Developments in remote sensing platforms, data and services

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Outline

Trends

Data, services and platforms

What is needed for sustainable use of RS for plant health applications

Recent trends in remote sensing (RS)

Increase in free and open resources

- Rapid increase in RS data availability and Big Data in general
- Open Source software for data handling, sharing and analysis

All part of a *digital economy* driven by data

Improved technology

- Cloud storage and cloud computing
- AI for analytics
- Sensor networks

Data, services and platforms

Source: ESA

The Copernicus Programme and Sentinel Missions

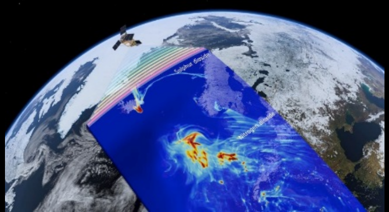
The Copernicus Programme provides satellite imagery with high spatial and temporal resolution for mapping and monitoring natural resources.

The program has long-term financing and planning security for current missions, Expansion missions (through to 2030) and Next Generation (2030 onwards).

Operates an Open Data policy – imagery and software tools available free of charge

Coverage of Europe with Sentinels at high spatial resolution (10-300m) almost daily

Source: ESA



Sentinel Launch Overview

S-1

Radar

- A – 3 Apr. 2014
- B – 25 Apr. 2016

S-2

High Resolution Optical

- A – 23 Jun. 2015
- B – 6 Mar. 2017

S-3

Medium Resolution Optical & Altimetry

- A – 16 Feb. 2016
- B – 2018

S-4

Atmospheric Chemistry (GEO)

- A – 2021
- B – 2027

S-5P

Atmospheric Chemistry (LEO)

- A – 13 Oct. 2017

S-5

Atmospheric Chemistry (LEO)

- A – 2021
- B – 2027

S-6

Altimetry

- A – 2020
- B – 2025

Slide from Status of ESA EO Programmes, presented at 54thESSC Plenary Meeting 24 November 2017, Maurice Borgeaud, ESA

Sentinel 1, SAR data that sees through the clouds

Sentinel 1A and 1B

- Synthetic Aperture Radar (SAR) – all weather, night/day observation potential that "sees through the clouds".
- 20m spatial resolution with coverage of all Europe every few days.
- Designed for regular monitoring of land and sea surfaces.
- Applications for mapping crop type, land management, forests, soil moisture, biomass, canopy structure, surface water, sea ice, oils spills, natural disasters.

Useful information in relation to plant health?

- Regular monitoring capability means that unexpected changes (compared to a "normal season") in canopy structure, biomass and moisture content can be detected. These changes would still require further inspection & diagnosis.
- Can also detect management practices such as tillage, duration of fallow period and agronomic flooding, which help to characterise production situations.

Sentinel 2, multispectral land surface information

Sentinel 2A and 2B

- Optical multispectral imagery that provides continuity for existing SPOT and Landsat missions
- 10-60m spatial resolution with coverage of all Europe every few days
- Designed for regular land observations
- Applications for land use and land cover mapping, coastal zone monitoring, lake and coastal pollution and disaster relief. Cloud cover, even in Europe is an issue.

Useful information in relation to plant health?

- Visible, red-edge and Near Infra Red bands (10-20m) provide information related to agricultural and forestry practices such as leaf area, chlorophyll and water content.
- Time series of red-edge information can be used to detect crop stress and monitor crop health, though diagnostic information is very limited.

