Repository on Digital Technologies in Agriculture and Water

SOPPECOM

December 2023

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Society for Promoting Participative Ecosystem Management (SOPPECOM)Pune

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Author: SOPPECOM

Supported by: TMG Research Group gGMBH, Berlin, Germany

Published by: Society for Promoting Participative Ecosystem Management (SOPPECOM)

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Website: www.soppecom.org

First Published: December 2023

Cover Photo: Stock Photos, Microsoft

Citation: SOPPECOM (2023). Repository on Digital Technologies in Agriculture and Water

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Acronyms

ACT	Arid Area Communities and Technologies
ACWADAM	Advanced Centre for Groundwater Resources and Development
AI	Artificial Intelligence
BRLF	Bharat Rural Livelihoods Foundation
CAPS	Cyber Agro-Physical Systems
CDVI	Community-Driven Visual Integrator
CLART	Composite Landscape Assessment and Restoration Tool
CSA	Climate Smart Agriculture
CSC	Common Service Centre
CSEI	Centre for Social and Environmental Innovation
DARE	Department of Agricultural Research and Education
DBT	Direct Benefit Transfer
DFS	Digital Financial Services
DPR	Detailed Project Report
e-NAM	Electronic National Agriculture Market
FAO	Food and Agriculture Organization
FCCI	Federation of Indian Chambers of Commerce & Industry
FES	Foundation for Ecological Security
FPO	Farmer Producer Organisation
GDP	Gross Domestic Product
GEET	GIS Enabled Entitlement Tracking Tool
GIS	Geographic Information Systems
IBIS	Indian Biodiversity Information System
ICAR	Indian Council of Agriculture Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and Communications Technology
IFMT	Integrated Forest Management Tool
IOT	Internet of Things

IRRI	International Rice Research Institute
ISRO	Indian Space Research Organisation
IVR	Interactive Voice Response
KCC	Kisan Call Centre
KSNMDC	Karnataka State Natural Disaster Monitoring Centre
KVK	Krishi Vigyan Kendra
MEITY	Ministry of Electronics and Information Technology
MGNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
ML	Machine Learning
MNCFC	Mahalanobis National Crop Forecast Centre
MoU	Memorandum of Understanding
MWBCIS	Modified Weather Based Crop Insurance Scheme
NASSCOM	National Association of Software and Service Companies
NEGD	National E-Governance Division NEGD, Department Of Electronics And Information Technology
NRM	Natural Resources Management
ODK	Open Data Kit
PA	Precision Agriculture
PAD	Precision Agriculture for Developement
PMFBY	Pradhan Mantri Fasal Bima Yojana
PM-KISAN	Pradhan Mantri Kisan Saman Nidhi
PPP	Public Private Partnership
SMS	Short Messaging Service
SOPPECOM	Society for Promoting Participative Ecosystem Management
UAV	Unmanned Aerial Vehicle
UNESCO	United Nations Educational, Scientific and Cultural Organization
WOTR	Watershed Organization Trust
WSI	Water Stewardship Initiative

Foreword and Acknowledgement

Society for Promoting Participative Ecosystem Management (SOPPECOM) is a non-profit, non-governmental organisation based in Pune, India, working in the area of natural resources management, primarily in rural areas. The organisation is committed to the principles of sustainable and rational use of natural resources, equity, and social justice in the distribution of benefits, especially to disadvantaged groups like Dalits, the landless, and women. As an organisation committed to these principles, SOPPECOM extends its support to grassroots groups working on NRM issues through training, resource literacy, participatory planning, research, and policy advocacy.

TMG Research gGmbH is a Berlin-based research organisation working on sustainability issues in the areas of sustainable management and responsible governance of land and oceans, food systems, and climate. As an organisation, TMG brings sound knowledge and practical experience in facilitating national, European, and international processes and is dedicated to the analysis and solution of new and complex challenges.

The Ecosystem-based adaptation (EbA) workstream of the SEWOH Lab investigated how local support systems can provide "last mile connectivity" through facilitating access to digital information in climate adaptation. The focus of the research was to understand how local institutions use digital tools in participatory water resource management. As a culmination of the research study under the EbA workstream, SOPPECOM and TMG conducted a workshop in Pune on 23rd and 24th January 2023, to bring together experts and practitioners who have worked extensively in the area of natural resources management. Through the discussions during the workshop, it was learned that there are a number of digital tools that have been developed in the natural resources management sector. However, there is no consolidated information of the different types of these tools and their capabilities in one place. This report attempts to put together a repository of all the digital tools developed for the agriculture and water sector. This report could serve as a good reference document for the organisations who would like to know the available technologies across government and private platforms.

This report is organized in seven sections. The first section gives a background to the report and the rationale behind the study. The introduction section gives a brief overview of the concept of digitalisation and its different application. Section three discusses the need of digitalisation in the agriculture sector. Section four gives a brief overview of the agriculture sector in India. Section five details out the different digital approaches in the agriculture sector. Section six titled 'How India uses digital technology' details out all the different digital tools available for the agriculture sector. The section differentiates these tools based on their functionality for example: weather forecasts, warning systems, monitoring and evaluation etc., and also according to who has developed them, for example, government, start-ups etc. Section seven is the discussion section which highlights the potential of digital technology for improving agriculture practices and the challenges of grounding digital tools and technologies.

First and foremost, we would like to thank Aarti Kelkar Khambete, an independent researcher, also working for India Water Portal for compiling this report for SOPPECOM. We understand that it required extensive literature review and we acknowledge her patience and dedication.

We thank the TMG Research Group for collaborating with us on this project and providing us the financial support. We are very thankful to Larissa Stiem-Bhatia from the TMG Research

group for coordinating with our team and sharing her valuable feedback with our team from time to time.

A special thank you to all the participants of the workshop organized in Pune on 23rd and 24th January 2023. Your inputs and ideas were useful for the shaping of this report.

Thank you to the SOPPECOM team consisting of K.J. Joy, Neha Bhadbhade, Sarita Bhagat, Kiran Lohakare and Abraham Samuel who were a part of this study and helped Aarti Khambete Kelkar to put the report together. Last but not the least thank you to SOPPECOM's administration team, Tanaji Nikam and Pratima Medhekar for their unending support.

SOPPECOM, Pune

1. Background

The SEWOH Lab, a project led by TMG Research Group, Berlin, analyses the linkages between digital and social innovations for achieving food security and sustainable livelihoods of smallholder farmers. The cornerstone of the project is unlocking the potential of digital solutions for inclusive rural and agricultural development in sub-Saharan Africa and India. Its primary focus lies on smallholder farmers and marginalised land users, including women. It is supported by the German Federal Ministry for Economic Cooperation and Development (BMZ).

Under the SEWOH Lab project, SOPPECOM has collaborated with the TMG Research Group on two distinct workstreams. The first workstream was the 'Ecosystems Restoration Workstream: Digital Tools to cover the last mile in restoration monitoring' and the second workstream was 'Ecosystem-based climate adaptation workstream: Digitalisation in ecosystem-based climate adaptation. Bridging the last mile through social innovations.

The Ecosystem Restoration work stream of the SEWOH Lab was dedicated to identifying the conditions under which ecosystem restoration in agricultural landscapes can contribute to enhance food security, rural livelihoods, and biodiversity. The research study under this workstream sought to understand the challenges involved in monitoring ecosystem and soil restoration projects, exploring social and digital innovations that can empower farmers and local communities in the monitoring of project activities, with a view to reduce transaction costs. It further sought to understand how the local monitoring data is connected to state/ national reporting on development and climate related goals, including the SDGs (e.g., poverty, food security, land degradation neutrality, biodiversity, climate adaptation and mitigation). The project's goal was to foster the participatory use and customisation of digital tools, marginalised land users, especially women, leading to more efficient and transparent monitoring and reporting of project activities.

The Ecosystem-based adaptation (EbA) workstream of the SEWOH Lab investigated how local support systems can provide "last mile connectivity" through facilitating access to digital information in climate adaptation. In this regard, digitalization is not regarded as an end in itself but as a means to enable farmers and other land users to make better informed decisions with a view to enhance the resilience of their production systems in the face of climate change. The focus of the research was to understand how local institutions use digital tools in participatory water resource management through various participatory mechanisms such as water resource monitoring, water budgeting, and water-sensitive crop planning among others. Here SOPPECOM and TMG did a deep-dive analysis of the Water Stewardship Initiative (WSI) of the Watershed Organization Trust (WOTR) and also visited three different sites across India to understand the use of digital tools in participatory water governance. These sites were - Foundation for Ecological Security (FES), Rajasthan, Arid Area Communities and Technologies (ACT), Gujarat and Gram Vikas, Odisha.

As a culmination of the research study under the EbA workstream, SOPPECOM and TMG conducted a workshop in Pune on 23rd and 24th January 2023, to bring together experts and practitioners who have worked extensively in the area of water management and governance and also of on the use of various digital tools and innovations in participatory water management.

The resource persons from the organisations visited were also invited to present their work and participate in the deliberations of the workshop. Through the discussions during the workshop, it was learned that there are a number of digital tools that have been developed in the natural resources management sector. However, there is no consolidated information of the different types of these tools and their capabilities in one place. Therefore, the following report attempts to create a repository of the different tools that are available for natural resources management with the focus on agriculture and water.

