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Technology Assisted Knowledge Agriculture for Sustainable Development Goals

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Abstract

The most challenging part of the 2030 Agenda for Sustainable Development (SDGs) of ending poverty in "all its form from the planet" is to provide food to 1.45 billion poor people including 689 million, children living in 103 countries. Our finding shows that most of farming communities don't possess knowledge and skill to use new methods of food and livestock production. The farmers in many countries are uneducated and depend upon traditional myths and methods for predicting the season and cultivation. They are deprived of the benefits of the modern researches and largely ignorant of their roles in preventing climate change and sustaining the planet's natural resources. Failure of states, its national economic and banking institutions, high level of corruption, poor implementation of policies, absence of proper marketing facilities, profit making behavior of middle men, lack of finances with the farmers are other key factors. They need to be skilled in areas such as precision farming, proper and optimal use of seeds and fertilizers, availing the benefits of the government policies and banking institutions, understanding the methods for selling their products profitably in the market, apart from the new tools and technology to enhance their production. In our studies, we found that it is possible only by use of ICT technology. Further, our study found that their interest in sustaining planet's natural resources, stopping the use of chemical fertilizers, growing organic food and maintaining climate requires sustained efforts in attitudinal changes. Execution of technology assisted skill development projects in part of India and Ethiopia and their sustained monitoring for many years by us showed that the farmers get motivated and use the new technology when they find the benefits in terms of improved yield and financial gains. They especially get encouraged to use technology to find solutions when they face draught, flood, pest/worm attack and for availing benefit of government schemes. The paper further propounds that the use of emerging technologies for smart farming needs a new radical approach to R&D and farmer's education.

Keywords: Developing countries; SDGs; Poverty alleviation; Skilling farmers; Smart farming; Agriculture extension

Introduction

The 17 Sustainable Development Goals (SDGs) seek to address issues relating to hunger, poverty alleviation, democratic governance and peace building, climate change and disaster risk, and economic inequality [1]. The global population is growing at a fast rate. The population has grown from 1.8 billion in 1915 to 7.5 billion in 2017, a fourfold population increase during a century. The world population will increase by 31 percent from estimated present of 7.5 billion to 9.8 billion in 2050 [2]. 1.45 billion people living in 103 countries are poor; 706 million (689 mn-48% children) live in extreme poverty and suffer from severe malnutrition and stenting [3]. Global child poverty is strikingly high. 11 per cent of the global population which converts to 815 mn population was hungry and suffered from malnutrition [4]. This is the first time in over a decade that the number of hungry people was found rising. Out of this number, "20 million people are at immediate risk of dying of hunger; Yemen 10 million, Nigeria (North East) 4-6 million, South Sudan 4-6 million, and Somalia 2-4 million" [5]. In addition, 18 countries are facing acute food shortages.

Agriculture is a profession that involves growing food and raising livestock (animal husbandry) on soil, soil-less medium (hydroponics), or in water (aquaculture). The food production involves growing crops, plants, flowers (floriculture) or maintaining forest (forestry). This raising of livestock includes rearing of pet animals such as cows, buffaloes, goats or farming of fish, aquatic plants and organisms (aquaculture). Asia is home to 4.5 billion population. Out of this 50 to 90 per cent population depends upon agriculture. This includes 70-95% small farmers [6]. The farming community depends on agriculture income for their livelihood. Further, out of a billion farmers in the world, about 95 million live in Asia and Africa as per 2011 data [7], which is also home to 805 million hungry people (Asia-520 million, Africa-243 million and Latin America (42 million); the total hungry people in the world are 825. The food and livestock production is not able to sustain even the present population. The estimated food requirement by 2050 is likely to increase by "59% to 98%" [8-13]. As such, a phenomenal increase in agriculture production will be the most important factor in achieving the SDGs that aim to ensure food for all, good health facilities, gender equality and an environment to sustain the future generations. A knowledge agriculture in Asian and African countries with skilled farmers capable of using the modern technological tools is crucial to achieve the desired goals aimed in SDGs.