Sentinel 3, land and sea monitoring

Sentinel 3A and 3B

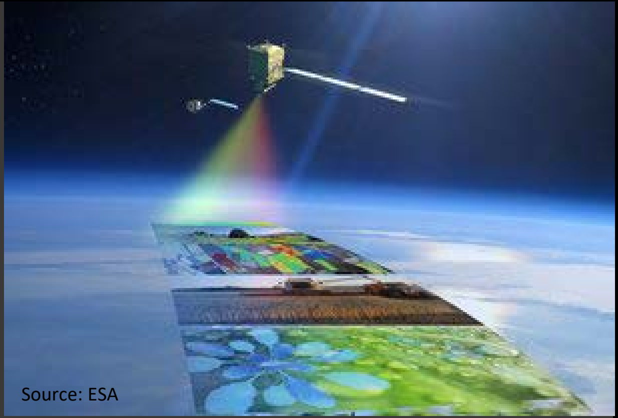
- Multiple sensors on board. The most relevant ones here measure land surface temperature and land “colour”.
- 300m resolution with coverage of all Europe every day
- Designed for regular land and seas observations.
- Applications for land use change, fire and forest cover monitoring. Cloud cover an issue, but 10 day and 30 day composite images are commonly used.

Useful information in relation to plant health?

- 300m resolution means applications are more at a landscape scale for monitoring vegetation condition based on vegetation indices and canopy surface temperature.
- Designed to provide continuity for long term monitoring of vegetation condition from 1998 to present.

Sentinel Expansion and Earth Explorer missions

Copernicus priorities include the enhanced continuity of observation capacity to 2030. Some planned and candidate missions include:



FLEX

- Mapping vegetation flourescence

Thermal Infrared (Sentinel)

- Land surface temperature imagery to support agricultural management and early detection of crop stress.

L band (long wavelength) SAR (Sentinel)

- Land monitoring for soil moisture, crop type mapping and biomass estimation.

Hyper Spectral Imaging Mission (Sentinel)

- Precise spectroscopic measurements with applications in plant health to detect spectral signatures representing the effects of specific pests and diseases.

Combining sources of RS and other data

- No single sensor can provide detailed and frequent observations across the spectrum (visible, near and thermal infrared, microwave).
- A combination of sensors, “cooperative sensing”, can increase the amount of RS-based information about the physical and chemical properties of an object.
- A combination of satellite information from space agencies and commercial sources can provide both very high resolution (sub meter) and very frequent observations.

Combining sources of RS and other data

- One of the biggest recent changes in RS is the miniaturisation of components and use of off-the shelf components.
- This has enabled companies like Planet to launch dozens of "cubesats or nanosats" at a time.

Dove *[Planet Labs]*

- These constellations provide multispectral imagery with high spatial and temporal resolution and even video capability (e.g. Iris from Urthecast), at a cost.
- Planet aims to image the entire Earth every day.

Combining sources of RS and other data

- The second biggest change has been in the development of civilian Unmanned Aerial Vehicles (UAV) platforms or drones. This has been accompanied by new, compact sensors and user friendly software for flight planning and imagery processing.

