Digital Technologies Transforming Indian Agriculture

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India is the world's largest sourcing destination for the information technology (IT) industry, accounting for approximately 67% of the US$124–130 billion market.[1] However, the emergence of farm technologies integrated with a robust information and communication technology (ICT) framework is still evolving in India, and it holds tremendous potential to both positively impact agricultural performance and enhance farmers' income. The impact of technology in unlocking value for the people at the bottom of the pyramid and improving access to critical services is well demonstrated in the healthcare sector in India, as observed in the case of mobile technology–enabled telemedicine and low-cost devices that can address health conditions such as anaemia in a large section of the population. Technology has powered Indian agriculture time and again by helping overcome productivity stagnation, strengthening market linkages, and enhancing farm management. In the past, Indian agriculture faced a formidable challenge to grow more food, but it faces an even more difficult challenge today and for the future: to grow more sustainably and inclusively. Major challenges confronting Indian agriculture include declining total productivity, diminishing and degrading natural resources, a rapidly growing demand for food (not just for quantity but also for quality), stagnating farm incomes, fragmented land holdings, and unprecedented climate change. It has been established that technology adoption modernizes farmers' production practices and leads to uniform annual returns for farmers, reduced risk of crop failure, and increased yields.[2]

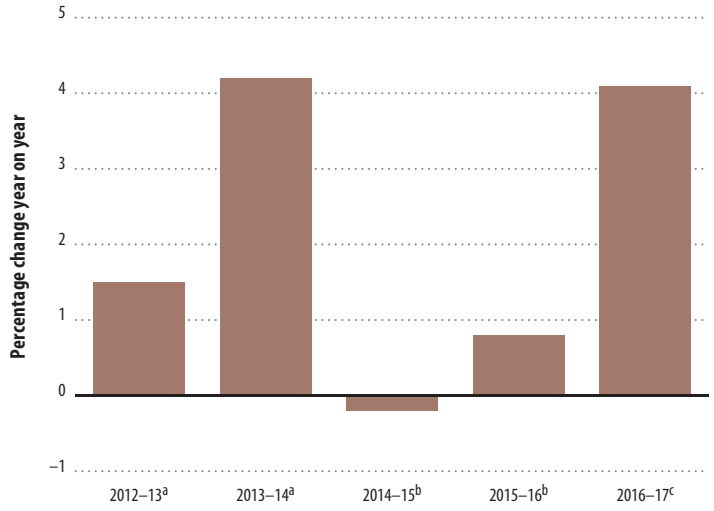
Direct applications of digital technology include remote sensing (via satellites), geographic information systems, crop and soil health monitoring, and livestock and farm management, among other applications. At the pre-harvest stage, digital technology can recommend crop and input selection and assist in obtaining credit and insurance. At the on-farm stage, there is need for weather advisories and disease- and pest-related assistance; and at the post-harvest stage, real-time data on both domestic and export markets are needed. The growth of competitive markets and demand for consistent food quality is making the adoption of such tech-based solutions imperative for the Indian farmer. Much of the scope for application and innovation remains to be exploited. The application of digital technology in agriculture has been instrumental in promoting data generation as well as the advanced analytics that allow farmers to make smart decisions about farming and to benefit from an economical use of inputs and labour.

Technology: A key driver for sustainable agriculture

India is one of the leading contributors to the global food basket. The country's food grain production stood at 252.23 million tonnes in 2015–16, and has a record production of 271.98 million tonnes in 2016–17.[3] India's horticulture output—comprising fruits and vegetables, floriculture, honey, plantation crops, medicinal plants, and spices—was around 283.4 million tonnes in 2015–16, surpassing food grains and making India the second largest fruit and vegetable producer in the world. India is also the world's largest producer of milk (155.5 million tonnes in 2015–16) and second largest producer of sugar, and the leading country in coconut production per government estimates. In 2016–17, after two successive years of sub-par monsoons, the growth of agriculture and allied sectors in India improved significantly (Figure 1). This growth is being primarily driven by the livestock and fisheries sectors, contributing to the diversification of the production basket towards high-value foods. Although fluctuating, the agricultural growth rate over the years reflects the increasing resilience of the sector to natural shocks and market volatility, an increase that also demonstrates the impact of favourable investments, technology uptake, and strategic policy efforts.

