

Review

An e-farming framework for sustainable agricultural development in Nigeria

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The concept of e-farming has been described as the integration and utilization of information technology (IT) in farming related operations. Farming is a traditional trade and operations involved in production have largely remained habitual in nature. Traditional methods of farming incorporated little to no use of IT, despite its potential for dramatically increasing operations efficiency. The incorporation of IT into farming involves the integration of diverse technologies, with each capable of positively impacting the efficiency of farming activities, thereby promoting sustainable agricultural practice. This paper reviews some proposed e-agriculture frameworks and presents a framework for the implementation of an e-farming system that can be used in aiding sustainable agricultural/farming practices.

Key words: E-farming, information and communication technology (ICT) in Agriculture, sustainable agriculture.

INTRODUCTION

The introduction of the Internet and online services has introduced new methods of carrying out many activities, which can be described as "e-computing". These include e-commerce; e-banking; e-learning; e-government/e-governance; e-voting etc. Corresponding to this, is also the innovative porting of such applications to mobile devices such as smart phones and Tablet devices called "m-computing" hence m-commerce, m-banking etc. These applications have tremendously changed the way we do things. The application of these concepts to traditional farming and agricultural activities can also be described as e-farming, e-agriculture (hence m-farming and m-agriculture).

The term "e-Farming" has been described as the integration and utilization of information technology in farming related operations (Scott's Blog, 2006). The incorporation of information technology into farming, involves the integration of diverse technologies, with each

capable of positively impacting the efficiency of farming activities. Because farming is a traditional trade, operations involved in production have largely remained habitual in nature. One of the main factors that have hindered the implementation of IT strategies in farming has been the general location of farms in rural areas. Access to technology like computers and the internet is generally lower in rural areas as well as wireless network availability; even electricity has proved to be unreliable in such areas (Scott's Blog, 2006).

E-Agriculture has been described as an emerging field focusing on the enhancement of agricultural and rural development through improved information and communication processes. More specifically, e-Agriculture involves the conceptualization, design, development, evaluation and application of innovative ways to use information and communication technologies in the rural domain, with a primary focus on agriculture (Wikipedia,

2013a). It is one of the action lines identified in the declaration and plan of action of the World Summit on Information Society (WSIS). The "Tunis Agenda for the Information Society," published on 18 November 2005, emphasizes the leading facilitating roles that the UN agencies need to play in the implementation of the Geneva Plan of Action. The Food and Agriculture Organization of the United Nations (FAO, 2013) has been assigned the responsibility of organizing activities related to the action line under C.7 ICT Applications on E-Agriculture (Wikipedia, 2013b).

The main phases of the agriculture industry are: crop cultivation; water management, fertilizer application; pest management; harvesting; post-harvest handling, transportation of food/food products; packaging; food preservation; food processing/value addition; food quality management; food safety; food storage and food marketing; also, all stakeholders of agricultural industry need information and knowledge about these phases to manage them efficiently. Any system applied for acquiring information and knowledge for making decisions in any industry should deliver accurate, complete and concise information on time. The information provided by the system must be in a user-friendly form, cost-effective and well protected from unauthorized accesses (Wikipedia, 2013a). Some suggested use of IT in farming activities include: mapping of natural resources; forecasting weather conditions; making information available on pest outbreaks; presenting information to local communities towards helping them manage their resources; creating business opportunities by providing agricultural market information for farmers and traders; speeding up application procedures in agricultural credit programs; protecting natural resources such as fish stocks and forest resources from illegal poachers and loggers; making information more easily available and enabling communication and knowledge exchange in online communities (Adegbite, 2006).

