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Information and Communication Technologies (ICTs) in Agriculture: A Review

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A B S T R A C T

Agricultural practices in India are facing many challenges such as change in climatic conditions, different geographical environment, conventional agricultural practices; economic and political scenario. Economic loss due to the lack of information on crop yield productivity is another major concern in the country. These hurdles can be overcome by the implementation of advanced technology in agriculture. Some of the trends observed are smart farming, digital agriculture and Big Data Analytics which provide useful information regarding various crop yields influencing factors and predicting the accurate amounts of crop yield. The exact prediction of crop yield helps formers to develop a suitable cultivation plan, crop health monitoring system, management of crop yield efficiently and also to establish the business strategy in order to decrease economic losses. This also makes the agricultural practices as one of the highly profitable ventures. This paper presents insights on the various applications of technology advancements in agriculture such as Digital Agriculture, Smart Farming or Internet of Agriculture Technology (IoAT), Crop Management, Weed and Pest control, Crop protection and Big data analytics.

Introduction

Information and communication technology in agriculture (ICT in agriculture), also known as e-agriculture, focuses 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 (ICTs) in the rural domain, with a primary focus on agriculture.(*"EU-Project Automatic milking"* Wageningen, 2008) ICT includes devices, networks, mobiles, services and applications; these range from innovative Internet-era technologies and sensors to other pre-existing aids such as fixed telephones, televisions, radios and satellites. Provisions of standards, norms, methodologies, and tools as well as development of individual and institutional capacities, and policy support are all key components of e-agriculture.

Many ICT in agriculture or e-agriculture interventions have been developed and tested around the world to help agriculturists improve their livelihoods through increased agricultural productivity and income, or by reducing risks. Some useful resources for learning about e-agriculture in practice are the World Bank's e-sourcebook ICT in agriculture – connecting smallholder farmers to knowledge, networks and institutions (2011), (*"FAO-ITU E-agriculture Strategy Guide"*, 2016) ICT uses for inclusive value chains (2013), (*"ICT uses for inclusive value chains* (2013)*"*, 2015) ICT uses for inclusive value chains (2013) (*"ICT uses for inclusive value chains* (2013)*"*, 2015) and Success stories on information and communication technologies for agriculture and rural development (*"Information and communication technologies for sustainable agriculture* (2013)*"*, 2016) have documented many cases of use of ICT in agriculture.

Agriculture is the backbone of Nepals' economic development as it shares about 27.10 percent of the country's Gross Domestic Product (GDP) with an increase rate of 2.72 percent. About 65.6 percent of the population are involved in agriculture among which 60.2 percent are male and 72.8 percent are female. (*"EU-Project Automatic milking"* Wageningen, 2008) Agriculture is the engine for the growth of pro-poor and development of the national economy as most of the poor households in the country are dependent on agriculture for their major source of earnings. (*"FAO-ITU E-agriculture Strategy Guide"*, 2016) To reduce the poverty from 14 to 4 percent and meet the target of Agriculture Development Strategy (ADS), modifications in the existing agricultural practices are of utmost importance through the introduction of modern new technologies. Though the percentage of people engaged in agriculture is higher, the return from the agriculture sector in the country is not as expected and it cannot meet the increased demand of the food grains for the country. Traditional and subsistence farming, lack of mechanization with different tools of agriculture information results in low production rates which acts as a major factor pushing the development of Nepalese agriculture backward. The fragmentation of land and poor extension services existing in agriculture information for the smallholder farmers has hindered the commercialization and development of Nepalese agriculture. The average land holding size of a farm in Nepal is estimated at 0.8 ha. (*"ICT uses for inclusive value chains* (2013)*"*, 2015) This shows that almost half of the total farms have less than 0.5 ha of land, while those with less than 1 ha of land constitute nearly three-fourths of all holdings and it is decreasing over time.

Though some initiations have been taken in availing the farm tools, extension services are very poor. Farmers lack the skills, techniques and knowledge of cultivation practices of the crops, control measures of disease-pests and other technological innovations in agriculture. Therefore, there's a need for suitable technology that farmers can adapt easily and solve the various problems related with extension services (Figure 1). Information and Communication Technology (ICT) can be one of the promising tools for the development of agriculture.

"ICT includes all digital technologies that facilitate the electronic capture, processing, storage and exchange of information". (*"ICT uses for inclusive value chains* (2013)*"*, 2015) The ICT tools help to solve all the issues of poor connectivity and disintegration of the agricultural market and delayed information to the farmers, small land holdings, and

non-adoption or less adoption of improved technology as they lack the reliable information due to less accessibility. There are various ICT devices such as radio, television, mobile phones, computers, tablets and networking, satellite systems which help in facilitating different farming activities and intercultural operations. (*"Information and communication technologies for sustainable agriculture* (2013), 2015) Research studies reveal that ICT has reformed the traditional agricultural system and made significant contributions in increasing agricultural productivity and sustainability by empowering farmers with the correct information at the right time and place. (*"Kenya Uses Text Messages To Track Elephant"*, 2009) Through the use of ICT, users can receive weather and price information, agro- advisories on agricultural products. ICT is a platform which provides solutions to the challenges in an agricultural sector.

Wireless technologies

Wireless technologies have numerous applications in agriculture. One major usage is the simplification of closed-circuit television camera systems; the use of wireless communications eliminates the need for the installation of coaxial cables.(*"Information and communication technologies for sustainable agriculture* (2013), 2015)

Global Positioning System (GPS)

In agriculture, the use of the Global Positioning System provides benefits in geo-fencing, map-making and surveying. GPS receivers dropped in price over the years, making it more popular for civilian use. With the use of GPS, civilians can produce simple yet highly accurate digitized map without the help of a professional cartographer.

In Kenya, for example, the solution to prevent an elephant bull from wandering into farms and destroying precious crops was to tag the elephant with a device that sends a text message when it crosses a geo-fence. Using the technology of SMS and GPS, the elephant can roam freely and the authorities are alerted whenever it is near the farm.(*"Kenya Uses Text Messages To Track Elephant"*, 2009)

Geographic information systems

Geographic information systems, or GiS, are extensively used in agriculture, especially in precision farming. Land is mapped digitally, and pertinent geodetic data such as topography and contours are combined with other statistical data for easier analysis of the soil. GIS is used in decision making such as what to plant and where to plant using historical data and sampling.

Computer-controlled devices (automated systems)

De Lavel milking station

Automatic milking systems are computer controlled stand alone systems that milk the dairy cattle without human labor. The complete automation of the milking process is controlled by an agricultural robot, complex herd management software, and specialized computers. Automatic milking eliminates the farmer from the actual milking process, allowing for more time for supervision of the farm and the herd. Farmers can also improve herd management by using the data gathered by the computer. By analyzing the effect of various animal feeds on milk yield, farmers may adjust accordingly to obtain optimal milk yields. Since the data is available down to individual level, each cow may be tracked and examined, and the farmer may be alerted when there are unusual changes that could mean sickness or injuries.(*"Malaysia begins RFID-enabled livestock tracking program"*, 2009)

The rural farmer and other actors along the agriculture value chain are handicapped by the lack of information about new technologies. Information and Communication Technologies supporting the development and delivery of timely, targeted information and services can make farming more

sustainable. They can also deliver safe, nutritious and affordable food; facilitate market integration and access to finance to make agriculture attractive and profitable.

The Intelligent Agricultural Systems Advisory Tool (ISAT)

Developed by a collaboration of Microsoft, Indian Meteorological Department (IMD), Acharya NG Ranga Agricultural University (ANGRAU), and ICRISAT, ISAT provides concise farm advisories to farmers on their phones. These messages are generated after analysis of local and global historical climate data, current and forecasted weather conditions, crop systems and soil-related information. The tool employs a decision-tree approach to generate SMSs, which are then relayed to farmers registered for the service.

Sowing App

Combined with a Personalized Village Advisory Dashboard, the Sowing App, pioneered for farmers of Andhra Pradesh utilizes powerful artificial intelligence to interface with weather-forecasting models (provided by USA-based a Where Inc.) and extensive data. This data includes rainfall over the last 45 years and 10 years of groundnut sowing progress data for Kurnool district. Such data about crops and fields is manually collected and uploaded to a cloud-based repository, and is used to provide important insights around soil health, fertilizer recommendations, sowing date suggestions and seven-day weather forecasts
The Sowing App has been made possible through a partnership between ICRISAT, Microsoft and the Andhra Pradesh government.

Plantix App

German company PEAT Gmbh's Plantix mobile app is customized to ICRISAT's mandate crops, enabling farmers to identify pests and diseases using their mobile phones. Farmers take pictures of the affected crop and upload them on the app; the pictures are analyzed using artificial intelligence algorithms, and results are then returned immediately to the farmer.

NADiRA: linking Earth Observation with IoT

Started in November 2017, NADiRA – Nurturing Africa's Digital Revolution for Agriculture – is an innovation action to develop agriculture in Africa using sustainable digital farming solutions. It includes the industrialization of Earth Observation (EO) products, sensors IoT data and mobile devices giving stakeholders the key information to invest in smallholder farming. Specifically, it involves the incorporation of Copernicus, other Earth Observation products and in-situ sensors via agCelerant™ – an agricultural value chain orchestration digital platform that connects producers with banks, insurers, input providers and agro-industries in smallholder contract farming.

The Measure M&E Platform

Monitoring and Evaluation of Agri-Science Uptake in Research and Extension (MEASURE) is a mobile web-based platform designed to collect real-time, geotagged data about farmers, farmland, livestock, other on-field interventions, and other key indicators of agriculture research and extension.

Originally developed as a field data-collection tool, MEASURE has now transformed into a full-fledged M&E platform to track activities, manage beneficiaries and provide real-time insights through visually enabled dashboards to the project teams. The MEASURE platform (i) collects geo-tagged data of farmers, farmland, crops, demo plots, capacity building activities in real-time (ii) provides a web-based multi-layered dashboard to visualize the collected data both spatially and temporally (iii) keeps track of the KPI and progress of the project implementation (iv) provides spatial distribution of the project intervention sites and the adoption (v) schedules and manage field level activities carried out by the partners/staff on the ground. In less than two years of the actual launch, MEASURE has

about 560,000 records from 20 different projects within and outside ICRISAT.

ISAT

By influencing planting decisions, the tool helped farmers increase yield on an average by 16% across locations.

The Sowing App

The Sowing App has helped farmers achieve optimal harvests by advising (via SMS in local languages) on the best time to sow crops. Farmers in Andhra Pradesh obtained 30% higher yield with timely advisories from the Sowing App. Read more: https://cio.economictimes.indiatimes.com/news/cloud-computing/ai-enabled-cloud-to-transform-millions-of-lives-in-india/71646634

The Plantix App

Farmers get critical information on symptoms, triggers, chemicals as well as biological treatments of crop diseases on time, preventing greater damage and loss of crop and income. Read more here: https://www.scidev.net/global/agriculture/feature/tailored-targeted-ai-apps-pave-way-for-smart-farming.html
https://edition.cnn.com/2019/10/21/tech/india-agriculture-tech-digital-green-plantix/index.html?utm_content=2019-1021T17%3A00%3A08&utm_term=link&utm_medium=social&utm_source=twbusiness

NADiRA

NADiRA is expected to help increase availability of credit, reduce exposure to climate risks, and improve smallholders' productivity.

Smartphone mobile apps in agriculture

The use of mobile technologies as a tool of intervention in agriculture is becoming increasingly popular. Smartphone penetration enhances the multi-dimensional positive impact on sustainable poverty reduction and identify accessibility as the main challenge in harnessing the full potential (Silarszky *et al.*, 2008) in agricultural space. The reach of smartphone even in rural areas extended the ICT services beyond simple voice or text messages. Several smartphone apps are available for agriculture, horticulture, animal husbandry and farm machinery.