India's population has nearly doubled since the 1970s; it is currently estimated at over 1.2 billion and is

Figure 1: Growth rate of gross value added in agriculture and allied sectors, 2011–12 base prices



Source: Government of India, 2017b; 2017c.
Note: Data are government estimates: [a] second revised estimate; [b] first advance estimate; [c] first revised estimate.

growing at 1.4% annually, putting pressure on natural resources such as land and water to produce enough food. Moreover, with rising incomes, a structural change in the dietary patterns of an average Indian is diversifying the country's food demand to include high-value foods. According to the National Sample Survey estimates for 2011–12, although cereals account for 26% (20%) of the total food consumption expenditure in rural (urban) India, high-value foods (milk, meat, eggs, fish, fruits, and vegetables) account for 42% (46%) in rural (urban) India.[4]

Sustaining food security in India holds a larger implication for global markets.[5] India's agricultural export value growth rate was the highest in the world for the decade ending 2013 (Figure 2), at 21.3%—more than the average annual percent increase in agricultural export value in countries such as Indonesia (17.6%), Brazil (14.9%), and China (11.8%).[6]

To respond successfully to the growing food demand both domestically and globally, India will have to produce more. Yields of major crops are low in India compared with those in other countries. For instance, the rice yield in India is 2.6 tonnes per hectare—far lower than the 4.7 in China, 3.7 in Brazil, 5.9 in the United States of America (USA), or 9.5 in Australia; that of wheat is 3.0 tonnes per hectare in India, 5.3 in China, and 3.1 in the USA; and the maize and soybean yields are 2.5 and 0.75 tonnes per hectare in India compared with 5.9 and 1.8 tonnes, respectively, in China.[7]

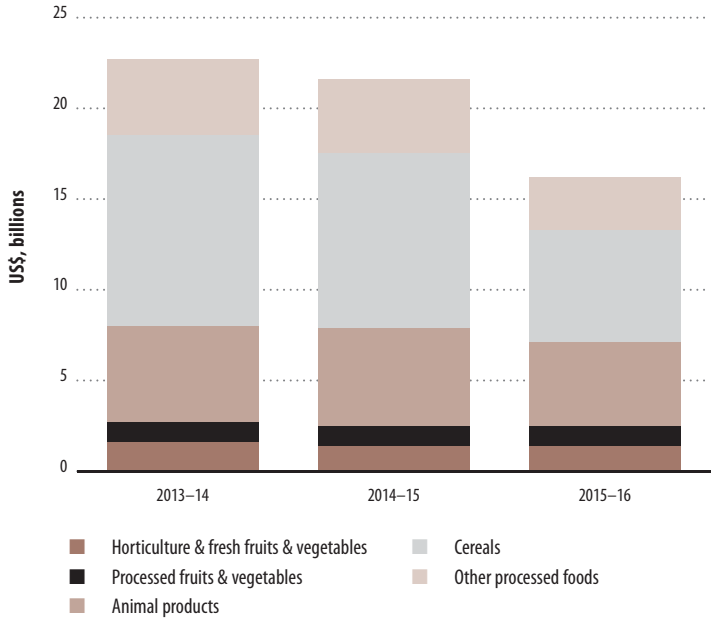
Leveraging technology to achieve higher and sustainable agricultural growth is not novel for farmers and other relevant stakeholders in India. Noteworthy are the green revolution (1966–67), the white revolution (1970–96), and the gene revolution (in cotton) in early 2000. The green revolution, which relied on extensive cultivation of high-yielding varieties of wheat, led to a fivefold increase in production and, as a result, also led to rising farmers' incomes.[8] The three decades from 1973 to 1999 can be regarded as the highlight in the timeline of agriculture productivity in India, when the food grain production nearly doubled.[9] It is interesting to note that the increase in production was more a result of an increase in the yield rather than an expansion of cultivated area. Similarly, the white revolution led to record milk production in India and enabled higher returns for dairy farmers. It established a national milk grid and introduced the crossbreeding of indigenous cows with high-milk-yielding European breeds, pasteurization of milk for long-duration storage, and refrigerated transport systems to distribute milk across the country. During the same period, agriculture machines were introduced on Indian farms; these primarily consisted of tractors and seed drills to improve productivity per unit of land and water. Following the successful adoption of Bacillus thuringiensis (Bt) cotton, India's cotton production increased from 14.0 million bales in 2000–01 to 38.6 million bales in 2014–15; it is estimated to be 35.1 million bales in 2016–17. India became the largest cotton producer in the world, accounting for 26% of the global production. Yield levels also increased from 278 kilograms (kg) per hectare to 511 kg per hectare to 568 kg per hectare during the above periods.[10] In 2015, India continued to have the largest area being cultivated with Bt cotton in the world—11.6 million hectares sowed by 7.7 million small farmers and an adoption rate of 95%. According to estimates, India enhanced farm income from Bt cotton by US$18.3 billion between 2002 and 2014 and US$1.6 billion in 2014.[11]