This paper presents a review of some e-agriculture frameworks and proposes a framework for the implementation of an e-farming system that can be used in aiding sustainable farming practices. Sustainable development refers to a mode of human development in which resource use aims to meet human needs while preserving the environment such that these needs can be met not only in the present, but also for generations to come. The term 'sustainable development' was first used by the Brundtland Commission report released by the United Nations in 1987 (Wikipedia, 2013b). The Brundtland Commission's brief definition of sustainable development is the "ability to make development sustainable- to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (Kates et al., 2005). It ties together concern for the carrying capacity of natural systems with the social challenges faced by humanity. It

has also been defined as, consisting of environmentally friendly methods of farming that allow the production of crops or livestock without damage to human or natural systems. More specifically, it might be said to include preventing adverse effects to soil, water, biodiversity, surrounding or downstream resources as well as to those working or living on the farms or in neighboring areas (Wikipedia, 2013).

AGRICULTURAL EXTENSION SERVICE

The proposed e-farming framework which is intended primarily to assist the farmer by making available the needed information for challenges faced in his activities is based on the automation of the agricultural extension worker (AEW) duties. According to Bokor (2005) agricultural extension is an applied behavioral science, which involves bringing about desirable changes in the behavioral complex of the farming community, usually through various strategies and programs of change, by applying latest scientific and technological innovation. The system of extension was first used in the United States of America (USA) to connote the "extension" of scientific agricultural production knowledge, from the agricultural colleges to the farming community through the process of informal education system (the word "extension meaning "reaching out"). The objectives of agricultural extension as proposed by Bokor, (2005) are:

- (1) Dissemination of the information relating to advanced technology in agricultural production, which includes usage of improved seeds and methods of chemical fertilizers.
 - (2) Application of advanced scientific knowledge to the farm and home of the rural people.
 - (3) Scientific management of land based farming such as horticulture, sericulture, dairying, poultry etc, by the farming community.
 - (4) Overall improvement of the quality of life of the rural people within the framework of the national economic and social policies as a whole.
- The essential role of the AEW is to create an effective learning situation (Bokor, 2005), and most effective learning situations require the following elements:
- (1) An Instructor, who is a village level worker with the information on scientific knowledge.
 - (2) The Learners, who are the farmers and village youths.
 - (3) Subject matter, which is the advanced scientific knowledge such as the practices of cultivation of hybrid varieties of seeds; fertilizers; its planned use; pesticides; improved implements; land and water management systems etc.
 - (4) Teaching aids such as charts, models, samples, slides, film shows flip charts etc.
 - (5) Physical facilities which includes places where farmers could sit around or go around for practical studies.

