Role of ICT in Crop Management

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Abstract

Every day, new and crucial difficulties and challenges are encountered in agriculture. Using information and communication technologies (ICTs) can be a key facilitation for more efficient crop production. Simply ICT is defined as hub of technologies that support in storage, processing data/information, communication of data/information, and distribution of data. ICT therefore comprises technologies such as computers (desktop and laptop), mobile phones, Internet connection, peripherals, and software that are projected to perform information processing and communication purposes. The application of ICT in agriculture

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is becoming progressively important. E-agriculture is a developing field aiming on the improvement and development of agricultural and rural sector through enhanced information and communication processes. More importantly, e-agriculture involves the concepts, design, development, assessment, and application of advanced methods to use information and communication technologies (ICT) in the rural area, focusing on crop production. All stakeholders of crop production system need information and understanding about these stages to manage them efficiently.

Keywords
Information and communication technologies · Agriculture · Remote sensing · Modeling

28.1 Introduction of ICT

Information and communication technology (ICT) indicates the technologies which allow access to information via telecommunications medium such as computers, cell phone, satellites, television, radio, and Internet including email, video conferencing, messaging, and social networking sites. These technologies help users around the world to communicate with each other and provide quick access to share ideas and information increasingly being used in all areas of human activity, including agriculture.

Agriculture is an art and science of all businesses associated with crop cultivation and animal husbandry for providing food and shelter and raising the standard of living for manhood. Agriculture is vital for mankind because it provides raw material, food, and employment for industries; others are source of income, foreign exchange, afforestation, provision of shelter, and regional development. In developing countries most of rural population depend upon agriculture. Agriculture sector is facing a major provocation of increasing production because natural resources are dwindling rapidly which are essential for production. However, the growing demand for agricultural products provides more opportunities for manufacturers to support and ameliorate their standard of living. ICTs play a significant role in defining these provocations and raising the standard of living of the rural people. Due to the urgent need for research in application of new and innovative technologies in agriculture, knowledge of agricultural scientists should be transformed into computer-understandable representation (Fig. 28.1) (Kumar 2013).

28.1.1 GIS and Remote Sensing

Geographic information system (GIS) is a combination of hardware, data, and software which provide acquisition, analysis, management, and presentation of

Fig. 28.1 Application of ICT in agriculture

geospatial (geographically referenced) information. In a GIS, layers of spatially accurate data are associated with tabular (attribute) data in relational databases and authorize the user to visualize and analyze patterns and trends.

ICT has been using GIS and remote sensing technologies to ensure viability and crop management (Fig. 28.2). Additionally, GIS applications have been widely used for environmental management, watershed management, and environmental impact assessment (EIA). GIS group also generate digital elevation model (DEM) using stereo pairs, land use maps, large-scale base maps, and terrain analysis. ICT has distinguished technical and non-technical resources (both hardware and software) and highly qualified professionals with extensive knowledge and experience to work on such digital/spatial data. Several national and international projects have

Fig. 28.2 Plant monitoring by remote sensing

been successfully completed using an extensive range of data including aerial photographs, satellite imageries, and GPS-guided topographical surveys (ICT 2018).

28.1.2 Computer Mapping

Computer mapping or geographic information systems (GIS) operations have diverse services in crop production and management. Any data can be mapped if it is associated with land address or located in space by latitude and longitude. One attains not only an attractive map but also a new level of spatial analysis useful in program and policy decision-making.

Crops mapping and identification is necessary for multiple purposes. Maps of crops are created by considerable number of national and multinational agricultural and insurance agencies and by regional agricultural research centers to organize a directory of what and when was cultivated in particular areas. This provide the aspiration of predicting yield, assisting crop variation and rotation records, mapping soil productivity, collecting crop production statistics, identification of factors inducing crop stress, evaluation of crop destruction due to hazards and disasters, and monitoring and analyzing farming activities.

Major computer mapping activities determine crop types and describing the amount of cultivation in acers or hectares. Traditionally this information is obtained by census and ground surveying methods. However, for standardize measurements (especially for international agencies and consortiums), remote sensing can deliver general strategies for data collection and withdrawal of information (CCRS 2002), (2010).

28.1.3 Telephone Network

To compete, telecommunications rely on a smooth workflow that includes information about marketing, demand forecasting, designing, engineering, costumer management, operation support, and fleet management. Although telecommunications

are usually an information provider for workflow management, it is different from company to company (ESRI 2001).

