Review Article

E-Agricultural Concepts for Improving Productivity: A Review

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Abstract: In the modern context, Information and Communications Technology can be simply defined as a collection of technologies that assist in storing, processing, dissemination and communication of data or information or both. Thus it includes technologies like hardware and software peripherals which are connected to the internet with the intention of fulfilling the function of communication and information processing. On the other hand, Agriculture is playing a major role in the economy of developing countries like Sri Lanka. Therefore the need to uplift the development of Agriculture is very important. E-Agriculture is a one of such concept that is playing an important part in the enhancement of processes involved in Agriculture. The major role of ICT in Agriculture is its potentiality to aid a wide access to information that will support knowledge sharing and decision making. The usage of Information and Communication Technology (ICT) in Agriculture is growing day by day. Within the recent past, probably within a decade, the attitude of farmers towards the accession of agricultural information has changed due to the rapid emergence of networking and ICT technologies. With this emergency, the use of ICT in Agriculture is also increasing day by day. Modern information technologies have the impact to potentially increase the agricultural productivity by transferring knowledge and information to agricultural practitioners from the rural communities. Application of ICT in Agriculture ranges from the need of each of these stakeholders who are directly or indirectly involve in Agriculture. Based on these principals, the application of emerging trends in ICT may be applied to almost all the processes involved in Agriculture as well as related to it. Thus, it will always be helpful in both the product efficiency and process efficiency by means of reducing the cost and time in the functionalities involved in Agriculture.
Keywords: E- Agriculture, Information and Communications Technology, Agricultural Productivity, Smart Farming.

INTRODUCTION

The widespread use of ICT and its importance for innovation and Economic growth has been recognized widely [1]. Nowadays application and use of Information and Communication Technologies in day to day life of the people has become common [2]. As we look on from the past, then, only television and radio were the electronic broadcasting technologies that were used to reach the rural communities. However, in recent years, there was a rapid emergence of internet and mobile based technologies [3]. As the result an easy and fast mode has emerged to reach the urban as well as rural communities.

In Sri Lanka, so many strategies have been developed and being executed with the aim of developing the Agriculture sector which is one of the main source of income in the north eastern and some of the north western parts of Sri Lanka. The traditional methods used in Agriculture have been in practiced by farmers for a long period. With the emergence of new technologies and its widespread use, the use of those technologies in Agriculture sector will probably create a positive effect on the growth and development of Agriculture. There are so many ways to incorporate the emerging trends in ICT with Agriculture that will aid on the enhancement of rural development and Agriculture sector via an efficient information and communication processes [4].

E-Agriculture as an emerging field in the intersection of agricultural informatics, agricultural development and entrepreneurship, referring to agricultural services, technology dissemination, and information delivered or enhanced through the Internet and related technologies [5]. The e-Agriculture concept, however, moves even beyond technology to the combination of knowledge and culture which is primarily focusing on the improvement of communication and the process of learning among the

different stakeholders of agricultural sector who are engaging at the different levels [6].

The main source of income of the rural communities in the north eastern Sri Lanka is Agriculture. According to the sources, out of the ten poorest Divisional Secretariats (D.S) divisions identified, nine are from the eastern province of Sri Lanka and the remaining one Syambalnduwa is lying on the border of the eastern province (Source: Census Department Reports, Sri Lanka). Since the main source of income in this area is Agriculture, the poverty reduction can only be done by improving the productivity. Since these are rural communities, people are still following the traditional ways in their production processes. One of the best strategies to overcome this challenge may be educating and introducing the deployment of Information and Communication Technology for the development of agricultural productivity. Hence, there is a need to study the nature of the problem. Objectives of this study was to increase agricultural productivity and decrease the poverty by introducing the new technologies to enhance Agricultural Processes and t**o** educate rural communities about the importance of introducing new technologies in their production process.