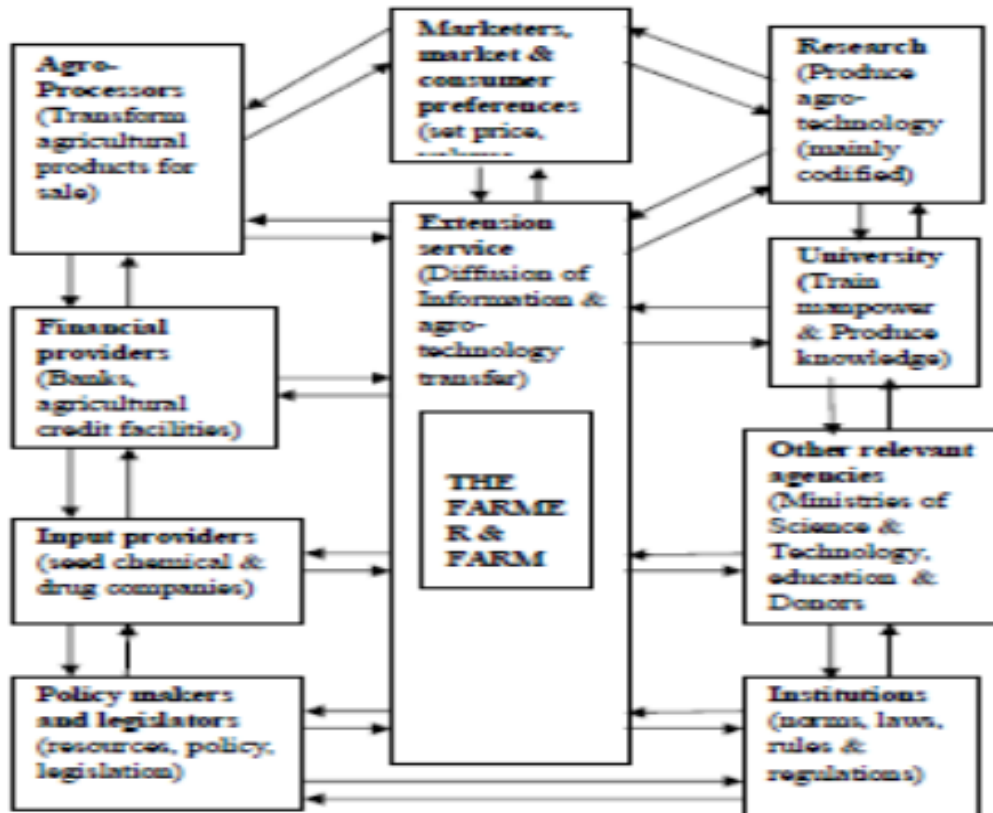


Figure 1. Linkages between key actors in extension system (Ovwigho (2009).

The following key actors in the extension system have been identified (Ovwigho, 2009):

- (1) Farms - small, medium and large;
- (2) Input providers and services (such as seed or feed, agro-chemicals, machinery/ equipment, transport, credit, insurance);
- (3) Agro-processing enterprises (small, medium or large);
- (4) Marketers, markets and consumers; wholesalers, retailers, super-markets, commodity boards;
- (5) Policy makers and legislators; organizations that influence policy and provide resources.
- (6) Agencies such as: ministries of agriculture, science & technology, education, industry and trade, finance and regulatory agencies (IP, ISO);
- (7) Research organizations (national, regional, international whether public, quasi-governmental, private);
- (8) Training institutions- universities and other institutions of higher learning;
- (9) Financial providers and business institutions- outfits that provide business services such as feasibility studies and business plans and help in the development of marketing strategy;
- (10) Extension service- organizations that provide information and agro-technology transfer services; agricultural extension workers, agricultural subject

specialist etc.

- (11) Farmers- farmers' associations, cooperatives or other non-governmental organizations (public, private, quasi-governmental) that facilitate networking;

Figure 1 (Ovwigho, 2009) shows the linkages between the key actors in the extension service system. In practice, AEWs present information that may positively impact local farmers and livestock producers (Kramer, 2013). They travel throughout their region or district to provide the latest industry information to farmers, community and youth groups. They may present information on scientific advances, farm management, marketing, production, and other topics that are relevant to agricultural businesses operating in their area. The agents must be familiar with the types of agricultural operations that are taking place in their territory. The AEWs may have to travel a lot, especially if the territory assigned is large and may have to visit farms, hatcheries, dairies, orchards, aquacultural facilities and a variety of other agricultural business locations during the course of the day. AEWs may also be required to attend a variety of community activities such as conventions, fairs, camps etc. They may be required to work evenings and weekends as their situation demands. The AEWs are usually employed or affiliated with government agencies

at federal, state or local levels or with non-governmental agencies and research organizations (Kramer, 2013).

Apart from the routine difficulties faced in daily work in rural areas by AEWs in developing countries, the challenges that most agricultural extension services face are mostly of technological and logistic nature (FAO Corporate Document Repository, 2013). Some examples are insect pest invasions, outbreak of serious diseases, locust attacks, severe climatic effects, natural disasters, intensive campaigns for an increase in agricultural production and health related issues like risk of HIV/AIDS contraction. Other extension services problems (Bokor, 2005) include: single line of command, dilution of efforts by assigning too many jobs to the workers, lack of vehicles (logistic support), lack of regular training to update the knowledge of the workers, lack of research findings appropriate to the condition of the farmers' fields, low status and morale of extension staff and duplication of services by various departments staff (many agencies involved at different level but with a lack of coordination among them to enable them solve problems).