The farmers in many countries are uneducated and depend upon traditional myths and methods for predicting the season and cultivation. They are deprived of the benefits of the modern researches and technology. Failure of institutions, especially political and economic, poor governance, failing states, corruption and dysfunctional markets, profit making behavior of middle men, lack of finances with the farmers are other key factors. Agriculture extension services have been undertaken for a long time to impart the knowledge and skill. Traditional extension services uses face to face interactions and delivery of information using SMS services and mass media (Radio and TV). The new complexities involved in smart farming needs much more than extension services. This is a tough task in the present global scenario. The present paper describes few of the case studies of using technology for extension services, their effectiveness and thereafter explores the emerging technologies being used in smart farming in many advanced countries. The paper further discusses the need for a radical change in education system for farming community to absorb and use new technologies.

Farmer's Education and Productivity

Several studies reveal a direct relation between the level of farmer's education and his productivity. Farming practices used from generation to generation cannot be used any more, as the Chinese adage from Sandong says, "Plant millet after millet and you will end by weeping" [14]. Agriculture productivity per worker in India is two percent as compared to a farmer in USA, primarily due to lack of education, skill, knowledge and capacity embodied in farmers of the country [15].

In a survey of effect of education on farmer productivity, it was confirmed that the education had positive effect on farmer's productivity in all 37 data sets considered in their review [16]. A large household survey was conducted in 1994 in Ethiopia to examine productivity and efficiency of farmers who had got primary education vis a vis those who had no education. The survey employed both average production functions and two-stage stochastic frontier production functions. The finding showed that four years of primary schooling had a significant effect upon farm productivity [17]. We will examine the present-day requirement of education of farming community after examining the type of technological interventions required to achieve the SDGs.

Technological Interventions for Extension Services

For the last two decades, Extension workers in many countries are using several technologies for skill building of farmers to increase their productivity. This has included field education using audio video devices, broadcasts through radio and TV, and mobile services [18]. Use of mass communication and ICT has enabled the extension education to serve a large population of farmers dispersed in several rural areas at distant locations. With the same amount of finance and with lesser efforts, it has made possible to reach ten times larger population in comparison to the traditional extension methods.

Radio broadcast provides coverage of large geographical area with the advantage that there is no language barrier and the broadcasts can be done in local languages and dialects to low-literacy farmers. This has been successfully used in several countries of Asia and Africa for extension services. However, there are several impediments in its use; high setup costs, varying regulations by different countries regarding issue of license, power of the transmitter that limits the coverage area, operational restrictions, meeting the recurring costs etc.

The other limitation is its "audio only" feature that forbids the broadcast of any picture or video of good practices. It is also only "one-way" medium that does not permit any interactivity with the farmer, albeit some interactivity has been tried by use of phone calls and SMSs [19,20]. Video is very effective in imparting training to farmers. Video permits the use of local language and dialect for ease of learning to low-literacy farmers. Video has been used for onsite field training, video broadcasts from a centrally located transmission station or using video conferencing system. These have been found very effective especially when the training was imparted in presence of an expert trainer present locally or available at a central location instantly accessible via a video conference. This permits the farmers to make multiple queries and seek answer from expert.

Community radio (CR)

Radio is the most powerful tool of communication with the farmers that has been used widely all over the world in agriculture extension. It is economical, crosses geographical barriers, communicates with people in their own language and can be received on a receiver costing one dollar. It does not need electricity and runs on battery. The radio receivers with crank shaft has been in use for a long period in Africa in regions which lack electricity. Radio transcends the literacy barrier. Radio is also known as 'women's medium' since they can perform their tasks even as they listen to the radio.