In the wake of concerns that intensive farming adversely impacts environmental balance, India will need to adopt sustainable farming practices that include employing efficient irrigation methods with a

simultaneous focus on groundwater regeneration, monitoring soil degradation, and adopting energy-efficient production methods. Adopting advanced technology has helped small countries, including the Netherlands and Israel. Notably, these countries, have augmented the production of high-value crops through enormous productivity breakthroughs and, even more importantly, by ensuring the optimal utilization of resources and maintaining the environmental balance.

Currently technologies that cater to the optimal utilization of resources (particularly those that are linked to natural resource availability and environmental impact), effective market linkages for improved service delivery, and the discovery of the highest price possible as observed in the case of India through the country's electronic National Agricultural Market (e-NAM)—a technology-driven unified market platform—have a brighter future in India. The success of technology adoption lies in customizing to address particular challenges at the local level, supporting institutions and policies to create an enabling ecosystem, and harnessing the potential of these technologies to scale and commercialize within a defined time period.

Figure 2: Key agricultural exports from India, US$ billions



Source: APEDA 2017, statistical data on agricultural exports, available at http://agriexchange.apeda.gov.in/indexp/exportstatement.aspx.

An emerging ecosystem of digital technologies in Indian agriculture: The rise of start-ups and young entrepreneurial firms

The agriculture sector has attracted large conglomerates, leading IT companies, investors, and young innovators in India; the ecosystem for technology and digital solutions is expanding at an impressive pace. The global market for precision agriculture is expected to grow at an annual growth rate of 13.09% to reach a market size of over US$6.34 billion by 2022.[12] Although Northern America will maintain its dominance in the sector, the fastest growth is projected for India and China, which are expected to see an annual growth rate of 18.29% until 2022.[13]

The agro-tech start-up ecosystem in India has also been receiving renewed interest from investors, and an estimated 34 ventures received US$295 million in investments in 2016 in the country—the highest investment amount recorded in India in the past three years.[14] In Asia, China had 10 deals totalling US$427 million, while 53 Indian start-ups raised US$313 million and four Japanese companies raised US$8.9 million. The most active geographies—those countries with the highest number of agriculture start-ups—remained consistent year-over-year, with the USA, India, Canada, the United Kingdom, Israel, and France remaining the top six by number of deals.[15]

Among the prominent ventures backed by large conglomerates in India is ITC's e-Choupal, a comprehensive digital knowledge hub for farmers, which has 6,100 installations covering over 35,000 villages and serving over 4 million farmers.[16] Launched in 2000, the first-of-its-kind initiative not only benefited the farmers doing business through their network, but this model also led to a ripple effect on the public sector–managed food grain management systems that resulted in an upgrade.