AGRICULTURAL EXTENSION SERVICE IN NIGERIA

According to Madukwe (2008) the beginning of recognizable agricultural extension practices in Nigeria started in 1954 with the establishment of three regional ministries of agriculture: one in the east, north and west. Each regional ministry of agriculture had a research station, a school of agriculture, and a field service division. The extension personnel trained by the school working under the field service division were deployed to teach farmers, innovative farming techniques. The Federal Department of Agricultural Research (FDAR) was retained, while extension work remained a regional responsibility. The research findings of the federal research stations under this arrangement were to be transmitted through regional ministries responsible for agriculture and natural resources.

The regionalization of agriculture and the consequent separation of research and extension reduced the focus on extension and laid the basis for the enduring weak linkages between research and extension. The official farm policy, even after independence concentrated attention on export commodities, in the belief that food production activities (which bordered on the indigenous knowledge and welfare of the farmers) could take care of themselves without any governmental intervention. The agricultural practices of the regional governments aimed at the modification of traditional farming methods. This was due to the weak capacity inherent in traditional practices to produce food to meet the needs of the rising population and urbanization. The federal ministry of agriculture and natural resources set up in the mid 60's had its structure reflected in the state ministries that came on board with the creation of states in the late 60's.

Agricultural extension under the ministry was a relatively small unit compared to other sections in the ministry. The roles of transferring and disseminating agricultural technologies in the ministry were therefore bugged with so many problems. The problems were lack of staff, weak linkages with agricultural research, poor staff mobility, inadequate qualified staff, and weak financial support (Madukwe, 2008).

It has been reported that there have been many government policies, programs and institutions established over the years by government in the agricultural sector each with its own agricultural extension component. Some extension methods that have been used include: conventional approach, community type extension approach, integrated rural development approach, integrated rural development extension approach, farming system research; extension approach and university organized extension system (Adegbite, 2012); despite all these, an ineffective extension service has been singled out to be the prime factor for inability of agricultural practices in Nigeria to solve our food crisis. This view is also supported by Ovwigho (2009); Chikwendu (2001), Koyenikan et al. (2012) and Adegbola and Bamishaiye (2013).

Some of the problems identified in Ovwigho (2009) were that the conventional extension system practiced in Nigeria cannot thrive well in a democracy; while the University Extension System in Nigeria which was used to promote the National Accelerated Food Production Program (NAFPP) in the 1970s involved implementing agricultural extension programs in farming communities around university locations. The system suffered a lot of set-backs which includes inadequately trained extension personnel, complicated extension packages, lack of co-ordination and insufficient funds. Another problem is from foreign agencies that fund extension programs; they usually have a preferred template which they impose on the local extension services without making allowances for cultural diversities that exist locally.

The most revolutionized extension system was the agricultural development projects (ADPs) extension system, otherwise known as Training and Visit Extension system. It made an appreciable impact on agricultural and rural development before the withdrawal of the World Bank loan. It was also noted that the T & V system assumed that a functioning research apparatus was already in place and this was not the case. The programs which served as links between research institutes and farmers were no longer in existence and participatory research extension system has not been fully practiced in Nigeria.

REVIEW OF SOME E-AGRICULTURE FRAMEWORKS

In Reddy (2004) a framework for a cost-effective agricultural information dissemination system (AgrIDS) to

disseminate expert agriculture knowledge to the farming community to improve crop productivity was proposed. The proposed system aims to improve agricultural productivity by disseminating fresh expert agricultural advice to the farmers both in a timely and personalized manner by using both the available agricultural technology related to the crop and the latest information about the crop situation received through the internet in the forms of text and images. The AgrIDS is made up of four parts:

- (1) Farmers
- (2) Coordinators
- (3) Agricultural experts and
- (4) Agricultural Information System (AIS).

All parts are connected through the internet. The farmers are the end users of the system; a coordinator is associated with a group of farmers and possesses the agricultural experience and basic data entry skills. He visits the crop fields of the farmers associated with him and enters the relevant data through text based forms and photographs into the system. When the system interprets the result, the coordinator contacts the concerned farmer and explains the personalized advice to him in a timely manner.