28.2 Role of ICT

28.2.1 Role of ICT in Plant Physiology

ICT is used to develop scientific devices for plant physiologists. The devices shown in Fig. 28.2 are designed for continuous and long-term monitoring of equipment. This has a great advantage over portable devices that are used only for on-site measurements. By constantly monitoring installations, you can record various and complex reactions to environmental exposures when they actually occur.

ICT has long been recognized as a huge potential for improving decision-making process in plant physiology. Information technology (IT) has joined the world globally and is currently dynamically changing our standard of living and social awareness. In all stages of the agricultural sector, information technology is fundamental to the management and business success. Agriculture is also significantly influenced by IT.

Information technologies are becoming rapidly visible in society and agriculture. IT refers to how we use information and how we evaluate and share information. User must have computer or smart mobile phone to participate in e-agriculture. One can make informed decisions; also a person can collect, process, and manipulate data of agriculture sector (ICT International 2014).

28.2.2 ICT and Agriculture in Future

Agriculture is of strategic importance for maintaining the livelihoods. The growth of e-agriculture has the potential to accelerate the development of agriculture and rural areas, ensure food security, and diminish rural poverty in emerging markets.

Although farmers and their machinery continue to play a key role in agricultural industry, ICT is playing a more significant role in enriching communities over the world. Basic computer training enables farmers to use ICT to increase efficiency, sustainability, and profitability of farming. ICTs can help farmers to build relationships with reliable suppliers of seeds and fertilizers; aggregation of purchases (i.e. when multiple buyers are involved) can lead to lower prices, better access to cultivation information, finest practices and a general decrease in labor costs and wastage (Theunissen 2015).

28.2.3 ICT Initiatives for Agricultural Development

E-agriculture is developing and handling advance ICT techniques in the rural areas, focusing on agriculture (Amin et al. 2015). It is a rising field aiming on improvement and development of rural and agricultural areas through communication and

Fig. 28.3 Instruments for plant monitoring

advance information. In this regard, ICT is a generic term covering all technologies and tools such as devices, applications, networks, and services, which include advance technologies and sensors of Internet era to other preexisting tools such as radios, televisions, landline telephones, and satellites. E-agriculture is constantly evolving as new ICT applications for agriculture sector. Particularly, e-agriculture includes the designed models, engineering, evaluation, development, and application of innovative methods of applying ICT in rural areas focusing on agriculture sector (Fig. 28.3). Its aim is to provide standards, methodologies, norms, and tools to upgrade individual and institutional capacities and supporting policies (Wikipedia 2018).

28.3 Water Management Through ICT

ICT-supported irrigation is demonstrated here as "application of water to a tree based on monitoring the need of each tree to optimize its yield." ICT monitors real-time water and nutrient consumption and the needs of each tree. The system (shown in Fig. 28.4) in turn remotely activates and provides a continuous, optimized supply of water and nutrients suitable for the farmer's current climate, soil conditions production plan. ICT is one of the most effective means to increase food production by improving land, crop, and water management. Since the ICT and automation are involved in management of water supply and irrigation system, it has been shown that there is an excellent improvement in water use efficiency in countries facing severe water shortages. It increased water use efficiency by 10–50%, increased per unit yield of land and water by 20–100% in irrigation, and improved agricultural productivity. ICT and automation allow optimizing pressure regimes in water supply networks, saving water and energy, and charging users to his actual consumption. Practically, ICT and automation ensured the adoption of volumetric (three-dimensional) approaches of water application in agriculture. These successes have facilitated to expand irrigated area, increase food production, and maximize profits for farmers (Amarasingam 2017).

Fig. 28.4 Water management methods

ICT is a strategic factor in the process of developing innovative solutions to address the problems of water scarcity. By collecting and analyzing environmental data, ICT facilitates researchers and climatologists to create more precise models for weather forecasting (ITU News 2015).

28.4 Role of ICT in Nutrient Management

The use of ICT is now being felt at the farm level. A rice farmer or extension worker who has a cell phone connected to the Internet can download an application called Nutrient Manager. He can log in and answer a series of questions. Based on the information he submits to a cloud server, instruction of fertilizer is automatically sent through his phone either as an image or as an SMS message. Similarly, a crop

Fig. 28.5 Nutrient management

advisor, extension worker, or a farmer who has access to a personal computer can also download the same application from the Internet through a web browser to get the same fertilizer guideline (Fig. 28.5).

Meanwhile, a farmer calls a specially assigned phone number using a simple GSM mobile phone to access the Nutrient Manager's voice recording via an IVR. After responding to the queries in the voice recording by pressing numbers keys on the telephone directory, he also receives a personalized fertilizer guideline.

