Training on the use of sensors for nitrogen efficiency.
Photo: CIMMYT

Doing more with less

Digital solutions can help to support farmers in their decision-making processes in order to achieve optimal farming systems of improved productivity while simultaneously minimising the use of resources and the impact to the environment. The International Maize and Wheat Improvement Center (CIMMYT) has been applying the corresponding technology in the context of its Sustainable Intensification Program for several years.

Over the next 50 years, the world will need to produce enough to feed 9.3 billion people, and global food production must meet expected demand despite climate change and without expanding the agricultural frontier at the cost of forests and wildlife. As a result, farmers around the world will have to produce more with the same amount of natural resources, or even less. This is not a distribution or a productivity issue. If we distributed the food produced in 2009 evenly among the population, we would still need to generate 974 calories per day/person by 2050. In addition, agriculture is responsible for nearly a quarter of the global GHG emissions, and it accounts for 37 per cent of land use and 70 per cent of freshwater consumption. We need to do a lot more with less, and this quest will be a matter of life and death for many. Aiming to face these challenges, and given their scale and complexity, we have to assume that linear transfers by which technology developed by specialists is passed on to farmers by extension intermediaries or face-to-face communication will not suffice.

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Innovative solutions with a regional focus

Over the last five years, the Sustainable Intensification Program (SIP) at the International Maize and Wheat Improvement Center (CIMMYT) has developed several projects in Latin America (including Mexico, Nicaragua, Guatemala, El Salvador and Haiti) where a strategy based on a systems approach to agriculture aims to offer practical solutions to these major issues. The strategy creates, validates and scales sustainable agri-food systems based on networks that promote innovation, technology transfers and adoption of improved maize seed, wheat and associated crops, as well as sustainable agronomic practices among small-scale farmers. When combined, these innovations lead to higher, more stable yields and increase farmers' income while reducing the impact of agricultural activity on the environment. The model lays special emphasis on the local context and actors by adopting a regional focus through innovation hubs, spaces for knowledge exchange, technology development, agronomic innovation and information sharing among the different actors that participate in the agri-food chain. The word 'hub' refers to the centre that holds together the spokes of a wheel. The term also stands for the central connection for managing cybernetic information as well as the centre of an activity or network.

Supporting farmers' decision-making processes

Within this context, Monitoring, Evaluation, Accountability and Learning (MEAL) strategies including innovative data analysis methods and visualisation tools acquire significant relevance. Efficient data collection, dimensional analysis and dissemination of agri-food systems and their integrated pathways could help to overcome the challenges of the future. Since traditional MEAL systems in agricultural projects are not understood as knowledge management systems so far, they still tend to measure indicators related to increased production and productivity with little attention to institutional, environmental, contextual and social issues, i.e. systemic questions. Therefore, the main objective of any MEAL system in agriculture should be to bring in the latest research and technology along value chains regarding precision agriculture and conservation farming practices to farmers of all scales, and support their decision-making processes in order to achieve optimal farming systems of improved productivity, minimal use of resources and impact to the environment. The organised data could also serve donor purposes and regional decision-making for targeting public and private efforts.

In Latin America, CIMMYT has been collecting defined indicators directly from farmers and has around 36,000 registered plots with 500 variables per cycle. In addition, different tools for data collection, cleaning, analysis and visualisation have been tested and developed to support decision-making, monitor and evaluate project activities, which are described in the following.

CIMMYT tools

Data collection

Field surveys: Farmers' data describing crop management practices, yields, costs, dates and crop status are captured in CIMMYT-developed field books that use two data collection tools: an in-house developed system (*Bitácora electrónica MasAgro*, BEM) and Geographical Open Data Kit (GeoODK) Collect. Both programmes allow for logic, entry constraints (i.e. ranges in the answers-input) substructure repetitions and geo-referenced information. Data collectors are extension agents who can work online and offline in the field, save submissions at any point and send them to CIMMYT servers. At present, GeoODK Collect uses an Android platform and supports a wide variety of question types: text, number, location, polygons, multimedia and barcodes.

Crowdsourcing: These tools collect data from other farmers and end-users who may not be working directly with an extension agent linked to the project. Typically, a crowdsourcing exercise would collect demographic information (e.g. geographic location, gender, field experience) and, in some cases, would include Entry Questionnaires to ensure that respondents meet the representative sample required.

Data cleaning and analytics

Several scripts have been developed in R-language (a language for statistical computing and graphics) which automatically obtain data from an Excel file, identify and separate outliers, and then graph for example, yield variation and net income per crop, region and production type.

In addition, other analytics are being tested. Farmers' data describing crop management practices, yields and crop status is pooled and combined with weather records and soil data at the field level. The data is subsequently completed by thorough characterisations of the actual conditions in which the crops grew and related to the yields achieved. Empirical modelling techniques are then used to mine the databases for correlations and/or patterns that inform about the main limiting factors and optimal management practices for each context. Typically, clustering, Principal component analysis (PCA), regressions and machine learning approaches (such as artificial neural network and classification, and regression trees) are part of the portfolio of techniques that can be employed. This process is performed in collaboration with the International Center for Tropical Agriculture (CIAT) Decision and Policy Analysis group and can be described as a wide-scale benchmarking exercise where crop performance is compared in groups of fields that share similar natural conditions.

Visualisation and dissemination

Geographic information system (GIS) and dynamic analytics for visualisation: Conservation Earth – an open source platform – provides a way to store geo-referenced information, as well as a combination of tools to visualise, analyse and manipulate field data to map our field activities (monitoring), dynamically interact with historical/regional/thematic layers, and support decision-making processes of end users.

An SMS platform offering free, site-specific technical advice also contributes to the dissemination strategy, by targeting farmers and extension agents depending on the crop they work with, the region and their production system type.