The Agricultural experts are agricultural scientists who give appropriate recommendation by studying the agricultural information system. They use research data, soil data, historical data, and other information to generate appropriate recommendation and store the result in the system. The Agricultural Information System is a computer based information system which contains all the relevant information. For example, it contains the details of the farmer with corresponding soil and crop information. It also contains information on the status of the crop, which is sent in the form of images and text by the coordinator. From the available agricultural technology, the details of various crops (such as the level of pest resistance, water requirement, and so on) are maintained. Each coordinator is associated with a group of farmers. The farmers register into the system by supplying the relevant information including soil data, water resources, and capital availability through the coordinator.

Also, a coordinator visits the crop on a daily or weekly basis and sends the crop details in the form of text and digital photographs through the internet. By accessing the soil data, farmer's details, crop database, and the information sent by the coordinators; the agricultural experts prepare the advice. The advice contains the steps the farmer should take towards improving crop productivity. The agricultural expert prepares the advice (which will be translated to the target language) and store it in the system. The coordinators get the advice by accessing the system through the internet. The coordinator then explains the advice to the farmer gets

the feedback and enters it into the system through via the internet.

In Bachu et al. (2006) the development and testing of an agricultural information system based on AgrIDS called eSagu ("Sagu" means cultivation in Telugu language) is presented. Some of the advantages the system is said to have over existing traditional system of extension are availability of a team of diversified experts at a single place; conservation of time; money and energy; enabling correct diagnosis of the problem; strong database to support decision-making; zooming facility which adds an extra dimension; accountability to the farmer; capacitating of rural livelihoods and employment generation; documentation of success stories and content development; and feedback which helps to evaluate and improve the performance etc.

In Armstrong and Diepeveen (2008), a farmer decision support framework (FDSF), which is a framework which has been created to assist growers in their decision making was presented. The delivery of cropping information collected from various sources such as paper-based publications, websites, agricultural advisors and other farmers in the Western Australian agriculture sector is through government and private consultants. Farmers value the customized information on crop performance provided for their local situation. However, acquiring this information and distributing it locally is often a challenge.

Consequently, information websites were established by breeding and seed companies with information about available crop varieties, enabling growers to access this information. The state government's Department of Agriculture and Food (DAFWA) provides Western Australian growers with a website which offers downloadable reports and the ability to compare varieties. Traditional growers usually seek information from standardized crop variety publications which are provided free to each grower. These growers also seek information from agricultural advisors through organized field days, who have limited skill sets in retrieving information using internet and other technologies. With the greater penetration of the internet into country areas, innovative growers are using computers much more to seek information and conduct their businesses. The DAFWA has provided Microsoft Excel based decision-aid systems which allow farmers to ask "what-if" questions for these recommended varieties to enable them make more informed decisions. The problem with this method of delivery is the program needs to be downloaded regularly in-order to get the latest information.

The FDSF takes information needed by farmers and utilizes processes that deliver this critical information. Information is collected from disparate sources, captured and validated according to defined rules. It is then processed and integrated by data mining tools and technologies into a format that can be readily used by the farmer. The FDSF was created using Unified Modeling

Language. Three types of participants are central to the information provision process; they are information generators, facilitators and users. Information generators make available the information to the information facilitators who receive, filter and process the information in a customizable format for the users. The framework may be applied to specific scenarios for decision making. It can also be used as a supportive tool, and to establish where new technologies, such as the use of internet and data mining can fit into the process.

In AEWSW (2013) it was reported that with the growth and adoption of Information and Communication Technology (ICT) in Kenya, as of 2009 World Bank statistics showed that 48.7% of the population owned and operated a mobile phone and 10% had Internet access. This has allowed the use of ICT tools in disseminating agricultural knowledge and technology. An example is the SMS-based services which offers farmers timely information (like prices), which they no longer have to wait for newspapers to publish. There is also the MUMIAS Information and Welfare Advances Project which in 2011 tested the effectiveness of sending cell phone messages to a subset of farmers on recommended agronomic practices such as weeding, rash-lining, and gapping. Also KACE launched an SMS-based Information Service (SokoSMS64) for farmers for receiving market prices in various market centers around the country through mobile phones. There is also the Infonet Biovision, a web-based information platform offering trainers, extension workers and farmers in East Africa a quick access to up-to-date and locally relevant information.