Nutrient Manager is a decision support tool that uses innovations in ICT and transforms site-specific nutrient management (SSNM) principles into easy-to-apply nutrient management guidelines for farmers. Developed by International Rice Research Institute (IRRI) through partnerships with Asian organizations, it delivers scientific principles for defining field- and crop-specific requirements of fertilizer (FFTC 2018).

28.5 Role of ICT in Pest Management

ICT has proved to be a powerful tool in pest forecasting as a prop to giving priority to prevention, as pest forecasting involves data acquisition, processing, and information dissemination. ICT can also be very helpful in terms of enforcing integrated pest management (IPM).

The use of information technology (IT) in pest management has gone through sensational developments over the last decade. IT has increased the efficiency of data collection and analysis, identification of pest, choice of control agent, and field

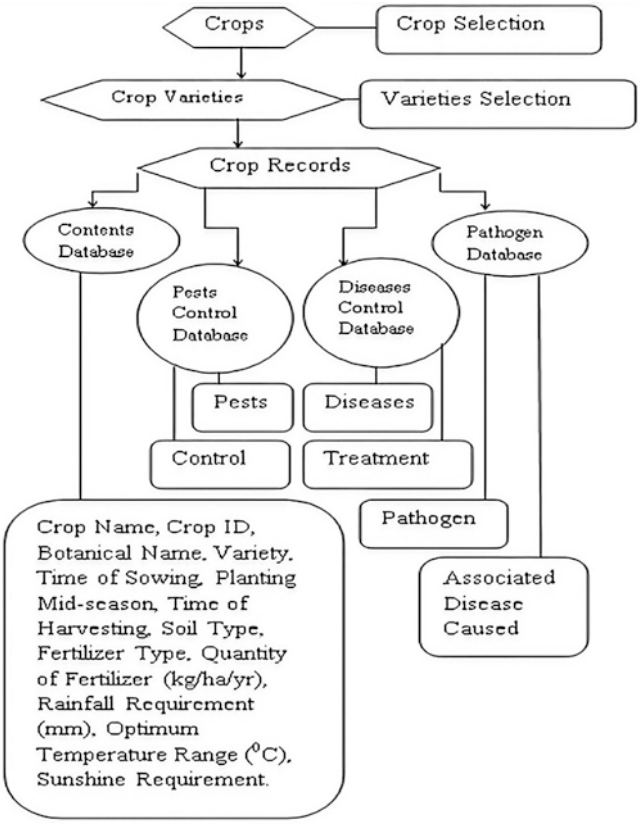

Fig. 28.6 Pest management by ICT

applications of pesticide (shown in Fig. 28.6). In addition, IT has improved our capabilities in research, training, education, and information circulation and management. We monitor pests for early warning, development of models for forecasting pests and decision support systems, which are crucial for the design and implementation of successful integrated pest management programs. Developing countries instantly need to create agrometeorological networks for specific crops with the main goal of predicting pests using models and decision support systems (Xia Roger and Suiter Ronald 2007), (Okpara 2015).

28.6 Factors Affecting Use of ICTs for Agriculture Extension

By the innovation in ICTs and its mechanism, rural expansion and advisory services will be dependent on ICTs so that they can find more effective, suitable, accurate, and innovative means to provide most advance agricultural expertise to farmers. Additionally, ICT-based information and advisory

services have an important role in providing agricultural expertise to farmers. ICTs' importance in agricultural progress is essential to promote the distribution of information through ICT to increase agricultural productivity and on the other hand provide a mechanism for the sustainable provision of information to agriculture. Introduction of ICTs in agriculture is quite complex and critical, because it includes numerous phases and factors of farmer life. Socioeconomic profile of farmer is one of the prominent factors because it influences adoption of ICTs by farmer in agriculture. Several studies have been engaged to examine socioeconomic profile of farmer that influences the behavior of farming community in relation to agricultural advisory services, methods, and other ICT-based social activities. These factors promote policies to adopt ICT-based agricultural practices by farmers in order to increase agricultural production. Contrarily, study has shown a significant correlation between statistical data such as age and education of farmers and their adaptation to technological knowledge (Yaseen et al. 2016).

28.6.1 Lack of Knowledge

NGOs do not have sufficient capacity to support and promote the active use of ICT for development. They have lack of experts, knowledge, or organizational capacity. IT use is often regarded as an acute problem to back office systems. Additionally, ICT has doubtful reputation due to previous unproductive or costly initiatives.

28.6.2 Pace of Change

In recent NGOs structures, staff and function have a strong impulse that is not easy to break or to lead. It is comparatively easy to use ICT to maintain and improve existing organizational structures and approaches, to achieve beneficial but gradual improvement. It is extremely hard to find new methods of working with organizational structure which are basically changed from current situation and need a change regarding strategies, capability, skills, and organizational structure.