Case study-1: We undertook a pilot project (2007-2009) and established five Community Radios in Agriculture Universities located in five different regions of India with the primary objective of increasing the income of farmers by broadcasting programmes on a variety of subjects related to farming and allied topics. The programmes on farming included growing of food, harvesting, storage and selling it with reasonable profit. The other topics related to management of cattle including the breeding, upkeep, managing disease etc. Special broadcasts were also made on climate and warning of flood/cyclone, etc. Community Radio was commissioned to enable agriculture Universities and science centers to educate farming community and harmonize the relation between agriculture scientists and farmers to share knowledge and mutually learn from each other's experience to promote agriculture in the region.

The pilot was implemented in five backward rural areas of the country, where about 39% male and 49% female were illiterate. For the balance population, the medium of education was Hindi and only about 6% population were computer literate. The programme content was developed in Hindi, Bhojpuri and Magahi (local dialects), based on following main themes.

- Agriculture (crop selection, land preparation, seed selection, seed sowing, irrigation, crop growth, use of fertilizer, harvesting, seasonal farming, gardening in home, growing of flowers, medicinal plants, aromatic plants etc.), Horticulture, animal husbandry (piggery farm/goat farm/nurseries/dairy farm), weather and season for crops, information to farmer based on Argo-met Advisory Service of Department of Agricultural, Physics and Meteorology, transfer of technology to the farmers from University and research centers, etc.
- Whole-sale market rates (on daily basis), business linkages with SHGs/NGOs of different villages, programs related to sale and marketing.
- Interview of legal advisors, career counselors, bank officials, scientists, experts, block officials, health educators, doctors.
- Gender sensitization and woman empowerment programmes.
- Local songs sung by local singers during sowing and harvesting seasons, folk songs and music.

Content was produced in local dialect intermixed with culture and livelihood programmes. Participation of community including women and children in programme production and running was given higher priority. The style of storytelling, traditional motivational and educational songs and local music was adapted. While planning content, focus was also on the quality of programmes to generate enough interest among the targeted segments of population and garner some business interest to use it as a medium of advertisement for self-sustenance.

Evaluation of usefulness of CRs was undertaken with the help of Universities and participating communities. Our study found that the CR changed many lives by enhancing the knowledge of farmers who started using the new farm technologies-hitherto confined to University Professors and scientists. Marked changes in their attitude was observed and over a period of short time the enhanced income improved their quality of life.

Information communication technology in extension

The use of ICT for agriculture extension was suggested in early eighties [21]. A survey was undertaken in India in 2010 to assess the farmer's inclination towards using new technology and ICT based extension services. An interview was conducted on a sample of seventy-five farmers chosen randomly. The result showed that most of farmers were inclined to use the ICT [22]. Another study to determine the effectiveness of extension using ICT was undertaken in 2012.

It was observed that using ICT, farmers located in large geographical areas can be imparted knowledge and skill regarding use of quality seeds, fertilizers, insecticides, safety standards, pricing, availability of market, state policies, banking, finance etc., [23]. A direct correlation between farm productivity and ICT uses has been observed in many developing countries [24]. It is now an acknowledged fact that availability of information on agricultural products, there market prices and other attributes benefits the farmers immensely in profitable marketing of their produce [25].

Case study-2: An "Agricultural Knowledge Dissemination System (ANDS)" was implemented in India (2011-12) in the State of Bihar, a poor state with per capita income of $148 a year, deploying 77% of population in agriculture profession. The literacy rate of Bihar is 61.8% (lowest in the country), with just about 6% population being computer literate. The state has two Agricultural Universities and 36 science centers entrusted with the responsibility of undertaking new research in the field of agriculture and allied sciences and share the knowledge with the farmers of the state to increase their farm yield and raise the standards of living.

The traditional system of face to face meeting and training of farmers dispersed in a vast area of 99200 sq. km. The ANDS involved creating a knowledge-base with data on various aspects of agriculture science; farming, raring of cattle, management of disease, harvesting, storage, marketing, etc. A central server in one of the universities was used to store the data. The selected science centers were connected to the central hub using high speed data network for video conferencing and training.