RFID for Animal identification

RFID tags for animals represent one of the oldest uses of RFID. Originally meant for large ranches and rough terrain, since the outbreak of mad-cow disease, RFID has become crucial in animal identification management. An implantable RFID tag or transponder can also be used for animal identification. The transponders are better known as PIT (Passive Integrated Transponder) tags, passive RFID, or "chips" on animals.(*"National Livestock Identification System"*, 2013) The Canadian Cattle Identification Agency began using RFID tags as a replacement for barcode tags. Currently CCIA tags are used in Wisconsin and by United States farmers on a voluntary basis. The USDA is currently developing its own program. RFID tags are required for all cattle sold in Australia and in some states, sheep and goats as well. (*"Partners - E-Agriculture"*, 2017)

The Veterinary Department of Malaysia's Ministry of Agriculture introduced a livestock-tracking program in 2009 to track the estimated 80,000 cattle all across the country. Each cattle is tagged with the use of RFID technology for easier identification, providing access to relevant data such as: bearer's location, name of breeder, origin of livestock, sex, and dates of movement. This program is the first of its kind in Asia, and is expected to increase the competitiveness of Malaysian livestock industry in international markets by satisfying the regulatory requirements of importing countries like United States, Europe and Middle East. Tracking by RFID will also help producers meet the dietary standards by the halal market. The program will also provide

improvements in controlling disease outbreaks in livestock.(*"Success stories on information and communication technologies for agriculture and rural development"*, 2015)

RFID tags have also been proposed as a means of monitoring animal health. One study involved using RFID to track drinking behavior in pigs as an indicator of overall health.(*"Wireless Camera Systems"*, 2013)

Role of ICT in agriculture

ICT has various roles in the field of agriculture to improve crop production and reduce loss. ICT can provide agricultural extension services easily, rapidly and in higher accuracy. (*"Kenya Uses Text Messages To Track Elephant"*, 2009; *"Malaysia begins RFID-enabled livestock tracking program"*, 2009; *"National Livestock Identification System"*, 2013) ICT also supports easy information access and communication in agricultural development.

Decision support tool

In agriculture, the right decision at the right time is absolutely necessary. ICT plays an indispensable role in agricultural development to support the farmers. Farmers can access the weather, market and efficient mechanisms related to information in the agriculture sector for higher production through ICT. The right information on agricultural practices of various crops and livestock can be subscribed through ICT (websites, apps, bulletins etc.). Through ICT, farmers can be benefited from the sowing to harvesting of the crops.(*"Partners - E-Agriculture"*, 2017) ICT not only provides the potential information but also protects the farmers from rumors and mis-communicated information.(*"Success stories on information and communication technologies for agriculture and rural development"*, 2015) Farmers can decide on the crop varieties to sow in their field as per their field conditions, sowing time, harvesting time, intercultural operation to be carried out, safe management of disease and insect, and harvesting time. Farmers can make decisions on production and effective marketing through the effective use of ICT.(*"Success stories on information and communication technologies for agriculture and rural development"*, 2015) Various people like agricultural producers, extension agents, crop consultants, forest managers and even policy makers may use the ICT in the decision making process on the basis of forecasts.(*"Wireless Camera Systems"*, 2013)

Reduce farmer's risk

Farmers are always at high risk in agriculture. Due to climate change, most of the smallholder farmers do not have enough resources and capacity to cope with climatic shocks which reduces agricultural productivity. These farmers have to face various risks in agriculture including new disease and pest outbreaks, adverse weather conditions and other risks.(*"World Bank's e-sourcebook ICT in agriculture – connecting smallholder farmers to knowledge, networks and institutions* (2011), 2015) Those agricultural information that are applied in the local communities about the climate and soil properties help farmers in identifying opportunities and reduction of risks that are associated with changes occurring in their land.(*"World Bank's e-sourcebook ICT in agriculture – connecting smallholder farmers to knowledge, networks and institutions* (2011), 2015) With a correct and reliable climate forecast, farmers can choose resilient crop varieties and can manage diseases and pest problems as per the information they receive. With the help of weather forecast information received through ICT tools, farmers are able to adjust their sowing dates of different crops and manage their on farm risks.

Strengthen the coordination and collaboration

ICT tools strengthen the coordination and collaboration of farming communities with various institutions, non-governmental organizations, and private companies through its wide networking.(*"Partners - E-Agriculture"*, 2017) Farmers can access the information generated by

various private sector companies and organizations working in the required field. The farmers receive information on weather forecasting and market information. ICT has developed where numbers of organizations and experts from the various fields expressed that the use of ICT tools such as mobile phones, applications, software and tablets for the collection of data, monitoring and evaluation purpose of the project, and working in close contact with the rural communities and taking their feedback.(Ali *et al.,* 2016)

Access quality products through market information

Through the use of ICT, farmers can be benefitted by shortening the value chain. An educated farmer having a mobile phone with an android processor can easily contact any vegetable, fruits, and cereals traders and negotiate directly with the sellers to minimize the cost to be paid to the middleman. Furthermore, they can also access the market information of the products through ICT and link directly with the customer/consumer and increase their return. In other ways, farmers can be provided with the market information with vegetable price which helps them to calculate the possible amount they can earn from each product as per the rate in the bigger market. The farmers are not well informed about the updated information on the commodity prices, places for selling their produce, consumer's preference and this acts as the major problems in the agriculture sector. In this context, ICT can play an instrumental role in increasing the market space of farmers by reaching directly to the consumers or other potential users so that they can gain maximum profits. Farmers can use ICT and contact the buyers directly in order to receive the information about the current market price of their produce.(*"Kenya Uses Text Messages To Track Elephant"*, 2009) Information about the price of commodities is the most widely shared information among farmers through ICT. Such information increases the bargaining power of smallholder farmers to negotiate the price with the traders and reduces the personal travel cost of the farmers.(Ali *et al.,* 2016) Following this system, farmers can sell their fresh produce on time at the maximum price and consumers can get quality products.

Information and Communication Technologies (ICTs)

Information and communication technologies (ICTs) in agriculture technology comprise those networks, mobiles, devices, services, and applications that aid the processing, management, and exchange of data, information, or knowledge with a target audience. They include a broad range of converging technologies, including traditional telecommunications, television and video, radio, CD-ROMs, cell phones and smart devices, and several modern technologies such as computers and the internet, sensors, Geographic Information Systems, satellites, and the like. Essentially, the purpose of ICT is to transfer information from one point to another.

Impact of ICT on Agriculture and Information Technology

When talking about modern farming technology, one needs to acknowledge the role of ICT as a decision support system for farmers. Through the assistance of ICT, farmers are able to stay updated with all recent information. This is inclusive of data about weather, agriculture, and newer and more advanced ways of enhancing crop quality and production.

ICTs have largely revolutionized the way people, governments, and businesses, both large and small, function in the modern world. Close to 60% of the global population has access to the internet, and mobile internet is now the most widely-used channel for internet access worldwide. The tremendous adoption of ICTs has made it possible to facilitate better communication and ensure the delivery of services and information to people who previously lacked access. The infusion of new, advanced agriculture technologies has allowed the global agriculture sector to surge ahead and transform the

way producers cultivate, harvest, and distribute agricultural commodities. The use of technology in Indian agriculture, or e-agriculture, has accelerated agricultural and rural development by adopting innovative ways to improve the existing information and communication processes. It has particularly revolutionized smallholder agriculture in several agrarian economies and has helped address several challenges associated with the traditional form of agriculture.

Understanding Modern: Technology Used in Agriculture

The agricultural scene today requires the integration of sophisticated technologies such as temperature and moisture sensors, robots, GPS technology, and aerial images, to name a few. On this note, ICT helps meet the elevated demand for newer approaches. Such digital farming tech also aids in empowering rural farmers by allowing better access to effective production strategies, banking and financial services, etc.

Empowering Smallholder Agriculture

In developing countries, ICT in agriculture provides farmers with vital information pertaining to sowing, crop protection, and improving soil fertility that enables them to improve agricultural productivity. Weather-related advisories and alerts help them prepare for sporadic events such as floods, drought, or even pest and disease outbreaks, thus preventing significant crop loss. ICTs also provide them with a reliable channel to seek the best market price in the local markets and other daily updates for their produce to ensure they receive fair returns.

The increasing penetration of budget-friendly mobile phones and the internet is an added advantage for farmers living in remote areas in several emerging nations. Access to inexpensive mobile devices has now made it easier for them to acquire additional information and services that enable informed decision-making. Now, the use of the latest technology in agriculture in the world has ensured that with a touch of a few buttons, agriculturists can connect with the global network of farmers, agronomists, businesses, and other service providers to stay up-to-date on the latest crop cultivation practices.

For policymakers, the advantage of adopting ICT in agriculture is that information sharing enables them to gain a better understanding of the situation at the ground level, which will contribute to the designing and implementation of agrarian and rural development policies that benefit the farmers. The ICT's extensive reach to even the remotest location can also help them address issues concerning gender bias, women empowerment, and other socioeconomic concerns.

Applications of ICT in the Developed World

The use of ICT in modern agriculture technology has also significantly transformed agriculture and farming in developed countries at a different scale. Internet of Things (IoT), Cloud Computing, and Big Data have all had a profound impact on the efficiency of current processes. Several farm holdings manage farms remotely using sensing technologies, drones, and other devices that gather vital data on soil properties, air, crop health, and weather conditions.

The data enables farmers and agribusinesses to closely monitor crop cultivation, optimize the use of agrochemicals and natural resources, and adapt quickly to changing environmental conditions. The application of precision farming and ICTs have resulted in increased efficiency and reduced costs. It has also delivered decision-making tools that boost agricultural productivity and help manage natural resources effectively.

IoT, in particular, has several applications in agriculture, from real-time monitoring of soil, plant, and animal health using in-situ sensors to tracking the origin of a product or agri-commodity and its environmental impact, as well as its storage environments along the supply chain.

Estimates suggest that by 2030, IoT could potentially evolve into the 'Internet of Action' where sensors and machines, based on in-built AI and data analytics capacity, will also be capable of self-optimizing and initiating activities on their own, without much human intervention.

The Role of ICT- Revamping Modern Agricultural Technology

ICT farming, particularly the use of multimedia technology and other innovative approaches to interactive knowledge transfer processes, is transforming agricultural extension services. ICT has been instrumental in empowering farmers through knowledge and building their capacity to achieve rural and agricultural developmental goals. Some of the key areas where ICT in agriculture plays a vital role are:

IOT Transforming: The Future of Agriculture

With the exponential growth of world population, according to the UN Food and Agriculture Organization**,** the world will need to produce 70% more food in 2050, shrinking agricultural lands, and depletion of finite natural resources, the need to enhance farm yield has become critical.

Limited availability of natural resources such as fresh water and arable land along with slowing yield trends in several staple crops, have further aggravated the problem. Another impeding concern over the farming industry is the shifting structure of agricultural workforce. Moreover, agricultural labor in most of the countries has declined. As a result of the declining agricultural workforce, adoption of internet connectivity solutions in farming practices has been triggered, to reduce the need for manual labor.

IoT solutions are focused on helping farmers close the supply demand gap**,** by ensuring high yields, profitability, and protection of the environment. The approach of using IoT technology to ensure optimum application of resources to achieve high crop yields and reduce operational costs is called precision agriculture. IoT in agriculture technologies comprise specialized equipment, wireless connectivity, software and IT services.

BI Intelligence survey expects that the adoption of IoT devices in the agriculture industry will reach 75 million in 2020**,** growing 20% annually. At the same time, the global smart agriculture market size is expected to triple by 2025**,** reaching $15.3 billion (compared to being slightly over $5 billion back in 2016).

Smart farming based on IoT technologies enables growers and farmers to reduce waste and enhance productivity ranging from the quantity of fertilizer utilized to the number of journeys the farm vehicles have made, and enabling efficient utilization of resources such as water, electricity, etc.

IoT smart farming solutions is a system that is built for monitoring the crop field with the help of sensors (light, humidity, temperature, soil moisture, crop health, etc.) and automating the irrigation system.

The farmers can monitor the field conditions from anywhere. They can also select between manual and automated options for taking necessary actions based on this data. For example, if the soil moisture level decreases, the farmer can deploy sensors to start the irrigation. Smart farming is highly efficient when compared with the conventional approach.

IoT have the potential to transform agriculture in many aspects and these are the main ones.

Data collected by smart agriculture sensors, in this approach of farm management, a key component are sensors, control systems, robotics, autonomous vehicles, automated hardware, variable rate technology, motion detectors, button camera, and wearable devices. This data can be used to track the state of the business in general as well as staff performance, equipment efficiency. The ability to foresee the output of production allows to plan for better product distribution.

Agricultural Drones

Ground-based and aerial-based drones are being used in agriculture in order to enhance various agricultural practices: crop health assessment, irrigation, crop monitoring, crop spraying, planting, and soil and field analysis.

Livestock tracking and geo fencing

Farm owners can utilize wireless IoT applications to collect data regarding the location, well-being, and health of their cattle. This information helps to prevent the spread of disease and also lowers labor costs.