2. Introduction

Digitalisation involves the integration of digital technologies into everyday life through digitisation of information – a process of converting information collected physically through sensors or written information, etc. and knowledge into a computer-readable language. This information can be used to inform people, take decisions on the ground through sharing it with different levels of stakeholders due to the ease of transmitting this information.

Many nations are focusing on achieving environmental sustainability through better use of land and water resources, and digital technologies can serve as a useful tool in the management of these natural resources. Digital solutions can have the potential to help improve the efficiency and impact of NRM activities (GSMA, 2020). Digital technologies are being used for a range of applications from monitoring disasters (floods, droughts, cyclones, storms etc), air and water pollution levels, protection and conservation of land, forests, wildlife, biodiversity and agriculture, soil and water management (GSMA, 2020). However, this review will focus on the use of digital technologies for soil, water and agricultural management.

3. The need for digitalisation in agriculture

Rise in population is increasing the demand for food, thus increasing pressure on agricultural systems globally. Changing climatic conditions leading to changes in temperature, rainfall patterns, carbon dioxide levels, increased frequency of extreme weather events like droughts, floods, cyclonic disturbances, and increased saline soils will pose further challenges to agriculture affecting production (Mondejar, M. E. et al. 2021). These can result in rise in costs and problems such as pest infestation and diseases, which can further increase pressure on global agricultural and land resources. It will be challenging to meet the food requirements of 9.7 billion people globally by 2050 under these circumstances (Mondejar, M. E. et al. 2021).

Digital technologies can help in sustainable management of agricultural land, soil and water resources as well as increase food and livelihood security worldwide. Digitalisation has already made rapid strides within the agricultural sector and is being used for land assessment, soil-crop suitability, weather information, crop-growth, biomass and productivity, precision farming, and in the various stages of the agricultural supply chain such as processing, packaging, delivery, consumption, and agro-waste management (Mondejar, M. E. et al. 2021). Drones and sophisticated technologies like IOT and precision agriculture have also entered the agricultural sector and are being used to improve agricultural productivity (Mondejar, M. E. et al. 2021). For

example, Remote sensing and GIS-based technologies are used for sustainable management of agricultural land

The use of mobile-based apps by farming, scientific and technical professionals is enabling information access related to climate-smart agricultural (CSA) practices. Precision agriculture can help in optimum use of agricultural resources by improving accuracy of usage. Modern unmanned aerial vehicles (UAVs) or drones contain various sensors and can be useful for predicting the real-time information on droughts, soil nutrients, plant growth, yield, diseases, pesticides and weeds, pests, weather parameters, soil types, moisture content, and spray pesticides and fertilisers. Data science is increasingly being used in agriculture to improve crop yield, nutritional value, stress tolerance, and dealing with the negative impacts of climate change. (Mondejar, M. E. et al. 2021). Under the SEWOH lab project, the focus is to understand the role of app-based services for data collection and advisories and how effective they are in management of natural resources like soil and water, especially in the context of agroecological systems in India.

4. Agriculture in India

Agriculture is the lifeline of the Indian economy and contributes to 16 percent of India's gross domestic product (GDP) while employing 43 percent of India's workforce (World Economic Forum, 2021).

Major challenges faced by the agricultural sector in India include:

- Shrinking land sizes leading to unsustainable farm incomes
- Unsustainable farming practices leading to soil degradation and water stress
- Lack of data at the farm, farmer and sector levels leading to higher costs of services
- Poor availability of market linkages, challenges in price discovery and price volatility in the market
- Lack of food processing, logistics and warehousing infrastructure near the farms leading to increasing wastage and the inconvenience, both physical and economic of transporting agricultural goods to the nearby markets.
- Challenges in financial and digital inclusivity
- Poor farm mechanisation due to lack of affordability (World Economic Forum, 2021).

Though the adoption of digital technologies can contribute to addressing some of these challenges, there are isolated examples of success in this area and these efforts have not been scaled up adequately.

Emerging technologies can help agriculture by:

- Generating sustainable farm incomes through establishing better connections in the farm-to-market supply chains
- Aiding in financial and digital inclusion of smallholder farmers
- Safe food systems: Emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), molecular science and computer vision can now be used to

ensure food safety and quality during production, procurement, storage and trade of agricultural commodities such as milk, tea, grains and spices. (Bhamra, T., 2022).

- Real-time monitoring of the environmental changes and their impacts
- Improved productivity and efficiency through farm mechanisation. For example, IOT based remotely controlled irrigation sensors can help in alternate wetting and drying of the soil depending on need and prevent wastage of water.
- Digital management of storage and logistics infrastructure for agricultural produce or food products to prevent wastage
- Smart management of climate related risks (World Economic Forum, 2021).

5. Digital Approaches in Agriculture

There are broadly four categories of digital approaches used in the agricultural sector in India (Cheruku, J.K and Katekar, V., n.d).

5.1. Data-Driven Agriculture

The availability of accurate data is crucial for improving the state of agriculture in India and includes satellite images, soil health information, land records, season-wise cropping patterns, market-related data, and farmer related data. Central and state governments can collect such data from different sources and use it for policy interventions in agriculture while farmers can access real-time weather-related data on smartphones, which can help them plan agricultural activities (Cheruku, J.K and Katekar, V., n.d).

5.2. Precision Agriculture (PA)

Precision Agriculture (PA) can help in improving agricultural production through optimal and sustainable use of resources and help increase small farmer incomes and enhance yield. It involves use of technologies such as drones, satellites, and IoT sensors fixed at the ground and linked with data platforms.

The Internet of Things (IoT) has various applications in the agricultural sector, as this technology uses a network of sensors and other devices to transform actions or processes into data. IoT-enabled devices can thus help in knowing the state of natural resources and encourage their optimal and sustainable use (Cheruku, J.K and Katekar, V.,n.d)

5.3. Digital Agriculture Extension

Many farmers do not have access to updated information on climate extremes such as droughts, storms, floods, dry spells, etc that can help them to plan for their crops in a better way. Digital agriculture extension employs digital tools and services that are used to deliver this information effectively and include Short Message Service (SMS), Interactive Voice Response (IVR), interactive radio, low-cost video that can reach a large number of farmers in a short period through timely reminders and alerts, weather forecasts, best practices for enabling farmers to enhance productivity, solve their queries etc.

Digital extension services have a number of advantages as they can be adapted to the local context, are demand-driven, connect multiple actors, are empowering and scalable and can greatly help in increasing productivity. A study by Mittal and Mehar (2012) has found that using technologies in agriculture has resulted in a 34.63 percent increase in yield. Issuing advisories through digital platforms has reduced input quantities by 15 to 20 percent, increased crop productivity by 18 percent and commercialisation by 5 to 7 percent. This has led to a 25 to 29 percent increase in the income of farmers (Rajkhowa, 2021)

Agricultural extension services include appropriate technology options and their use, farm management techniques, information on quality and pricing of farm inputs, consumer and market demand for farm products, ways of encouraging collective action, access to credit and off-farm income generation options (Cheruku, J.K and Katekar, V., n.d).

5.4. Digital Financial Services (DFS)

Digital Financial Services (DFS) became a reality after implementing the JAM trinity in India, i.e. Jan Dhan bank accounts, Aadhar card and availability of mobile phones in both urban and rural areas. Under the Direct Benefit Transfer (DBT) schemes, the Aadhaar card is directly linked with the bank accounts of the farmers and their land records and credit is directly transferred into their accounts.

Electronic National Agricultural Market (e-NAM), digital platforms link farmers with the national level markets. Pradhan Mantri Kisan Saman Nidhi (PM-KISAN) has simplified the process of providing input credit to farmers by transferring it directly in their Aadhar linked bank accounts without any bureaucratic interference.

State governments also use DFS to provide input subsidies, post-disaster help and loan waiver to the farmers. The Government of India has also been using DFS to improve the performance of insurance service in the agriculture sector through Pradhan Mantri Fasal Bima Yojana (PMFBY) (Cheruku, J.K and Katekar, V.,n.d).

DFS can be useful in crop and input selection and help in obtaining credit and insurance in the preharvest stage, for weather advisories and disease- and pest-related assistance on the farm and for providing real-time data on domestic and export markets in the post-harvest stage (FAO and ICRISAT, 2022).

6. How has India used digital technologies

A review of articles shows that digital agriculture initiatives include those developed and used by the government, startups, public private partnerships and industries. The Digital Agriculture Mission 2021–2025 was launched in September 2021 and five Memorandum of Understandings (MoUs) were signed to pilot digital agriculture initiatives with Cisco, Ninjacart, Jio Platforms Limited, ITC Limited, and National Commodity and Derivatives Exchange (NCDEX) e-markets Limited (NeML). The Digital Agriculture Mission 2021–2025 aims to encourage projects using cutting-edge technologies such as AI, blockchain, remote sensing, robots, and drones (SIRU, 2022). India has over 1,000 agri-tech start-ups who have been helping farmers in improving farming techniques and produce (SIRU, 2022). The section below provides a brief review of the

types of agricultural technologies developed and used by governmental organisations, public private partnerships, startups, industries and non-governmental organisations based on the specific functions they provide.