Mahindra & Mahindra (M&M), one of India's leading producers of tractors and farm equipment, is innovating alongside expanding its core business. M&M's Trringo, a mobile-based app enabling farmers to rent tractors, is a unique example of leveraging technology to help farmers use machinery without having to make the large investment (US$7,500) of buying tractors.[17] Through Trringo,

the farmers benefit from available latest machines, freeing labour as well as raising productivity and product quality. In addition, the farmers are required to pay only for the services they use without locking any money in as capital. This is particularly revolutionary in a country such as India, where agriculture is characterized by smallholders (who operate on less than 2 hectares of land) and who are often resource poor and lack access to formal channels of credit. The 'uberization' of tractors and farm machines (as some have coined it—a concept similar to uber taxis, which is a platform aggregating demand and supply of taxi services and connecting both through a mobile app) has the potential to fast-track farm mechanization and take it to regions within India where farm sizes are really small, yet abundant in water and exhibit suitable soil and climate conditions that could produce much more than their current output.

In another example, Tata Consultancy Services (TCS), India's leading IT firm, offers personalized advisory services in voice and visual formats using communication devices such as mobile phones through its mKRISHI platform. The growing penetration of mobile phones in rural regions of India is driving the development of several mobile-based applications by government departments, entrepreneurs, and the private sector.[18] The rural subscriber base in India for mobile services has been growing at steady pace, reaching approximately 342 million subscribers in 2012–13, 378 million in 2013–14, and 414 million at the end of 2014–15.[19] With easier access to mobile phones, farmers can connect with traders and other farmers. Small farmers can also utilize their mobile phones to seek information on input availability or market prices, thereby reducing costs—both because they do not have spend the time needed to get into town to find this information, and because it allows them to get competing prices and choose the best one. Other benefits that have been recorded are improved access to information about selecting seed varieties appropriate to a particular farm; and how to identify best cultivation practices, protect from weather-related damage, and get a better handle on plant diseases.[20]

Digital technology in Indian agriculture is not about big box solutions only. A large number of young entrepreneurs have ventured into this sector to tackle specific challenges. The technology thrust of these ventures has been on reducing the time duration of crop cycles, saving on water and energy, reducing the usage of agro-chemicals, automating for efficient farm management, strengthening farmer market linkages, and improving cold chain logistics for higher value addition.

Examples of these leading start-ups include Stellapps Technologies, which is providing dairy farm optimization and monitoring services with a special focus on small- and medium-herd farms. Their applications and tools leverage the Internet of Things, big data, the cloud, mobility, and data analytics to improve milk production, milk procurement, and the cold chain, and to boost animal insurance and farmer payments.[21] Ekgaon Technologies, an IT-based network integrator, offers a range of services to farmers, rural businesses, and women. The ekgaon OneVillageOneWorld Network is leveraging mobile communication technology to encourage the sustainable development of women-self-help-groups (SHGs) and small farmers across India. The platform has over 900,000 women and 300,000 farmers spread across villages in India.[22]

Drones and robotics are also increasingly used in Indian agriculture, although the ventures in this area are still budding and there is a long way to go before these technologies are scaled up in any major way. Agnext, an Indian start-up, has developed drones among other digital technologies with the objective of creating an integrated hyperlocal farm data collection and crop analytics platform.

A number of new start-ups are developing solutions to tackle climate change challenges. For example, Skymet Weather Services is involved in monitoring and predicting weather and providing agri-risk solutions.[23] Skymet can measure and predict yield at the village level for any crop with a high level of accuracy and can also accurately forecast the weather in the short, medium, and long term. Ecozen Solutions has developed state-of-the-art solar-powered products for irrigation and cold storage, with the aim of catering to smallholder farms and regions with limited or no electricity.[24] Barrix Agro Sciences offers eco-friendly crop protection methods that have the potential to minimize a significant proportion of the damage caused by pests and diseases without overdosing crops and plants with chemicals, thus preventing soil and water contamination.[25]