Smart Greenhouses

A smart greenhouse designed with the help of IoT intelligently monitors as well as controls the climate, eliminating the need for manual intervention.

Predictive analytics for smart farming

Crop predication plays a key role, it helps the farmer to decide future plan regarding the production of the crop, its storage, marketing techniques and risk management. To predict production rate of the crop artificial network use information collected by sensors from the farm. This information includes parameters such as soil, temperature, pressure, rainfall, and humidity. The farmers can get an accurate soil data either by the dashboard or a customized mobile application.

Factors affecting use of ICT

There are various factors that affect the use of ICT in the agriculture sector.

Awareness among the people

There are technical challenges for the dissemination of ICT in Nepal.(Al-Thani *et al.*, 2020) The development in information and communication is rapidly increasing in Nepal, however it's still new for the people residing in the rural areas. There are various ICT tools that can help the farmers but they are unaware about the facilities and even do not have the capacity to use these technologies and get benefit from the agriculture production. At present, 63 percent of the Nepalese people have access to the internet and smartphones.(*"Kenya Uses Text Messages To Track Elephant"*, 2009) ICT can play a pivotal role in the Nepalese agriculture to take it to the next level. There are various television channels and FM radio which are broadcasting programmes and different mobile applications and websites from where farmers can get the reliable information related to agriculture. However, farmers lack access to such information. Awareness is pivotal to provide guidance for using these extension services. Agriculture is the basis for food security and survival. Mankind living on the globe depends majorly on the Agricultural based crops for their survival. India is an agricultural dependent country and the fact that the majority of the populations are vegetarians and solely depends on the agricultural products for their survival. Being an agricultural based nation, country's economy is principally influenced by annual crop yields of agricultural practices. Recent survey indicates that more than 60 % of the population is in to agriculture and the majority among the rest is connected to the other aspects of agricultural practices. The other facets of agricultural practices include agricultural machinery companies, fertilizer companies, crop yield marketing and sales companies etc. Agriculture activities help humans to raise the most principle food crops with ideal animal population to achieve environmental balance. In the country like India, farmers cultivate major food crops such as rice, wheat, cereals, pulses, different vegetables known as onions, potatoes, sugarcane, oil seeds, mango, orange, red chilli and also various commercial crops such as coconut, coffee, tea, cotton, rubber and jute. The majority of the rural population close to 70% depends on the agriculture for their household. Agriculture contributes approximately 18% to the total GDP of the country and provides employment to over 60 to 70 % of the population in India (1, 2). India is home to 1.3 billion people, and globally

ranks second in terms of the agricultural output. The agriculture, forestry and fishing sector accounted for 16.4% of the gross value added (GVA) in 2021. In contrast, the sector is serving as a primary source of livelihood for more than 50% of the country's population. Low and stagnant income across these sectors remains a focal point of policy debate in India. These sectors accounts for the majority of the poor of the country. Recent estimates show that about 220 million people are poor in India. One of the most prominent pathways to enhance farmers' income is the adoption of improved agricultural technologies. The literature reveals that adoption of improved technologies is the key to increase agricultural productivity and farmers' income (Matushcke *et al.,* 2007; Subramanian and Qaim 2009; Duflo *et al.,* 2011; Mason and Smale 2013; Kumar *et al.,* 2020). Despite a very strong impact on the well-being of farmers, the adoption of improved technologies is low, especially in the context of developing regions and countries. Bothdemandandsupplysidefactorsplay a crucial roleforthe adoption and diffusion of improved agricultural technologies. Demand side factors include awareness and knowledge about technology, access to credit and relevant inputs, risk implications and marginal returns (Feder *et al.,* 1985; Besley and Case 1993; Morris *et al.,* 2007; Barrett *et al.,* 2010; Duflo *et al.,* 2011; Kumar *et al.,* 2017; Varshney *et al.,* 2019a). Supply side fact- ors include policy support, investment in agricultural research and extension system, availability of infrastructure, and institutional arrangements for the delivery and benefit sharing of technologies. A perfect blending of demand and supply side factors ac- celerate the penetration rate of improved technologies for achieving desired outcomes. In India, the public sector agriculture research system is primarily responsible for the development and dissemination of improved technologies. With the passage of time, the private sector is gradually contributing to developing and marketing of improved technologies. Delivery of improved technologies through agricultural extension mechanisms play a key role in their up-scaling and out-scaling. In fact, agricultural extension system addresses demand side factors such as awareness creation, risk reduction and proficiency improvement (Babu *et al.,* 2013; Gulati *et al.,* 2018). All these factors are significant in the widespread adoption and dissemination of improved technologies.

Internet of Things (IoT)

The phrase "Internet of Things" (IoT) was coined in 1999 by a British futurist named Kevin Ashton. The Internet of Things paradigm will create a technological universe in which many physical objects or "Things," such as sensors, everyday tools, and materials enhanced by computing power and networking capabilities, will be able to take part, either as individual units or as a networked collaborating group of embedded systems, as the phrase "Internet of Things" suggests. Agriculture has become one of the areas that IoT improvements are expected to have a significant impact on. According to the United Nations' Food and Agricultural Organization (FAO), the global population will reach 8 billion by 2025 and 9.6 billion by 2050. (FAO, 2009). This effectively means that global food production must increase by 70% by 2050. The rapid growth of the world population, as well as the growing demand for high-quality goods, necessitate the modernization and improvement of agricultural operations. Precision agriculture is one of the most promising technologies, with the potential to make a large contribution to the needed increase in food production while remaining sustainable. Precision agriculture focuses on optimizing and improving agricultural processes for maximum productivity, and it necessitates quick, reliable, decentralized measurements in order to provide growers with a more detailed picture of the current situation in their cultivation area and to coordinate automated machinery in a very way that energy, water, and pesticide use are reduced (Zhang *et al.,* 2002). After collecting data from a variety of different systems, well-evaluated scientific knowledge can be presented in the form of smart algorithms to improve understanding of ongoing processes, perform current situation reasoning and predict

outcomes based on diversified inputs, generate timely alerts about potential cultivar dangers, and improve automated control signals based on plant responses. The algorithms necessary to deal with remote data in real time are just too complex to perform on a low-power Wireless Sensor Network (WSN) node locally. However, because all of the objects in the IoT will be connected, the computational overhead may be easily moved to the cloud or distributed among multiple networked devices (Tzounis *et al.,* 2017).

IoT Application in Agriculture

Water Management

Water management can be efficiently managed by IoT Technology to avoid the wastage of water using different types of sensors. The sensors are used to check the level of water, by placing the sensor into water tank and data is stored on the cloud by using mobile application. Farmers can check level of water through their mobile phones. According to this technology the motor will work automatically. If the level of water is low, then motor will automatically have switched on, and if level of water is up then it will shut down motor. In traditional irrigation system, as much as 50% of this water is wasted due to overwatering caused by inefficiencies in traditional irrigation methods and systems (*"ICT uses for inclusive value chains (2013)"*, 2015). To solve this problem, smart irrigation system using IoT helps farmers to avoid wastages of water, improve quality of crops by irrigating at correct time. In smart irrigation system, Temperature sensor and Soil sensor are placed on the fields, these sensors send fields information to farmers through information gateway. Weather based smart irrigation controllers use local weather information to maintain and adjust irrigation schedules

Crop Management

IOT technology helps in collecting information about conditions like weather, moisture, temperature and fertility of soil, crop online monitoring enables detection of weed, level of water, pest detection, animal intrusion in to the field, crop growth, agriculture (*"ICT uses for inclusive value chains* (2013)*"*, 2015). Wireless Sensor Network and Micro Controllers are used to monitor and control the farm processes. By using this technology, the farmer can guess the fertility of soil and decide which type of crop grows.

Soil Management

Soil Management using IoT helps farmers to monitor the soil and decide the crop to be planted in the soil. Farmers can check the soil temperature, pH rate and humidity on regularly basis. The farmers can check soil monitoring report from their mobile phone via wireless network at any time. If they notice abnormalities, they can immediately notice their land and use pesticides to overcome the abnormalities (*"Information and communication technologies for sustainable agriculture* (2013), 2015).

To test the soil different type of sensors are used such as temperature sensor, pH sensor, humidity sensor. Different crops require different irrigation strategies and using real time data of soil moisture a farmer can increase yield by maintaining an optimal soil moisture for a specific crop (*"Information and communication technologies for sustainable agriculture* (2013), 2015)

Smart Greenhouses

Smart greenhouses help the farmers to do work in their farms automatically without the use of manual power. Greenhouse is being used to protect the plants from extreme weather like pest attacks, insect, ultraviolet radiations, wind and hailstorm. The irrigation of agriculture field is carried out using automatic drip irrigation, which operates according to the soil moisture threshold set accordingly so as optimal amount of water is applied to the plants (*"Kenya Uses Text Messages To Track Elephant"*, 2009). Based on data collected about the soil, an amount of potassium, nitrogen and other minerals

are applied to fields using different techniques. IoT devices are very helpful for dairy farmers who have multiple cows that need to be milked several times a day. Robots are used for milking sessions. Sensor is attached around a cow's neck which give signal to the robot that cow about to be milked. It also checks animal's milking speed, quality and quantity of milk produced, diet of each animal. It helps farmer to determine which cows are able to produce maximum milk.

Agriculture Drones

Agricultural drone has play important role in agriculture. The Drones provide in-flight observation and monitoring. It helps the farmer in various ways such as soil fertilizing, spraying pesticides and seeding. Different types of Drones are used in Agriculture like Crop Spraying Drones, Surveillance Drones, Seeding Drones to improve productivity.

From the drone data, we can draw insights regarding plant health indices, plant counting and yield prediction, plant height measurement, canopy cover mapping, field water ponsing mapping, scouting reports, stockpile measuring, chlorophyll measurement, nitrogen content in wheat, drainage mapping, weed pressure mapping, and so on. (*"National Livestock Identification System"*, 2013) To use

Livestock Monitoring

IoT Technology helps farmers to monitor the health of their livestock, eating habits, location and reproductive cycle etc. Connected sensors in the wearable can monitor blood pressure, heart rate, respiratory rate, digestion, temperature and other vitals that allow a farmer to be alerted at the first sign of illness (*"Malaysia begins RFID-enabled livestock tracking program"*, 2009).

IoT can also help farmers during a cow's reproductive cycle to monitor when they are ready to give birth. IoT devices notify the farmer about the condition of cow's. IoT wearable sensor devices are also track the location of an animal which helps farmers to immediately locate a sick animal and give them proper treatment. At present India stands second globally in terms of agricultural based products. Cultivation of various agricultural crops influences the economy of the country at broadest range and plays a pivotal role in the overall in socio-economic structure of the country. The success rates of agri practices majorly influenced by certain factors namely soil fertility, climatic conditions, weather forecast, temperature, water level with the rainfall measures, irrigation condition, fertilizers availability, pesticide used, controlling of weed population, process of cultivation, harvesting methods employed and economic and political scenarios (*"ICT uses for inclusive value chains (2013)"*, 2015). Majority of the former communities in India predict crop yield based on the conventional practice with the knowledge of previous experiences, but this approaches alone may not be efficient as the climatic conditions keep changing drastically due to the overall change in the weather forecast at global level. In order to address this issue, a more scientific methodology with technology advent known as *agro based big data analytics* is essential. Big data analytics provides an opportunity to analyze the significant factors that controls the crop yield and also about the socio, economic and political impacts on the success rates of the various agricultural practices (*"ICT uses for inclusive value chains (2013)"*, 2015). Higher crop yield can be achieved by increasing the overall cultivable land suitable for the growth of particular crop and also by decreasing the crop damage, overall operating cost through implementation of good agricultural practices. The enhanced crop yield can be reported by controlling the major factors of the agricultural practice such as fertilizer type and quantity, water resources and levels, quality of the seed used for cropping, minimization of biotic stress caused by weeds, pests and the control of abiotic stress (*"Information and communication technologies for sustainable agriculture (2013)"*, 2015). Manual and conventional methods such as physical crop inspection and manual removal of

weeds and contaminants are not very effective approaches and do possess significant limitations in supporting the higher crop yield (*"Information and communication technologies for sustainable agriculture (2013)"*, 2015). On the other hand, the sensor mounted practices can be effective in understanding the needs of the agricultural conditions of the growing crop in a much scientific way (*"ICT uses for inclusive value chains (2013)"*, 2015; *"Kenya Uses Text Messages To Track Elephant"*, 2009). The Big data analytics is one such technology, which provides an opportunity to analyse the various crop yield influencing factors to provide an optimum condition for the enhanced crop yields and also helps in designing the strategies for crop yield marketing (*"Malaysia begins RFID-enabled livestock tracking program"*, 2009; *"National Livestock Identification System"*, 2013).