6.1 Early warning/forecasting/weather advisories

6.1.1 Government

The Mahalanobis National Crop Forecast Centre (MNCFC) was established by the Ministry of Agriculture, Government of India. The centre helps in providing technological solutions for seasonal crop forecasts and assessment of drought situations using innovative tools developed by the Indian Space Research Organisation (ISRO). MNCFC works with State Agricultural Departments across the country, ICAR, ISRO, National and State Agricultural Universities, and several other institutions on a number of projects that include:

• FASAL – Pre-harvest crop production forecasting for eight major Indian crops at the national, state and district level.

• NADAMS – Satellite data-based drought assessment at district and sub-district level (FACE and CII, 2020).

6.1.2 Public private

NITI Aayog has teamed up with International Business Machines (IBM) to create a crop yield prediction model using artificial intelligence (AI) to provide real time advisories to enhance crop output, soil quality, agricultural input control, and early disease outbreak warning (SIRU, 2022). The scope of this project is to introduce climate aware cognitive farming techniques and identify systems for crop monitoring, for early warning systems on pests and disease outbreaks based on advanced AI innovations.

It also involves use of weather advisories, enhanced weather forecasting information along with IT and mobile applications with a focus on improving the crop yield and cost saving through better farm management. The first phase has been planned to be developed as a model in Assam, Bihar, Jharkhand, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh (FirstPost, 2018).

Digital Green, Vassar Labs, ICRISAT, International Rice Research Institute (IRRI) and Precision Agriculture for Development (PxD) have partnered with extension officers to deliver customised advisory to farmers (MEITY, NEGD and NASSCOM, 2020). Amnex and Niruthi have collaborated with state governments in estimating potential yields using remote sensing data and also advise state governments in smart agriculture (MEITY, NEGD and NASSCOM, 2020). SkyMet has collaborated with the Government of Maharashtra to provide granular weather information to farmers (MEITY, NEGD and NASSCOM, 2020).

6.1.3 Startups

SourceTrace generates advisories on weather forecasts, crop calendars, pest and disease prevention and control, market alerts and communicates through audio/text messages after analysing data from satellite, on-ground and surveys (FAO and ICRISAT, 2022).

6.1.4 Enterprises

BKC Weather Sys Pvt. Ltd's '*Fasal Salah*' app, helps farmers to get weather advisory in advance, which is related to the crops that they grow. This app can also act as a tool for crop insurance. Over 1 lakh farmers are using the app to estimate yield, get information about traders, input providers, mandi prices, and receive personalised and local weather forecasts (MEITY, NEGD and NASSCOM, 2020).

Samadhan14 (Hindi for Solution) app has a platform that enables technology to reach the farmer and the farm in an efficient and affordable manner through a network of farm centers. These farm centres are managed through IT enabled systems, supported by by agri-professionals and equipped to handle a comprehensive range of basic and precision farm operations throughout the entire crop production cycle (Beriya, A., 2020).

6.2 Crop and pest advisories

6.2.1 Government

The ICAR, supported by its 113 research institutes and 716 KVKs, has created '*Cyber Agro-Physical Systems (CAPS)*', a digital agricultural platform to make farming in India more viable, self-sustaining and internationally competitive. CAPS uses sensors with computers, satellite imagery and supercomputing facilities, and aims at reducing uncertainty and risk in agricultural operations through AI-enabled farmers' advisories for important agricultural activities, especially during extreme weather events (PWC and FCCI, 2020).

Krishi Vigyan Kendras (KVKs) provide SMS services to 612.95 lakh farmers through the mKisan portal, on improved farming practices as well as weather-based advisories and information on various Government schemes (PWC and FCCI, 2020.

6.2.2 Public/Private

JioKrishi (Reliance India Enterprise) signed an MOU with the Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare. The Jio Krishi platform is designed to bring all major stakeholders in the agri-value chain on a common platform and help in increasing efficiency of farm, around the farm and beyond the farm related activities and processes. The basic features of the platform use stand-alone data on apps to provide advisories, while the advanced features combine data from different sources to provide accurate personalised advisories (SIRU, 2022).

The Tamil Nadu E- governance Agency (TNeGA). Most of farmlands are owned by small and marginal farmers in India who do not have access to relevant resources, face crop losses due to pests and crop diseases and are often misguided by fertiliser vendors leading to loss of crops and

incomes. TNeGA has piloted a farmer friendly and easily accessible, AI-powered solution which can work on smart mobile phones, and can help farmers with early identification of pests and diseases. TNeGA along with the Agriculture Department has been able to respond to 10,000 requests from farmers in a span of 3-4 months and has been using the local language to communicate farmer's concerns thus reaching more farmers and has built a dataset by working with the Agricultural Department to identify stressed regions and warn for onset of any diseases or pests by visualising the patterns in the data. (MEITY, NEGD and NASSCOM, 2020).

6.2.3 Startups

Aquaconnect, a full-stack aquaculture technology company has developed an AI-based app — FarmMOJO — that advises small scale shrimp farmers by tracking their farming practices and identifying any drawbacks that require attention (FAO and ICRISAT (2022).

Cotton is an important crop in India and 75 percent is grown by small holder farmers. One of the critical challenges that the farmers face is managing pests on the crop despite the heavy use of pesticides and traps to catch pests. Wadhwani AI or Wadhwani Institute for Artificial Intelligence, a Mumbai-based independent and non-profit research institute, has developed an AI-based pest management platform that can be easily used on smartphones by farmers/ field workers. The system has been piloted in partnership with the Better Cotton Initiative and the Maharashtra Government and is being used in in Gujarat, Maharashtra, and Telangana by over 18000 farmers who have noticed a 25 percent gain in yield (FAO and ICRISAT, 2022).

There are a number of apps that combine IoT and SMART technology for different kinds of agro-advirsories like crop health, sowing and harvesting times, crop risks and crop yield and crop water requirements. Some of these are cFog, Kuza, SatSure's SPARTA, BharatAgri, Vasar Labs, Wadhwani AI, Marut Drone tech, SenseAcre, Kisan Raja and Agrostar.

IRRI has partnered with the Government of Odisha to implement Rice Crop Manager (RCM), which will provide site specific nutrient recommendations for rice crops (FAO and ICRISAT, 2022). IRRI uses existing extension officers to deliver soil advisories generated from Rice Crop Manager. IRRI has partnered with PAD to disseminate this information through SMS and voice calls. The Rice Crop Manager tool analyses field data on irrigation, soil health and yield and generates site specific fertiliser recommendations that are communicated to farmers through SMS and voice calls. IRRI has also partnered with local Common Service Centre (CSC) operators and input dealers to convey information back to farmers. PAD uses two-way voice-based mobile phone extension system that delivers customised and voice-based advisories to farmers every week. It also partners with local actors to increase the uptake of advisories (FAO and ICRISAT, 2022).

6.2.4 Enterprises

Ekgaon Technologies, an IT-based network integrator, offers a range of services to farmers, rural businesses, and women. The platform has over 900,000 women and 300,000 farmers spread across villages in India (Upadhyay, M., 2019).

Plantix11 a mobile application has a huge database of pictures that can be used to identify diseases and aid in diagnosis and treatment of crops. The facility is now also available over

WhatsApp where just an image of the infected leaf is required to be sent to the Plantix WhatsApp number and the diagnosis is messaged back to the sender via WhatsApp in real time. Many farmers in India are using this service (Beriya, A., 2020).

Barrix Agro Sciences provides advice on eco-friendly crop protection methods that prevents the damage caused by pests and diseases without overdosing crops and plants with chemicals, thus preventing soil and water contamination (Seth, A. and Ganguly, K., 2017).

6.2.5 NGOs

The Watershed Organisation Trust (WOTR), an NGO in Pune, has also developed "FarmPrecise"- an android-based mobile application that provides crop-specific weather-based information on up-to-date farming techniques, fertiliser and nutrient management, integrated pest, and disease management, irrigation water management, and market prices of different crops in nearby markets to help village communities take decisions on the selection of crops based on the weather patterns.

6.3 Knowledge, Information, Education, Data

6.3.1 Government

The Department of Agricultural Research and Education (DARE) has launched the agricultural education portal Ekikrit Krishi Shiksha Takniki Ayaam (EKTA). The portal has an integrated online management information system and nine mobile apps for mango, e-kalpa, oil palm (English, Hindi and Telugu), pomegranate, onion and garlic, black pepper and mushroom cultivation and two mobile apps for the farming community (Kisan Suvidha and Pusa Krishi). (PWC and FCCI, 2020).

The Bhoomi project was developed by the Government of Karnataka with an aim to digitise all the land records in the state. Several aspects of farming such as types of soils, land-holding, types and number of crops grown etc. were digitised and made available through a dedicated software. The software enables biometric login of users that include both authorities and farmers, for updation of records or to print reports. The project aims at bringing about transparency in maintenance and updating of land records and provide farmers easy access to their land records (Thammaiah, D.M., Syal, R., 2019). However, the Bhoomi project has been criticised as fraudulent records have gone online, government officials have been accused of corruption and exploitation of rural poor through manipulation of ownership records and legitimisation of old land grabs and lack of control of farmers over the data as many of them are illiterate (CommonFloor Editorial Team, 2017).

6.3.2 Public Private

In August 2019, Cisco created an Agricultural Digital Infrastructure (ADI) solution to improve farming practices and encourage knowledge exchange. This was included in the data pool that the Department of Agriculture developed under the National Agri Stack (SIRU, 2022).