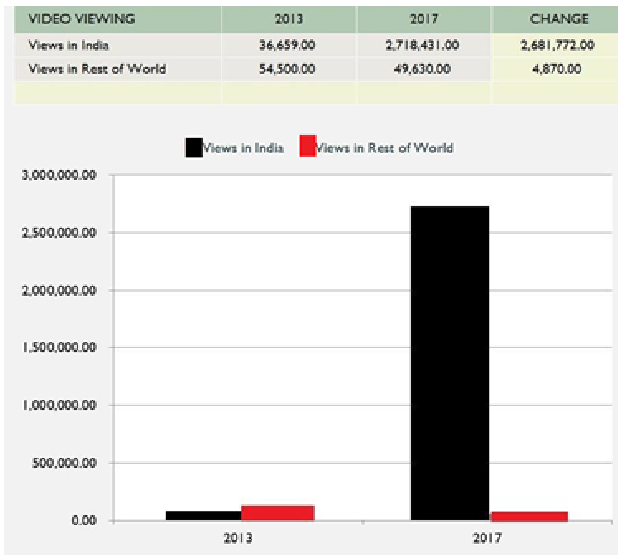

Figure 1: Impact of ICT based extension services in India.

The knowledge was made accessible to farmers through video conferencing with local science centers (farmers assemble in various science centers located at different places), an interactive website in local language, via internet (You Tube) for wider dissemination or through a community radio (local service in audio only).

The impacts on productivity and motivation of farmers in using the videos for knowledge were analyzed after six months and after four years of implementation. The study indicated that the number of users of the system grew from a mere 36 thousand in 2013 to more than 2.7 million in 2017 (Figure 1). The other interesting observation was about the shift in user age group. While most of users (38%) in 2013 were in 55-64 age group, in 2017,40% of users were in the age group 25-35.

This shift in user age group can be attributed to the spurt in popularity of mobile phones in younger farmers in India. The young farmers have been motivated to use the system due to increased monitory income. They are keen to increase the yield by using optimal inputs based on weather and related information from the system.

Smart Farming and Emerging Technologies

SDGs aim to increase agriculture yield without harming the environment and sustaining the resources on the planet. This means using the optimum amount of seed, water, fertilizer, chemicals, that are encompassed in Smart farming.

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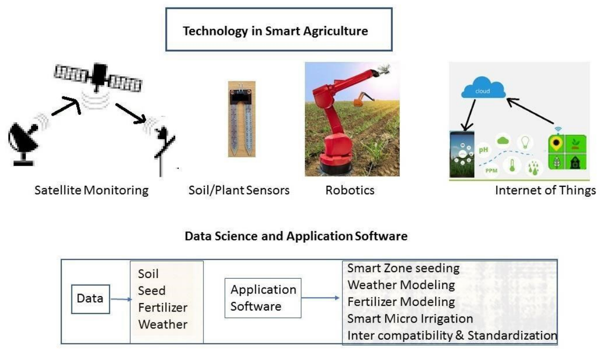

Figure 2: Emerging Technology for smart farming.

Many emerging technologies are being used in developed countries to increase food production using optimal use of resources taking help of modern technology. A few emerging technologies used in smart farming are shown in Figure 2. We will discuss a few of them and then proceed to propound a new way of education for farmers, beyond extension services.

Video cloud-based intervention

The term "cloud computing" was conceived in 1996 with an idea that all the applications, data, and information are stored on some servers maintained by a service provider and the user is able to access these from remote locations anywhere in the world. In this model, the data computation and manipulations are done on these servers remotely and the result is shared by a set of users who may also be located at different locations. The access is via internet which is termed as "cloud". The system relieves the users from the botheration of maintaining an elaborate computer system with expert staff including programmers and system administrators. The system became so popular that by 2009, google, Microsoft, amazon, IBM, Brightcove and many more not only started using this system but also started offering this service to others [26].