The following are the main benefits of adopting IoT to improve farming

Improving water management

Land is being continuously monitored so that early-stage safeguards can be done.

Agriculture becomes more productive as time is saved, labour costs are decreased, and productivity is increased.

Crop monitoring is simple

The farmer can quickly determine the moisture content and pH level of the soil, and seeds can be shown accordingly.

Plant and crop diseases can be identified with the use of sensors and RFID chips. The reader receives the EPC (information) from RFID tags, which is then transferred over the internet. A farmer or scientist can receive this information remotely and take necessary action to protect crops from disease outbreaks (Arunlal and Rajkiran, 2018). Crop sales in the global market will increase. Farmers may connect directly to the global market no matter where they are in the world.

IoT Agriculture Apps

Agricultural IoT apps monitor sensor data and prepare it for predictive analytics. Here are a few IoT farm apps that are leading the way in the green revolution's second wave:

Phenonet Project (Open IoT)

Phenonet is an Internet of Things network of wireless sensor nodes that collect data from an area of experimental crops. Phenomics is the study of how an organism's genetic makeup influences its appearance, function, growth, and performance. Plant phenomics is a multidisciplinary method that investigates the relationship between cells, leaves, and the entire plant, as well as the relationship between crop and canopy. The Phenonet's purpose is to provide a platform for enhanced crop analysis in real-world growing circumstances for Scientists and farmers. Analyzing the size, development, and performance of plants in a greenhouse or on the farm may be time-consuming and tedious. More specifically, when a field site is located in a remote location, sending workers out to the field becomes prohibitively expensive. For plant scientists and farmers, the capacity to collect data from faraway sites and transmit it back to the lab in real time is a priceless tool (Jayaraman *et al.*, 2015).

CLAAS Equipment

CLAAS is a world leader in agricultural engineering tools, producing equipment that runs on autopilot and gives recommendations on how to increase crop flow and reduce losses. Farmers can tailor the programme to their own needs or let it optimize the equipment for them automatically. The major goal of Claas' Telematics system is to boost overall fleet productivity. This is performed by using a time analysis to optimize the process performance, adjusting the parameters of the equipment used, capturing, collecting, and analyzing data, increasing machine operational dependability, and enhancing maintenance work planning. The location of the machines is determined using GPS satellites, and

over 200 distinct characteristics such as GPS coordinates, time and nature of the work performed, and technical indicators of the machines are relayed to the unified server at regular intervals via mobile communications (Goltyapin and Golubev, 2020).

Precision Hawk's Eye UAV Sensor Platform

Precision Hawk has developed an unmanned aerial vehicle (UAV) that can undertake a variety of land-related jobs that were previously performed by humans. This entails land surveying, imaging, and mapping (Puri *et al.,* 2017).

Precision Agriculture

"Precision agriculture is a management technique that uses information technology to gather useable data from a variety of sources in order to aid crop production choices" (Shankar *et al.,* 2020). The geographical and temporal variability of each agricultural unit must be identified, verified, quantified, and recorded. In this way, tailored agronomic management for each unique location in this manner is provided. PA dates back to the early 1980s and is defined by its ability to effectively use resources, reduce wasteful financial investments and environmental damage, and reap economic, social, and environmental benefits (Salcedo *et al.,* 2011).

Precision agriculture comprise any agricultural strategies that employ information technology to alter supply usage in order to achieve the desired result, or to monitor the outcome. IT for PA includes things like variable rate technology, yield tracking, and various sorts of sensors. PA's solutions consist of both hardware and software components that interpret the data acquired by the sensors and give critical information for decision-making (Cisternas *et al.,* 2020). The decrease in the usage of water, fertilizers, herbicides, and pesticides, as also the needed personnel, are among of the most important advantages of PA. Rather to managing the entire field based on hypothetical average circumstances that may or may not be accurate, a PA strategy identifies the unique characteristics of the lands and changes the needed management activities accordingly. PA has the ability to make data collection and analysis more automated and simple. It even enables speedy decision-making and execution of management activities for tiny sections in large fields (Mutale and Xianbao, 2021).

Remote Sensing

Remote sensing is the science and art of obtaining data about real-world objects or regions at a distance without physically touching them. Remote sensing is a method of monitoring the earth's resources that combines satellite technology with terrestrial observations for greater precision and accuracy. Remote sensing distinguishes plants, bare soil, water, and other comparable characteristics by utilizing the electromagnetic spectrum (visible, infrared, and microwaves) for assessing the earth's properties. They can be used to distinguish between plants, bare soil, water, and other similar phenomena because the usual responses of the targets to various wavelength regions change. It can be used for crop growth monitoring, land use pattern and land cover changes, water resources mapping and water status in field conditions, disease and pest infestation monitoring, harvest date forecasting and estimation of yield, precision farming, and weather forecasting purposes, as well as field observations (Shanmugapriya *et al.,* 2019). There are two forms of remote sensing:

Passive remote sensing

Electromagnetic radiation reflected (blue, green, red, and near-infrared light) or emitted (thermal infrared radiation) from the Earth's surface is recorded by passive remote sensing devices.

Table.1 Technique Used in Agriculture

S. No	Techniques used	Advantages	Disadvantages
1.	Water Management	Use water only when and where needed.	**To set up sensor system is expensive.**
2.	Crop Management	Avoid crop losses through diseases or Adverse weather. High quality crop production	**Time consuming. Require intensive labour to collect data regularly.**
3.	Soil Management	Farmers can check the soil temperature, pH rate andhumidity on regularly basis	**Lack of accuracy in sandy soils due to their large particles.Requiring periodic service. Need for each soil type is calibrated.**
4.	Smart Greenhouses	Measure and control the environmental parameters according to plant requirement.	**Smart Greenhouse farming can get expensive. Require constant care with maintaining temperature.**
5.	Livestock Monitoring	Used to detect reproduction and heath of animals earlier.	**It involves lots of money and time.**
6.	**Agriculture Drones**	**It provide in-flight observation and monitoring. It helps the farmer in various ways such as soil fertilising, spraying pesticides and seeding**	**Flight area and time. farmers needs to take Federal Aviation Administration (FAA) operator Traning. Drones are dependent to climatic conditions..**

Fig.1 Agro technology, dubbed 'Agri-Tech,' has quickly grown in popularity across French farms, as it improves efficiency.

Fig.2

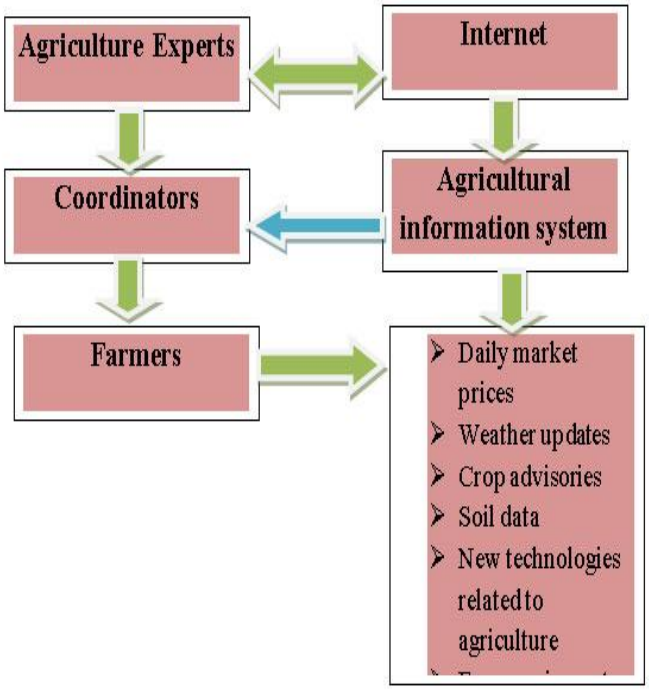

Figure 2: Framework of ICT programmes in India

Fig.3 ICT Innovation and smart farming

Fig.4 ICT Innovation and smart farming with Expert

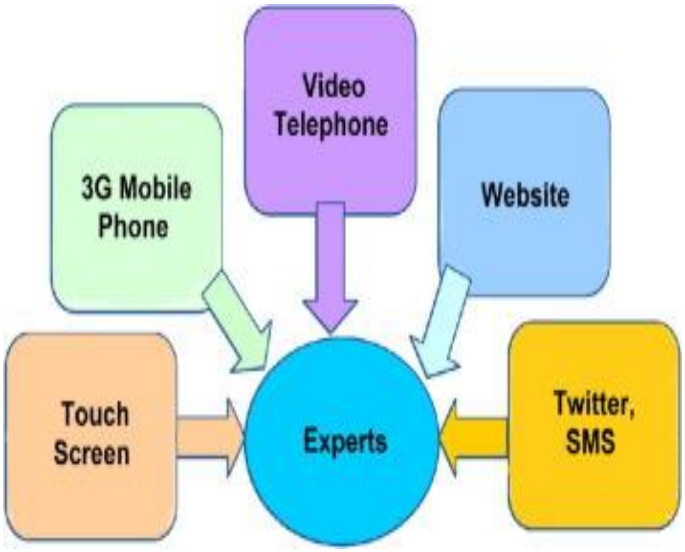

Fig.5 Agricultural Information and communication technology

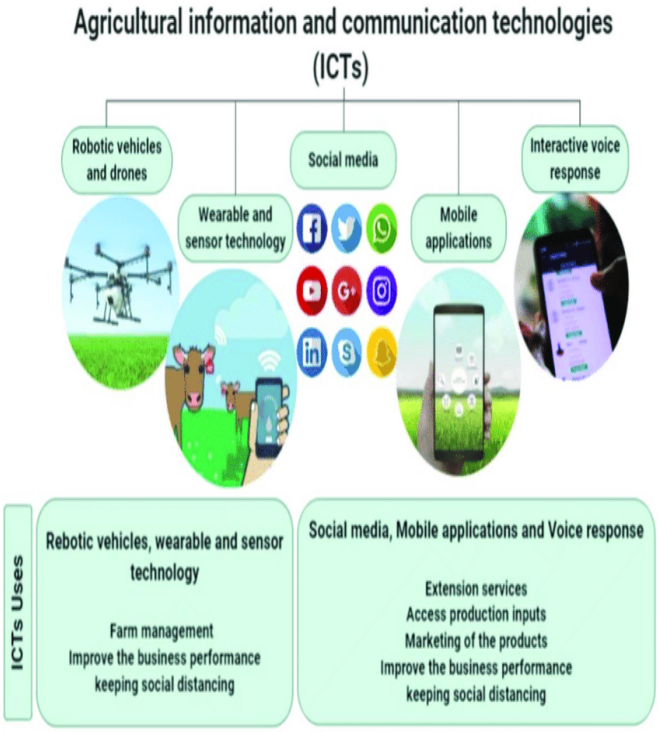

Fig.6 ICT to Strengthen Elements of Agricultural communication.