The farmer's portal is a single umbrella platform that provides information on crop insurance, storage, crop advisories, farm inputs, and market prices to the farmers. Central and state

governments also use mKisan, an SMS platform, to send messages to farmers in their local language. Kisan Call Centre (KCC) and Kisan TV channel also deliver extension content in regional languages to help farmers (MEITY, NEGD and NASSCOM, 2020).

Six institutions have got together as a part of the government's Sensor-based Smart Agriculture (SENSAGRI) programme which plans to use drones over land areas to gather information and communicate the information to farmers. The government is also planning to use AI to revolutionise agricultural and farming trends and giving financial support to agri-tech firms (SIRU, 2022).

6.3.3 Startups

Digital Green and Kuza work with local youth and train them as digital volunteers. These youths create videos of local best agricultural practices and disseminate this information among peer farmers (FAO and ICRISAT, 2022). eFresh partners with local farmers and works with them to adopt good agricultural practices (FAO and ICRISAT, 2022). Expert agronomists provide customised advisories to farmers through the Agrostar call centre (FAO and ICRISAT, 2022).

Krishi Vigyan Kendras (KVKs) field units, have been set up by ICAR to test new seed varieties, agronomic practices, and machinery. There are 721 KVKs across the country that provide demand-driven services and information to farmers and also conduct on-farm trials and frontline demonstrations (FAO and ICRISAT, 2022).

Niruthi uses remote sensing data and on-ground data collected to produce various value-added datasets. Bankers use such information to know if the loan has been utilised to sow the declared crop and alert farmers in case of any risks. Insurance companies use Niruthi's product to estimate average yields and reduce risk (FAO and ICRISAT, 2022).

Vassar Labs Agricultural Information Management System uses datasets to understand historical cropping patterns, climatic conditions, frequency of dry spells, and combines it with latest information on irrigation sources and seasonal water availability to advise on agro-climatic zones planning (FAO and ICRISAT, 2022).

DATAGREEN, a product by SOURCE TRACE, digitalises the entire agricultural transactions and provides this information to certification authorities. Ready-to-use certification templates are made available to FPOs/farmer groups on the digital platform.

Skysense, a product of SkyMet, combines data generated from various sources such as IoT sensors (including AWS), remote sensing, drones, crowd sourced ground truth data and governments to provide historical, current and forecasted weather information to users across India. Skysense's Agriculture Risk Monitoring System (ARMS) helps to quantify crop risks for financial institutions and also uses drones to provide crop loss estimates (FAO and ICRISAT, 2022).

6.3.4 Enterprises

Supported by ITC, e-Choupal seeks to unlock the business potential of farmers in rural areas with tools that help farmers manage and market their businesses more efficiently, place orders

for new agricultural inputs to improve yields, and to conduct online business with customers. (UNESCO, 2018).

Digital Green works with local communities and videos are co-produced, digitised, and stored online or copied to a DVD, so they can be screened in public. Local and relevant content is delivered in a format that is easily understandable to people with low literacy levels. (UNESCO 2018), FAO 2015).

6.3.5 NGOs

Watershed Organisation Trust (WOTR), an NGO in Pune, which has focused on the use of technologies such as Community-Driven Visual Integrator (CoDriVE-VI or CDVI) to generate an operational 3D map of the local aquifers. This is to help communities in drought prone areas of Maharashtra visualise aquifers in their village, mobilise them to consider water as a common pool resource and manage the demand for water through crop water budgeting.

Foundation for Ecological Security (FES) on the other hand has focused on democratising access to socioeconomic and ecological information through spatial and temporal representation for sustainable management of natural resources and supporting local livelihoods for local level decision-making.

The India Observatory is a collaborative technology initiative by FES that presents detailed information on India's social, ecological, and economic parameters related to natural resources on a single spatial and temporal platform and brings together data on over 1600+ parameters, ranging from village to national level presented in the form of maps, graphs, tables and infographics. It also has a set of unique platforms and tools, namely, the Indian Biodiversity Information System (IBIS), the Composite Landscape Assessment and Restoration Tool (CLART), a geographic information system (GIS) tool developed to plan soil and water conservation measures by making location and context-specific data available; the Crop water budgeting tool, a geographic information system (GIS) tool developed to plan soil and water conservation measures by making location and context-specific data available; The Integrated Forest Management Tool (IFMT), the GIS Enabled Entitlement Tracking Tool (GEET) and the The Groundwater monitoring tool (Napo Jal Bachao Kal)

Arid Communities and Technologies (ACT) works in the Kutch region where conserving water through recharging aquifers becomes crucial. For this, information presented in the form of water resource, aquifer and watershed maps is made available by using data collected by people on the ground level related to surface and groundwater sources, aquifer-wide groundwater level and quality, local weather data, and water and soil quality and moisture data. The maps are used to make informed farm-level decisions to become water secure. The technology used for monitoring data is gradually or stagewise introduced and includes data collected and stored in digital form using equipment and manually collected data. Static data such as farm geometry, location, soil type, hydrogeology, geomorphology, and water resources is combined with variable data that is regularly monitored by people at the ground level and water security plans are made. ACT plans to develop comprehensive mobile applications to monitor data, train Bhujal Jankars to use this data, and develop laboratories for the maintenance of technical equipments.

Gram Vikas, Odisha uses mWATER, an open-source tool used to estimate groundwater availability in a given area and can be compared to a Bank Passbook, which makes it easier for the community to understand the concept and use it to plan for water use and allocation. Information on water levels is collected using a tool called Transect walk and recharge and discharge areas are demarcated and aquifers identified. After aquifer mapping, aquifer area and aquifer thickness can be estimated using GIS platforms and the storativity of the aquifer is calculated, which gets fed into the water passbook tool to estimate groundwater availability on any given day.

Centre for Social and Environmental Innovation (CSEI) has developed Jaltol, a free and open-source digital tool for water budget estimation. Since most agencies working in water sector are in need of water budget assessment and estimation of water balance and as most of them are small and do not have the inhouse capacity, the tool is an attempt to fill that gap where the CSOs with minimum inputs can get water budget estimation of their watersheds.

Advanced Centre for Groundwater Resources and Development (ACWADAM) is using the mWaterapp for assessing the groundwater potential in various villages of Atpadi Taluka in Sangli District and working along with SOPPECOM and People's movement for equitable water distribution and Irrigation Department, Govt of Maharashtra in Atpadi to aid in equitable distribution of irrigation water through integration of various sources.

Bharat Rural Livelihoods Foundation (BRLF) is implementing Jivi Daah Hasa means Life (JDH), a watershed project with the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) Cell, Rural Development Department, Government of Jharkhand in collaboration with civil society organisations to build planning capacities in MGNREGA to support livelihoods. The project aims at enhancing the incomes of marginal farmers while securing livelihoods and climate resilience through regenerating agroecology. BRLF has been using the Open Data Kit (ODK) tool to prepare village DPRs for watershed treatment that collects data using android-based mobile devices which is submitted to an online server and a report is generated in the JDH web portal through ODK data. BRLF plans to integrate this data with the MGNREGA in the future.

6.4 Communication/Connecting farmers/Digital platform for farmers

6.4.1 Public/private

Jio with its agriculture centric platform JioKrishi has signed an MOU with the Department of Agriculture & Farmers Welfare, Ministry of Agriculture & Farmers Welfare. The Jio Agri (Jio Krishi) platform is designed to bring all major stakeholders in the agri value chain on a common platform and help in increasing efficiency of farm, around the farm and beyond the farm related activities and processes. The basic features of the platform include availability of stand-alone data on apps to provide advisories and advanced features include combining data from different sources to provide accurate personalised advisories (SIRU, 2022).

Six institutions have got together as a part of the government's Sensor-based Smart Agriculture (SENSAGRI) programme which plans to use drones over land areas to gather information and communicate the information to farmers. The government is also planning to use AI to

revolutionise agricultural and farming trends and giving financial support to agri-tech firms (SIRU, 2022).

6.4.2 Startups

Gram Vaani, a two-way interactional platform, helps farmers and agri-experts exchange messages as in a social media platform.

Voice based Quora platform also helps farmers access solutions available in the local database.

eFresh, Kalgudi, Digital Green, SourceTrace and TraceX, work with FPOs so that farmers can get input products at a discounted price and connect to wider markets (FAO and ICRISAT, 2022).

6.4.3 Enterprises

Farmers in India have to wait till their crops get harvested and the yield measured to estimate income from farm yield. A trading platform eMarketplace that enables farmers to sell their produce at an optimum price has been implemented by Microsoft for CropData. On this platform, CropData, connects farmers with buyers, and prospective quality and yield is predicted. Microsoft has developed numerous tools and technologies for this on the eMarketplace platform for farmers that include Dr. Krishi that provides advisory services while Agriota connects all the stakeholders in the agri value-chain through the use of blockchain.

By the year 2020, the CropData platform has been implemented in 30 districts across eight states. The Agriota platform has been launched with 18 farm commodities/ produce, each having five to ten varieties. The program aims at attracting 150,000 farmers to the marketplace in the first year of implementation and five million farmers in five years. If these goals are met, the impact and benefit in terms of gross merchandise value (of transactions) is expected to be USD 250 million in the first year and USD 8.5 billion over five years (MEITY, NEGD and NASSCOM, 2020).

eKutir Global provides an online mobile based platform to connect marginal farmers with stakeholders for access to soil-testing labs, suppliers of seeds and fertilisers, banks, exporters, food-processing units, and branded retailers (Seth, A. and Ganguly, K., 2017).

