IMPROVING AGRICULTURAL & RURAL STATISTICS

Global Strategy

Use of remote sensing for agricultural statistics

Harnessing new technologies to improve the availability and quality of agricultural statistics

Remote sensing: what is it?

"**Remote sensing** is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on-site observation."

For instance, with remote sensing, regions of the Earth can be explored without physically being in those locations.

Which tools collect remote sensing information?

- Cameras on ships, aircraft, satellites or other spacecraft
- Unmanned Aerial Vehicles (UAVs)
- Sonar, radar, light detection and ranging (LIDAR) systems
- Handheld radiometers

Examples of remote sensing information

Increasingly, the capacity of remote sensing to produce standardized, faster, and possibly cheaper information, in a wide range of applications has been recognized

Remote sensing: general uses

Fields in which remote sensing is widely used

- Geography and most Earth Science disciplines (hydrology, ecology, oceanography, glaciology, geology)
- Military and intelligence studies
- Air traffic control
- Commercial and economic planning
- Humanitarian and emergency assistance
- Statistics (sampling, area estimation, classification, land surveying , support to fieldwork, etc)

Examples of remote sensing applications

- Land cover and crop mapping, crop area estimation, crop yield estimation, etc.
- Tracking the growth of a city and changes in farmland or forests over several years or even decades
- Remote observation of the ocean floor
- Monitoring of temperature changes in the oceans
- Tracking clouds to help predict the weather or watch erupting volcanos, and help watch for dust storms
- Observation of large forest fires, allowing rangers to see a much larger area than from the ground

Land cover assessment and monitoring are essential to the sustainable management of agricultural and natural resources, environmental protection, and for food security and humanitarian programs generally

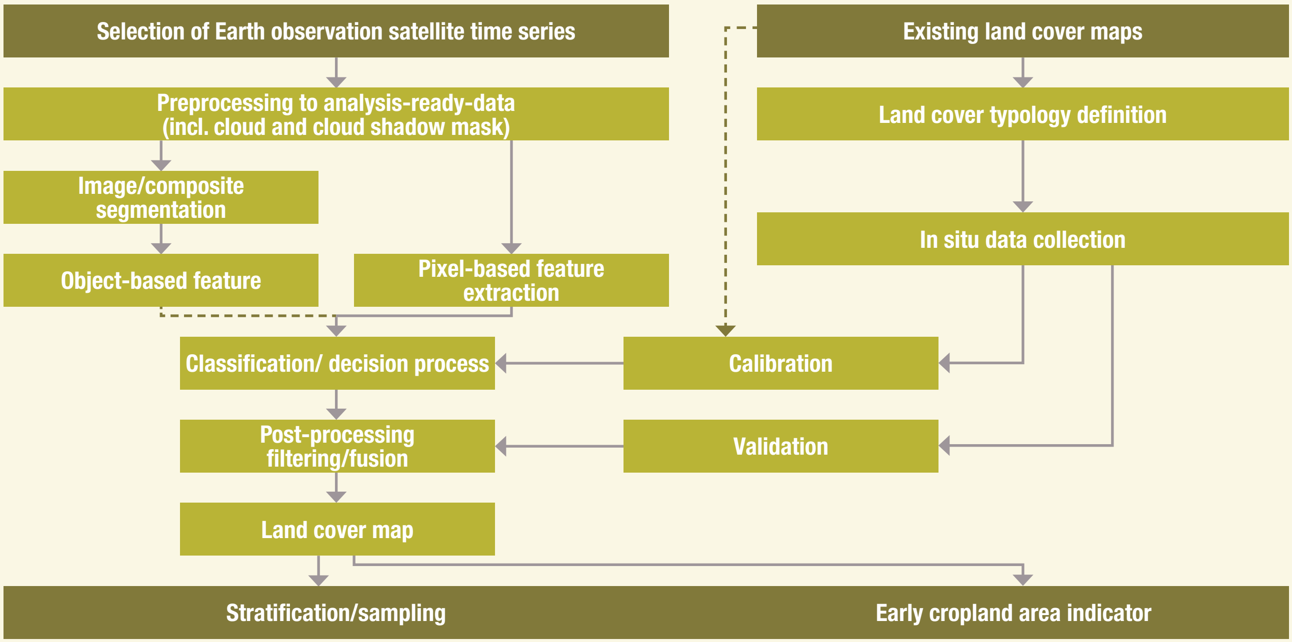
How can remote sensing contribute to the production of agricultural statistics?

1. Land cover mapping and monitoring

Land cover can be observed directly by means of remote sensing, in combination with direct observation in the field or in situ data for calibration and validation.

In the context of agricultural surveys, land cover maps can be used to support the **stratification and exclusion of non-agricultural strata** at the sampling design stage. They can also assist in identifying **annual cropland** and monitoring with **monitoring inter-annual changes of land cover**, resulting for example from cropland extension or the abandonment of cultivated lands.