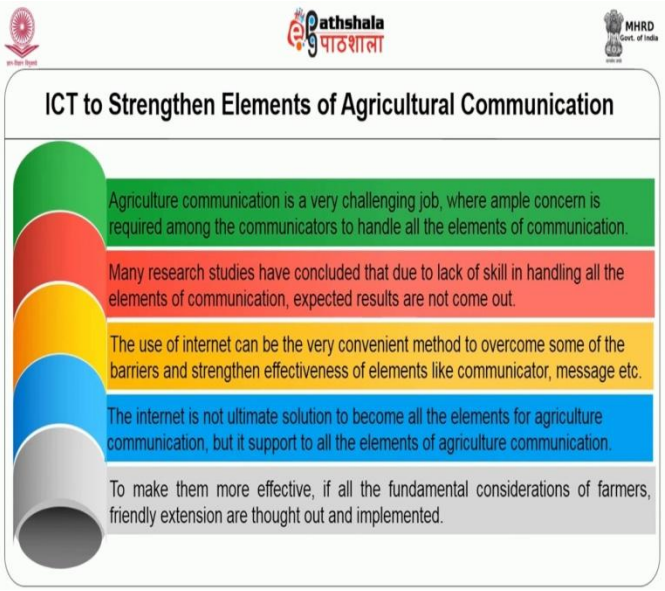

Fig.7

Fig.8 Steps of Information and communication technology (ICTs)

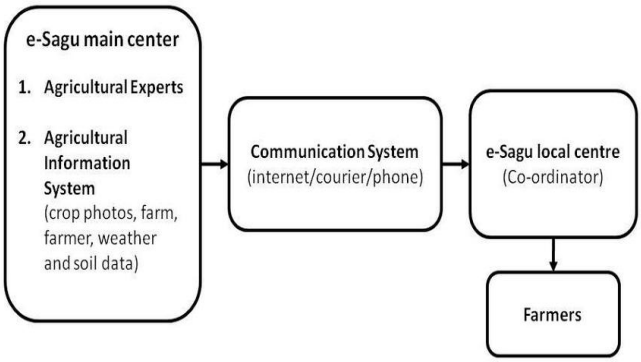

Fig.9 Agricultural Information and communication technology (ICTs)

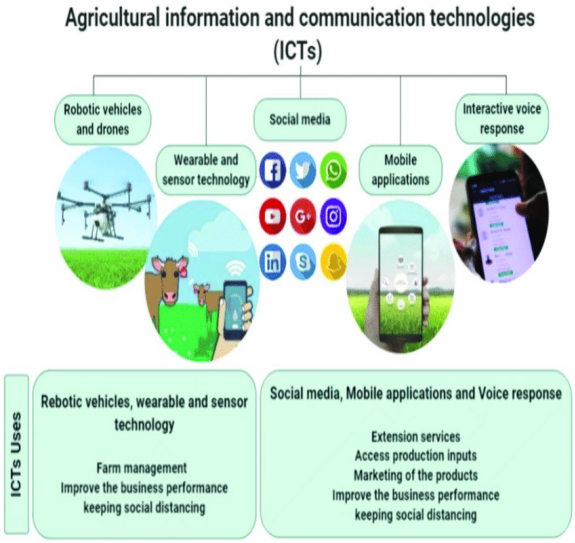

Fig.10 Views of Information and communication technology (ICTs) in Agriculture

Fig.11 Views of Agricultural Production through ICTs

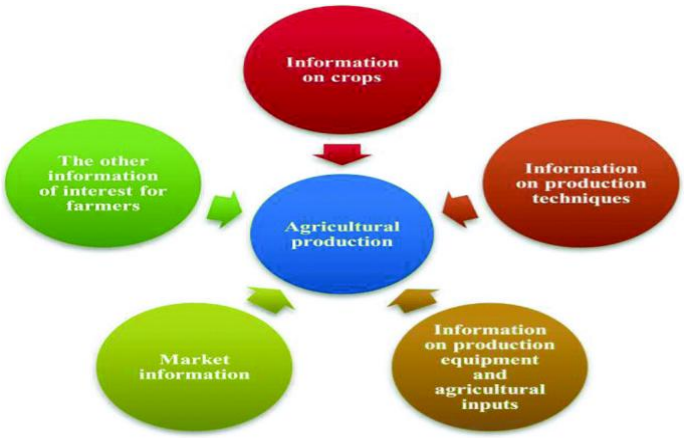

Fig.12 Empowering Smallholder Agriculture

Fig.13

Active remote sensing

Active remote sensing systems are not reliant on the Sun's electromagnetic radiation (EMR) or the Earth's thermal characteristics. Active remote sensors generate their own electromagnetic energy, which is:

Delivered from the sensor toward the landscape

Interacted with the environment, resulting in energy backscatter

Recorded by the remote sensor's receiver (Guo *et al.*, 2020).

Application of Remote Sensing in Agriculture

Recognition of the Crop.

Estimation of crop acreage.

Crop health analysis and stress detection.

Dates for planting and harvesting are planned ahead of time

Modeling and estimate of crop yields.

Detection of pests and disease outbreaks.
Estimation of soil moisture.

Irrigation management and monitoring.

Soil mapping through remotely sensed images.

Droughts are being monitored.

Mapping of land cover and degradation

Identification of Problematic soil.

Drones and the Indian Agriculture Industry

India is primarily an agricultural country, with agriculture employing more than half of the people. The rise in population leads to an increase in agricultural output and protection.
Insects have a tendency to harm crops, lowering yield, and are thus eliminated with pesticides. Agricultural fields sometimes suffer devastating losses owing to crop disease.

Quad copters might therefore be utilized for automatic fertilizer spraying and agricultural surveillance, as well as other uses including search and rescue, Hazmat, police, code inspections, Emergency Management, and firefighting.

Quad rotors offer quick mobility, increased payload, great lifting force, and stability. Quad copters are easier to fly than other aircraft. Quad copters are employed in high-risk situations as well as indoor and outdoor environments. It has a universal sprayer that can be used to spray liquid as well as solid objects.

Although the stress pump is only used for pesticide spraying and not fertilizer spraying, the universal nozzle is used to spray pesticides and fertilizers. In wide regions, the GPS may be used to autonomously direct the quad copter and control it remotely (Bhattacharya *et al.*, 2020b). The autopilot controller controls the quad copter, while the RF Transmitter and motors control the payload (Devi *et al.*, 2020). Figure 3 depicts a diagram of crop monitoring using unmanned aerial vehicles (UAVs).

Agricultural Drone Applications Examples

Seedling Emergence Assessment

A popular agricultural use of images captured with UAS is seedling emergence monitoring and mapping. If crop germination is sluggish or ineffective in some areas of the plot based on environmental factors, the producer generally has a small window of opportunity to replant following plant emergence. The field may be mapped at extremely high resolution in the early phases of crop growth to examine seedlings and identify zones where germination was failed (Sankaran *et al.*, 2015). Some crops, such as wheat, have thin, wispy

leaves that are difficult to distinguish from above during emergence, necessitating the use of spatial drones in agriculture have a resolution of 19 pixels, although other crops have bigger leaves that do not require the same precise resolution to map well. Prior to canopy coalescence, aerial imaging of the field should be done so that individual plants may be seen clearly in the imagery. While RGB photography may be used for emergence mapping, multispectral imaging allows for more flexibility when computing other vegetation indices that use a near-infrared spectral range. When spectrally distinguishing tiny leaves from the surrounding soil backdrop, vegetation indices frequently produce superior results (Merwe *et al.,* 2020).

Weed Detection and Mapping

"Weed mapping is a commonly used application of remote sensing in agriculture and drones has an advantages in this application due to the high spatial resolution flexibility" (Roslim*et al.,* 2021). In terms of how the aerial mapping phase is accomplished and how the data is processed, weed mapping is comparable to seedling emergence mapping. Multispectral imaging is typically the best solution for mapping weeds in an agricultural area. To guarantee that the weed's morphology and phenology, as well as how they differ from the crop species, the agronomist must work closely with the image analyst (Merwe *et al.,* 2020). Some weeds are morphologically and spectrally similar to crop species, making differentiation difficult or impossible, while others are physically and spectrally different, allowing weed identification and categorization using aerial imagery (Singh *et al.,* 2020).

Crop Damage Assessment

Crops currently in production Agriculture can be harmed in a number of ways, resulting in structural and spectral changes. Wind and hail may cause physical damage to the crops. Drone mapping can help locate and quantify agricultural damage caused by weather events, as well as a range of other factors such as insects and diseases. These changes can vary from a little change in the vegetation index to a full change in colour, such as when sorghum leaves are covered in sooty mould. Drones are being employed in studies to determine appropriate inspection intervals, which will be used in conjunction with current mapping assets such as satellites and manned planes. The improvement of this sensor ecosystem will facilitate early detection of pest infestations and disease propagation, as well as a reduction in their consequences, as a result of better-informed management efforts (Koparan *et al.,* 2018).

Water Management

Water shortage is currently the most pressing issues of agriculture, and future demands on water supplies are likely to increase. Water management technologies that respond to changing water needs in near real time, as well as trustworthy data that indicates rising water shortages before they cause production loss, are required to protect crops from drought-related losses. To evaluate soil moisture loss in the soil profile, soil moisture sensors are generally put at a few specified points throughout the field. Irrigation system managers assessed water demands using data from soil moisture sensors, as well as prior knowledge of crop type, soil properties, and climatic factors such as temperature, precipitation, and humidity (Merwe *et al.,* 2020).

Livestock Application

The use of drones in livestock production systems has grown significantly as a result of the increasing availability of low-cost consumer drones that are simple to operate and can provide high-quality video and still images.

With a few notable exceptions, such as the use of thermography, the use of drones in animal mustering, and the use of drones to track animals tagged with radio transmitters, the vast majority of livestock applications revolve around the simple observation of livestock and livestock production systems from the improved perspective of a drone,

using visible light cameras to stream video directly to the operator or to generate aerial images, with visible light cameras to stream video directly to the operator or to generate aerial images (Merwe *et al.,* 2020).

Documenting animal numbers and whereabouts, pasture quality and indicators of degradation owing to causes such as woody plant invasion and erosion, feedlot fill status, and monitoring the supply status of bulk feeding items which including silage and hay bales are just a few of the responsibilities.

Although most of these duties may be done from the ground, drones have the potential to considerably improve the efficiency of regular observations required in livestock production systems management (Thani *et al.,* 2020).

Because high body temperature is often associated with infectious disorders in cattle, body temperature monitoring is an important approach in the monitoring of livestock for the detecting infections in livestock. Local variations in blood flow patterns linked to inflammation can be applied to detect inflammatory lesions, and skin surface temperature can also be used to identify heat stress in cattle (Silva *et al.,* 2020).

Narendra Modi's government has launched Android apps for farmers (www.sarkariyojna.co.in)

Farmers may get the Android applications from the official website mkisan.gov.in or the Google Play store. The following is a list of all Android applications for farmers that Narendra Modi's government has released.

Kisan Suvidha

This app was created to assist farmers by providing information on current weather or forecasted weather for the next five days, market value, traders, agro counseling, plant safety, and IPM methods, among other things.

Agri Market

This smartphone app uses GPS technology to report crop market prices within a 50-kilometer radius. By turning off the GPS, you may get the market price of any other market.

Farm-o-pedia App

This software was created for rural Gujarat and is beneficial to agriculturists and anybody else interested in the agricultural industry. It contains useful information on crops according to soil and season, crop-specific information, meteorological data, and domestic animal management.

M Kisan Application

Agriculturists and stakeholders can use this Android app to access information from experts and government authorities. It is possible to use the portal without registering.

Pusa Krishi

The Pusa Krishi app assists farmers in learning about the cultural traditions and facts associated with various types of crops.

Crop Insurance Application

This programme can compute insurance premiums for notified crops depending on area, coverage amount, and loan amount in the case of loanee farmers. It also includes facts on the sum insured, premiums, and subsidy information for the recommended crop in the advised location.

Shetkari Masik Application

The software may be used to download Shetkari Masik magazine and read it without having to be connected to the internet. Since 1965, the Maharashtra Department of Agriculture has produced the "Shetkari Masik" magazine in the agricultural sector.

Other Android Applications developed for farmers in India

Agri App

This app is developed by Criyagen, AgriApp communication and it can provide information related to crop, helps in videos and calls and to place orders. It is available in English, Hindi and Kannada.

Kisan Books

It provides E-books magazines and booklets for agriculture and this app was developed by Kisan forum Pvt. Ltd. It is available in English and Hindi and five different local languages of India.

Kisan Yojana

It gives information about various government schemes and it is developed by ANN India.

Water Reporter

It helps to track, discover and examine pollution issues that effects our ecosystem and human health through user- initiated monitoring programs.

Agri Smart

It is developed by Punjab Agricultural Department and it focus on effective agriculture developments and pest warnings.

My RML

It is available in 18 states of India in 9 different languages and aims at agriculture advisory, information related to market price, various government schemes, weather forecasting and unit converter.

Digital Mandi

Developed by Appkiddo, it provides information about Indian agricultural commodity and market price list, it is available in 15 states of India.

Fertilizer Calculator

Helps in estimating and calculating the fertilizer requirement of various crops by the correct input by farmers. This app was developed by Dr. Vishwanath Koti.

Future Perspectives

The current research goal is to find areas where information technology development can be used to boost the effectiveness of these services and technologies, as well as to develop cost-effective information technology-based systems that improve the living standards and agricultural production of the rural population.

The art of communication, in the form of ICT, has a great untapped potential that has to be fully developed and disseminated in order to tackle a slew of challenges affecting Indian agriculture in the modern day. The Indian agriculture industry has a bright future thanks to ICT and the different applications that are being developed.