APPLICATION OF ICT TOOLS IN AGRICULTURE SECTOR
Geographical Information System
A Geographical Information System (GIS) makes visual comparisons between different types of data possible. It helps to establish relationships between different data sets and is important in the production of maps, and charts and additional information associated with coordinates and time. It helps in the analysis of post-harvest variation in crop yield measures, and provides a holistic view of the production system (GIS Development, 2006). GIS is a computerized data storage and retrieval system, which can be used to manage and analyze spatial data relating crop productivity and agronomic factors. It can integrate all types of information and interface with other decision support tools. GIS can display analyzed information in maps that allow (a) better understanding of interactions among yield, fertility, pests, weeds and other factors and (b) decision-making based on such spatial relationships [4].

Handheld Personal Computer
Handheld Personal Computers are small, light, and robust and have been used for providing access to information, mobile mapping and other data gathering activities [7].

Mobile (Cellular) Phone Applications
The cellular phone has provided market links for farmers and entrepreneurs. Growth in mobile phones has been explosive and now reaches more than a third of the population. This has reduced transaction costs, broadened trade networks and facilitated searches for employment [8]. Bertolini [9] observes that the 'telephone is the only ICT used (if any) by the majority of farmers in Africa'. Some of the respondents in the study considered the cellular phone applications such as the SMS to be one of the most important emerging ICT applications.

Community Radio Stations
Community radio is one of the important tools of ICT that offer farmers and the people a voice and help development of the community. Community radio is owned and operated by a community or members of a community [4]. Radio is an important mechanism for disseminating knowledge and information in different languages and formats [10], especially to poor people [11]. In Zambia, the Radio Farm Forum (RFF), a government initiative, has shown that radio is important in addressing the common needs and problems of resource-deficient rural farmers by giving them an opportunity to listen to a radio discussion programme on agricultural problems and techniques [12].

Internet and Web-Based Applications
The Internet, e-mail, web sites and web-based applications are becoming increasingly important in sharing and in disseminating agricultural information and there are many ongoing web-based application initiatives in worldwide. The FAO and partners are implementing e-Agriculture – aimed at the intersection of agricultural informatics, agricultural development and entrepreneurship, focusing on agricultural services, technology dissemination and information delivered through the internet. E-Agriculture is intended to promote the integration of agricultural stakeholders and technology with multimedia, knowledge and culture, and aims to improve communication and learning processes [13].

Global Positioning System
The Global Positioning System (GPS) is a satellite-based navigation system that can be used to locate positions anywhere on the earth. GPS provides continuous (24 hours/day), real-time, 3- dimensional positioning, navigation and timing worldwide in any weather condition. More recently farmers have gained access to site specific technology though GPS. GPS makes use of a series of satellites that identify the location of farm equipment within a meter of an actual site in the field. The availability of GPS approaches to farming will allow all field-based variables to be tied together. This tool has proven to be the unifying connection among field variables such as weeds, crop yield, soil moisture and remote sensing data [4].

ROLE OF ICT IN AGRONOMIC PRACTICES

Deloitte, *et al.,* [14] reported that, in identifying the ways in which ICT can help Agriculture, it is useful to view the farming life cycle as a three-stage process such as;

- *Pre-cultivation*: Including crop selection, land selection, calendar definition, access to credit, etc.
- *Crop cultivation and harvesting*: Including land preparation and sowing, input management, water management and fertilization, pest management, etc.
- *Post-harvest*: Including marketing, transportation, packaging, food processing, etc.

Crop Variety Selection

This sub-system advises the users about the most suitable variety for his/her plantation based on the specific circumstances of the farm and the user requirements. The domain knowledge of this sub-system contains two models, namely: suggestion, and selection. The inference knowledge contains three inference steps namely: specify, select, and count. The suggestion model contains a relation between the environmental conditions and the suitable varieties that is used by 'specify' inference step to suggest the paddy varieties suitable for the surrounding environments. The selection model contains a relation between user requirements and the corresponding varieties that is used by 'select' inference step to select, the most suitable varieties reflecting the user requirements. The 'count' inference step just counts the specified varieties [15].