6.5 Quality Check

6.5.1 Public private

The Punjab Agri Export Corporation (PAGREXCO) has partnered with Bengaluru based CropIn to enable the traceability of potato seeds in the entire value chain. This has helped seed potato growers in Punjab to cultivate superior quality seeds and improve their efficiency (MEITY, NEGD and NASSCOM, 2020).

6.5.2 Startups

Intello Labs uses image recognition technology and deep learning algorithms for testing and grading of wheat, corn, tomato, soybean, potato, and onion (MEITY, NEGD and NASSCOM, 2020). Quality Assaying was traditionally done manually, look a long time and was open to

malpractices. Intello Labs has developed an AI-based platform to grade and monitor the quality of agricultural commodities. The app meets the requirements of all members in the agri supply chain that include growers, packers, aggregators, exporters, foodservice and retailers. This has not only reduced the testing time from 15 to 2 minutes, but also improved the accuracy by more than 95 percent (FAO and ICRISAT, 2022).

AgNext has developed an AI-based application called TragNext to identify the quality of agricultural produce, including tea leaves in association with the Tea Research Association and reduced the time taken for the quality-checking process and improved accuracy (FAO and ICRISAT, 2022). AgNext and Intello Labs use imagery analysis while cFog and Stellaps use IoT sensors to analyse quality of produce, which can help farmers get the right price for agricultural produce.

ITC's Agri-Business Division (ABD) is one of India's largest enterprises that helps in maintaining quality of tobacco leaves by minimising manual involvement in the leaf inspection process. The solution has reduced costs by reducing the time taken in the inspection process and enhanced efficiency by grading 100 percent of the tobacco leaves instead of the 10 percent carried out in the manual process (FAO and ICRISAT, 2022).

FARMMORE platform captures transactional data that is used by FPOs to access credit. The bank uses this data to project FPO income and structure a repayment schedule in line with the FPO's debt servicing capability (FAO and ICRISAT, 2022).

Dvara E-Registry (DER) uses a digital platform that has farmer land details and this along with remote sensing data is used to determine the credit profile and to assess crop health (FAO and ICRISAT, 2022).

Stellapps uses IoT devices to monitor milk quality by digitalising the information across value chain, and identifies inefficiencies in the value chain. Stellapps and cFog use IoT devices to monitor health of milk and shrimp (FAO and ICRISAT, 2022).

eFresh helps in export certification requirements in regional languages and auditors certify the quality of produce.

6.5.3 Enterprises

Tiger Analytics has used drone images of the farm with deep-learning based image processing techniques to estimate the leaf area index in a pilot study that has been done on corn plants. The company also plans to use the platform for other plants (MEITY, NEGD and NASSCOM, 2020).

AgNext19 has created a technology platform Qualix, to assess trade quality and safety parameters for multiple commodities (grains, pulses, tea, spices, herbs, milk and honey etc.) in a minute. (Beriya, A., 2020).

6.6 Monitoring and evaluation

6.6.1 Startups

Wadhwani AI solutions use ML based algorithms for the identification of pests, and recommendations to deal with pests.

Kalgudi and Vassar Labs' Agricultural Information Management System uses ML algorithms to identify the probability of pest attack and provide solutions.

PEAT Gmbh's Plantix app identifies plant pests and diseases from the picture uploaded by the user on the Plantix mobile app (FAO and ICRISAT, 2022).

SatSure's SPARTA platform combines satellite imagery (SI) with weather, IoT, social and economic datasets to generate insights on sowing and harvesting times, crop risks and and crop yield. SPARTA also helps financial Institutions to identify risks, loan monitoring and product diversification.

Skymet and Dvara E-Registry (DER) use machine learning (ML) products to quantify the risks to land. Financial companies now leverage this information to monitor crop risks and reduce their own NPAs in the process.

Niruthi uses remote sensing data and on-ground data to produce various datasets. Bankers use this information to know if the loan has been utilised to sow the declared crop and alert farmers in case of any risks. Insurance companies use Niruthi's product to estimate average yields and reduce risk (FAO and ICRISAT, 2022).

AgNext and IntelloLabs use advanced image analytics to monitor quality of farm produce. AgNext) and GramWorkX use IoT sensors to monitor soil moisture and estimate water requirements (FAO and ICRISAT, 2022). AgNext scanner helps by grading quality of farm produce (tea, coffee, and spices (turmeric and ginger) (FAO and ICRISAT, 2022).

Skymet uses IoT sensors to monitor soil moisture, soil temperature, leaf wetness and solar radiation.

IntelloLabs uses advanced deep-learning techniques to monitor the quality of farm produce based on the imagery collected through a smartphone.

Stellapps and cFog use IoT devices to monitor milk quality by digitalising the information across value chain, and identifies inefficiencies in the value chain (FAO and ICRISAT, 2022).

Skysense's Agriculture Risk Monitoring System (ARMS) helps to quantify risks associated with a parcel of land for financial institutions.

Trithi, Marut Dronetech, Senseacre, Piatrika Biosystems and Thanos are start-ups using drone data to monitor crop health and for targeted spraying.

Eruvaka and cFog use IoT sensors to monitor oxygen requirements of shrimp.

KisanRaja and HiHillTech use IoT sensors to monitor crop water requirements. Farmers can operate their water pumps remotely and receive alerts in case of erratic power supply, motor malfunction, dry run, or theft attempt.

Amnex uses IoT sensors to monitor crop health.

Plantix app and Wadhwani AI are using imagery data collected from smartphones to detect pest infestation, which is supplemented with recommendations to eradicate pests (FAO and ICRISAT, 2022).

Marut Dronetech uses Drones, IoT and AI to warn farmers about pests, stress to crops and recommends input spraying.

Senseacre uses drones for precision farming, land planning, aerial image capturing, weed and pest detection, aerial spraying, and crop analysis.

Dvara E-Registry (DER) provides granular data on land owned by a farmer under assessment.

Skysense, a product of SkyMet, combines data generated from various sources such as IoT sensors (including AWS), remote sensing, drones, crowd sourced ground truth data and governments to provide historical, current and forecasted weather information to users across India. Skysense's Agriculture Risk Monitoring System (ARMS) helps to quantify risks associated for financial institutions and also uses drones to provide crop loss estimates.

Niruthi's product uses remote sensing data to monitor crop performance and estimate yield.

6.6.2 Academic institutions

IIT Kharagpur has developed an AI based prediction model for detecting arsenic in India's drinking water and its health risks in affected areas, using AI algorithms (MEITY, NEGD and NASSCOM, 2020).

6.6.3 Enterprises

Mahindra & Mahindra's Farm Equipment Sector (FES) has developed Krish-e Nidaan, an advanced crop disease and pest recognition solution, to enable Indian farmers improve farm yields. The Krish-e-Nidaan solution has increased the yield of farmers by 15 percent and brought down the cost of farming by 8-12 percent. The tool has helped increase profits by Rs 6000 per acre. (MEITY, NEGD and NASSCOM, 2020).

The Intelligent Dairy Farm Assistant is a combination of two advanced technologies – AI & motor sensors that are tied to the cow's neck to transmit data and the AI can decipher patterns after an adequate amount of data is collected. Accordingly, alerts can be sent to the farmer when there's a change in pattern that could raise concerns about cattle health that demands action (MEITY, NEGD and NASSCOM, 2020).

Nano Ganesh enables farmers, who are often low skilled, low literate and with limited financial resources, to water crops using electronically controlled devices. Thus, farmers can activate and monitor pumps located at a distance by placing a call or sending an SMS thus saving time. The service is simple to use and involves phone call-based activation, making it easy for farmers with little or no education to use. (FAO, 2017)

Stellapps technologies provide dairy farm optimisation and monitoring services with a special focus on small- and medium-herd farms (Upadhyay, M., 2019).

Skymet Weather Services is involved in monitoring and predicting weather and providing solutions in case of crop risks. (Seth, A. and Ganguly, K., 2017).

AgroPad10 developed by IBM, is a paper device about the size of a business card. When a drop of water or soil sample is placed on the AgroPad, the set of circles on the back of the card provide colorimetric test results. A farmer can take a snapshot of this using a smartphone and immediately receive a chemical test result for a water or soil sample (Beriya, A., 2020).

Yuktix Technologies is an Agritech startup based out of Bangalore that focuses on creating digital tools for agriculture farm monitoring and risk management. The solution helps growers make decisions and implement best practices that increase yield and cut losses. (Beriya, A., 2020).

6.7 Boosting incomes

6.7.1 Government

The Mahalanobis National Crop Forecast Centre (MNCFC) was established by the Ministry of Agriculture, Government of India. The centre helps in providing technological solutions for seasonal crop forecasts and assessment of drought situations using innovative tools developed by the Indian Space Research Organisation (ISRO).

MNCFC works with State Agricultural Departments across the country, ICAR, ISRO, National and State Agricultural Universities, and several other institutions on a number of projects that include:

• KISAN – Uses satellite data for crop insurance under the Pradhan Mantri Fasal Bima Yojana and is useful in assessing crop losses, land area assessments and conflict resolution. etc.

• NADAMS – Satellite data-based drought assessment at district and sub-district level.

• CHAMAN – Estimates crop productivity through remote sensing and geo-spatial analysis for seven major horticultural crops at the national, state and district levels.