ICT Technology in Agriculture

Digital agriculture

Digital agriculture is the use of new and advanced technologies, integrated into one system, to enable farmers and other stakeholders within the agriculture value chain to improve food production. In comparison with conventional and sensor based approaches, an advanced approach termed as digital agriculture can help the farmers to understand their agricultural practices in a much better and effective way in a real time manner. Thus, digital agriculture holds profound impact on the crop yield enhancements, by empowering the formers with required scientific knowledge to implement good agricultural practices as shown in Figure 1. The user interface system used in digital agriculture provides opportunity to the formers to share their ideas.

This also helps them to get knowledge about different kind of cultivation procedures implemented in the different parts of the globe for the particular crop and equip them with technological advances and business skills to make their agricultural practices as successful venture. Digital agriculture helps formers in maintaining their inherent agricultural practices and at the same time provides useful information to update their knowledge and the skills. It also provides an opportunity to review the historical information in understanding the various situations and difficulties to gain an essential knowledge in taking the right decisions.

The composite agricultural practices combined with rigorous and enhanced crop yield require an implementation of robust automated systems with less development time at low cost. Agricultural safety is a big concern in current scenario which can be implemented by controlling the various contaminants that promote crop damage. Agricultural automation systems including field machinery, irrigation systems, greenhouse automation, animal automation systems, and automation of fruit production systems helps in achieving enhanced crop yields (*"Success stories on information and communication technologies for agriculture and rural development"*, 2015)

Smart farming

Smart Farming is a development that emphasizes the use of information and communication technology in the cyber-physical farm management cycle (*"Wireless Camera Systems"*, 2013). Smart Farming represents the application of modern Information and Communication Technologies (ICT) into agriculture, leading to what can be called a Third Green Revolution. Agricultural based practices in India needs indefinite transition from the conventional methods to the smart farming approaches in order to achieve sustainable and profitable agricultural practices. Smart forming also termed as Internet of Agriculture Technology (IoAT), employs Information and Communication Technologies (ICT) in understanding the various aspects of the farming practices and help the farmers to maintain the optimum conditions with least effort and higher cost benefits to achieve more proficient, highly productive, cost effective and profitable farming enterprises. Smart farming models are found to be more generic, easy to understand and easy to adapt by the farmers. As per the recent survey, the world population is going to reach close to 10 billion by the year 2050. Providing the food for these mammoth populations is considered to be a big challenge for the governments, and it is highly impossible with less cultivable land available and conventional agricultural approaches. The only way to deal this ample task is the implantation of smart agricultural practices and the application of IoT technology in agriculture to overcome the crop limiting hurdles such as biotic and abiotic stress, crop failure, crop damage, loss of productivity and wastage to achieve progression in the agricultural practices. IoAT refer to the application of various sensors to monitor the different conditions such as light intensity, humidity percent, temperature measures, soil moisture content etc. in real-time situation and also helps in the automation of irrigation system to reduce water wastage. The benefits provided by the IoAT is ample and some of the most important benefits are listed to be sensor based field monitoring, effective resource mapping, remote crop monitoring, climate monitoring & forecasting, controlled usage of fertilizers and pesticides and finally the accurate prediction of crop yield (*"World Bank's e-sourcebook ICT in agriculture – connecting smallholder farmers to knowledge, networks and institutions (2011)"*, 2015; Ali *et al.*, 2016).

Supply chain strategies

Food security is one of the most important, critical and major concerns globally today and world is going to face an immense food crisis in coming years. To accommodate future needs of the growing population with the limited availability of cultivable land, it is imperative to decrease product and food losses by strengthening the food security measures through automated food security supply chain

approaches as shown in Figure 3. Automation is very much essential in all the stages of cultivation i.e., selection of quality seed, process of planting seeds, growing the young plantlets, establishing protection from pets to avoid crop damage, supplying the nutrients and water at optimal level to decrease crop failure and increase crop productivity. Other applications of automation include controlled and effective harvesting method to decrease crop wastage, post harvest collection of crop, processing of collected crop and transportation for marketing. Food safety measure brings confidence and increase acceptability of the consumers on products or food items. This can be achieved by denoting the safety measures implemented in all the stages i.e process of cultivation, harvest and post harvest operations, of crop management. Safety measures implanted through automated food chain approaches give more business to the industry and also furnish reputation to the formers which increase their confidence and attract more people towards agricultural practices. Application of big data analytics certainly helps in overcoming the hurdles in food supply chain by integrating with Application Programming Interface (API) system. Big data analytics can certainly add value to the agricultural practice in many regards such as bringing the returns from scientific investments, establishing the good agricultural practice, implementation of precision agricultural based techniques at field level, efficient food supply chain mechanism and automation of the total process for the profitable agriculture (Al-Thani *et al.,* 2020; Anderson and Feder, 2007).

Data mining and analytics

Decision support system (DSS) in the field of agriculture is ably supported by data mining tools. The main aim of the processes involved in data mining is to extract the information from the currently available data sets and then transform the same using specific tools to a unique format that is easily understandable and can be used for advanced purposes as shown in Figure 4. Data mining helps in soil fertility studies and empowers the farmers in making a decision to sow specific variety of the crop that results in a better yield. The main aim of soil classification is to predict the engineering properties and fertilizer of soil there by order the choices for use.

The currently available statistical techniques and the laboratory test consume lot of time, energy and money. It is possible to develop more efficient techniques for solving complex and large data sets of soil with improved accuracy and effectiveness. Data mining techniques based on GPS, k-means approach, SVMs, K-nearest fertilize method are useful to study the soil characteristics, pollution in atmosphere, the factors that influence the crop yield. Soil tests are normally conducted to study the fertility of the soil, impurity and other deficiencies if any in soil that to be removed. Most of the Soil testing laboratories that are owned by either government or private sector offer different protocols for analysis of the soil and the literature pertaining to the soil characteristics. Suitable fertilizers are recommended based on the data available with reference to the soil composition. This helps the formers to apply a suitable fertilizer for specific crops during that season (Arunlal and Rajkiran, 2018; Bakari *et al.,* 2018).

Weather forecasting techniques

One of the greatest challenges for agriculture is climate change and its impact on human life. In contrary to other fields like e-commerce and advertising where Big Data has played big role in their success, there is little impact on advanced understanding of the environment. This inconsistency curtails the climate data with complex nature. Big data analytics has been in use to mine large datasets of climate with more focus of differences between the traditional big data and mining climate data approaches (Bhattacharyay *et al.,* 2020b). In India the impact of climate change effects plant growth development and subsequently crop yield. Due to the increase in the temperatures, there is a drastic reduction in the duration of the crop. Increase in crop respiration rate had resulted in pattern change of pest attack. Most of the crops have

adjusted to the growing season, day lengths of the middle and lower latitudes and with poor response to the much longer days of the summer. Increased temperature accelerates the rate of release of CO_2 during warmer seasons resulting in reduced crop yield. By collecting the data of rainfall and temperature of last 5 years one can analyze the data by using different big data analytics tools to get the exact change in the Indian agricultural climate (Bhattacharyay *et al.,* 2020a). Sensors play a vital role in predicting the effectiveness of the certain seeds, fertilizer in different section of the farm as shown in Figure 5. To achieve an optimum crop yield, software guides the farmers to sow the hybrid varieties seeds at one corner and different variety at another corner (Bohara, 2008).

Agriculture/ crop management

Various seasonal, economic and biological factors influence the crop production but unpredictable changes in these factors lead to a great loss to farmers (Brdar *et al.,* 2011). Crop protection & weed control solutions need to be developed to reduce the crop damage and in turn increase the overall yield of the crop. The existing models consist of three major elements: (i) Data Capture & Storing. (ii) Data Analysis and (iii) Recommendations based on analytics. This unified solution need concurrent advances in the domains of agricultural science, collaboration between supply chain partners and in ICT. New techniques are required to use the historical data for prediction of the occurrence of pests, weeds and other diseases (Buschmann *et al.,* 2000; Baseca *et al.,* 2019).

Integrated Crop Management System (ICMs) is a technique of agricultural practices that balances the necessities of organizing a profitable agri based business with environmental accountability as shown in Figure 6. ICMs includes practices that helps to reduce waste, boost energy efficiency and diminish pollution. Technology used for agriculture has positive impact (Sekhar *et al.,* 2018; Cespedes, 2013; Chang *et al.,* 2006; Chen *et al.,* 2015; Christensen *et al.,* 2009; Cisternas *et al.,* 2020; Kinzli *et al.,* 2011; Devi *et al.,* 2020; Dhivya *et al.,* 2017).

From the survey of technology usage in agriculture, it can be observed that there are numerous approaches that can be used for improving the quality and quantity of crops. In contrast to other developed countries, in India it is a big challenge to achieve the anticipated growth due to non-maintenance of resources on which the production systems depend. Various elements influence the successful use of quality farming.

The field of information and communication technology has seen enormous advancements in the recent decade. These advances aiming at fusing the ICT and agriculture sectors have a lot of potential to deliver some surprising and exciting outcomes. The new ICT-based distribution system appears to be the most potential addition to the current systems. ICT implementation in rural regions and agriculture cannot be accomplished by a single entity. As a result, sectors that have a significant impact on agriculture, such as fertilizers and food, should collaborate to begin and encourage the use of ICT in agriculture. The unique agro-ICT applications discussed in this study resulted from a greater understanding of the agricultural and associated technologies involved on the one hand, and current ICT breakthroughs on the other. There is little question that the agro-ICT method will continue to grow and expand at a rapid pace in the future, with new applications appearing.

The usage of technology in agriculture domain has resulted in digital agriculture, precision agriculture, analytics for crop yield etc. In India, large numbers of people are engaged in agriculture and there is a gap between the farmers and technology. Governments have introduced various methods into agriculture to help the farmers to take the advantage of technology. In spite of this, there is a scope for user friendly easily understandable agro advisory systems to help farmers to take decision on crops to be sown. Also at different levels of crops growth, these technological inventions should help farmers to extract best yield with reduced expenses.

There exists a scope for research in this area. Conclusion Farming play important role in the growth of nations. Thus there is need of smart farming using Internet of Things. It helps farmers to grow different types of crops in their fields with minimum efforts. it increase efficiency, global market, productivity and other features. Farmers can get required information or data about their fileds through their smart phones and IoT devices. IoT works in different domains like Water Management, Crop Management, Smart Greenhouses, Soil Management, Livestock Monitoring etc.

References

"EU-Project Automatic milking". Wageningen UR. 20 February 2008. Archived from the original on 20 February 2006. Retrieved 15 March 2013.

"FAO-ITU E-agriculture Strategy Guide" (PDF). FAO. 20 May 2016. Retrieved 9 June 2016.

"ICT uses for inclusive value chains (2013)" (PDF). FAO. 20 May 2015. Retrieved 9 June 2016.

"ICT uses for inclusive value chains (2013)" (PDF). FAO. 20 May 2015. Retrieved 9 June 2016.

"Information and communication technologies for sustainable agriculture (2013)" (PDF). FAO. 20 May 2015. Retrieved 9 June 2016.

"Information and communication technologies for sustainable agriculture (2013)" (PDF). FAO. 20 May 2015. Retrieved 9 June 2016.

"Kenya Uses Text Messages To Track Elephant". CBS News. 11 February 2009. Retrieved 15 March 2013.

"Malaysia begins RFID-enabled livestock tracking program". RFIDNews. 6 April 2009. Retrieved 15 March 2013.

"National Livestock Identification System". Meat & Livestock Australia Limited. Archived from the original on 20 August 2013. Retrieved 3 September 2013.

"Partners - E-Agriculture". Archived from the original on 1 April 2017. Retrieved 13 February 2019.

"Success stories on information and communication technologies for agriculture and rural development" (PDF). FAO. 20 May 2015. Retrieved 9 June 2016.

"Success stories on information and communication technologies for agriculture and rural development" (PDF). FAO. 20 May 2015. Retrieved 9 June 2016.

"Wireless Camera Systems". AgriCamera. Retrieved 14 March 2013.

"World Bank's e-sourcebook ICT in agriculture – connecting smallholder farmers to knowledge, networks and institutions (2011)". World Bank. 20 May 2015. Archived from the original on 20 March 2016. Retrieved 9 June 2016.

"World Bank's e-sourcebook ICT in agriculture – connecting smallholder farmers to knowledge, networks and institutions (2011)". World Bank. 20 May 2015. Archived from the original on 20 March 2016. Retrieved 9 June 2016.