Standard workflow land cover mapping process



Dashed lines correspond to alternative pathways

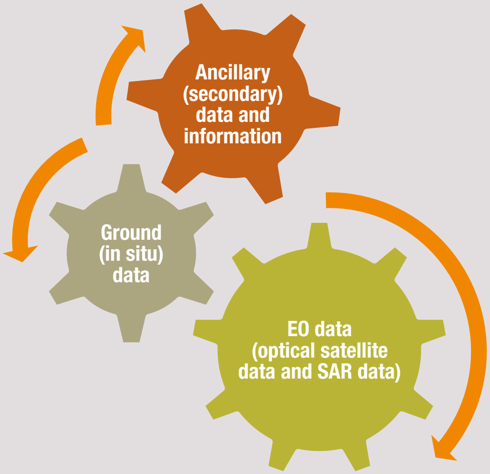
2. Sampling frames and improved sampling designs for agricultural surveys

Remote sensing information can be used at the **sampling design level in both list and area frames**, in particular:

- To define or optimize sampling design options
- To replace absent or obsolete reference maps and enable a clear delimitation of the Enumeration Area (EA), the counting of dwellings and a better planning of the field workload
- To define a more efficient stratification scheme linked to the overall percentage of cropland or to the dominance of specific crops, allowing for reductions in sampling variance and variations of sampling fractions that are proportional to agricultural intensity
- To construct and use area frames, which tend to become obsolete less rapidly than list frames

Examples of sampling design optimization

- The implementation of the Land Use and Cover Area Frame Survey (LUCAS) in Europe in 2001 resulted in significant reductions of the variances for crop area estimates, ranging from 30 percent (potato) to 50 percent (sunflower).
- It was determined that if a non-agricultural stratum covers one third of the administrative area of interest, the reallocation of the entire sample to the remaining strata – including cropland areas – will provide a relative stratification efficiency of 1.51 at almost no cost.



3. Detailed annual crop mapping (Crop Data Layers)

The basic principle guiding the use of remote sensing in the context of crop identification and classification is founded on the fact that crops look different (have different spectral signatures) in multispectral data because of their different structure, physiology, cultural practice and phenology.

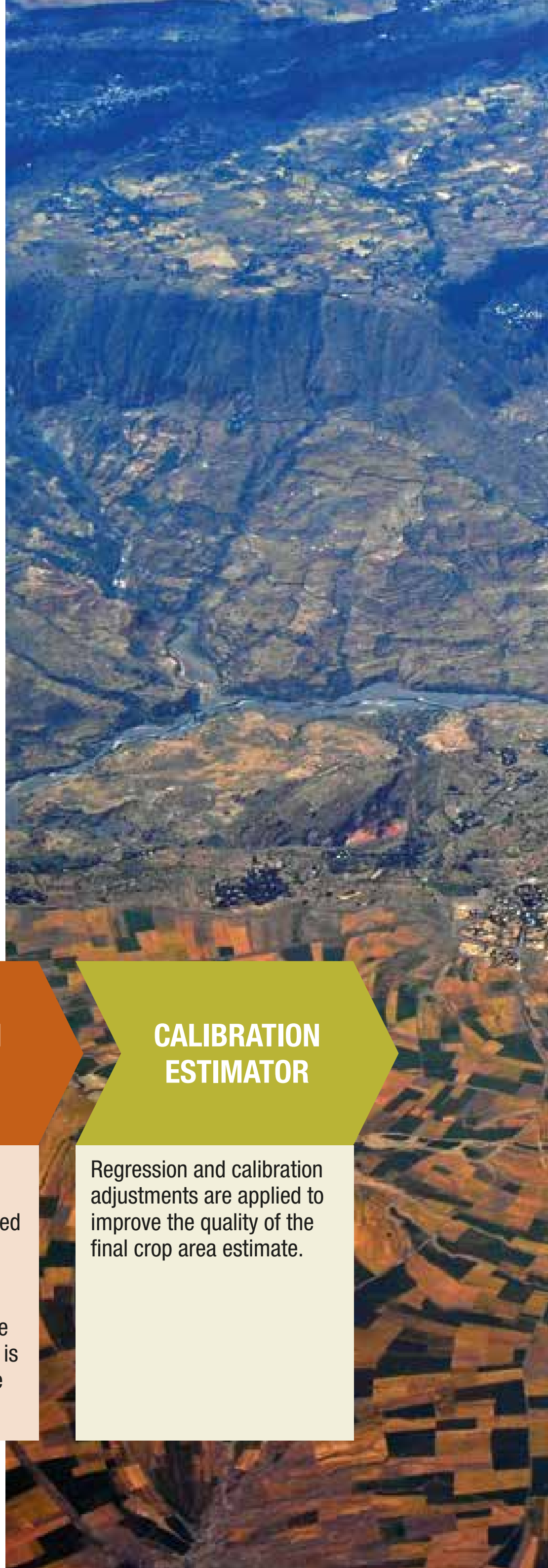
Input data required for detailed crop mapping

Delivering an accurate inventory of crops requires the selection of appropriate satellite data, the collection of quality ground information, the availability of ancillary data, the application of suitable pre- and post-processing methods and the implementation of robust methodologies.

