# Technological Innovations in the Census of Agriculture

**Jairo Castano**[1] | *Food and Agriculture Organization of the United Nations (FAO), Rome, Italy*

***Abstract***

Unparalleled changes in technology such as remote sensing, mobile devices (e.g. tablets, smartphones), Web questionnaires, online dissemination of results (e.g. infographics, social media) as well as electronic data archiving and anonymization of micro-data, are increasingly transforming the way countries conduct agricultural censuses and sample surveys. Their use facilitate both data collection and data dissemination by enhancing reliability, timeliness, readability and comprehensibility of census results. This is discussed in Volume 2 of the new FAO guidelines on the World Programme for Census of Agriculture 2020 (WCA 2020) and summarized in this paper. [2]

| ***Keywords*** | ***JEL code*** |
|---|---|
| *World Programme for the Census of Agriculture 2020 (WCA 2020), international guidelines* | *C10* |

## INTRODUCTION

FAO is the leading United Nations agency for providing technical guidelines and support to member countries for the conduct of national censuses of agriculture. In 2015, FAO published its latest decennial census programme *World Programme for the Census of Agriculture 2020 (WCA 2020), Volume 1 "Programme, concepts and definitions*" (FAO, 2015). This was the tenth decennial programme and presents de-facto international standard that provides the methodological basis for the implementation of national agricultural censuses in the 2016–2025 decade.

To complement Volume 1, FAO prepared *Volume 2 "Operational Guidelines*" of the WCA 2020 (FAO, 2018). Volume 2 is a revised and updated edition of *"Conducting Agricultural Censuses and Surveys*" (FAO, 1996). It supplements the new census programme by providing practical guidance to national census practitioners on the main stages involved in the preparation and implementation of the census of agriculture. The 49th session of the United Nations Statistical Commission (UNSC, New York, March 2018) encouraged member countries to use Volume 2 as a reference for the implementation of the 2020 round of censuses of agriculture.

The revision was opportune not only in view of the new census programme and methodology but also in view of the substantial changes witnessed in the census technological environment over the last two decades. Fast technological developments are shaping the way agricultural censuses and sample surveys are planned and implemented in this millennium. This paper discusses some of the innovations in these operations introduced by the use of recent technology.

[1] Senior Statistician, Leader, Agricultural Censuses Team, Statistics Division (ESS), Economic & Social Dev. Dept. (ES), Food and Agriculture Organization of the United Nations (FAO), Viale delle Terme di Caracalla, 00153 Rome, Italy. E-mail: Jairo.Castano@fao.org.

[2] This article is based on contribution at the *IAOS* conference in September 2018 in Paris, France.

## 1 INFORMATION TECHNOLOGY IN THE AGRICULTURAL CENSUS

Census agencies have seen considerable developments and changes in the statistical methodology and technology environment at the turn of the century. These include an increasing use of administrative sources to meet the growing data needs and phenomenal advances in technological tools at relatively lower costs facilitating census and survey operations.

Volume 2 of the WCA 2020 guidelines acknowledges these developments and emphasizes the use of information technology (IT) on various stages of census implementation, such as:

- Planning of fieldwork (e.g. digital frame construction and geo-referencing).
- Data collection and processing (e.g. use of tablets and online questionnaires).
- Combined census (e.g. using data from administrative sources in combination with collection of field data).
- Data archiving (digital preservation of microdata for wider use or reuse of data over the long term).
- Data dissemination (e.g. interactive outputs and web-based data (dynamic tables, infographics, thematic maps, access to anonymised micro-data).

The next sections discuss these uses in more detail.

## 2 INFORMATION TECHNOLOGY SUPPORT TO CENSUS FIELDWORK

Technologies can be used in agricultural censuses and sample surveys to support fieldwork both for planning and facilitating field operations. These technologies include Remote Sensing (RS), aerial/ortophotos, Geographic Information System (GIS) and Global Positioning System (GPS) (Global Strategy, 2015).