The advantage of such an architecture is that the cloud service provider takes the responsibility of the hardware and software resources, sparing end users from the burden of maintaining the complex computer centers. The popularity and ease of use of video cloud technology is amply proved with its success of cloud in diverse areas; WhatsApp-one billion users [27], Facebook -2 billion users [28], YouTube-1 B users. Other successful users of this platform are American Airlines, City Corp, Bank of America, Merrill Corp.

Our finding of case study-2 enforces the belief that facilitator assisted training with the use of well-prepared videos is effective in enhancing farm production and there is growing trend in the younger generation to seek information from the knowledge-base. Duplicating knowledge-bases with meta data at several locations is a costly proposition apart from the need of experts for system operation and maintenance at several locations.

Cloud based video system for storage and computation of the information based on query of farmer appears to be viable solution. This is having multiple advantages namely, anytime, anywhere access on any digital device using any operating system. It can also help storage of a variety of data captured from sensors and enable the farmer for timely intervention. There are added advantages of multibit encoding on the cloud and streaming on different bit rates based on the farmer's internet speed. The farmers may directly interact with a purchaser and sell their product. The system architecture of cloud-based extension is shown in Figure 3. The benefits of cloud-based agriculture services are described in Table 1.

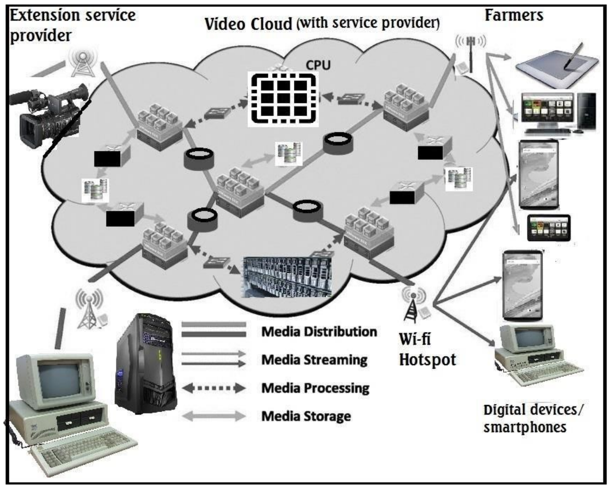

Figure 3: Concept of use of Video Cloud Technology for knowledge agriculture.

S No	Parameter	Response
1	Coverage	• Worldwide or in selected geographical locations. • Can be in any language or dialect and directed to less educated farmers. • Anytime content accessibility.
2	Complexity	Handled by service providers
3	Reliability and Scalability	High level
4	Interaction and use in locations with low internet speed	• High level. • Encoding of video at different rates in cloud allows the user to receive the video at his internet speed without buffering and freezing. • Any digital device such as smart TV, PC, Tablet, laptop, smart phone can be used to receive.

		• Any Operating System such as Window, Android, IOS can be used. • Network independent. • Quick display due to HTML5 player.
5	Metadata and subtitles in several languages	Automatic or user assisted
6	Superiority over traditional TV	• Analytic tools pay per view. • Lower capital cost. • Quick setup time.
7	Advertising models	• Advertisements can be programmed for automatic playback at specified cuts in video. • Target user specific advertisement based on user's preference/need/profile statistics.
8	Live training programmes	Yes
9	Archive	Yes
10	On demand access	Yes. Several service providers are using AI and cognitive technologies.

Table 1: Video cloud-based agriculture knowledge/data delivery features.