Ali S, Jabeen U, Nikhitha A. Impact of ICT on Agricultural Productivity. *European Journal of Business, Economics, and Accountancy*. 2016;4(5):82–92.

Ali S, Jabeen U, Nikhitha A. Impact of ICT on Agricultural Productivity. *European Journal of Business, Economics, and Accountancy*. 2016;4(5):82–92.

Al-Thani, N., Albuainain, A., Alnaimi, F., & Zorba, N. (2020, June). Drones for sheep livestock monitoring. In *2020 IEEE 20th Mediterranean Electrotechnical Conference* (MELECON) IEEE, pp. 672-676.

Anderson, J. R., &Feder, G. (2007). Agricultural extension. *Handbook of Agricultural Economics 3*,2343-2378.

Arunlal, K. S. and Rajkiran, S. N. (2018). Smart agriculture: IoT based precise and productive farming approach. *International Journal of advanced Research, Ideas and Innovations in Technology*, 4(6),771-775.

Bakari D, Gisilanbe SA, Chia JI. *et al.*, Evaluation of factors affecting use of Information and Communication Technology among farmers in Taraba state, Nigeria. *International Journal of Agriculture, Environment and Bioresearch*. *2018*;3:388–396.

Bakari D, Gisilanbe SA, Chia JI. *et al.*, Evaluation of factors affecting use of Information and Communication Technology among farmers in Taraba state, Nigeria. *International Journal of Agriculture, Environment and Bioresearch*. *2018*; 3:388–396.

Bhattacharyay, D., Maitra, S. and Sandipan Pine, S. (2020b). Unmanned Aerial Vehicle Applications in Smart AgricultureIn: *Protected Cultivation and Smart Agriculture*, Eds. Maitra, S., Gaikwad, D. J., Shankar, T., New Delhi Publishers, pp.349-353.

Bhattacharyay, D., Maitra, S., Pine, S., Shankar, T. and PeddaGhousePeera, S. K. (2020a). Future of Precision Agriculture in India. *Protected Cultivation and Smart Agriculture*,1,289-299.

Bohara A. Strategic Implementation of ICTS in Agriculture Information Dissemination: A case of Gulmi Districts. *In Proceedings of IOE Graduate*

Conference. 2008. p. 61–75.

Bohara A. Strategic Implementation of ICTS in Agriculture Information Dissemination: A case of Gulmi Districts. *In Proceedings of IOE Graduate Conference*. 2008. p. 61–75.

Brdar, *et al.*, "Support vector machines with features contribution analysis for agricultural yield prediction," *Proceedings of the Second International Workshop on Sensing Technologies in Agriculture, Forestry and Environment (EcoSense)*, Belgrade, pp. 43-47, 2011.

Buschmann, C.; Langsdorf, G.; Lichtenthaler, H.K. (1 November 2000). "Imaging of the Blue, Green, and Red Fluorescence Emission of Plants: An Overview". Photosynthetica. Institute of Experimental Botany (Academy of Sciences of the Czech Republic). 38 (4): 483–491. https://doi.org/10.1023/a:1012440903014. ISSN 0300-3604.

Baseca, C. *et al.*, "A Smart Decision System for Digital Farming," *Agronomy*, vol. 9, no. 5, pp. 216-234, 2019.

Sekhar, C. *et al.*, "Effective use of Big Data Analytics in Crop planning to increase Agriculture Production in India," *International Journal of Advanced Science and Technology*, vol. 113, pp. 31-40, 2018.

Cespedes L M. How ICT tools are increasing efficiency of Agricultural development. 2013.

Cespedes L M. How ICT tools are increasing efficiency of Agricultural development. 2013.

Chang, *et al.*, "Bigtable: a distributed storage system for structured data," *7th USENIX Symposium on Operating Systems Design and Implementation (OSDI)*, pp. 205-218, 2006.

Chen, N., Zhang, X. and Wang, C. (2015). Integrated open geospatial web service enabled cyber-physical information infrastructure for precision agriculture monitoring. *Computers and Electronics in Agriculture*, *111*,78- 91.

Christensen, *et al.*, "Site-specific weed control technologies," *Weed Research*, vol. 49, pp. 233-241, 2009.

Cisternas, I., Velásquez, I., Caro, A., & Rodríguez, A. (2020). Systematic literature review of implementations of precision agriculture. *Computers and Electronics in Agriculture*, 176, 105626.

Kinzli, D., *et al.*, "Linking a developed decision support system with advanced methodologies for optimized agricultural water delivery, Efficient Decision Support Systems-Practice and Challenges in Multidisciplinary Domains," *Intech Open*, pp. 187-212, 2011.

Devi, G., Sowmiya, N., Yasoda, K., Muthulakshmi, K., &Balasubramanian, K. (2020). Review on application of drones for crop health monitoring and spraying pesticides and fertilizer. *J. Crit. Rev*, *7*, 667-672.

Dhivya B. H., *et al.*, "A Survey on Crop Yield Prediction based on Agricultural Data," *International Journal of Innovative Research in Science, Engineering and Technology*, vol. 6, no. 3, pp. 4177-4182, 2017.

Donatelli, *et al.*, "Modelling the impacts of pests and diseases on agricultural systems," *Agricultural Systems*, vol. 155, pp. 213-224, 2017.

Dufty N, Jackson T. Information and communication technology use in Australian agriculture. *Australian Bureau of Agricultural and Resource Economics and Sciences*. 2018.

Elijah, *et al.*, "Production of strawberry using internet of things: a review," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 15, no. 3, pp. 1621-1628, 2019.

Abouziena F. and W. M. Haggag, "Weed control in clean agriculture: A review," *Planta daninha*, vol. 34, no. 2, pp. 377-392, 2016.

Codd, F., "A relational model of data for large shared data banks," *Communications of the ACM*, vol. 13, no. 6, pp. 377-387, 1970.

Fafchamps M, Hill R V. Price transmission and trader entry in domestic commodity markets. *Economic Development and cultural change*. 2008;56(4):729–766.

Fafchamps M, Hill R V. Price transmission and trader entry in domestic commodity markets. *Economic Development and cultural change*. 2008;56(4):729–766.

FAO (2021). Sustainable Development Goals, 17 Goals to Transform Our World. http://www.fao.org/3/i6583e/i6583e.pdf (Accessed 30th April, 2022).

Fraisse CW, Breuer NE, Zierden D, *et al.*, Ag Climate: A climate forecast information system for agricultural risk management in the southeastern USA. Computers and electronics in agriculture. 2006;53(1):13–27.

Fraisse CW, Breuer NE, Zierden D, *et al.*, Ag Climate: A climate forecast information system for agricultural risk management in the southeastern USA. Computers and electronics in agriculture. 2006;53(1):13–27.

Fu, W., Ma, J., Chen, P., & Chen, F. (2020). Remote sensing satellites for digital earth. In *Manual of digital earth*. Springer, Singapore, pp. 55-123.

Babu G., and G. A. Babu, "Data Analytics to Produce Big Results in the Agricultural Sector," *International Journal of Advanced Research in Biology*

Engineering Science and Technology, vol. 2, no. 3, pp. 67-75, 2016.

Gauchan D. Agricultural development in Nepal: contribution to economic growth, food security and poverty reduction. Socio–Economic Development Panorama. 2008;14;1(3):49–64.

Goltyapin, V., & Golubev, I. (2020). Global trends in the development of monitoring systems for mobile agricultural equipment. In *E3S Web of Conferences*. EDP Sciences.157,01013

Hailu, M. Engaging women's in ICT solutions for Agriculture. 2018.

Hailu, M. Engaging women's in ICT solutions for Agriculture. 2018.

Harvey C A, Rakotobe Z L, Rao N S, *et al.*, Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society B:Biological Sciences*. 2014; 369(1639):20130089.

Harvey C A, Rakotobe Z L, Rao N S, *et al.*, Extreme vulnerability of smallholder farmers to agricultural risks and climate change in Madagascar. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 2014; 369(1639):20130089.

Hiltz S R, Gonzalez JJ, Turoff M. ICT support and the effectiveness of decision making in disasters:A preliminary system dynamics model. *InISCRAM*. 2013.

International Institute for Communication and Development (IICD). Youth, ICTs and agriculture: Exploring how digital tools and skills influence the motivation of young farmers. IICD, The Hague, The Netherlands; 2013.

International Institute for Communication and Development (IICD). Youth, ICTs and agriculture: Exploring how digital tools and skills influence the motivation of young farmers. IICD, The Hague, The Netherlands; 2013.

Irungu K R, Mbugua D, Muia J. Information and communication technologies (ICTs) attract youth into profitable agriculture in Kenya. *East African Agricultural and Forestry Journal*. 2015;81(1):24–33.

Irungu K R, Mbugua D, Muia J. Information and communication technologies (ICTs) attract youth into profitable agriculture in Kenya. *East African Agricultural and Forestry Journal*. 2015;81(1):24–33.

Jones, J. W., *et al.*, "Toward a new generation of agricultural system data, models, and knowledge products: State of agricultural systems science," *Agricultural Systems*, pp. 269-288, 2017.

Jayaraman, P. P., Palmer, D., Zaslavsky, A., Salehi, A. and Georgakopoulos, D. (2015). Addressing information

Jiménez, *et al.*, "From Observation to Information: Data-Driven Understanding of on Farm Yield Variation," *PloS ONE*, vol. 11, no. 3, pp. 1-20, 2016.

Chaerle, Laury; Lenk, Sándor; Leinonen, Ilkka; Jones, Hamlyn G.; Van Der Straeten, Dominique; Buschmann, Claus (2009). "Multi-sensor plant imaging: Towards the development of a stress-catalogue". Biotechnology Journal. Wiley-VCH. 4 (8): 1152–1167.

Kusnierek K., and A. Korsaeth, "Simultaneous identification of spring wheat nitrogen and water status using visible and near infrared spectra and powered partial least squares regression," *Computers and Electronics in Agriculture*, vol. 117, pp. 200-213, 2015.

Arjun, K. M., "Indian Agriculture- Status, Importance and Role in Indian Economy," *International Journal of Agriculture and Food Science Technology*, vol. 4, no. 4, pp. 343-346, 2013.

Van Evert, K., *et al.*, "Big Data for weed control and crop protection," John Wiley & Sons Ltd on behalf of European Weed Research Society, pp. 218-233, 2017.

Kabir K H. Attitude and level of knowledge of farmers on ICT based farming. *European Academic Research.* 2015; 2(10):13177–13196.

Kabir K H. Attitude and level of knowledge of farmers on ICT based farming. *European Academic Research.* 2015;2(10):13177–13196.

Kaddu S B. Information and Communication Technologies'(ICTs) contribution to the access and utilisation of agricultural information by the rural women in Uganda. Makerere University. 2011.

Kaddu S B. Information and Communication Technologies'(ICTs) contribution to the access and utilisation of agricultural information by the rural women in Uganda. Makerere University. 2011.

Kante M, Oboko R, Chepken C. Factors affecting the use of ICTs on agricultural input information by farmers in developing countries. *AIMS Agriculture and Food*. 2016;20;1(3):315–329.

Karthikeyan C. e–Velanmai–An ICT Enabled Agricultural Extension Model. *International Journal of Extension Education*. 2012;8:24–30.

Kashem, M. A., Faroque, M. A. A., Ahmed, G. M. F. and Bilkas, S. E. (2010). The complementary roles of

Kashyap, *et al.*, "Big data Analytics in Bioinformatics: A Machine Learning Perspective," *Journal of Latex Class Files*, vol. 13, no. 9, pp. 1-20, 2014.

Kaur, S. and Dhindsa, K. S. (2018). Comparative study of

android-based M-apps for farmers. In *International Conference on Intelligent Computing and Applications* Springer, Singapore, pp. 173-183.

Kempenaar, *et al.*, "Towards data-intensive, more sustainable farming: advances in predicting crop growth and use of variable rate technology in arable crops in the Netherlands," *13th International Conference on Precision Agriculture (ICPA)*, St. Louis, MO, USA, 2016.

Koparan, C., Koc, A. B., Privette, C. V., Sawyer, C. B., & Sharp, J. L. (2018). Evaluation of a UAV-assisted autonomous water sampling. *Water*, 10(5),655.

Krishi Diary. Agriculture Information and Training Centre, Hariharbhawan, Kathmandu; 2019.