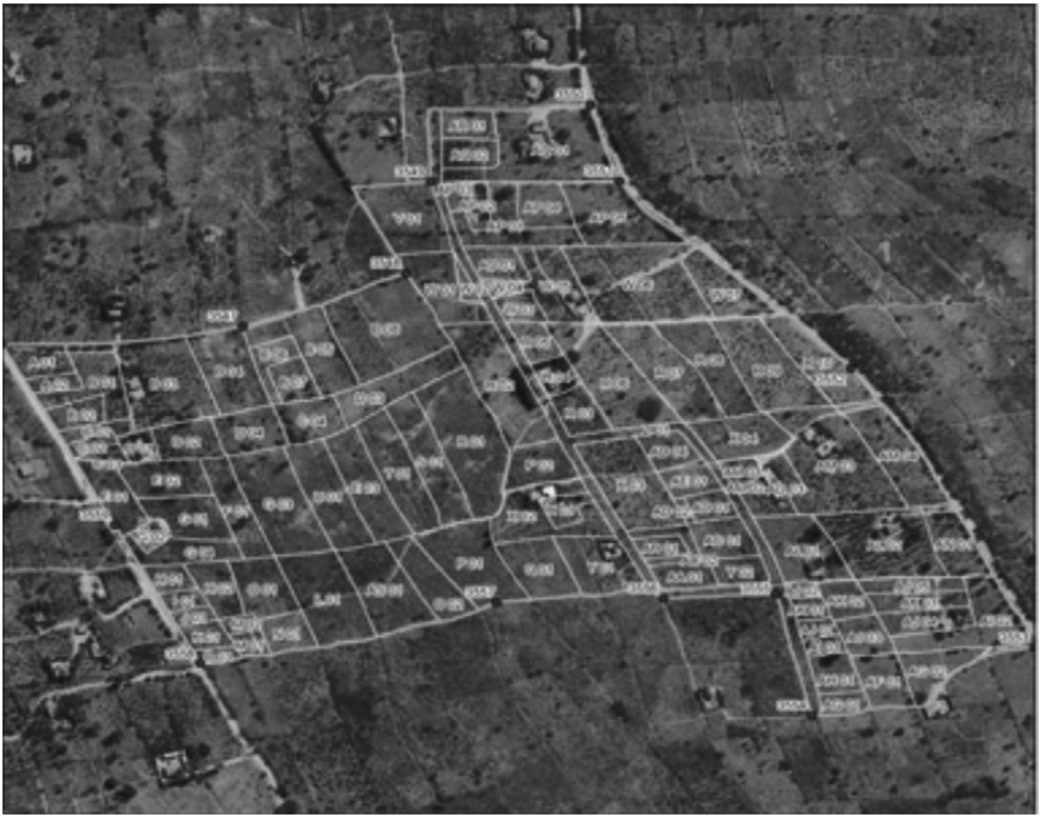
RS and aerial photos are useful for monitoring land cover/land use, cartography and area frame construction, support censuses/surveys fieldwork, crop area estimation and crop yield forecasting/ monitoring. RS imagery is used to update land use maps by photo-interpretation and automatic classification of the various land uses. Stratification can be carried out using the total crop area classified by RS (e.g. agricultural land and other, irrigated and rainfed crops, and permanent and temporary crops). In the census of agriculture, RS and aerial photos are used for census cartography and frame building. Area frames can be built using several types of sampling units (e.g. segments, points, transects) together with related sampling techniques. Figure 1 shows a segment with a number of plots used in an agricultural survey in Rwanda.The Census of Agriculture 2016 of Morocco and the Census of Agriculture 2015 of Colombia, also provide good examples of use of RS images and ortophotos for conducting agricultural census. The Global Strategy (2018) provides country examples on frames building using these technologies.