Auto-steering and controlled-traffic farming (CTF)

Precision agriculture (PA) is a method that uses sensors and instruments including satellites to remotely detect crop and soil properties in quasi-real time. Sensors are used to detect physical quantities such as moisture, heat, light, pressure and send it to a processor for computation. Global Navigation Satellite System (GNSS) technology have been used for machinery guidance, auto-steering and controlled-traffic farming (CTF). CTF provides sustainability, economic benefits and social benefits. It reduces compaction, controls input overlap, improves timeliness of operations, and reduces driver fatigue. This form of Precision Agriculture (PA) technology using information technology (IT) that aims to improve production, minimize environmental impact and includes the supply chain from the farm gate to the consumer may be a new dawn [29]. GPS guided farm machines such as tractor, drones, etc. connected in a network or via internet that can be managed and controlled using a digital device has become a boon for agriculture productivity.

The unmanned aerial vehicles (UAV) platforms, characterized by small size and low cost has offered a new solution for crop management and monitoring [30]. In coming days, drones will be used extensively for capturing data on soil, aerial crop spraying avoiding collision, crop monitoring, irrigation identifying dry fields and identifying plants needing attention [31]. For this purpose, various types of sensors will be mounted on drones to capture changes during the crop life cycle, analyzing with the pre-stored data and sending alert signals to the farmers for the corrective actions.

"Big data" is transforming many industries. Big data acquisition and analysis allows farmers to make smarter data driven decisions. A selection of hardware and software can enable the farmers to routinely gather data, map that data, and allow the farmers using a Decision Support System (DSS), to make optimized decisions such as tending each plant with water, fertilizers as per its need during the life cycle; eliminating the weeds by selective burning, spraying of pesticides or tilling, without damaging the desired plant. Big Data requires multi-player operations and as a result involves major shifts in roles and power relations among different players apart from the farmers, in traditional food supply chain networks There are number of parties involved in this type of farming.

The farmer hires a third-party who installs hardware and software including sensors in his field. The third-party captures data regarding soil for the specific field and provides a survey report that includes, productivity of soils, suitability of soils for raising specific crops, etc. These data along with details of time for planting, crop to be planted, row spacing, desired yield, waste recycling, water supply etc., are then provided to another DSS company who develops main and alternate planting recommendations. The farmer chooses the option and follows the methods [32].

Use of internet of things (IoT) in knowledge agriculture

IoT-based smart farming, basically uses sensors to check light, humidity, temperature, soil moisture etc. for monitoring the crop field and automating the irrigation system [33]. IoT is used in agriculture for tracking the vehicle, drones, livestock, capturing data from the sensors installed on these, and then applying various controls manually or from remote using AI and robotics. A few examples are stated below.

- Collars with sensors can be placed on cattle to monitor their locations. It makes easy to identify the location of an animal that has moved away from the group.
- Sensors can be located at various places, on ground, on drones, on trees or plants to gather precise data on various parameters such as need for nutrient, water or pesticide which can help farmers to analyze, monitor and take corrective actions.
- Information captured from RFID tags regarding diseased crops can be shared with farmers from a remote place and enable the farmer to take necessary actions to protect the crop from coming diseases. Similarly, the information in case of cattle can be used to isolate the identified animal.
- Getting skilled labor has always been a challenge facing farmers. Self-driving tractors programmable via tablet, offer the possibility of autonomous seeding, planting and tillage.

IoT provides exciting opportunities as well as challenges. Issues such as power needs of long term sensor deployment, drain on power in use of GPS and the transmission of data via GPRS etc., need consideration. Use of solar panel-based power could be a solution, provided the location has enough sun shine. Additionally, the analysis of data at the site of its capture may reduce the data upload putting less burden on networks. A critical examination of cost benefit analysis and link budgeting is required.