28.6.3 Funding

Proper planning and funding the use of ICTs in development programs are also a serious problem, due to cyclical donor for funding and need to reduce administrative and management costs. It is often difficult for NGOs to invest financial and human resources in ICT as a major potential for planning and using development programs.

28.6.4 Changing Roles and Norms

The emergence of new ICTs may raise more number of necessary and far-reaching issues that challenge or even undermine the assumptions made by NGOs. When we think about why NGOs were formerly created, we can identify multiple specific gaps between rich and poor communities in the world. For example, when we think about gaps in understanding and lack of information, traditionally NGOs helped us understand the needs of communities in the poorest parts of the world. There are also gaps in access, communication, and resources where NGOs have done efficient work in the past (Devex 2013).

28.7 Information Needs of Farmer

Growing crops is a complex process that includes multiple activities such as tillage, land preparation, irrigation, planting, nutrient management, pest control, harvesting, marketing, etc. The entire crop production cycle requires a lot of information from farmers. Despite many efforts that have been made over the years of distributing agricultural knowledge and transferring it to the farmers, the majority of experts and specialists are still unavailable. Agricultural knowledge can be stored in a corporate database or remain undocumented in the minds of researchers or even stored in places unknown to most of the organizations employees. A significant part of farming community, especially the rural population, does not have access to the knowledge gained by extension centers, agricultural universities, and research centers. In this regard the biggest problem is the search for knowledge and its application in decision-making process related to development of agriculture. Currently the main problem for an organization is to identify, locate, and apply this specialized knowledge, embedded in organizational databases, to develop as a different production aspect to raise productivity and competitiveness.

28.7.1 Variety Selection

This subsystem advises users on the varieties most suitable for their plantation, based on the specific conditions of the farms and user's requirements. The knowledge of the subject area of this subsystem holds two models, namely, suggestion and selection. The evidence-based knowledge holds three inference steps, namely, specify, select, and count. The proposed model defines a relationship between the environmental conditions and the suitable varieties used by "specify" inference step to offer paddy varieties suitable for the environments. The selected model defines relationship between user needs and varieties used by "select" inference stage to select the most appropriate varieties that meet the user requirements. The "count" inference step just counts the number of varieties.

28.7.2 Land Use Planning and Management

Sustainable agriculture is a combination of methods that specify present and future social requirements for food/fiber without threatening land degradation (Hammad et al. 2018). GIS offers the possibility of combining several information layers, from diverse sources, in one spatial representation. GIS is especially useful when a spatial planning consensus is reached and when users have different values and preferences for a particular area. Similarly, RS techniques are important tools for observing land resources (e.g., water bodies, vegetation, etc.), particularly when a single object is responsible for monitoring a large area. Soil cultivation provides specific recommendations to the user about preparation of particular land for cultivation and appropriate planting techniques according to particular user's inputs data. The field model of this subsystem holds two models: establishment plan and assignment. The scientific knowledge holds three inference steps: establish, assign, and select. The organizational structure model contains a relationship among farm description and strategic plans, which is used by organizational structure to create a recommended plan and an alternative.

28.7.3 Soil Quality Assessment

Soil quality assessment can be conducted at farm level and at regional level. At the regional level, this may be based on land, climate, and land use. Some beneficial technologies help to understand nature of soil and its problems associated with agricultural and management practices. In recent years ICTs have developed dramatically. Assessment of soil quality is carried out with the help of some beneficial technologies, like RS (remote sensing).

28.7.4 Input Procurement

Farmers often acquire information about the various resources they need in the field, like seeds, labor, pesticides, fertilizers, transport, etc. regarding cost, quality resources, and availability.

28.7.5 Strategic Information

During cultivation farmers need information at several stages to support planning and minimize risk. Information regarding the agricultural practices like characteristics of various varieties, pest control techniques, planting, irrigation and harvesting schedule, mechanization, inter-cropping, etc. can be attributed to strategic information. Information of appropriate technologies for protection and production is required for optimal and sustainable agriculture.

28.7.6 Past Trends

Background information in terms of varieties, area, production, pest infestation, climatic conditions, utilization, environmental problems, etc. are very helpful in decision-making for cultivation. For example, previous climatic trends can help farmers to plan crop cultivation techniques for optimal production and stress management.

28.7.7 Government Policy Decisions

Government policies regarding agriculture, labor laws, land ownership, products marketing, rural development, etc. are key factors while decision-making. This information should be obtained by farmers in the shortest possible time, so that a farmer can make accurate decision for maximum productivity and revenue. Currently, IT tools are now available to record and distribute decision support information and provide information about support facilities and government policies.