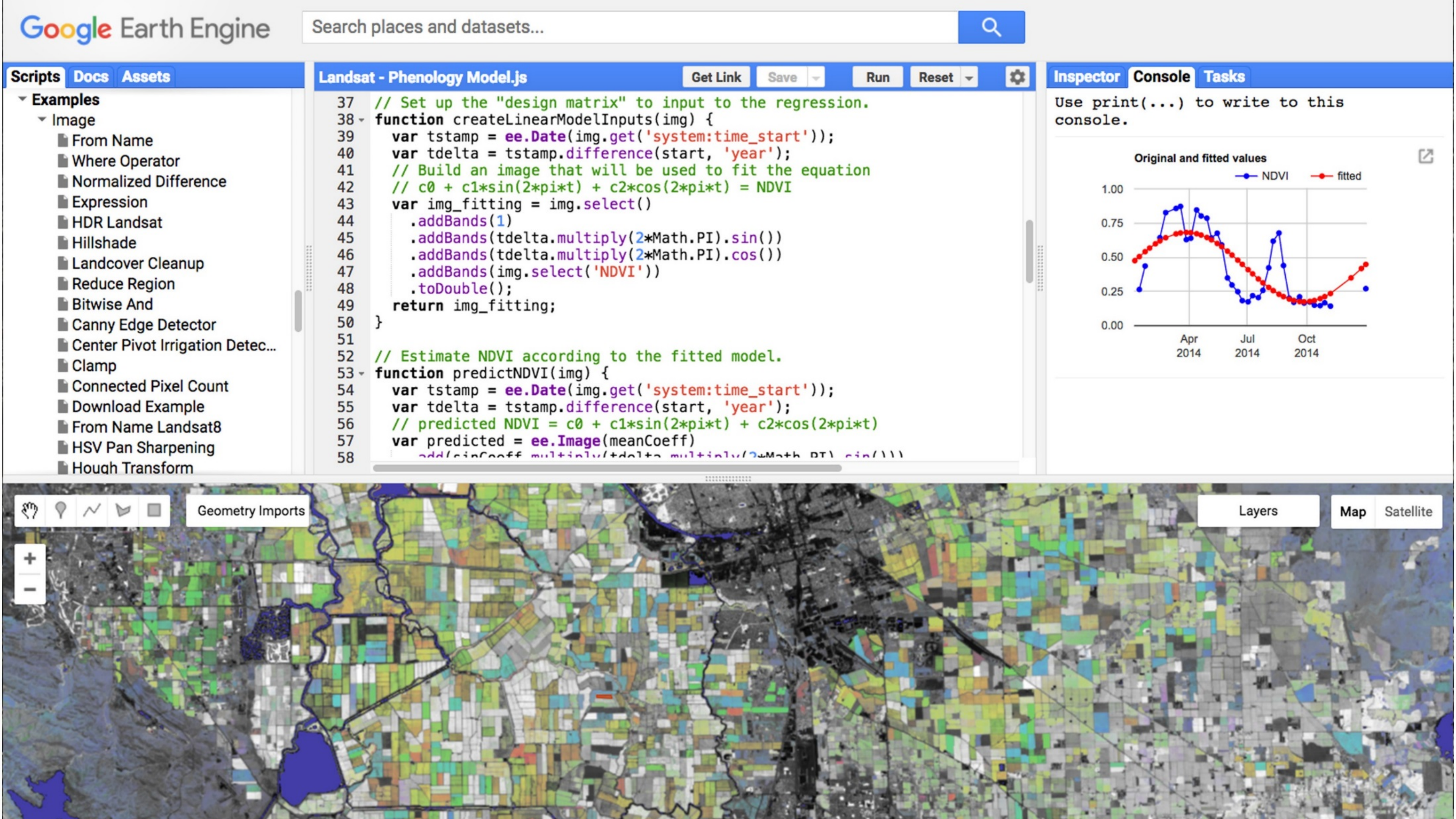
- UAV platforms can carry simple optical cameras, multispectral, hyperspectral and thermal sensors. UAV lidar is an emerging technology and there is progress in the miniaturisation of components for SAR.
- The very high resolution of UAV images, and their fly-on-demand nature, has a wide range of applications for monitoring plant and crop health.