Lin and H. Zhongwei, "Analysis of agricultural products e-commerce models based on supply chain management," *International Conference on E-Business and E-Government (ICEE)*, pp. 1-3, 2011.

Lizarazo Salcedo, I. A., & Alfonso Carvajal, O. A. (2011). Precision Agriculture Applications in the Cultivation of ElaeisGuineensis and Hybrid O x G Oil Palms. *Revista de Ingeniería*, 33,124-130.

Lokeswari K. A study of the use of ICT among rural farmers. *International Journal of Communication Research*. 2016;6(3):232.

Lokeswari K. A study of the use of ICT among rural farmers. *Internation Journal of Communication Research*. 2016;6(3):232.

M. (2021). Using remote sensing and an unmanned aerial system for weed management in agricultural crops: A review. Agronomy, 11(9),1809.

O'Grady, M. J. and G. M. P. O'Hare, "Modelling the smart farm," *Information Processing in Agriculture*, vol. 4, no. 3, pp. 179-187, 2017.

Sagar M., and Cauvery N. K., "Agriculture Data Analytics in Crop Yield Estimation: A Critical Review," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 12, no. 3, pp. 1087-1093, 2018. http://breakthrough.unglobalcompact.org/disruptive-technologies/digital-agriculture/.

Maitra, S. (2018). Role of intercropping system in agricultural sustainability. Centurion Journal of Multidisciplinary Research. 8(1), 77-90.

Maitra, S. and Pine, S. (2020). Smart Irrigation for Food Security and Agricultural Sustainability. *Indian Journal of Natural Sciences*, 10(60), 20435-20439.

Majumdar, *et al.*, "Analysis of agriculture data using datamining techniques: application of big data," *Journal of Bigdata*, vol. 4, pp. 1-15, 2017.

Mangstl, A. (2008). "Emerging Issues, Priorities and Commitments in e-Agriculture". AgInfo Worldwide. 1 (1).

Mariani and A. Ferrante, "Agronomic Management for Enhancing Plant Tolerance to Abiotic Stresses—Drought, Salinity, Hypoxia, and Lodging," *Horticulturae*, vol. 3, no. 4, pp. 52-69, 2017.

Maselyne, J.; Adriaens, I.; Huybrechts, T.; De Ketelaere, B.; Millet, S.; Vangeyte, J.; Van Nuffel, A.; Saeys, W. (11 May 2015). "Measuring the drinking behaviour of individual pigs housed in group using radio frequency identification (RFID)". Animal. 10 (9): 1557–1566. doi:10.1017/s1751731115000774. ISSN 1751-7311. PMID 25959418.

Mihalache, D., Vanghele, N., Petre, A., &Matache, A. (2021). The Use Of Drones In Modern Agriculture. *Annals of the University of Craiova-Agriculture, Montanology, Cadastre Series*, 50(2),349-354.

Mirjankar and S. Hiremath, "Application of Data Mining in Agriculture Field," *International Journal of Computer Engineering and Applications (iCCSTAR-2016)*, pp. 363-368, 2016.

Muinde, F. *Investigation of factors affecting the adoption of information and communication technologies for communication of research output in research institutions in Kenya* (Unpublished doctoral dissertation). Victoria University of Wellington, Wellington, New Zealand; 2009.

Mutale, B. and Xianbao, L. (2021). Precision Agriculture in Denmark and China: A Comprehensive Comparative Review with Policy Implications for China. *Precision Agriculture*, *76*,71-84

Nakasone E, Torero M. A text message away: ICTs as a tool to improve food security. Agricultural Economics. 2016;47(S1):49–59.

Nakasone E, Torero M. A text message away: ICTs as a tool to improve food security. Agricultural Economics. 2016;47(S1):49–59.

Nehra, K. S., Jangra, M., Jangra, S. and Kumar, R. (2018). Role of information Technology in Agriculture. *Crop*

Njenga PK, Mugo F, Opiyo R. Youth and women empowerment through agriculture in Kenya. VSO Jitolee; 2011.

Njenga PK, Mugo F, Opiyo R. Youth and women empowerment through agriculture in Kenya. VSO Jitolee; 2011.

Nozari, *et al.*, "Differentially private distributed convex optimization via objective Perturbation," *American Control Conference (ACC)*, Boston, MA, USA, pp. 2061-2066, 2016.

Nsibirano R. "Him and Her"–gender differentials in ICT uptake: A critical literature review and research agenda. International Journal of Education and Development using ICT. 2009;5(5):33–42.

Nsibirano R. "Him and Her"–gender differentials in ICT

uptake: A critical literature review and research agenda. International Journal of Education and Development using ICT. 2009;5(5):33–42.

Oakley, P., & Garforth, C. (1985). *Guide to extension training Food & Agriculture Org.*11,1-193.

Jayaraman, P., *et al.*, "Internet of Things Platform for Smart Farming: Experiences and Lessons Learnt," *Sensors*, vol. 16, pp. 1-17, 2016.

Pande N, Deshmukh P. ICT:A path towards rural empowerment through telecommunication, egovernance, and e–agriculture. *IBMRD's Journal of Management & Research*. 2015;4(2):47–54.

Pandey, N. (2017). Role of information and communication technology in agriculture development: a study of Nabarangpur district. *Scholedge International Journal of Business Policy & Governance* 4,2394-3351.

Peknic`ova and K. B. Bimova, "Application of species distribution models for protected areas threatened by invasive plants," *Journal for Nature Conservation*, vol. 34, pp. 1-7, 2016.

Puri, V., Nayyar, A. and Raja, L. (2017). Agriculture drones: A modern breakthrough in precision processing needs of digital agriculture with OpenIoT platform. In *Interoperability and Open-Source Solutions for the Internet of Things* Springer, Cham, pp. 137-152.

Shamshiri, R., *et al.*, "Advances in greenhouse automation and controlled environment agriculture: A transition to plant factories and urban agriculture," *International Journal of Agricultural & Biological Engineering*, vol. 11, no. 1, pp. 1-22, 2018.

Ramesh and B. V. Vardhan, "Data Mining Techniques and Applications to Agricultural Yield Data," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 2, no. 9, pp. 3477-3480, 2013.

Robert Chapman; Tom Slaymaker; John Young. "Livelihoods Approaches to Information and Communication in Support of Rural Poverty Elimination and Food Security" (PDF). Overseas Development Institute. Retrieved 25 September 2016.

Roháček, Karel; Soukupová, Julie; Barták, Miloš (2008). "3 Chlorophyll fluorescence: A wonderful tool to study plant physiology and plant stress". In Schoefs, Benoît (ed.). Plant Cell Compartments - Selected Topics. Kerala, India: Research Signpost. ISBN 978-81-308-0104-9. OCLC 299502085.

Roslim, M. H. M., Juraimi, A. S., Che'Ya, N. N., Sulaiman, N., Manaf, M. N. H. A., Ramli, Z. and Motmainna,

Pongnumkul, S., *et al.*, "Applications of Smartphone-Based Sensors in Agriculture: A Systematic Review of Research," *Journal of Sensors*, vol. 2015, pp. 1-18, 2015.

Rani, S., "The Impact of Data Analytics in Crop Management based on Weather Conditions," *International Journal of Engineering Technology Science and Research*, vol. 4, no. 5, pp. 299-308, 2017.

Sarnin, S. S., "Smart insects repeller," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 17, no. 1, pp. 205-212, 2020. https://ecmltd.co.uk/integrated-crop-management/.

Wolfert, S., *et al.*, "A Future Internet Collaboration Platform for Safe and Healthy Food from Farm to Fork," *Annual SRII. Global Conference*, San Jose, CA, USA, pp. 266-273, 2014.

Samriddhi Foundation. Commercialization of Agriculture in Nepal.

Sankaran, S., Zhou, J., Khot, L. R., Trapp, J. J., Mndolwa, E. and Miklas, P. N. (2018). High-throughput field phenotyping in dry bean using small unmanned aerial vehicle based multispectral imagery. Computers and Electronics in Agriculture, 151, 84-92.

Sebastian, Richard (7 June 2010). "RFID in Malaysia – Tracing the ROI". Frost & Sullivan. Retrieved 15 March 2013.

Shanmugapriya, P., Rathika, S., Ramesh, T. and Janaki, P. (2019). Applications of remote sensing in agriculture- A Review. International Journal of Current Microbiology and Applied Sciences, 8(01), 2270-2283.

Shrestha, A. 63 Percent of Nepal's Population Connected to the Internet.

Silva, R. A. B. D., Pandorfi, H., Almeida, G. L. P. D., & Silva, M. V. D. (2020). Exploratory data inference for detecting mastitis in dairy cattle. ActaScientiarum. Animal Sciences, 42,e46394

Singh S, Ahlawat S, Sanwal S. Role of ICT in Agriculture: Policy implications. *Oriental Journal of Computer Science and Technology*. 2017;10(3):691–697.

Singh, V., Rana, A., Bishop, M., Filippi, A. M., Cope, D., Rajan, N. and Bagavathiannan, M. (2020). Unmanned aircraft systems for precision weed detection and management: Prospects and challenges. Advances in Agronomy, 159,93-134.

Sishodia, R. P., Ray, R. L. and Singh, S. K. (2020). Applications of remote sensing in precision agriculture: A review. Remote Sensing, 12(19):3136.

Tonny N B, Palash M S, Moniruzzaman M. Use of ICT in decision making of agricultural marketing: Factors determining of farmers' involvement. *Journal of the Bangladesh Agricultural University.*

2019;17(2):226–231.

Tonny N B, Palash M S, Moniruzzaman M. Use of ICT in decision making of agricultural marketing: Factors determining of farmers' involvement. *Journal of the Bangladesh Agricultural University*. 2019;17(2):226–231.

Tripathi and A. K. Mishra, "Knowledge and passive adaptation to climate change: An example from Indian farmers," *Climate Risk Management*, vol. 16, pp. 195-207, 2017.

Tsiolias, *et al.*, "Big Data and Agricultural Supply Chains: Opportunities for Increased Food Security, *Proceedings of the Homburg International conference of Logistics (HICL)*, vol. 22, pp. 331-354, 2015.

Tzounis, A., Katsoulas, N., Bartzanas, T. and Kittas, C. (2017). Internet of Things in agriculture, recent advances and future challenges. Biosystems engineering, 164,31-48.

van der Merwe, D., Burchfield, D. R., Witt, T. D., Price, K. P. and Sharda, A. (2020). Drones in agriculture. Advances in agronomy, 162, 1-30.

Van der Merwe, D., Burchfield, D. R., Witt, T. D., Price, K. P. and Sharda, A. (2020). Drones in agriculture. Advances in Agronomy, 162,1-30.

Vosough A, Eghtedari N, Binaian A. Factors affecting ICT adoption in rural area:a case study of rural users in Iran. *Research Journal of Fisheries and Hydrobiology*. 2015;10(10):611–616.

Vosough A, Eghtedari N, Binaian A. Factors affecting ICT adoption in rural area:a case study of rural users in Iran. *Research Journal of Fisheries and Hydrobiology*. 2015;10(10):611–616.

Wijesooriya, M. A. L. H. and Kankanamge, P. How to Attract Sri Lankan Youth for Agriculture by Using Information Technology. Revitalizing The Economy Through Sustainable Strategies, 104,334

World Bank. ICT in agriculture: connecting smallholders to knowledge, networks, and institutions. World Bank. 2011.

World Bank. World development report 2016: Digital dividends.

Wratt D S, Tait A, Griffiths G, *et al.*, Climate for crops: integrating climate data with information about soils and crop requirements to reduce risks in agricultural decision-making. *Meteorological Applications:A journal of forecasting, practical applications, training techniques and modelling*. 2006;13(4):305–315.

Wratt DS, Tait A, Griffiths G, *et al.*, Climate for crops: integrating climate data with information about soils and crop requirements to reduce risks in agricultural decision-making. *Meteorological Applications:A journal of forecasting, practical applications, training techniques and modelling*. 2006;13(4):305–315.

Edan, Y. *et al.*, "Automation in Agriculture," *Springer Handbook of Automation*, pp. 1095- 1128, 2009.

Zamani GH, Karami E. Rural leadership and sustainable agriculture: criteria for recruiting leaders. *Journal of Food Agriculture and Environment*. 2006;4(3/4):228.

Zamani GH, Karami E. Rural leadership and sustainable agriculture: criteria for recruiting leaders. *Journal of Food Agriculture and Environment*. 2006;4(3/4):228.

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