Satellite images and aerial photos also support field work by helping enumerators optimize their displacements and facilitate localization of holdings and fields. These tools allow enumerators to navigate from holding to holding within an enumeration area and differentiate a household from a holding or from an enterprise holding. This minimizes the likelihood of enumerator going to incorrect units. In this manner, enumerators can plan their best route, which overall maximizes the efficiency of logistics and reduces data collection time. Used as paper prints or on a mobile device, imagery will also minimize the obvious declaration and measurement errors improving data quality.

RS and aerial photography can also be used for area estimation in sample surveys. However, the use of these tools for measuring areas of fields in agricultural censuses is limited by the fact that data are collected from agricultural holdings. With technological advances, high-resolution aerial photographs and ortophotos are becoming less costly but still requiring substantial resources to ensure that up-to-date photos are available at the time of the enumerator's visit.

GIS is used for storing and combining different information layers, which may be required to build an area sampling frame, select a sample and compute expansion factors, as well as information generated while conducting a survey. The layers in a GIS may include boundaries of administrative areas,

**Figure 1** A segment (outer boundary) with plots (inner boundaries) in Rwanda



**Source:** FAO (2018)

boundaries of plots and water points coming from administrative registers and could be in the form of points, lines, polygons or nearly-continuous surfaces ("rasters" or pixels). Tools in a GIS environment are used to manipulate and operate these layers in order to identify the most suitable area sampling frame for a specific survey. A wide range of GIS software tools exist and some packages are free of charge and most are open source. These include GRASS (Geographic Resources Analysis Support System), QGIS (Quantum GIS) and Arc-GIS.

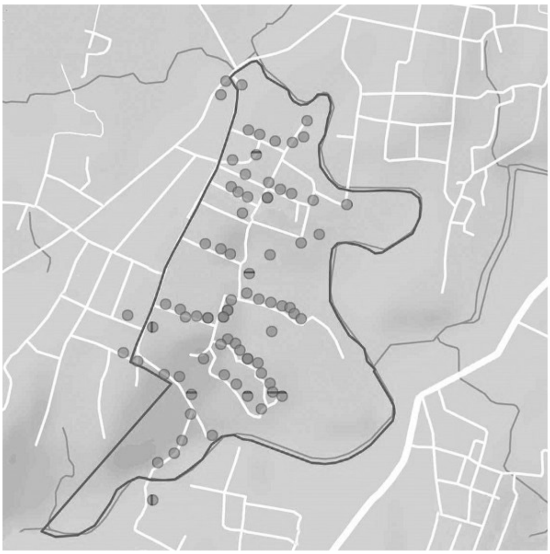
GPS provides support to field activities such as: geo-referencing plots or holdings; locating the known coordinates of holdings; building frames; or measuring area of plots or a landscape patch. The measurement of area of plots is mainly used in agricultural sample surveys.

## 3 INFORMATION TECHNOLOGY IN CENSUS DATA COLLECTION AND PROCESSING

In the last couple of decades, there has been an increased use of electronic questionnaires for data collection, in particular in computer-assisted personal interviewing (CAPI), computer-assisted self-interviewing/ web-interviewing (CASI/CAWI) and computer-assisted telephone interviewing (CATI). The use of these methods has resulted in significant reductions of processing time and improvement in the reliability and timeliness of census results. When these methods are used, traditional activities related to monitoring questionnaires, data entry, part of the computer editing and coding, and transmission of questionnaires are undertaken during the enumeration. This results in significant efficiencies and drastically reduces the time lag between data collection and data analysis.

CAPI involves face-to-face interviews using mobile devices such as tablets or smartphones. Unlike paper questionnaires, CAPI electronic questionnaires allow a drop-down menu for answering, pre-programmed automatic jumps in the questions and consistency checking during the interview. The technology allows direct data transmission to field and central offices. When equipped with in-built GPS, CAPI can be also used for geo-referencing holdings, measuring plots, optimizing logistics and supporting enumerators, and for collecting and compiling paradata (e.g. current location, date and time of interview, duration, completion, approval, etc.) for effective monitoring of fieldwork progress. Figure 2 illustrates the daily performance of enumerators in an enumeration area.