Police trained eagles in the Netherlands to intercept illegal UAVs

Services and platforms to make sense of all this data

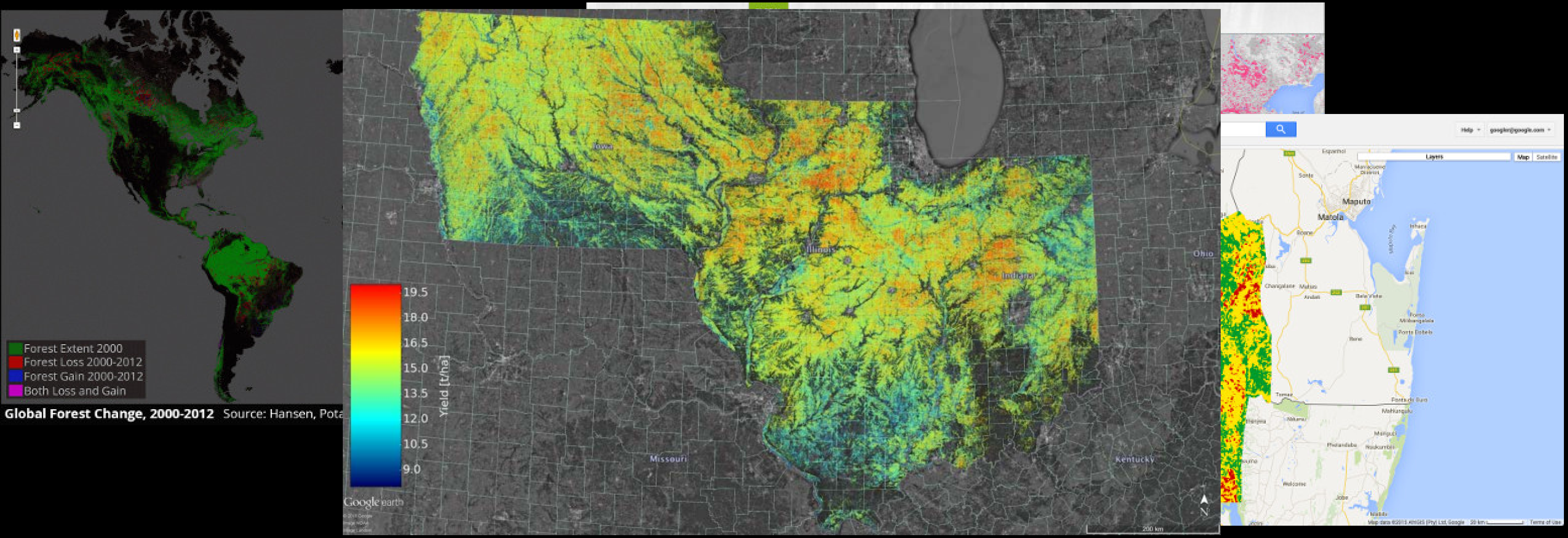
Platforms like Google Earth Engine have shown how massive amounts of storage and processing capability can be used to easily analyse vast quantities of remote sensing data in a "bring your algorithm to the data approach."

The first major application was global forest monitoring.


Google Earth Engine
Search places and datasets...
Scripts
Docs
Assets
Examples
Image
From Name
Where Operator
Normalized Difference
Expression
HDR Landsat
Hillshade
Landcover Cleanup
Reduce Region
Bitwise And
Canny Edge Detector
Center Pivot Irrigation Detec...
Clamp
Connected Pixel Count
Download Example
From Name Landsat8
HSV Pan Sharpening
Hough Transform
Landsat - Phenology Model.js
Get Link
Save
Run
Reset
// Set up the "design matrix" to input to the regression.
function createLinearModelInputs(img) {
var tstamp = ee.Date(img.get('system:time_start'));
var tdelta = tstamp.difference(start, 'year');
// Build an image that will be used to fit the equation
// c0 + c1*sin(2*pi*t) + c2*cos(2*pi*t) = NDVI
var img_fitting = img.select()
.addBands(1)
.addBands(tdelta.multiply(2*Math.PI).sin())
.addBands(tdelta.multiply(2*Math.PI).cos())
.addBands(img.select('NDVI'))
.toDouble();
return img_fitting;
}
// Estimate NDVI according to the fitted model.
function predictNDVI(img) {
var tstamp = ee.Date(img.get('system:time_start'));
var tdelta = tstamp.difference(start, 'year');
// predicted NDVI = c0 + c1*sin(2*pi*t) + c2*cos(2*pi*t)
var predicted = ee.Image(meanCoeff)
Inspector
Console
Tasks
Use print(...) to write to this console.
Original and fitted values
NDVI
fitted
1.00
0.75
0.50
0.25
0.00
Apr 2014
Jul 2014
Oct 2014
Geometry Imports
Layers
Map
Satellite

Services and platforms to make sense of all this data

Google Earth Engine is being used for crop yield estimation, predicting malaria outbreaks, mapping land use change, mapping deforestation, monitoring habitats, mapping access to resources and others.



Services and platforms to make sense of all this data

Amazon has joined the game, DigitalGlobe too, and also Microsoft.

No major European platform?

The Copernicus Data and Information Access Services (DIAS) is a European entry into this arena.