Greenhouse technology

Greenhouse technology is a technique to grow plants in adverse climatic environment by providing the plants protection from excessive cold, wind, precipitation, insects and diseases. Using the technology high value crop is grown in temperate and unfavorable regions. This is done by erecting a glasshouse; using diffused light, pretreated air, artificial fog, solar energy etc., for controlling the environment. Cameras and sensors installed inside the greenhouse are used to monitor desired parameters such as moisture content in soil, temperature and humidity. An app on laptop/smart phone can remotely control the soil moisture, humidity, check temperature and switch on the required device. Computer vision combined with artificial intelligence (AI) is helping the farmers in analyzing data gathered from their fields. AI software has been trained to recognize trouble, such as insect infestations or dying plants. The technology is being used at one of Nature Sweet's farms in Arizona. Nature Sweet, a company that grows, harvests, packages tomato and sells in the United States, Canada, and Mexico, believes “artificial intelligence will eventually improve greenhouses tomato yields by 20%”. The benefits of using greenhouse are:

- Greenhouse provides an ideal environment for growing crops since it is not affected by direct sunrays, rain, dust and insects.
- It prevents fungal diseases.
- It reduces the use of chemicals as compared to the open field.
- The yield and quality of crops in the greenhouse is high, water usage is controlled.

The winter season in Finland is very harsh. During this season, it gets sunlight only for few hours in a day. This type of climate is unsuited for growing vegetables such as leafy lettuce or baby greens. This forces the country to import vegetables during winter months from neighboring countries where the climate suits for their production. The time taken in import results in the citizens not getting the fresh supply. In order to grow the vegetables in the country and to ensure fresh supply in all the seasons, Fujitsu has implemented Greenhouse Technology in Finland to create an artificial environment and grow vegetables. The factory is equipped with devices such as LEDs to provide artificial light, rotating trays on which the seeds are planted, humidity controller and controlled air conditioning units [34]. The system combines two technologies developed in Japan, namely SaaS and UECS. SaaS is a cloud-based management system that uses sensors to collect data, monitor the production parameters and control equipment from a remote location [35]. UECS is acronym for proprietary communication standard developed by Japan and known as “Ubiquitous Environment Control System”. The standard is used to interconnect various devices and equipment deployed in greenhouse.

Smart farming software

The type of agriculture technology discussed above needs a variety of software applications such as mapping (GIS) software, predictive analytics software (such as expected waste, yield size, and profitability in relation to market values), precision agriculture software, farm management software etc. UAV software automates the creation and maintenance of UAV flight plans, provides and manages visibility into monitoring analyses data. Precision Agriculture software determines ideal planting and harvesting schedules based on weather and yield data, along with other factors.

The Predictive software computes factors such as seeding plans and space utilization for optimum yield and revenue for the crop. Farm Management software provides tools to improve production efficiency and profitability, tracks and provides insights into the day to-day operations and crop management functionality. There are many application management software available in the market; some have similar features, some have streamlined functions, and some have higher end tools. There is no one size fits all, magic bullet or one click button for any solution. Two farmers are neither going to need the same things nor experience the same success with it.

New Education Needs for Farmers

Farmers worldwide and specially in Asia and Africa are required to quickly raise their level of food production to cope with the present scarcity of food availability and meet the further growing food demand by 2050. These needs raising yield per acre by taking several actions such as use of improved seeds, manures, irrigation systems, post-harvest management etc. They need to use new tools and technology and resort to knowledge agriculture. This type of knowledge agriculture requires knowledge and skills to use optimal inputs, sustaining environment, proper storage and marketing. The knowledge of computer and technology-based tools such as use of sensors to monitor the health of field and crop, use of digital devices to control the parameters essential for a good yield are inherent to achieve the SDGs. As of now, very few farmers in developing countries even know about SDGs, implication of environment changes and the growing damage to environment using traditional farm practices due to excessive use of inorganic fertilizers and pesticides. Even if a few know about it, they are too busy in making both ends meet.