**Figure 2** Monitoring fieldwork in real time



**Interviews completed on 1/2/2015**

| TEAMS | ENUMERATORS | INTERVIEWS |
|---|---|---|
| Team A | Interviewer 1 | 3 |
| Team A | Interviewer 2 | 2 |
| Team A | Interviewer 3 | 3 |
| Team B | Interviewer 4 | 1 |
| Team B | Interviewer 5 | 1 |
| Team B | Interviewer 6 | 2 |
| Team C | Interviewer 7 | 2 |
| Team C | Interviewer 8 | 2 |
| Team C | Interviewer 9 | 3 |
| Team D | Interviewer 10 | 0 |
| Team D | Interviewer 11 | 2 |
| Team D | Interviewer 12 | 3 |

**Source:** FAO (2018)

The CASI/CAWI method requires sending a notice to respondents with instructions on how to access the online questionnaires with their secure access code, phone number to call for help and how to complete it online. Respondents can complete the questionnaire over a number of sessions before submission. This method reduces burdens as some respondents prefer to fill-up the questionnaires at a convenient time for them and at their own pace. In Canada, 11% of the agricultural holders opted for CAWI in the 2011 census of agriculture. This percentage went up to 55% in the 2016 census of agriculture and is expected to reach 70% in 2021. Similar trends are seen in other countries.

The CATI method requires interviewers to contact respondents by phone and entering the data into electronic questionnaires. A notice letter is mailed in advance to help respondents to prepare prior to the phone interviews.

Table 1 lists some advantages and disadvantages of electronic questionnaires in CAPI and CASI/CAWI methods.

Table 2 shows countries that have used CAPI and CASI/CAWI in agricultural censuses since 2006. The use of these methods in agricultural sample surveys are not included in the table.

**Table 1** Advantages and disadvantages of electronic questionnaires

| Pros | |
|---|---|
| **In CAPI** | **In CASI/CAWI** |
| 1. Eliminates printing and distribution costs<br>2. Easy to manage in the field<br>3. Editing checks and jumps are automatic<br>4. Allows smoother and faster interviews<br>5. Allows the use of multiple questionnaires according to the answers received<br>5. Allows quick links to maps, satellite imagery and GPS to help enumerators do the fieldwork<br>6. Allows applying supplementary questionnaires to selected sample holdings<br>6. Can easily switch languages<br>7. Allows drop-down menus | 1. Low cost<br>2. Easy to implement<br>3. Editing checks and jumps are automatic<br>4. Fast processing<br>5. Allows the use of different languages<br>6. Allows the drop-down menus |
| **Cons** | |
| **In CAPI** | **In CASI/CAWI** |
| 1. Requires field testing in the most difficult conditions and a good training programme<br>2. High fixed cost, but devices cost can be shared with other surveys<br>3. Special skills needed for programming the devices<br>4. Requires good Internet or satellite connectivity<br>5. Vulnerability to weather, batteries and access to power for charging | 1. Works well with educated respondents (computer/web literate)<br>2. Respondents need to be in some way trained to respond rightly<br>3. Security required to avoid hacking and protect confidentiality<br>4. Requires good Internet or satellite connectivity |

**Source:** FAO (2018)

**Table 2** Countries using electronic questionnaires in agricultural censuses since 2006

| | |
|---|---|
| **CAPI** | Argentina (2008), Brazil (2006), Colombia (2013/2014), Cote d'Ivoire (2014/2015), Equatorial Guinea (2015), Cape Verde (2014/2015), France (2010), French Guyana (2010), Iran (Islamic Republic of) (2014), Jordan (2007), Malta (2010), Martinique (2010), Mexico (2007), Morocco (2016), Mozambique (2009/2010), Namibia (2013/2014), Thailand (2013), Venezuela (Bolivarian Republic of) (2008) |
| **CASI/CAWI, CATI, CAPI combined** | Australia (2010/2011), Austria (2010), Brazil (2017), Canada (2011), Estonia (2010), Finland (2010), Iceland (2010), Italy (2010), Latvia (2010), Lithuania (2010), Mexico* (2017), Poland (2010), Slovenia (2010), Spain (2009/2010), Sweden (2010), the Netherlands (2010), United States of America (2012) |