28.7.8 Expert System

An expert system is an IT-based intelligent computer database, which uses interventions and knowledge to deal with those problems that are quite complex and need considerable mortal experience. Expert system for production and protection of a crop is a modern innovative tool for farmers in decision-making process. It can recommend an appropriate crop variety, irrigation, field preparation methods, sowing methods, and fertilizer application. Expert system also offers farmers diagnosis and treatment of disorders in crops.

28.7.9 Simulation and Modeling

Simulation and modeling and technologies help to simulate an ideal crop situation and growth prediction by extrapolation and other methods by taking into account a particular crop environment (Mubeen et al. 2013; Amin et al. 2017a). Crop models can be designed to characterize environment, improve crop management and disease and pest management, study the impacts of climate change and effective crop scheduling, predict crop yield, etc. (Amin et al. 2017b, 2018a, 2018b). After one is assured that model mimic the real world effectively, the system can be controlled and managed by performing computer experiment for hundred or even thousands of times for particular environment. For example, decision support system for agrotechnology transfer (DSSAT) was designed to operationalize this approach and make its application available worldwide. DSSAT assist decision-makers to save time and resource to analyze complex alternate decisions (Tsuji 1998; Jones et al. 2003).

28.7.10 Multimedia Tools

Multimedia is a term which means number of media like text, video, graphics, animations, music, narrated sound, and special effects. They are controlled, integrated, and coordinated by a computer. Simply multimedia is multiple forms of media that are integrated with each other. It contains encyclopedia, instructional tools, videos, tutorials, etc. which help improve not only the text messaging but also the understanding, receiving, and retention of information (FAO 2017).

28.7.11 Agricultural Advisory

Information priorities of farmer consist of precise weather forecasts, specific crop advisory depending on the phases of crop cycle, and marketing information. Using ICT, one can get real-time weather data through remote sensors, track raw material prices using mobile technologies, and update crop-related research findings obtained from web platforms of agricultural universities and research centers.

The collected information is stored in a database and automatically activated to distribute as personalized and localized information about weather, prices of goods, equipment's and raw material personalized, and cultivated crop among registered farmers through short messaging service (SMS) and interactive voice response (IVR). This updated information empowers farmer to be more informed and prepared to use resources for better revenue.

28.7.12 Financial Services

Availability and access to adequate, timely, and low-cost credit from banks are of great importance for sustainable and profitable farming. The challenges to bring all farmers within the banking reach at affordable cost have been fulfilled through remote bank transactions assisted by handheld biometric transaction devices.

The banks facilitate financial services such as savings, credit, insurance, and remittance with the help of these devices accessed through smart cards. Smart cards hold farmers' information regarding the land details, crop history, and financial transactions, which help bank to process and sanction crop loan faster. Thus, the farmer needs to initiate the loan procedure through the handheld device available at the village and visit the bank to collect the loan amount upon confirmation on loan sanction. This saves the farmer's valuable time and energy to obtain institutional loans.

28.7.13 Agricultural Marketing

The coverage and size of agricultural market have improved over the years due to connections with distant and foreign markets. Farmers use multiple ICT platforms

like mobile phones, information kiosks, web-portals, electronic markets, etc. for product marketing. ICT platform provides market analysis and enables farmer's confidence in understanding the product demand and increase ability to manage production and supply chains. It also facilitates farmers to directly deal with wholesalers, exporters, and processors instead of small-scale dealers.

ICT platforms help to develop a wide network of contacts which will facilitate farmer to make better decision regarding cheaper resources, supply and demand, price, location, transportation, and logistics (Mathur 2015).

28.8 Conclusion

ICTs can facilitate farmer to access relevant and precise information to improve agricultural methods and production. Information access is critical in farming families, which is conflicting, mainly family-based labor, production of diversified goods, and defined access to productive resources.

ICTs, particularly smart phone applications, facilitate every single farmer about cultivation, management, and marketing of crops. The digital financial services (DFS) revolution have great impact on the family business with the proliferation of smart mobile phones in the remote areas of the world; efforts are strengthening farmers to use innovative mobile technology for better agriculture practices and outcomes. The combination ovgeographic information system) and mobile technology provides specific, accurate, and micro information of soil, water, and nutrients to farmers for decision-making,

enabling ICT connectivity of rural areas with globe through sound policies and strategies and ensuring low-cost and high-quality access to technologies, which will support smooth exchange and distribution of agricultural information to farmers.

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