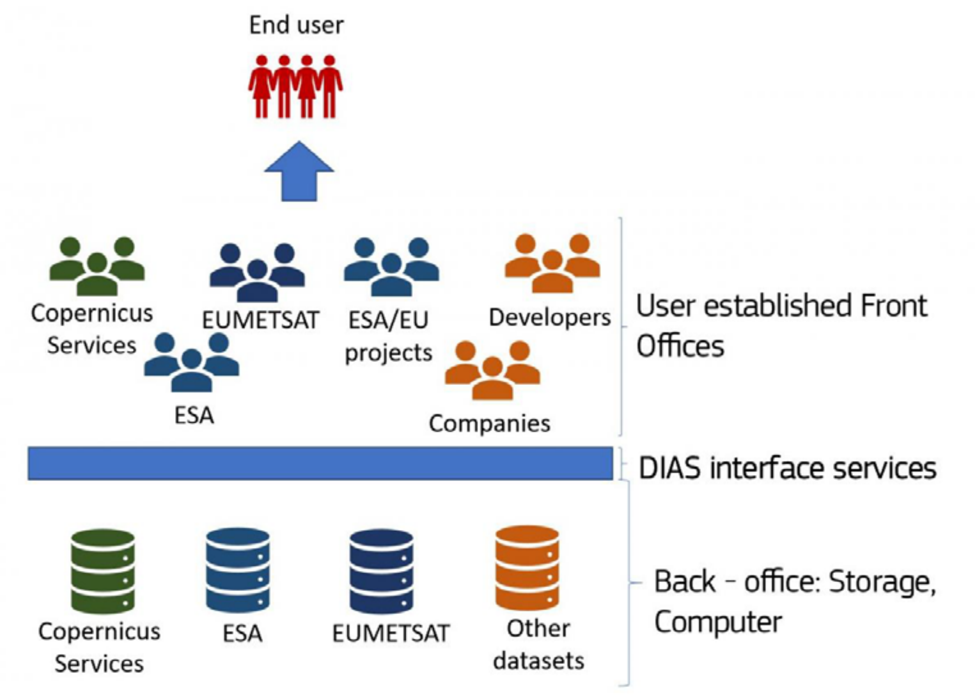
The Sentinel missions are one component of Copernicus. DIAS is another.

Why DIAS?

- The European Commission has identified a widely shared need to access the Copernicus data and information close to processing facilities that allow further value extraction from the data.
- When all Sentinel satellites are operational, they will deliver > 10 petabytes of data each year.
- This makes Copernicus the third largest data provider in the world, creating great opportunities, but also presenting great challenges.
- No cloud processing service is currently offered by Copernicus to its users.
- DIAS will kick start the development of a European data access and cloud processing service, open for entrepreneurs, developers and the general public to build and exploit their Copernicus-based services.
- **The data are free, but value added services come at cost.**

Who will be the users of DIAS?

- Small and large companies, entrepreneurs and developers will then able to create their own front offices to build flexible value chains based on the DIAS computing and storage resources at a competitive cost. They will be able to develop their own applications based on the free Copernicus data, and any other data made available through the system.
- This front office environment will make it easier for all users, including the ones without expertise in Earth Observation or Copernicus services, to fully take advantage of the wealth of information Copernicus makes available.



What is expected of DIAS?

- Operational with guaranteed performance and scalablity
- Collocation of Copernicus data and information with computing resources allowing Big Data analytics and fusion with non-EO data and information
- Bring together different data sources (both EO and non-EO) and know-how (EO, ICT, thematic)
- Attract European EO industry and grow the market
- Provide EU Member States a mutualised offering
- Support and facilitate third-party value-added services (e.g. data/ information/applications)
- DIAS as an enabler: stimulate the emergence of an ecosystem
- Each community can build their own environment on top of DIAS

The enabling environment for RS in a sustainable global food system

Remote sensing will continue to contribute to the development of plant health surveillance and planning. The degree to which this happens will depend on a number of technical, institutional, political and social conditions.