**Note:** * Mexico (2017) pilot census.
**Source:** FAO (2018)

In practice, however, countries use a combination of data collections methods. For instance, CASI/CAWI might be applied in large holdings of the non-household sector while CAPI or paper questionnaires might be used in small holdings in the household sector. The increasing use of technology in data collection operations results in significant efficiencies and drastically shortens the time prior to data analysis. However, the use of the methods above discussed depends on the country's information and communication technology capacity (ICT). CAPI, for instance, should be first tested in small-scale operations such as sample surveys before it is used in large operations such as the agricultural census. There have been cases where countries underestimated the time needed to master the method and allocated inadequate sessions for testing and training with unwanted results.

## 4 INFORMATION TECHNOLOGY SUPPORT FOR COMBINED CENSUS

A growing number of statistical offices, particularly in countries with more developed national statistical systems, are moving towards increasing use of data from administrative sources in the statistical data production process. This has been driven by increasing demand for data at a low administrative or geographical level more frequently and pressures to reduce census costs and burden on respondents. As a result, some countries have been implementing combined censuses of agriculture, that is using data from administrative sources in combination with field data collection to generate data items required for the census of agriculture.

Therefore, the improvement in administrative registers in many countries and tremendous revolution in technology are inducing methodological developments in conducting the census of agriculture. The use of registers may involve one or more administrative registers, with each register providing part of the required variables or data for all or a subset of the target population. Thus, a common identifier is of crucial importance for record linkage between the various databases.

In addition to institutional and legal preconditions, the implementation of a combined census requires well-developed administrative systems, adequate IT infrastructures and skills, and the use of special software for data transfer and data matching. Examples of combined agricultural census are found mainly in Europe, in countries such as Denmark, Finland, Norway, Sweden, Estonia, Latvia, Lithuania, Austria, Hungary and the Netherlands (UNECE, 2018).

## 5 INFORMATION TECHNOLOGY FOR DATA ARCHIVING

Census data archiving is used to digitally preserve microdata. It enables wider use or reuse of data, time series and other types of historical analysis, and helps justify the high cost of the census. Evidence shows that this valuable data can be destroyed unintentionally by natural disasters, fires, power failures, programming errors, theft or sabotage. The new technological environment provides conditions for proper archiving of census microdata and other census material such as technical documentation, IT programs, etc. using appropriate technical tools.

Unlike physical materials, digital data must be actively maintained over time (to ensure reuse) and documented. This includes guarding against hardware and software obsolescence, such as outmoded floppy disks and unreadable file formats, so that digital material is accessible and independently understandable over the long term.

Fortunately, digital preservation standards make it possible now for census offices to manage digital data over the long term. One major standard is the Open Archival Information System (OAIS) Reference Model, which became an ISO International Standard in 2003 (CCSDS, 2012; DPC, 2014). The OAIS Reference Model defines the roles, functions of and information necessary for managing digital material over the long term and making it accessible to interested users.

## 6 INFORMATION TECHNOLOGY FOR ONLINE DISSEMINATION OF RESULTS

Remarkable developments in ICT is allowing innovative and user-friendly methods of dissemination and access of census results. Methods include providing access to summarized data, including macro-databases, using interactive Web products (e.g. dynamic tables, data visualization, interactive infographics and thematic GIS maps), social media and by providing safe access to (anonymized) microdata files, including metadata, for more in-depth analysis.