Crop mapping methods

In most cases, crop maps are generated using supervised classification, through the following generic steps:

STEP 1	STEP 2	STEP 3	STEP 4
An image analyst uses in situ (ground) observations to identify locations in the image data that correspond to each of the surface types (target classes) to be mapped	A classification algorithm matches these reference locations to the image data (and available secondary data) to statistically define the spectral (and non-spectral when possible) characteristics of each target class	The algorithm then compares each pixel in the image to these signatures and assigns it to the target class that it resembles most closely	The accuracy of the final classification is evaluated (validated) using a selection of ground reference points that had not been used to train the classification (that is, the validation sample)



4. Crop area estimation

Crop area estimation can be done using satellite-derived crop maps (for example, derived by pixel-based classification methods). However, this must be carried out with caution and incorporate methods for assessing and correcting bias.

For example, bias occurs because pixel counting frequently underestimates the seeded area of minor crops and overestimates the seeded area of major crops. These disparities are caused by inconsistencies in the sample size and spatial distribution of the in situ data used to train classifications.

Bias can be reduced through the use of statistical tools, such as the regression and calibration estimators, a method that combines unbiased information measured on a sample (ground surveys) or unbiased auxiliary information with exhaustive but inaccurate and biased information (classified satellite images).

Four broad approaches for crop area estimation using remote sensing data

Using remote sensing information, the following approaches to estimate crop areas can be applies:

AREA SAMPLING FRAME (ASF) DESIGN

An area frame containing appropriate geographical boundaries and stratification information is developed.

DIRECT ESTIMATION OR PIXEL COUNTING

Crop classification is done for a sample of geographic units (segments) or for the whole geographic targeted area using pixel-based classification methods.

REGRESSION ESTIMATOR

Crop area is obtained by multiplying the estimated number of pixels associated with the targeted crop within the geographic units' boundaries by pixel size (In the case of sample segments, total crop area is extrapolated based on the sampling design).

CALIBRATION ESTIMATOR

Regression and calibration adjustments are applied to improve the quality of the final crop area estimate.

5. Early Warning Systems (EWS) and crop yield estimation

Early Warning Systems (EWS) focusing on agriculture and food security monitor people's access to food, to provide timely notice of an impending food crisis and thus to elicit an appropriate response.

Forecasting crop yields and aggregated production is of significant importance for these EWS. It can be done using simple regression between climate variables or more elaborated yield functions, introducing remote sensing products and general circulation models.

Advances in imagery and information technology capabilities have enabled the rapid advance of remote sensing applications in EWS and crop forecasting models, providing decision-makers with more reliable and timely information to anticipate both livelihood crises and humanitarian emergencies.

6. Forest cover and deforestation monitoring

Remote sensing information can also be used to estimate forest cover and deforestation from global to national scales. Tropical forest mapping and monitoring is a key application domain for Earth Observation (EO). Some EO images lead mainly to the creation of tree cover percentages or forest/non-forest binary maps, which are released at yearly intervals. As a result, major forest degradation can be detected by means of remote sensing methods.

Main constraints on the use of remote sensing information

When using remote sensing information, statistical systems must be ready to face challenges and complexities. Some are highlighted below.

Challenges

The techniques associated with remote sensing raise challenges pertaining to:

- **Sensor suitability**
  - Wide range of sensor resolution (optical or radar),
  - Wide range of image resolution (300 m, 30 cm to 5 m)
  - Large gaps between revisit (one hour to 16 days)
  - Presence of clouds, atmospheric water vapour, sun or shadow
- **Image and resource availability and accessibility**
  - Lack of resources and skilled staff to acquire and use this technology
  - High cost of very high resolution imagery and aerial photographs
- **Technological constraints**
  - Computer and server capacity to manipulate large data files
  - Technological restrictions of open source tools and software upon using GIS and image-processing

Issues related to agricultural statistics: examples for crop area assessment

- Small field sizes require high-resolution remote sensing data for crop identification
- Persistent cloud cover during the rainy season compromises detailed crop mapping
- The use of remote sensing may not be efficient in the presence of:
  - diverse cropping and agronomic practices
  - mixed and intercropping systems
  - large varieties of crops grown in a small area

The ***Handbook on remote sensing for agricultural statistics*** deals with these challenges and complexities and describes how to alleviate them.