There are also ventures that started out as agri-tech start-ups in India but, owing to their innovative solutions, are now operating as medium-scale businesses. EM3 AgriServices, founded in 2014, has quickly risen to become a pioneer in the farming-as-a-service (FaaS) model. EM3's *Samadhan techno kheti centres* offer machines needed to perform all critical farm operations on a pay-for-use basis.[26] At their centres, the organization employs agri-professionals who are well versed in the agronomy of the target area. Another

such noteworthy venture, eKutir Global, offers an online and mobile-based platform to connect marginal farmers with stakeholders across the value chain such as soil-testing labs, suppliers of seeds and fertilizers, banks, exporters, food-processing units, and branded retailers. Agri Suite by eKutir offers a one-stop solution for all the needs of a farmer; their field partners also train farmers to use their application.[27] Over time, services that go beyond merely selling a product but that also provide training about how to use, maintain, and repair that product, as well as supplementary components such as advisory and marketing services, have become an increasingly important and integral part of any product offering. Technology is playing an important role in bringing these elements together.

Despite the tremendous gains achieved, the long-term impact of the earlier technology revolutions was limited to selected agricultural pockets in the country, and further efforts to advance these revolutions lost momentum over time. In the context of start-ups, the common barriers to commercialization and the scaling up of technology are related to access to finance, which is in turn related to operational finance, funding/capital deficiencies, and cash flow management; gaps in technology infrastructure; and issues concerned with cyber security. Furthermore, limited access to farmer networks for effective piloting of the products is seen to impede the commercialization plans of start-ups. For innovation and entrepreneurship to be effective in transforming agriculture in India, it will be important to address these issues and create an enabling environment in which they can grow and flourish. To a large extent, the effort towards this transformation has been catalysed by the government's special programme on start-ups, Startup India.[28] Moreover, large companies with knowledge about the diversity of Indian agriculture could also support these start-ups by mentoring, which would help them pilot and scale up their activities for potential commercialization.

Policy and institutions: Key enablers for scaling up digital technologies in India

India's present public policy with regard to agriculture is focused on encouraging innovation and entrepreneurship, and out-of-box thinking towards achieving sustainable higher growth and income security in the farm sector. Because more than 50% of the working population is in agriculture and farm size is shrinking, the per capita output is small. Thus it is true and desirable that people move out of agriculture and bring the current percentage of the workforce employed in agriculture from 54.6 % down many fold. New forms of engagement have emerged in this sector that could make agriculture more remunerative and exciting for the new generation. The government—through its flagship programme Startup India, launched in 2016—aims to boost start-ups across sectors by providing handholding services, access to funding, and incubation. This programme is of immense significance for the agriculture sector. The other flagship programme—Digital India, which seeks to empower people through access to digital technology riding an increasingly robust infrastructure and service platform—has equally immense potential to positively impact agriculture. The government has also launched the Custom Hiring Centre, a rental model for using tractors and other farm equipment with the twin objective of encouraging rural entrepreneurship and fast-tracking the mechanization of Indian agriculture.

The budget for 2016–17 announced by the central government confirms its commitment to modernize agriculture systems in India through a slew of measures such as setting up a dedicated micro-irrigation fund, establishing new mini labs in the Krishi Vigyan Kendras (KVKs) agricultural extension centre, ensuring 100% coverage of all 648 KVKs in the country for soil sample testing, and expanding the coverage of the e-NAM from 250 markets to 585 markets.[29]

According to the Department of Industrial Policy and Promotion (DIPP) of the Ministry of Commerce and Industry, the Indian agricultural services and machinery sectors have cumulatively attracted foreign direct investment equity inflow of about US$2,278.3 million from April 2000 to March 2016.[30] This reveals the trend of global and domestic partnerships being forged across the value chain to keep agriculture on a path of fast-track growth. Some notable developments include the launch of an Agritech laboratory with a focus on agri-biotech in Hyderabad by the Intertek Group, a UK-based total quality assurance provider; Mahindra and Mahindra Ltd acquisition of a 35% stake in a Finnish combine harvesters manufacturer, Sampo Roselnew Oy; ICRISAT's plan to set up a Rs.100 crore (US$14.67 million) fund in a year to help small entrepreneurs in the agribusiness space; and the Indian Farmers Fertiliser Cooperative (IFFCO)'s joint venture with Japanese firm Mitsubishi Corp for manufacturing agrochemicals in India.