1. The level of readiness of the technology
2. The generation of new validation and calibration datasets
3. The complementary use of RS alongside established measures
4. Increased up take of information technology within agriculture
5. New institutional frameworks to ensure fair and open access to RS
6. Ethics and governance issues
7. Developing the capacity of practitioners

Nelson, A. (2019) Remote sensing for sustainable agricultural managment. In: Creating a sustainable global food supply. Zeigler, B. (Ed). CSIRO Publishing, Clayton, Australia.

1 The level of readiness of the technology

- This refers to the technology (to collect and process data, to store and deliver information) for timely, reliable and cost effective large scale implementation.
- The level of readiness ranges from operational systems to cutting edge research in air borne and space borne sensor development and platform miniaturisation that will allow more accurate, detailed and frequent observations.
- The growth in the size and number of companies and service providers in the RS sector means there are more options for implementation which should reduce the cost of acquiring the information and improve the usability of it.
- There are open questions whether technologies, such as large constellations of miniaturised platforms, can meet investor expectations by offering disruptive yet profitable costs per square kilometre for high resolution imagery.

2 The generation of new validation and calibration datasets

- The ability to map and monitor the globe on a daily time step with unprecedented levels of spatial and thematic detail requires new approaches to collect sufficient ground truth data.
- Our ability to map the earth far outstrips our ability to validate the results.
- These needs to be as extensive and representative as the new RS information.
- Citizen science, integrated ground based sensor networks and the Internet of Things will all likely play a role in ground truthing remote observations.
- This increasing amount of crowdsensed data may itself become a valuable source of geospatial information in future.

3 The complementary use of RS alongside established measures

- There are cases where remote sensing can replace existing measures, but the most likely use is as a complementary source of information.
- In many instances, remote sensing information cannot replace expert knowledge in other domains, nor can it replace detailed, farmer, field and laboratory derived information.
- There is a need to further develop these formal links between the remote sensing community and scientists across the agricultural sciences, through open dialogue on the needs, potential and eventual use of earth observation data.

4 Increased up take of information technology within agriculture

- Agriculture has lagged behind other sectors, such as energy, in the use of Big Data
- However, investments have increased rapidly since 2013, especially in agricultural analytics for precision agriculture and on farm decision support and the opportunities to exploit it are large.
- The proliferation of low cost mobile apps and information services that rely on remote sensing and other sources of information to deliver site specific information to farmers on water, crops and pest management also suggests that the sector is catching up rapidly.

5 New institutional frameworks to ensure fair and open access to RS

- Open and collaborative systems are needed.
- These should involve both the public and private sector.
- These systems will need to leverage ground, air and space borne sensor networks, and the support communication between those networks, to fill data gaps and reduce costs.
- This needs to happen in the developed world and in emerging economies otherwise the digital divide between them will only increase.
- As RS becomes part of the Big Data revolution, there are concerns that the technology to manage and deliver Big Data are in the hands of a small number of multinational companies.

6 Ethics and governance issues

- These include including data ownership, privacy, security, responsibility and liability.
- For example, there are large differences in national policies regarding the acceptable use of UAV platforms to collect highly detailed spatial data.
- There are large differences in national arrangements regarding RS data; some have adopted open data initiatives or have already integrated remote sensing into their development planning operations or sectoral growth programmes, while others have not.
- Moving towards more open data often requires substantial changes in culture within an organisation or government with solid value propositions for doing so.

7 Developing the capacity of practitioners

- Especially in government, development agencies and the private sector.
- RS contributes to daily lives through weather forecasts and mobile mapping applications
- There is still a large knowledge gap between this use and the understanding of the underlying spatial information.
- As the technology to acquire information and deliver services develops, so must the coordination of education and development activities.
- This need aligns with the mission of my own institute, ITC. Since its inception in 1950 ITC has trained over 25,000 students in all aspects of Geoinformation science including the use of RS for crop and plant health.
- Learn more about our courses, research, expertise and impact areas - www.itc.nl

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