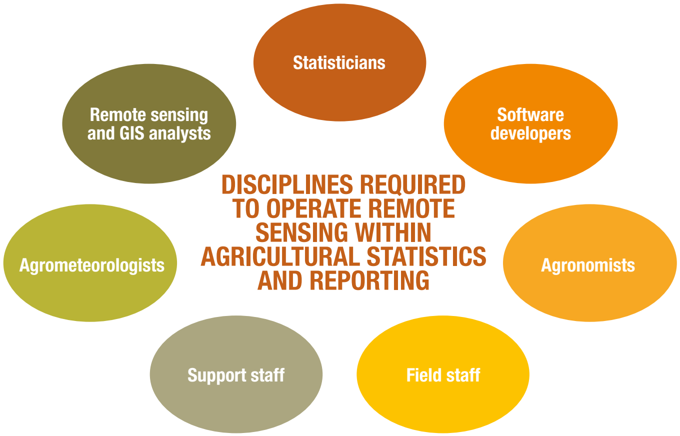
With the decrease in image prices and the growing availability of free-of-charge open-source technologies, several studies have demonstrated the cost-efficiency of using remote sensing data in several remote sensing application for agricultural statistics

Remote sensing-oriented teams must necessarily be multidisciplinary in nature, capable of simultaneously integrating information from satellite remote sensing, GIS, statistics, agronomy, agrometeorology, economics and software development

Resources and competences for adopting remote sensing in agricultural statistics

Disciplines required to integrate remote sensing information within agricultural statistics and reporting

A wide range of disciplines must be combined and collaborate with one another to support the use of remote sensing in the production of agricultural statistics.



Training and capacity development requirement

The technical requirements for the use of remote sensing and geographic information systems (GIS) call for investments in training and capacity development.

Potential topics to be covered in a comprehensive training to support the application of remote sensing and GIS:

- Basic concepts of remote sensing, GIS, statistics and agronomy
- Remote sensing and image preprocessing, classification, analysis and reporting
- GIS data creation, editing, geodatabase development and geospatial tools for analysis
- Land cover classification approaches
- Integration of agro-environmental parameters derived from remote sensing data and ground-based information for yield forecasting
- Use of remote sensing and GIS in sampling design
- GIS software for constructing and using area sample design
- GPS operation and field data collection for enumerators

Acquisition of input data

A number of factors determine the suitability of different image sources, such as spatial and temporal resolution, frequency of coverage, spectral resolution and sensor type, with consequent implications for the sourcing and costs of acquisition and processing.

Data inputs also include remote sensing validation and field survey data, which must also to be factored into the costs of using remote sensing.

Laboratories: hardware and software requirements

Laboratories are required to accommodate the necessary manpower and equipment. The acquisition of relevant hardware and software is also necessary.

HARDWARES

- **Workstation**
- **Laptop/tablet**
- **GPS**
- **Smartphone/tablets**
- **Camera**
- **Printer/plotter**
- **Scanner**
- **Storage/backup server (16Tb)**
- **Network (to connect workstations)**

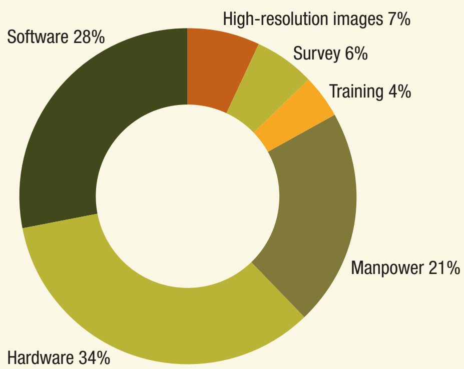
SOFTWARES

- **Statistical:** SPSS, Excel Stat, R
- **GIS/remote sensing:** ArcGIS 10.x, QGIS, ERDAS Imagine 9.x, ENVI, E-Cognition, FME
- **Mobile survey applications and CAPI:** ODK, Survey Solutions (World Bank), Collecte Mobile (FAO), etc.
- **Metadata/data**
- **Dissemination:** Geonetwork, Web mapping applications

Integrating remote sensing into agricultural statistics requires the allocation of appropriate funding levels

The costs for national statistical purposes may be defrayed by using imagery for multipurpose applications, and ensuring multiple-use licensing is important.

Distribution of costs within an agricultural monitoring system based on remote sensing or GIS



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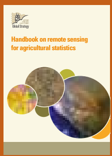
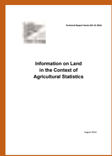


Handbook on remote sensing for agricultural statistics

Technical Report on Cost-Effectiveness of Remote Sensing for Agricultural Statistics in Developing and Emerging Economies



Information on Land in the Context of Agricultural Statistics

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