Conclusions

A successful future growth strategy for agriculture will need to perceive

agriculture as a business enterprise involving constant innovation and catering to dynamic market demand. Although agricultural technologies are fast evolving in India and a mix of business models are driving the ecosystem, there is a need to design the pathway to successful commercialization and to scale it up by utilizing the right incentives and policy support. Technology will continue to play an important role while the dynamics of the agriculture sector changes and produces new challenges. With the private sector playing an increasingly important role in investments, operations, and expertise, agriculture will gain immensely as the public sector catalyses these efforts. The IT revolution in India was brought forward by the private sector, with the public sector creating an enabling environment.

Uptake of technologies at market prices in a sector that has traditionally been heavily subsidized remains challenging, but farmers are prompt to identify what works in their interest and are ready to pay for it. Digital technologies offer the potential to achieve the necessary conditions for scale, with distributed low cost and customized delivery, creating a unique opportunity for private enterprise and innovation to thrive. The challenge before India lies in balancing high growth with inclusive growth; leveraging technology to achieve these twin goals will be a fascinating journey to track.

A developed agriculture system is based on three key pillars: knowledge, infrastructure, and a robust delivery mechanism. Supporting the research and development ecosystem in agriculture directly contributes to creating knowledge and preparing for the future. To strengthen the supporting framework for growth, it will be important to focus on creating new physical markets, improving storage and transport facilities, making better roads, and ensuring a continued electricity and water supply. These system components also facilitate efficient mechanisms for delivery and the monitoring of relevant government schemes and extension services that will accelerate the pace of development. The public policy regime in India has been supporting technology-led agricultural growth and has been increasingly developing new institutions to ease access and affordability of technology adoption among farmers.

Notes

1 IBEF, 2017.

2 Emerick et al., 2016.

3 Government of India, 2017a.

4 Government of India, 2013.

5 If India has to depend on imports, it will be difficult to supply enough because the volume of the need is so high. If India is able to grow more than it needs, it can be a global exporter. Both import and export impact price in different ways.

6 USDA-FAS, 2014.

7 OECD, 2017.

8 Dastagiri et al., 2014.

9 Government of India, 2017d.

10 The Cotton Corporation of India Ltd, 2017.

11 ISAAA, 2015.

12 BIS Research 2015.

13 Tech Mahindra, No date.

14 Shashwati, 2017.

15 Agfunder, 2017.

16 Information on ITC's e-Choupal is available at http://www.itcportal.com/businesses/agri-business/agri-commodities-and-rural-services.aspx, accessed 11 February 2017.

17 Information on M&M's Trringo comes from https://www.trringo.com/about-us/, accessed 11 February 2017.

18 For more information about TATA Consultancy Services, see https://www.tcs.com/.

19 TRAI, various issues.

20 Mittal and Mehar, 2013.

21 This information on Stellapps comes from http://www.stellapps.com/index.php/about-stellapps/, accessed 11 February 2017.

22 Information about ekgaon and its OneVillageOneWorld Network can be found at http://ekgaon.co.in/ekg/index.php, accessed 11 February 2017.

23 Information about Skymet Weather Services comes from http://www.skymetweather.com/, accessed 11 February 2017.

24 Information about Ecozen Solutions can be found at http://www.ecozensolutions.com/about-us, accessed 11 February 2017.

25 Information about Barrix Agro Sciences can be found at http://www.barrix.in/About-Us, accessed 11 February 2017.

26 Information about EM3 AgriServices is available at http://www.em3agri.com/, accessed 11 February 2017.

27 Information about eKutir Global is available at http://www.ekutirsb.com/, accessed 11 February 2017.

28 Information about Startup India is available at http://www.startupindia.gov.in/.

29 Key features of the budget can be found at the Government of India's Union Budget 2017–18, available at http://indiabudget.nic.in/ub2017-18/bh/bh1.pdf.

30 GBV, 2017.

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