• Many other projects including crop intensification, yield assessment etc (FACE and CII, 2020).

SAMRAKSHANE is an end-to-end e-governance solution for crop insurance under the Pradhan Mantri Fasal Bima Yojana (PMFBY) programme and the Modified Weather Based Crop Insurance Scheme (MWBCIS). It coordinates with the Karnataka State Natural Disaster Monitoring Centre (KSNMDC) to compute weather-related data and provide compensation under the MWBCIS (FACE and CII, 2020).

6.7.2 Public/Private

Microsoft and the Indian government have joined hands to support India's small-holder farmers by running a pilot programme in 100 villages of Uttar Pradesh, Madhya Pradesh, Gujarat, Haryana, Rajasthan and Andhra Pradesh called 'Unified Farmer Services Interface' that aims at boosting farmers' incomes through improved price management and increased agricultural yield using AI sensors (SIRU, 2022).

This is a part of the Ministry's plan to create 'AgriStack' (a collection of technology-based interventions in agriculture), on which this will be built. The government aims to provide 'required data sets' of farmers' personal information to Microsoft to develop a farmer interface for 'smart and well-organised agriculture' through this MoU.

The Ministry has also signed four other MoUs — with Star Agribazaar, Patanjali Organic Research Institute for agricultural management and services, Amazon Internet Services, and Esri India for different operations under AgriStack.

However, this initiative has been vehemently opposed by farmers groups and experts who have raised concerns about sharing of farmer's data with private companies, information asymmetry, data privacy and consent, profiling of farmers, mismanaged land records and corporatisation of agriculture (DownToEarth, 2021).

Experts hope that the government adopts a consultative process with all stakeholders to resolve the genuine concerns and seek continuous feedback of these initiatives through third party evaluations and independent studies so that a robust digital ecosystem in Indian Agriculture can be established that benefits the Indian farmer (Beriya, A., 2022; Garg, R., 2020).

Many a times, farmers are unable to secure optimum price for the harvest and have to depend on middle men and traders. To deal with this, Agri10x has developed a decentralised platform that has a transparent ecosystem and gives farmers greater autonomy over their harvest.

Initially, farmers from the state of Maharashtra were included and now the platform has expanded to states such as Bihar, UP, Jharkhand, Karnataka and Tripura etc. Agri10x has also built an influencer campaign by involving farmers as influencers or 'Village Entrepreneurs'to spread awareness about this initiative (FAO and ICRISAT, 2022).

eFresh partners with FPOs and makes farm inputs available at discounted rates compared to market price.

Kuza platform collects farm input requirements from agripreneurs and matches demand with supply directly from manufacturers, thereby bringing in better prices (FAO and ICRISAT, 2022).

Kalgudi market linkage platform connects farmers directly to the market ensuring right price for farmers (FAO and ICRISAT, 2022).

Kalgudi and the national agriculture market linkage platforms (eNAM) provide real time price information to farmers (FAO and ICRISAT, 2022).

Farmley combines various datasets to predict grade-wise prices for commodities. The quality standards are also made available to farmers using a mobile app. Farmley platform also facilitates e-commerce by connecting FPOs to sellers across the country.

SourceTrace platform combines predicted harvest date, yield estimates and crop calendar to estimate crop volumes, which in turn is used to predict price information (FAO and ICRISAT, 2022).

eNAM is an electronic trading and marketing portal that connects 585 APMC markets. Farmers can participate in e-auction and sell produce to the highest bidder compared to the prevailing practice of selling at minimum support price. e-NAM also offers integrated services such as quality grading, packaging and transporting.

Kalgudi and eFresh connect producers to the wider market and ensures higher price for the agricultural produce and also offer certification of produce (FAO and ICRISAT, 2022).

Kalgudi, SourceTrace and eFresh offer certification solutions to farmers that helps them get a higher price for the produce.

TraceX) uses blockchain based solutions to ensure end-to-end transparency in the agricultural value chain (FAO and ICRISAT, 2022).

eFresh, Kalgudi Digital Green, SourceTrace and TraceX work with FPOs so that farmers can get input products at a discounted price and connect to wider markets (FAO and ICRISAT, 2022).

TraceX's blockchain platform connects all stakeholders – farmers, FPOs, food processors, financial institutions, logistics providers, and others, involved in a value chain and helps in efficient money management throughout the entire chain of interactions where all of them are digitalised (FAO and ICRISAT, 2022).

6.7.3 Enterprises

Supported by ITC, e-Choupal seeks to unlock the business potential of farmers in rural areas with tools that help farmers manage and market their businesses more efficiently, place orders for new agricultural inputs to improve yields, and to conduct online business with customers. (UNESCO, 2018).

Ergos has developed a "Grain Bank model" that is providing doorstep access to end-to-end post-harvest supply chain solutions to small and marginal farmers. The Ergos model provides the farmers the flexibility to store/ withdraw grains which offers them better incomes, as they do not need to sell all their produce at once at the prevailing market rates during the harvest season (Beriya, A., 2020).

6.8 Smart agriculture/Technology

6.8.1 Public/Private

CropIn Technologies worked as the Agtech partner in a public-private project with the Government of India and the World Bank for developing agricultural technology for climate resilience. The project spanned an area of 1650+ hectares.

- SmartFarm was developed that enabled digitisation of farms.
- SmartRisk was developed for agri-business leveraging and risk mitigation and forecasting.
- mWarehouse helped farm to fork traceability and compliance, quality control and inventory management.
- AcreSquare was a mobile application that enabled companies/cooperatives to directly interact with farmers.

The project helped empower farmers to adopt climate resilient practices and helped around 8300 farmers while digitising 12,000 plots (MEITY, NEGD and NASSCOM, 2020).

6.8.2 Startups

In India, crop cultivation mostly depends on rain or flood irrigation and knowing the exact amount of water needed for crops often becomes challenging for farmers as they have to think of 10-12 parameters before reaching a decision.

CultYvate's Smart Irrigation System leverages IoT, Predictive Analytics, and AI and calculates the precise amount of water required for crops. This has reduced consumption of water by 50 percent in sugarcane farms, while increased yield by 100 percent (FAO and ICRISAT, 2022).

Bengaluru-based agritech startup, TartanSense has developed a small, land-based robot to carry out weeding and pest control. Named Brijbot, the robot moves in the farm, identifies weeds, and sprays the targeted weed with weedicides and pesticides. TartanSense offers the robot as a subscription service to farmers as opposed to a direct sale FAO and ICRISAT (2022).

cFog and Eruvaka use IoT devices that monitor dissolved oxygen, pH and temperature conditions in shrimp farming and in agricultural fields to detect crop stress conditions.

Stellapps uses IoT devices to detect and monitor milk quality across dairy value chains.

Intech harness Pvt Ltd combines IoT and micro-controller devices to maximise water-use efficiency and thus helps farmers reduce energy costs and protect groundwater table.

Marut Dronetech, Thanos and Senseacre use drones for identifying pest-prone areas and targeted spraying, (FAO and ICRISAT, 2022).

Wadhwani AI solution use ML based algorithms for the identification of pests, and recommendations to deal with pests.

Kalgudi and Vassar Labs' Agricultural Information Management System uses ML algorithms to identify the probability of pest attack and provide solutions.

PEAT Gmbh's Plantix app identifies plant pests and diseases from the picture uploaded by the user on the Plantix mobile app (FAO and ICRISAT, 2022).

SatSure's. SPARTA platform combines satellite imagery (SI) with weather, IoT, social and economic datasets to generate insights on sowing and harvesting times, crop risks and crop yield. SPARTA helps financial Institutions to identify risks, loan monitoring and product diversification.

Skymet and Dvara E-Registry (DER) use machine learning (ML) products to quantify the risks to land. Financial companies now leverage such information to monitor crop risks and reduce their own NPAs in the process.

Niruthi uses remote sensing data and on-ground data collected to produce various value-added datasets. Bankers use such information to know if the loan has been utilised to sow the declared crop and alert farmers in case of any risks. Insurance companies use Niruthi's product to estimate average yields and reduce basis risk (FAO and ICRISAT, 2022).

AgNext and IntelloLabs use advanced image analytics to monitor quality of farm produce.

Stellapps uses IoT devices to monitor quality of the produce (FAO and ICRISAT, 2022).

Marut Dronetech uses drones for targeted aerial spraying of fertilisers and pesticides. Marut was able to reduce input cost from INR 15 000 per acre to INR 11 380 per acre.

Senseacre uses drones to identify location of weeds/pests and for targeted aerial spraying of pesticides/weedicides. SenseAcre has also reduced input application by 72 percent (FAO and ICRISAT, 2022).

HDFC ERGO General has developed an app to upload geotagged images from the field to get updates on the crop situation.

6.9 Drones in agricultural research

ICRISAT's GEMS (Genotype by Environment by Management by Society) team, along with local and international experts, is developing an open platform to provide quality phenotyping services under standardized sets of protocols, which can help in comparisons across partner networks (FAO and ICRISAT, 2022).

Skymet has partnered with the Government of Maharashtra to deploy over 2100 automatic weather stations (AWS) across the state and provide real-time weather data and historic and forecasted weather data to farmers. Skymet has also deployed about 600 agricultural sensors that measure soil moisture, soil temperature, leaf wetness and solar radiation, which can help in crop health monitoring

Trithi , Marut Dronetech , Senseacre , Piatrika Biosystems and Thanos are start-ups using drone data to monitor crop health and for targeted spraying.