ICT usage impact in agri-food systems: risks, advantages and trends

As stated by Hopkins et al. (2013), ICTs can be classified according to how they affect performance in the agricultural sector:

(a) Systemic – indirect – impacts on productivity, innovation and networking are generic and not unique to agriculture and affect factors like the flow of information, public policy-making and administration and risk management;

(b) Enabling impacts which improve efficiency and reduce transaction costs throughout the value chain, for example, improving access to markets, or processing financial transactions; and

(c) Direct impacts which encompass ICT applications that have a primary use in agricultural production processes, with clear impacts on the sector's productivity and efficiency.

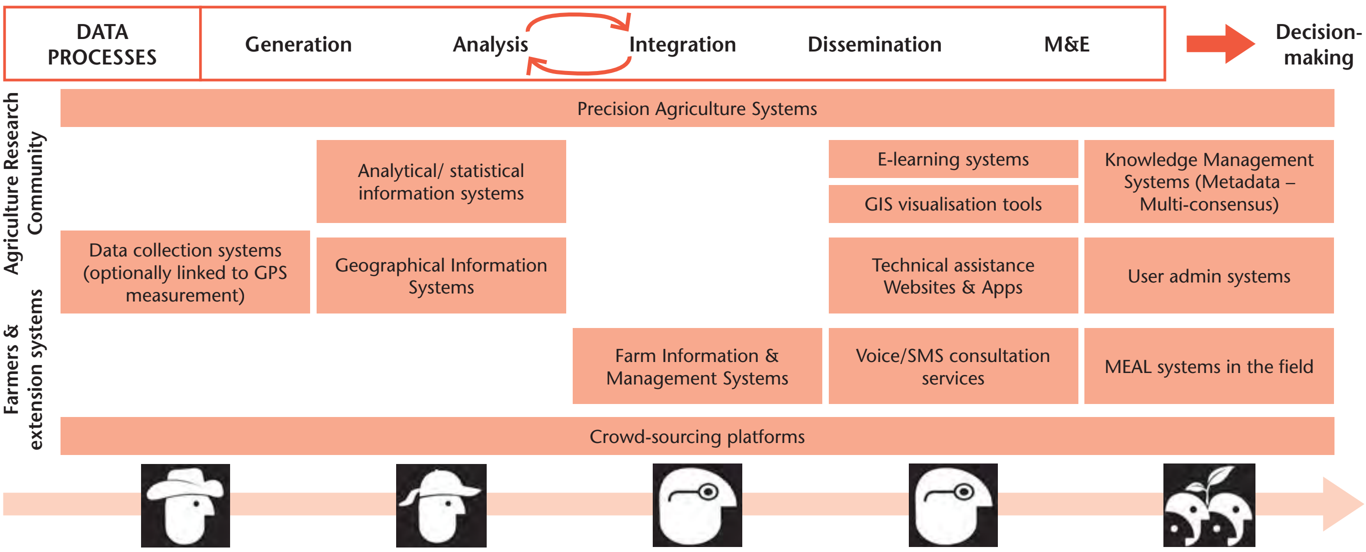
Following this approach, an efficient digitisation strategy for agriculture would need to include a complete toolbox for systemic, enabling and direct impacts where not only linear processes but also systemic relations are taken into account (see Diagram). Functional data collection systems, able to gather real data on time integrated with data cleaning protocols and analytics, can serve as decision support systems regarding any type of impact. In addition to the tools, a complete MEAL strategy aiming to return added-value information adapted to farmers and final users is crucial to achieve the potential of ICT usage in agriculture.

High costs and limited access to the Internet are still significant limitations. Sophisticated early warning systems, precision agriculture, and traceability strategies, for example, require the use of fairly costly and robust technologies and users with the requisite technical skills. Open source software adapted to development contexts, relevant capacity building targeted to innovative farmers able to replicate success and public policy alignment appear as solid paths that should be developed and implemented in order to consolidate impact.

Finally, evaluating and measuring not only agri-food systems performance but also the digitisation strategies is essential to identify and manage risks efficiently. Risk and uncertainty aspects range from weather, pests and diseases through commodity prices to volatile market conditions and politics. Regarding ICT strategies, high investments with no evaluation processes can generate massive losses. Therefore, timely information to inform agricultural and project management at different levels is also a topic to be considered.

For a list of references and related links, see online version of this article at:
➤ www.rural21.com

How can ICT help farmers in decision-making? CIMMYT examples and lessons learnt.



CIMMYT example	Farmers collect dates, costs, and management activities per cycle at a paper-based system printed from. http://bem.cimmyt.org	Extension agents visit farmers and input data into the electronic logbook system including dates, costs, and management activities per cycle. http://bem.cimmyt.org	CIMMYT experts clean data, review outliers in the field and automatically generate added-value information based on descriptive, diagnostic, prescriptive or predictive analytics per sub-region or production system type. https://github.com/luizvargaz/grainYield/blob/master/procesoRendimientoChart.Rmd http://rpubs.com/luisVargas/mPV2016	Communication experts transform added-value information into communication products for farmers and final users. http://conservacion.cimmyt.org/es/don-crecencio	Farmers receive SMS with specific information for their region or system type, and a GIS tool serves to visualise analysis. http://104.239.241.61:8080 /MasAgroTTF/v2/Estado/GTO/
Learnings	Paper-based is still a good tool to engage farmers in knowledge management and digitisation processes.	Extension services are key knowledge brokers and a successful way through to digitisation.	Crowdsourced data needs to be cleaned, organised, validated and integrated before starting any analysis. Open source software should be used to guarantee scaling and scalability.	Results need to be translated/adapted depending on the final user needs by using proper language, presentation and channels.	Relevant content depends on several variables; therefore, info products need to be targeted for very specific groups.