Land Use Planning and Management

Among the various ICT tools, Geographic Information Systems (GIS) and Remote Sensing (RS) techniques represent two key tools for land planning and management. GIS offers the opportunity to gather multiple layers of information, drawn from different sources, into one spatial representation. This can be particularly useful in reaching consensus over land planning when users have different values and preferences linked to a given territory. Similarly, RS techniques are a valuable tool for monitoring land resources (e.g. Vegetation, water bodies, etc.), especially when a single institution is in charge of monitoring a wide area [16]. Land Preparation and Planting Land preparation gives specific advises to the user about how to prepare specific land for paddy cultivation, while planting gives the suitable planting methods according to user specific inputs data. The domain model of this subsystem contains two models namely: establishment plan and assignment. The inference knowledge contains three inference steps namely: establish, assign, and select. The establishment plan model contains a relation between farm description and strategic plans that is used by establish inference step to generate a recommended plan and an alternative plans [17].

Soil Quality Assessment

Assessment of soil quality can be done in farm level and also in regional level. In regional level it can be done based on soil, climate and land uses. Some useful technologies aid to understand nature of soil and its problems due to management practices. ICTs have developed several folds in the recent past. Soil quality assessment is being done with some useful technologies, like remote sensing. Remote sensing is a process that collects data about an object from a remote location [4].

Water Management Technology

Information and Communication Technologies (ICT) supported Irrigation is demonstrated here as "application of water to a tree based on monitoring each tree's needs to optimize its yield". ICT monitors each tree's real time water and nutrient consumption and needs. The system in turn remotely activates an ongoing, optimized supply of water and nutrients suited to the current climate, soil conditions and the farmer's production plan [18]. ICT is one of the most effective means in upgrading of land and water management and increasing food production. Since the middle of the 20th century, automation and ICT are increasingly employed in water supply and irrigation management. Outstanding contribution to water use efficiency was achieved mainly in countries that are exposed to strict water scarcity and benefit of high technology development. Adoption of ICT and automation enhanced water use efficiency in irrigation by 10% - 50%, increased yield per land and water unit by 20% - 100% and improved produce quality [19]. In water supply plants and networks, ICT and automation facilitated optimization of pressure regime in delivery networks, savings of water and energy and the invoicing of consumers according to their actual water consumption. Conceptually, ICT and automation triggered the adoption of volumetric approach in water application. These achievements enabled expansion of the irrigated area, increased food production and higher profits for farmers [19].

Fertilizer Management

Fertilizers, pesticides and quality of yield were the major factors of concern in agriculture. Most of the time the expertise were required to analyze the problems and which may be time consuming and costlier issue in developing countries. Image processing was one of the tools which can be applied to measure the parameters related to agronomy with accuracy and economy. Applications of image processing in agriculture can be broadly classified in two categories:

first one depends upon the imaging techniques and second one based on applications [20].

Identification of Nutrient Deficiencies

The software has revolutionized the method to find nitrogen content in Maize leaves. Approach was to turn the manual process to a software application using image processing. Image of the Maize leaf is captured and preprocessed to remove the noise of source image. The color and texture characters of maize leave are extracted. Color characteristics analyzed using the RGB and the HSV model. A relationship between extracted features and nitrogen content was developed [21]. A new technique based upon a commercially available hand-held scanner which overcomes the problems. They proposed algorithm to determine chlorophyll content, which non-linearly maps the normalized value of G, with respect to R and B, using a Logarithmic sigmoid transfer functions [22]. The fertilization system gives fertilization schedule, which includes fertilizer type, fertilizer quantity, fertilizer name, and application time The domain model of fertilization subsystems consists of three models namely: 'determining fertilization requirements', 'fertilization selection', and 'instantiation' [17].

Pest and Disease Management

Latha *et al.,* [23] developed a method by which we can detect weed by using image processing. Then we gave the input of the weed blocks to the automatic sprayer which sprays only in these blocks. By doing so we can reduce the usage of weedicides, thus saving the environment. Rastogi, *et al.,* [24] presented scenario of image processing and computer vision in agriculture field as innovative and important problem solving techniques since these techniques are more accurate and quicker than manual methods. For solving agricultural image processing problems in efficient and effective way authors of this paper also suggested to use artificial neural network for agricultural plant leaf disease recognition and classification. After disease classification, grading of disease is also done by calculating amount of infected area of leaf because of disease by using fuzzy logic.

