverage</td>
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<td>■ Operational, economical and high degree of availability</td>
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Which sensors can meet these requirements

- Operational meteorological sensors (AVHRR, MSG, METOP) and operational land sensors (MODIS, VGT):
  - Low spatial resolution (\( \geq 1\text{km} \))
  - high temporal resolution (\( \leq 1\text{day} \))

- Land satellites/sensors to be continued in the near future by PROBA-V, Sentinel-3 and VIIRS
How are satellite data used in practice

- Mainly by characterizing the current growing season through time-series analysis on vegetation indices
- Usually on the level of ‘cropland’
- Qualitative indicators of current season vs. the previous year or long term average
- Quantitative input in regression models or scenario analysis (accumulated NDVI, maximum NDVI)
MODIS-based crop monitoring in China (2)

Growth Monitoring for Winter Wheat

Time Span: Nov 24, 09 – Dec 7, 09
Data Source: EOS/MODIS

Legend
- **Better**
- **Normal**
- **Worse**
- **Could/ND**

Courtesy: Chinese Academy of Agricultural Sciences
Use of SPOT-VGT within FAO-GIEWS

Normalized Difference Vegetation Index (SPOT-4)
Difference between Current Dekad and Average (1996-2004)

FAO - ARTEMIS
© SPOT Image SA
Satellite image generated by WinDisp

Dekad: 3 / Month: 09

Legend:
- Large Decrease
- Small Decrease
- No Change
- Small Increase
- Large Increase
Use of SPOT-VGT within the MARS system (1)

Courtesy: JRC – Agri4Cast
Use of SPOT-VGT within the MARS system (2)

Andalucía (ES)

Crop - SPOT-VGT-P. Normalized Difference Vegetation Index of CLC_GLC: arable land - 2

Source: JRC

Courtesy: JRC – Agri4Cast
Towards a bio-physical interpretation of the satellite sensor signal:
- Improving modelling of crop response to environmental and management conditions
- Improving signal understanding: radiative-transfer modelling of crop canopies
- Inclusion in biophysical crop models through data assimilation techniques

Need to move from ‘cropland’ monitoring to ‘crop-specific’ monitoring
Operational (1km) sensors and landscape scale

- Germany
- Iowa - US
- N-Spain
- Ethiopia
- Bangladesh
- N-China plain

Matogrosso
Crop-specific monitoring is hampered by
- Mismatch between landscape and satellite sensor
- ‘not knowing where the crops are’

Assimilation of satellite data in crop-specific models is a challenge

Need for rapid within-season crop mapping
- Provide exact location of specific crops
- Can be used for estimating crop area (needed for total crop production)
Data assimilation using MODIS-250m

Illinois - US

Assimilating LAI into the EPIC Model (1)

North China Plain

1. LAI estimated from RS
   - RS
     - Multi-temporal TM
     - Geometric correction
     - Radiometric correction
     - Atmospheric correction
   - RS+GIS+EPIC
     - Retrieved LAI
     - Simulated LAI
     - Lookup table method
     - Optimizing Algorithm
     - Recalibrating model Parameters

2. EPIC model calibration
   - EPIC Model
     - Calibration & Validation
     - GIS
     - GIS-based EPIC Model

3. Assimilation RS
   - Field Observation

4. Yield assessment
   - Estimation of regional yield
   - County level census yields
   - YIELD

Courtesy: Chinese Academy of Agricultural Sciences
Assimilating LAI into the EPIC Model (2)

North China Plain

N application (kg/ha)  Density (plants/m²)  Sowing date (DOY)

Courtesy: Chinese Academy of Agricultural Sciences
Assimilating MODIS-250m LAI in WOFOST

Belgium

Purity [%]
- 75 - 79
- 80 - 84
- 85 - 89
- 90 - 94
- 95 - 99

Courtesy: Belgian funded GLOBAM project
Optimizing the WOFOST model for given LAI profile

Courtesy: Belgian funded GLOBAM project
Derived joint distributions of TDWI/SPAN

Walloon area – Belgium

2003

2004

2005

2006

2007

2009

Courtesy: Belgian funded GLOBAM project
Impact on total biomass simulated
Walloon area – Belgium
Local studies show benefit of data assimilation in crop models

However:

- Operational application requires within-season crop maps;
- Application over large areas to be demonstrated;
- Time lag between observation and system output;
- Precocity needs to be demonstrated.
EO requirements – crop yield forecasting

For current applications:
- Continuity and consistency of EO sensors
- Take sensor inter-calibration into design

For future applications:
- Daily revisit capability with global coverage
- Spatial resolution matching landscape scale (50 - 100 meter)
- VSWIR sensor (red-edge) as well as TIR coverage
Thank you for your attention