FRAMEWORK for E-FARMING IMPLEMENTATION IN NIGERIA

From the review of the practice of agricultural extension service in the country, it is apparent that the whole system needs a system re-engineering to make it effective. It has been said that the computerization of an inefficient system only magnifies its inefficiency. The automation of the processes that constitute the major activities will not succeed unless this system re-engineering is carried out first. The proposed e-farming framework will compliment but not replace the role of the extension services in the country.

Agricultural extension focuses on the dissemination of information. This information is supposed to be from current research activities, agricultural product specialist and from the experience of the extension workers on the field. If the information is not available, or if available and not in a form that is amenable to being brought to the end user then the process stalls at this point. Therefore a key component of the automation process is the creation of a data store which will be a repository for this information. The agricultural sector will benefit immensely from the implementation of agricultural data marts and/or data

warehouse(s) which will serve as the knowledge base for the automation process.

Current statistics according to Nigerian Communications Commission (NCC), posted by Channels TV (May, 2013) shows that the number of people accessing the internet over GSM mobile networks in Nigeria has now reached 32.3 million. Between the end of 2012 and February 2013, the number of people logging on to the worldwide web via their mobile device has increased from 30.9 million to 32.3. Of this number MTN Nigeria had 21.31 million users (65.9 per cent market share), Airtel Nigeria had 5.87 million users (18.16 per cent market share), Etisalat had 4.35 million users (13.47 per cent market share) and Glo had 801,218 users (2.48 per cent market share). This implies that Decision Support Software (DSS) applications running on both Internet/mobile telephony platforms using Web 2.0 tools (which will enable two-way interactions) and other GSM services such as the sms (short message service) can be used for the dissemination of information to both farmers and extension workers. There is also the need for close cooperation between agricultural professional and IT professionals in the development of the software applications required.

The proposed e-farming framework will have the following participants shown in Figure 2:

- (1) The Farmer
- (2) The Agricultural Extension Worker (AEW)
- (3) Thee Help Desk officer(s), who are trained extension services officers with enough experience to respond to farmers and AEWs queries
- (3) The Application Server(s), which host the agricultural decision support systems (DSS), web portals, SMS (short message service) and WAP (wireless application protocol) applications that can be consulted by users of the system. It is noted that nearly all entry level (cheap) phones being sold nowadays have wap browsers and all GSM networks have SMS as a standard service on their networks.

The information disseminated to the farmers are compiled from the input providers, agro-processing enterprises, marketers, markets and consumers, policy makers, legislators, agencies, research organizations, training institutions, financial providers and business institutions herein referred to as Information Providers (IP), in both structured and un-structured format, reformatted and uploaded to the data marts or data warehouse(s) at the Local or State level. This information can be accessed directly by the farmers (depending on their level of education) or through the agricultural extension worker, through application servers/internet at the Local or State level; and agricultural help desk centers set up at each LGA or State level by telephone or SMS based applications.