The other important factor is advanced post-harvest logistics, such as availability of storage systems, easy transportation, and markets are to be given due attention to ensure that the food is available in desired geographies at affordable rates. The 2030 Agenda also aims to check the climate change and sustain the planet's natural resources, a whole new set of challenges that make the task even more daunting. The agriculture is becoming complex requiring knowledge such as; precision farming, an approach to farm management that ensures that the crops and soil receive exactly what they need for optimum health and productivity; smart farm technologies that can decrease the fuel consumption, reduce usage of fertilizer or crop protection products; reduced chemical fertilizers or organic farming; genetically modified foods: safety, risks and public concerns and many more. There are 750 million illiterate adults around the world [36]. Over one billion population of the world including 60% children (107 million) depend on agriculture sector including fishing, forestry, animal husbandry and aquaculture, for their livelihood [37]. We found that technology can be employed to impart knowledge, skill and make attitudinal changes of a billion farmers who are mostly illiterate or semiliterate. However, the use of emerging technologies for smart farming needs a new radical approach to farmer's education.

It is amply clear, that the population engaged in agriculture needs knowledge of technology and should also be able to use the computing hardware and software with ease. They need to have basic knowledge of application software based on AI, DSS and should be able to analyze the data for various corrective actions. There are also greater needs for attitudinal change. They need to get away from myths and traditions and develop scientific temper and be sensitive to their role. Agriculture Universities and science centers need to devise new curriculums keeping in view the specific needs of new type of education for farmers in the present era.

New curriculum in agriculture universities

A new knowledge agriculture is in offing which replaces traditional agriculture based on bullocks pulling plough with mechanized intelligent computer-based monitoring and control system using data science, cloud computing, IS, DSS and complex software. Smart farming (SF) needs to be taught as a new techno-economic paradigm in agriculture. The agriculture education requires to include in its curriculum, agriculture as a science and business encompassing production tools, analytics and marketing strategies. The course may include web-based application software for farm management, planning, and record keeping, available as open source, license. Open source software can be freely used, changed, and shared. There are several software, such as farmOS, farmier, available under this category. These are based on Drupal, an open source content management system for developers. There is also urgent need for building repository of learning modules, including a range of educator resources. Smart Farm Learning Hub has produced educational content with the support of Australian Government, Department of Education and Training [38]. Alabama Cooperative Extension System has started Precision Ag courses online and creating repository [39,40]. Agriculture is to be treated more as a science than art. Research organizations need to evaluate the degree of efficiencies of these technologies and innovative processes.

Adoption in Developing Countries

Lack of education, knowledge and skill, high costs of technology adoption for individual farms are the main hurdles for using these practices in developing countries. As such, the access to these technologies are at present, limited to big and industrialized farms in developed countries. Digitalization of agriculture is likely to influence employment opportunities and job profiles of farmers. This may face resistance from the large labor force. Combining the farmers' knowledge and experiences with these new technologies is the greatest challenge. Development of proactive legal policies and a framework to support smart farming coupled with necessary marketing infrastructure, a dialogue among farming technology supporters and skeptics, an extensive training and education of farmers, a high motivation shall be a key to success.

Conclusion

Farming needs to use high-tech systems to provide food to growing world population and remove hunger from the planet and at the same type sustaining planet resources. We foresee the future of farming; a field having different type of sensors mounted on tractors, poles, drones etc., placed at strategic locations capturing data on various parameters and sending the data to the cloud, cloud system accessing the data and computing complex field maps, farmer receiving the information on his smart device, irrespective of his location vis-à-vis the farm. Farmer uses DSS software available on cloud or his digital device that makes extremely precise calculation of nutrient or pesticide needs for specific plant or specific area of the field. The farmer remotely controls the UAVs, Robots or auto navigated tractors to spray the seed or nutrients, as required. This results lower input costs, lesser use of fertilizers or pesticides, reduces fatigue and provides greater health and environment benefits. However, this type of farming needs a massive change in R&D, development of new curriculum for agriculture colleges and stress on education of farming community. There is need to develop resources and make it accessible in multiple languages apart from field training. The farmer's need of education is much more than traditional extension education. They need to have basic education, understand the technology and then they need specialized education suited to their environment and their country. This may be key in achieving SDGs 2030.

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