Plantix (https://plantix.net/en/) and Wadhwani AI (https://www.wadhwaniai.org/) are using imagery data collected from smartphones to detect pest infestation, which is supplemented with recommendations to eradicate pests (FAO and ICRISAT, 2022).

Marut Dronetech uses Drones, IoT and AI to warn farmers about pests, stress to crops and recommends input spraying

Senseacre uses drones for precision farming, land planning, aerial image capturing, weed and pest detection, aerial spraying, and crop analysis FAO and ICRISAT (2022).

6.10. Enterprises

6.10.1 AI-based farmer advisory services to improve farm yield and income

IBM has developed a robust technology platform that combines data from the Weather Company, satellites, and the IoT-based field data using AI technology to provide timely, localised and actionable agriculture advisory to farmers (MEITY, NEGD and NASSCOM, 2020).

BKC WeatherSys Pvt. Ltd's Fasal Salah app, helps farmers to get weather advisory in advance, which is related to the crops that they grow. This app can also act as a tool for crop insurance.

Over 1 lakh farmers are using the app to estimate yield, get information about traders, input providers, mandi prices, and receive personalised and local weather forecasts (MEITY, NEGD and NASSCOM, 2020).

Microsoft has partnered with the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) to develop an AI-powered sowing app for farmers to identify the optimal time for sowing the seeds. Use of this app has resulted in an increase of 10-30 percent yield per hectare (MEITY, NEGD and NASSCOM, 2020).

The Intelligent Dairy Farm Assistant is a combination of two advanced technologies – AI & motor sensors that are tied to the cow's neck to transmit data and the AI can decipher patterns after an adequate amount of data is collected. Accordingly, alerts can be sent to the farmer when there's a change in pattern that could raise concerns about cattle health that warrants action (MEITY, NEGD and NASSCOM, 2020).

Drones are being used by the Agriculture Ministries both at the central and the state levels for anti-locust spraying in states such as Rajasthan, Gujarat, Madhya Pradesh and Uttar Pradesh (Beriya, A., 2020).

The Government of India recently launched the 'Swamitva18 scheme' under which Drones will draw a digital map of every property falling within the geographical limits of a village and demarcate the boundaries of every revenue area. Property card for every property in the village will be prepared by states using accurate measurements delivered by such drone-mapping. (Beriya, A., 2020).

The table below provides a snapshot of the types of agricultural technologies developed and used by governmental organisations, public private partnerships, startups, industries and non-governmental organisations.

Table 1: Repository of different digital tools developed for agriculture and water sector

	Early warning/forecasting/ weather advisories	**Crop and pest Advisories**	**Knowledge/Info/ Education/data**	**Communication /connecting farmers**	**Quality check**	**Monitoring**	**Boosting incomes**	**Smart agriculture/ Technology**
Government	FASAL NADAMS	CAPS mKisan	EKTA mKisan Bhoomi (land records)				KISAN CHAMAN SAMRAKSHANE (crop insurance)	
Public/ Private	NITI Aayog and IBM, Digital Green, Vassar Labs, ICRISAT, International Rice Research Institute (IRRI), Precision Agriculture for Development (PxD) Amnex, Niruthi, Skymet	JioKrishi TNeGA	Cisco Agristack SENSAGRI mKisan	Jiokrishi SENSAGRI	PAGREX CO, Intellolabs		United farmer Services Interface	CropIn
Startups	SourceTrace	Aquaconnect Wadhwani AI Satsure BharatAgri,	Digital Green Kuza KVKs Agrostar, Niruthi, Skymet, Vassar Labs,	Gram Vaani, Quora Platform Kalgudi, TraceX, SourceTrace, FoodPrint, eFresh,	TragNext IntelloLabs ITC Agribusiness Division (ABD)	Stellaps, Intello Labs, Eruvaka, cFog, Wadhwani AI, Kalgudi,	Agri10X eFresh, Kuza, eNAM, Kalgudi,	CultYvate TartanSense Kalgudi Farmly, SourceTrace, eFresh,

	Early warning/forecasting/ weather advisories	Crop and pest Advisories	Knowledge/Info/ Education/data	Communication /connecting farmers	Quality check	Monitoring	Boosting incomes	Smart agriculture/ Technology
		Vasar labs, Marut Drone Tech, SenseAcre Kisan Raja, Eruvaka, IRRI, AgroStar Call centre, SPARTA, IRRI Rice Crop Manager, cFog, Kuza, PAD, mKrishi, SourceTrace	DATAGREEN, SPARTA, Dvara E, Skysense	eNAM, Digital Green,	AgNext, CFog, eFresh, Stellaps, DATAGREEN, FARMMORE, Dvara E-Registry (DER), TraceX,	Vassar Labs, AgNext, eFresh, TraceX, KisanRaja, HiHillTech, Amnex, Plantix, MarutDrone, SenseAcre, Niruthi	TraceX, Agrostar	Intech harness Pvt Ltd, Marut Dronetech, Thanos, Senseacre, Plantix, GEMS (Genotype by Environment by Management by Society), IRRI's Rice Crop Manager, CFog, AgNext, GramWorkX, SkyMet, Kalgudi
Academic Institutions						AI based model to detect arsenic in drionking water-IIT Kharagpur		

	Early warning/forecasting/ weather advisories	**Crop and pest Advisories**	**Knowledge/Info/ Education/data**	**Communication /connecting farmers**	**Quality check**	**Monitoring**	**Boosting incomes**	**Smart agriculture/ Technology**
Enterprises	IBM, FasalSalah, Skymet, Agrosciences, Samadhan14	Ekgaon Technologies, Barrix	DIGITAL GREEN, e-Choupal,	CropData, e Kutir	Tiger Analytics, Agnext 19,	Krish- e-Nidaan,The Intelligent Dairy Form Assistant, Stellaps, Agropad, Yultix technologies, Greensense	eChoupal, Ergos,	Microsoft, ICRISAT, NanoGanesh, Trringo, Agnext, EM3 Agriservices, Drones,
NGOs		WOTR	WOTR, FES, ACT, Gram Vikas, CSEI, ACWADAM, BRLF					

7. Discussion

7.1 Startups are playing an important role in digital agriculture

The literature review reveals that while efforts have been made by the government, public private partnerships, enterprises and startups, startups are playing a major role in taking up digital technologies to farmers, almost taking up 60 percent of the space.

Data by NASSCOM reveals that India has around 450 agritech startups in 2022, and the number is expected to grow at 25 percent every year. Agritech startups in India present a $24 billion opportunity, and the industry's potential still remains untapped (Roma, P., 2023). Start-ups are playing an important role in promoting farm mechanisation, for example, drones are being used for the application of fertilisers and pesticides, drones and remote-sensing are facilitating crop health monitoring and reducing dependence on physical field inspections. The emergence of Uber-style digital platforms are helping to connect farmers to the suppliers of mechanical implements such as tractors in real-time (FAO and ICRISAT, 2022).

Start-ups are also using methods such as precision farming, equipment rentals, supply chain aggregation and cloud-based analytics for decision making. Data shows that Indian agri-food and AgTech start-ups have raised USD 1.05 billion through 133 deals, registering a year-on-year (YoY) growth of 6.4 percent in the FY 2020 (PWC and FCCI, 2020).

However, the applications of AI, cloud computing and related technologies in various agricultural activities across different stages of the agri value chain are still in a very early stage in India.

An FCCI report states that "*Currently the market size of agri tech, including AI-based agri innovation start-ups in India, is estimated to be worth USD 204 million, while only 1 percent of the current market opportunity worth USD 24 billion is being utilised by the country*". (PWC and FCCI, 2020: p 19).

There has been an increase in rate of adoption of digital technologies in the last one-and a-half decade which has been helped by internet penetration, the availability of affordable data services, proliferation of feature phones as well as budget smartphones and the rise of innovative digital services. Internet users in India are now spread across urban as well as rural areas. In 2019, the number of users in urban and rural areas were 205 and 227 million respectively, and the number of internet users in rural India are growing at 18 percent per annum (PWC, FCCI, 2020).

However, many of these efforts at digital uptake are at a pilot stage or are localised efforts and serve specific issues in particular states or at intermediate levels. Government support for the creation of a connected ecosystem along with low-cost access to capital will give a major boost to digital technology uptake in agriculture (PWC, FCCI, 2020).

7.2 E-extension services, AI and PA are seeing increasing uptake in agricultural services provided to farmers

Institutionalised advisory services in India are provided by extension officers. However, smartphone penetration and access to mobile internet has opened up new opportunities for

delivering extension services through digital routes. The review shows that many startups are using digital extensions via audio and video content, in addition to SMS in local languages. Many companies are combining datasets such as remote sensing, drone, weather, and local conditions to generate local advisories that are much more localised and accurate than the general advisories provided by traditional extension services (FAO and ICRISAT, 2022).

Many of the services are also trying to facilitate two-way interactions and are including farmers as co-producers of knowledge. In addition, several companies are innovating at the intersection of technology, social capital and business models to provide services to underserved as well as unserved populations, helping in making the services more inclusive. Partnerships with FPOs, progressive farmers, community-based organisations as well as publicly funded institutions are at being made to use technology that is inclusive for local farmers, the underserved, underprivileged and the marginalised (FAO and ICRISAT, 2022).