The use of interactive outputs and web-based data as well as access to anonymised micro-data has enhanced accessibility, clarity and interpretability of census results. Novel and user-friendly dissemination tools support informed-decision making, unleash the analytical creativity of users and elevate the value of census data for agricultural policy purposes, research and business, in addition to the usual statistical uses.

The advantages of online dissemination are found primarily in terms of speed, flexibility, cost and accessibility of the results. Information can be static or dynamic. Most users accessing the census website seek for data in static format, as it is faster to download. Specialized users prefer to run data extraction on online databases as a dynamic way of accessing the census information.

Advanced interactive Web products are growing in popularity. Interactive products allow for complex maps and visualizations, various cross-tabulations and other customized data queries. Making a census database available online along with integrated searching, tabulating, graphing, mapping and analysis capabilities is an important way to improve the effectiveness of census data dissemination. Security measures, including passwords and callback procedures, are required to prevent unauthorized access to data.

Social media has become another tool for disseminating census results, other information and marketing statistical products. Interacting with followers and users on these platforms provides the census agency with an opportunity to disseminate information, build relationships with established and new users, and engage the public on a regular basis. Free mobile phone applications can be used to make census results and data releases available anywhere at anytime.

## CONCLUSIONS

The increasing availability of digital and mobile computing tools for data capture at affordable prices, such as smartphones or tablets, geo-positioning tools like handheld GPS devices, and more precise and cheaper RS images now provide new and cost-effective alternatives to traditional methods of collecting, centralizing and processing census data.

Technology is evolving fast and there may be technologies that will be available in the next decade that are either unknown or not yet affordable now. The extent of the use and benefits of new technology depend largely on the national ICT infrastructure. Some countries might be unable to fully benefit from ICTs because of poor connectivity, high cost of access and lack of necessary skills. Other countries could leapfrog their way into the use of recent technology, but adequate time for testing and training before its adoption should not be underestimated. Census and survey managers should consider the trade-off between the safety of proven systems and the benefits of using new technology.

Fast-evolving technologies have a potential to attain substantial efficiencies in census and surveys operations and offer governments an unprecedented opportunity to achieve sustainable development and improve the well-being of their citizens.

Wider and user-friendly access to census and survey data has acquired greater importance for their contribution to monitoring the Sustainable Development Goals (SDGs) and informing in national and regional policy decisions. Data use will grow exponentially in the next decade and will offer the ability to systematically analyze and act in real time in solving more complex sectoral problems, creating more competitive advantage and making better informed decisions in a tightly connected world.

## *References*

CASTANO, J. The increasing use of technology in the census of agriculture. *16th Conference of International Association for Official Statistics (IAOS)*, Paris, France: OECD, 2018.

CCSDS. *Reference Model for an Open Archival Information System (OAIS).* Consultative Committee for Space Data Systems, 2012.

DPC. *Open Archival Information System (OAIS) Reference Model: Introductory Guide.* 2nd Ed. Great Britain: Digital Preservation Coalition, 2014.

FAO. *World Programme for the Census of Agriculture 2020 Volume 2: Operational Guidelines.* Rome: FAO, 2018.

FAO. *World Programme for the Census of Agriculture 2020 Volume 1: Programme, concepts and definitions.* Rome: FAO, 2015

GLOBAL STRATEGY. *Handbook on Master Sampling Frames for Agriculture – Supplement on Selected Country Experiences.* Technical Report Series GO-31-2018, Rome: FAO, 2018.

GLOBAL STRATEGY. *Handbook on Master Sampling Frames for Agricultural Statistics.* Rome: FAO, 2015.

NAMAN, K. AND CASTANO, J. Overview of the new international guidelines on the World Programme for Census of Agriculture 2020. *61st ISI World Statistics Congress (WSC)*, Marrakech, Morocco, 2017.
UNECE. Guidelines on the use of registers and administrative data for population and housing censuses. *Conference of European Statisticians*, Sixty-sixth plenary session, United Nations Economic Commission for Europe, Geneva, 18–20 June 2018, ECE/CES/2018/4/Rev.1.