Table 1: Pest control Mechanisms in literature using Wireless Sensor Network (WSN)

Authors	Analysis of Symptoms	Identification of Pests	Management Pest
Datir, [25]	Real times system that detect Downy Mildew pest based on weather data.	No identification mechanism.	Spraying of pesticides automatically if disease probability is Severed.
Srivastav, [26]	Continuously observe the noise level being collected by the various sensors and comparator that is set to a particular threshold level.	No identification mechanism for specifying pest.	An alarm signal to turn inform the operator and farmer can then take the necessary measures to spray insecticides.

Harvesting and Post-Harvest Technology
Application of Image processing in Grading Agricultural Products

Computer vision system offers quantitative method for estimation of morphological parameters and quality of agricultural products to obtain quick and more accurate results [27] and [28]. [29] Naik and Patel proposed a generalized model for speedy, inexpensive, safe, accurate and automated fruit sorting. They surveyed list of various features and algorithm's accuracy in grading fruits viz. apples, tomatoes, mango, strawberry, date, cherries, orange, and lemon.

Harvest Automation

At the moment, mangoes are mainly hand-picked or plucked with a harvester. These methods are tiresome and involve human capital. Also mangoes can be harvested with mechanical vibrators, but they are power driven, inefficient and cause heavy loss of unripe fruits. During harvesting, the latex trickles down the fruit surface from the point of detachment imparting a shabby appearance to it upon storage. To avoid these problems a solution with a robotic arm attached hexacopter programmed using HSV color detection algorithm [30], Stereo vision [31] with little modification can be employed to fulfil the purpose of safe and effective mango harvesting. Over the past two decades, yield monitors have been one of the most significant developments in harvesting technology. Manufacturers continue to improve these systems to provide yield and moisture measurements to the operator during harvesting operations as well as computer software for post-processing. Many producers utilize using automatic steering systems on harvesters to improve field efficiency. Most systems rely on GPS for guidance, however, systems have been developed which sense the stalks at the header to improve automated steering while harvesting corn [32].

ROLE OF ICT IN LIVESTOCK PRODUCTION

Farmer participation and buy-in Due to the livestock management activities that farmers are able to enter, they willingly participate on a daily basis to update the system with: New birth records and animal

registrations; Regular weight recordings; Regular procedure or treatment records; Mating and breeding records; Pregnancy determination records; Movement records within their own herds (mobs / flocks etc.); Deaths or losses of animals; Early warning mechanism whereby the stock theft department could be notified, more quickly; Contribute to livestock statistics; Contribute to the national statistics of reproduction and production; Use more functions of the system to improve their livestock operations (multi-species); Grow with the additional functionalities (become more self-reliant rather than spoon-fed as with certain systems); Allows more public–private interactions vs purely a dominant public sector service[14].

ROLE OF ICT IN AGRO-METEOROLOGICAL KNOWLEDGE AND WEATHER FORECASTING

A common problem in developing countries is the lack of integrated means of processing and delivering agro meteorological information to small scale farmers. Even with improved agricultural technology and improved level of farm inputs the agricultural sectors of these countries operate below their potential level owing to the challenges imposed by the marked weather and climate variability [33]. The above model shows the flow of information from various sources such as the farmers, the agricultural research institutes, meteorological stations and agricultural extension officers. The knowledge from these sources is brought together in the Knowledge Base (KB). This is then processed by the inference engine with some the algorithms as shown in the diagram. The system can perform various actions as shown. Small scale farmers can then interact with the system through short message services (SMS). The farmers can also obtain information through mass media [34].

Weather Forecasting

The International Center for Agricultural Research in the Dry Areas (ICARDA) uses weather forecasting ICT tools, including meteorological stations and global information systems (GIS), so that scientists can collect and elaborate data to address the challenges that rural communities in dry areas face from the climatic stresses of aridity, drought, heat and cold. Weather stations are used to collect daily climatic data (for example precipitation, air temperature, and land temperature) that are analyzed by researchers to determine timely planting, crop development, climatic risk assessment and water-use efficiency practices [2]. ICTs in Weather Forecasting Weather plays an important role in agricultural production. It has a profound influence on the growth, development and yields of a crop, incidence of pests and diseases, water needs and fertilizer requirements in terms of differences in nutrient mobilization due to water stresses and

timeliness and effectiveness of prophylactic and cultural operations on crops. ICT has a crucial role to play in all links of the chain, from detection to modelling and forecasting to advance warning and localization [4].