The agricultural sector is also seeing a rapid adoption of AI, both in terms of agricultural products and management techniques. AI can help farmers with information on quality of soil, what to sow, when to sow, when to apply fertiliser and water and the quantity as well, when to spray herbicide/weedicide/ pesticide, when to harvest, where to sell and at what price to sell.

Precision farming is also being used increasingly in agriculture such as use of drones to target areas for application of inputs, use of ICT tools for individual crop and farmer-based advisories, use of IoT sensors for automating crop monitoring, use of ML to monitor crop health. However, uptake and successful applications of these technologies will need to address the following barriers:

7.2.1 Diverse soil conditions and cropping patterns and blanket approach to assessment of technology related requirements and dissemination

Accomodating variable conditions to achieve scale can become difficult in the Indian context and it is thus difficult to develop geographical and crop based customised AI technologies or products. While developing AI based technology, accessibility and adaptability considerations are important, most solutions based on AI technologies are often not localised and unable to meet geographical, sociocultural and demography related needs of populations. This hinders the taking up of technologies. Small farm sizes also make it difficult to own technologies individually and make them cost ineffective (PWC and FCCI, 2020).

7.2.2 Poor digital literacy among farmers

Experience indicates that new technologies will be adopted by farmers only if they are digitally literate. Thus, initiatives must recognise the digital literacy gaps and provide solutions that address the requirements of illiterate farmers, address the gender-digital divide and focus on local sensitivities to get positive outcomes.

Thus training, capacity building, handholding of farmers and other stakeholders involved at various levels to help them use technology, adapting the data obtained to make it more understandable at the farmer level, use of local language and adapting the technologies to socio cultural realities is very important (UNESCO, 2018).

Thus:

- Designing technologies in partnership with users who have low levels of skills and literacy will help in developing effective digital technologies that address their needs.
- Local content generated by users and in local languages is important for interactive technology adoption by people who have few digital skills and a low level of literacy
- When solutions offer a mix of media, such as text and audio, or text accompanied by bold and relevant graphics, they can be understood and be useful to a wider range of users.
- Simple user interfaces that make use of pictures, illustrations, simple messages to guide and explain content can substantially improve the usability of a technology for people with few digital skills and low literacy levels like content produced by Digital Green.
- Users with low levels of skills and literacy will need handholding and support while learning to use digital solutions (UNESCO, 2018).
- The correct selection of tools is also important taking into consideration the scale at which data is needed.

7.2.3 Use of technology might not automatically lead to decision-making and produce results on the ground

Mere access to information does not guarantee that this information will be used by people at the ground level to produce the desired results. Making the effort sustainable beyond the completion of the project can be challenging and depends on the understanding and motivation of the community to bring about the desired change.

To what extent does the farmer own the technology, what is the value of the technology for the farmer is an aspect that needs to be explored. How to incentivise farmers to keep monitoring and reporting data is a challenge that also needs to be addressed in the future.

While technologies have made the invisible, visible and helped to create awareness among people, has this awareness translated into changes in water use practices among people, has it led the community to formulate rules to use water sustainably and improve water governance? Do external factors such as market dynamics affect water use practices? Do digital tools bring transparency and how do local institutions cope with it are larger questions that need to be addressed in the future.

7.2.4 Hierarchies among communities can impact technology outreach

Access to digital technologies may not be uniform among communities. The sociocultural contexts and village-level hierarchies often determine who has access to information and can participate in decision-making. There is data and information asymmetry in our communities. For example, women, poor, marginalised, and tribal populations continue to have poor access to resources and technologies. Including them in the mainstream will require efforts that expand beyond the adaptation of technologies to bring about social changes at the ground level.

7.2.5 Who needs, controls and owns the data and technology can affect outcomes

Technologies do not function in a vacuum and their uses can be influenced determined/controlled by the sociocultural and political contexts where they are used. Thus. power relations at the village level can influence who has access to data and can influence

decision-making and equitable distribution of resources. How far technology can lead to democratic decision-making and equitable distribution of resources remains to be seen.

7.2.6 Technology can act as a double-edged sword

While technology can play an important role in empowering communities with information and aiding them in taking decisions on the ground level, it can also act as a double-edged sword. One needs to be wary of using technology as a solution to all evils. Questions such as who needs and controls technology, who uses it and what is it used for need to be placed at the centre of all discourses on the use of technology for the last mile.

7.2.7 Infrastructural expansion crucial for technology uptake

Uptake of technologies in urban and rural areas also call for the need for the government to invest in trunk infrastructure, especially to improve connectivity speed and access. The government can play an enabling role in scaling such digital solutions by encouraging public-private partnerships (PPP), promoting trunk infrastructure, and subsidising access to small and marginal farmers (FAO and ICRISAT, 2022).

7.2.8 Availability of meaningful, contextualised and open data at different scales is crucial

Availability of open data becomes critical to encourage adoption or uptake of extension services. There are over 654, 000 villages, 130 million farmers speaking around 800 languages under 127 agro-climatic zones in the country and trying to combine different kinds of datasets at these different levels and drawing inferences from them in a meaningful way is a huge challenge. Bigdata-based ML platforms using remote sensing data must be customised for each region due to language, sociocultural and behavioural variations across India (FAO and ICRISAT, 2022, p 11).

7.2.9 Gaps between micro and macro level data sets can make drawing inferences difficult

Data is very important for finding solutions by making connections. For example, agricultural, ML models require a range of data sets at different levels such as topography, climate, soil, seed varieties, crop diseases, pest management, etc. and of good quality. Thus, availability of good quality and open data for a range of parameters and at different levels and scales is important to make it into meaningful information that can be handed over to the stakeholders who would be using it.

There is a huge gap between data sets that are available at the governmental level and that are collected at the ground level by people. Bridging this gap between micro and macro level data sets in terms of granularity and aiding the integration of data is important.

Furthermore, governments (state as well as central) also collect huge volumes of disaggregated data from their field personnel, but have no clear policy or a coordination mechanism to make this data available in a responsible way to support AI/ML based innovations through private sector. Checks and balances for data access and its use are not currently in place i.e. regulatory mechanisms to ensure data ownership, privacy of data, reliability of data are not in place, thus

hampering public interest as well as social values as regards AI in agriculture. Making this data available in an open form for all stakeholders to use is crucial for scaling up of digital technologies in the country (FAO and ICRISAT, 2022; FACE, CII, 2020).

7.3 Lack of standardisation hinders E-commerce and scaling digital technologies for food safety

Rising smart phones and internet connections, favourable policies, e commerce portals, large domestic consumer base have led to a rise in e-commerce in India. However, a number of barriers are leading to insufficient penetration of e-commerce services in the country. For example, India currently processes less than 10 percent of its agri-output and most of the processing done is primary processing, which includes preliminary activities such as cutting, cleaning, packaging, storage and refrigeration of raw foods to ensure that they are not spoilt before they reach the consumer Lack of cold chain infrastructure and limited presence of quality grading laboratories hinder scalability of e-commerce products. Lack of standardisation and harmonisation in commodity grading, lack of compatibility of current certification mechanisms of agricultural produce with new techniques such based on AI, ML and IoT for use in commodity grading and assaying, poor data governance mechanisms that include protection against data, traceability, payments and transactions hinder scaling up of agriculture/food-based e-commerce. Farmers continue to rely on traditional laboratory testing for grading services and these are still non-accredited. It is thus important to digitalise the entire farm-to-fork supply chain through use of digital technologies and platforms coupled with capacity development of various stakeholders for upscaling of E commerce in India (FAO and ICRISAT, 2022).

7.4 Fintech in agriculture

Fintech includes a wide range of financial services such as mobile payments, peer-to-peer lending, cryptocurrency, insurance, and credit aggregators. The challenges to uptake of fintech in agriculture is uncertainty in farmer's incomes. Seasonality in farmer's incomes needs to be considered as credit uptakes by farmers is higher when loan repayment is planned following the harvest or when insurance premium payment terms are deferred. The financial products designed for farmers therefore could take a livelihood approach rather than purely crop loans. This is especially critical since agriculture linked incomes/profits are available only towards the end of a crop cycle, whereas the investment is staggered all through the crop growing cycle.

Trust in technology is still low, rural farm households have heterogeneous needs and poor connectivity, making scalability a huge challenge. This is also the reason for the slow scale of digital financial services (DFS) solutions in agriculture. Limited funds available for firms and a highly fragmented supply chain increases distribution costs thus acting as barriers to scaling up of fintech in agriculture. Solutions are thought only in terms of exported goods rather than in domestic markets where there is less demand because of lower standards, low enforcement, low consumer demand, and prohibitive costs for implementation.

Meeting regulatory standards is a major challenge and it is difficult to know how much to charge farmers owing to price sensitivity and the farmers' inability to pay. Subsidy continues to be a critical success factor as regards driving adoption among small and marginal farmers because of

the economics of smallholder agriculture. In addition, evidence collected in India indicates that indexing products like rainfall-insurance will enable farmers to shift from subsistence crops to cash crops. However, in order to generate enough demand, insurance products must be heavily subsidised.

Fintech needs to achieve a balance between promoting consumer benefit and ensuring protection against risks, while embracing technology (FAO and ICRISAT, 2022).

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