The Help desk officers can also have access to the

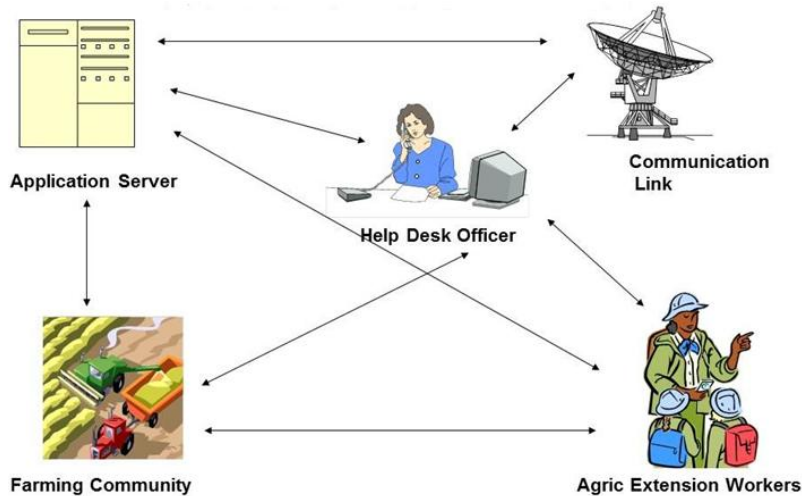


Figure 2. E-farming framework.



Figure 3. Main screen.



Figure 4. Main Menu screen.

Application Servers and the Internet applications when information is required from them to be passed as response to queries by either the farmers or the AEWs. A bottom-up modeling system is proposed. Using this model the farmer and his farm forms the core of the system. The farm/farmer resides in a particular locality which is part of a LGA in the State. The AEW who has been posted to that area will have direct contact with both the farmer in his locality and the LGA or State office either physically or through the computing/mobile (Internet or WAP based) platforms. The farmer also using

his computing/mobile platform can have access to the AEW or the LGA or State office application server or Help Desk officer.

Figures 3 to 5 show screenshots of a demo WAP based e-farming application running in a smart phone simulator. The WAP based application can store and retrieve information directly from agricultural databases, data marts or data warehouses using DSS applications. The various LGAs or States can also be linked to form a nationwide network. Farmers who are using the system should be able to get timely advice on: scheduling of crop

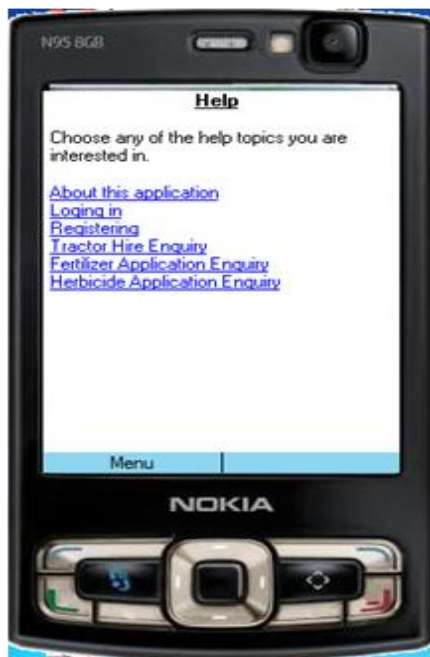


Figure 5. Help screen

activities; choice of the crops to be based on soil tests; tractor hire service; land management; pest warning and control; fertilizer use in terms of amount and timing; information on cost, profit, and risk factors for various crops; weather information; marketing and strategic planning information. The system also serves as a medium for accessing software applications, web portals, WAP and SMS application software for farmer enumeration/registration for distribution of farm inputs, application for special loan facilities etc.

CONCLUSION

In this paper a framework for the application of e-farming has been proposed. The framework will build on existing IT infrastructure such as access to the Internet, the GSM service and web browsing using mobile devices. In some cases new infrastructural facilities will also be needed for the development of agricultural databases, data marts and data warehouses. Also, software applications (WAP applications) using Web 2.0 tools that can provide two-way interactions that can be ported onto mobile devices and web portals for disseminating information to farmers and agricultural extension workers will have to be developed.

The increasing amount of IT education and the increasing spread of wireless communication technology will also positively affect the introduction of e-farming techniques in the farming sector. Farmer literacy level problems can initially be overcome since the framework proposed is meant to compliment and replace the

extension service. On the role of government, the extension services at all levels should be empowered to do their work. Adequate provision of logistic support, training opportunities and provision of funds for the development of IT infrastructure is needed, while the continuity of on-going extension programs should be ensured. Further work will focus on the prototype implementation of an e-farming system.

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