ICT TOOLS FOR CLIMATE CHANGE AND RISK MANAGEMENT

In the intersection between climate change and Agriculture there are several tools available, because of the high number of crops and because of the complexity of replicating the same conditions across different regions. Every tool allows analyzing different processes of the agricultural sector, from local crop modelling under climate change conditions to the management of economic impacts of climate change on the Agriculture sector (soil value variations, demand and supply, production, etc.), and so on. As many tools exist, it's interesting to focus on their common aspects rather than their specific peculiarities [4]. It imperative to know the extent to which ICTs are contributing to climate change before we can use them as a tool for combating climate change otherwise we end drawing circles in a desert. Concerning this issue, ITU [35] indicates that ICTs are far from innocent in contributing to climate change and the major contribution of ICTs to climate change comes from the proliferation of user devices, all of which need power and radiate heat. Information and communication technologies play an important role in significantly mitigating climate change and these technologies can be used in both developed and developing countries even though developing nations lack the much needed information and communication technology infrastructure when it comes to mitigating climate change. On some of the solutions that can used to mitigate climate change, Ospina and Heeks [36] suggest the use ICTs in controlling carbon dioxide emissions through smart grids, dematerialization or intelligent transport systems and buildings.

CONSTRAINTS AND ISSUES OF IMPLEMENTING THE ICT

The uses of computers in agriculture do have some real constraints such as, the lack of hardware and software infrastructure, training and skills, and research priorities. However, once these are overcome, the use of computers goes past automation and software application. In fact, it could be instrumental in bridging the digital divide and bringing prosperity to agriculturists not only in the United States, but also in other developing and emerging economies around the world [37].

Key issues of implementing the ICT in agriculture. Specifics comments and insights were collated under the following groupings: [38]
1. People/Community Issues.
2. Training and Research.

3. Political Issues.
4. Adoption Barriers and their alleviation

RECOMMENDATIONS

The recommendations of the adoption of ICT enabled Information Systems for Agriculture Development is straightforward. Some of those are:

- Focus and consolidate all national and public ICT policies, budgets and investments for agriculture and rural sector.
- Involve all ICT stake holders in setting of the ICT R&D priorities and the measures needed to attain the successful transfer of these technologies.
- Strengthen the "Agriculture ICT" curriculums in the formal and informal educational and training programs.
- Focus ICT training for teachers/researchers/extension and farmers on practical implementations.
- Link village knowledge centres and agriclinics to farmer's needs. Where possible involve unemployed university graduates in this activity.

CONCLUSIONS

The primary challenge confronted in Agriculture sector is the need for increased production with the increasing population and decreasing natural resources needed for production. The key factors that impact on this are the scarcity of water, declining of the soil fertility level, effects of climate changes and the decreasing fertile lands that were utilized in cultivation in the past, due to rapid urbanization. However, this rapidly growing demand and the need for high quality products provide opportunities for the improvement of the livelihood of the rural communities. Therefore the Agriculture sector has to be enhanced with the aim of increased productivity that will lead to combat both rural and urban poverty and foster sustainable development through this. Based on this opportunity, the people engaged in Agriculture are in need of producing quality products with quality standards and regulations which will yield high. One of the best strategies to achieve this is the application and utilization of the rapid growing technologies in Information and Communication Technology. Although this is a new phenomenon, there are enough evidences to prove that the contribution of ICT to Agriculture has led to poverty alleviation and development in the livelihood of the stakeholders involved in Agriculture. And probably the appropriate use of ICT at different levels of agricultural processes will lead to betterment in the efficiency and increased productivity. If the needs and importance of ICT to Agriculture is realized and deployed at proper places, they will be the most powerful tools that will lead to both economic and social empowerment.

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