IT FOR CHANGE | AUGUST 2019

Taking Stock of AI in Indian Agriculture

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List of Abbreviations

AI: Artificial Intelligence
APMC: Agricultural Produce Market Committees
API: Application Programming Interface
AUS: Aarav Unmanned Systems
CoE: Center of Excellence
e-NAM: Electronic National Market
FaaS: Farming as a Service
FICCI: Federation of Indian Chambers of Commerce & Industry
FMCG: Fast Moving Consumer Good
FPO: Farmer Producer Organisation
GPU: Graphical Processor Units
ICRISAT: International Crops Research Institute for the Semi-Arid Tropics
IIT: Indian Institute of Technology
IoT: Internet of Things
MUDRA: Micro Units Development and Refinance Agency Bank
NASSCOM: National Association of Software and Services Companies
RBI: Reserve Bank of India
SME: Small and Medium Enterprise
TNC: Transnational Corporation
UPL: United Phosphorous Limited

Taking Stock of AI in Indian Agriculture

1. How is AI Revolutionising Agriculture

At two ends of the world, in Tokyo and San Francisco, fully automated "vertical indoor farms" powered by Artificial Intelligence (AI) technologies and operated by robots are bringing to life the idea of a "next-generation control environment agriculture."[1]

As countries in the global North grapple with a shrinking agricultural labour force, robots are being tested and trained to pick fruit by tedious trial and error methods.[2] Like in manufacturing and services, an emerging tide of data-based disruption functioning on a new layer of knowledge activities enabled through AI technologies is also transforming agriculture. With challenges of resource scarcity, industrial scale of food wastage and climate change posing immediate imperatives for food security, digital innovations are being looked to as the game-changer in being able to address these issues.[3] The future of food is unequivocally digital, and the future of digital is inevitably AI.

Broadly, AI can be defined as "an area of computer science devoted to developing systems that can learn or be taught to make decisions and predictions within specific contexts."[4] AI applications can undertake a host of intelligent behaviours, such as process optimisation and predictive modelling, based *inter alia*, on pattern recognition, natural language processing and machine translation. All of these capabilities funnel the power of data and algorithms, the key drivers of industry 4.0. Consider the following facts. Deloitte estimates that by 2019, 70 percent of companies will acquire AI capabilities through cloud-based enterprise software.[5] By 2025, over 85 percent of all businesses will have effectively transitioned to the cloud.[6] Cloud computing will thus be able to drive large-scale AI implementation with more assured returns on investment across verticals. This will have implications across a range of sectors, including education, healthcare, criminal justice and agriculture.

Today, terms such as "digital farming," "the use of new and advanced technologies integrated into one system, to enable farmers and other stakeholders within the agriculture value chain to improve food production"[7] and "precision agriculture," where temporal, spatial and individual data are combined with other information to generate analysis that supports site-specific farming decisions, have become common place.[8] From gene sequencing in seed production to Internet of Things (IoT) networks of implements and sensors that generate data and image recognition technologies that assay and grade crops and commodities, AI applications are being deployed across different aspects of agriculture.

In broad terms, AI in agriculture spans three categories:[9]

- Agricultural robotics; This involves the development of autonomous and intelligent systems that can undertake tasks and functions on farms, such as sowing, irrigating, harvesting. For example: Blue River's 'see and spray' herbicide robots.

- Crop and soil monitoring: This involves capturing and processing data through drones, sensors, GPS chips, etc., to monitor crop and soil health through computer vision and deep learning techniques. For example: Plantix, a deep learning application that can assess soil health through image recognition.
- Predictive analytics: This involves creating predictive models and digital intelligence around a host of agro-parameters, including inputs, market prices and linkages, and can also apply to allied services, such as credit and insurance, fintech, logistics, etc. For example: aWhere, an analytics company that harnesses satellite data to provide intelligence on weather, soil, crop health, etc.

Additionally, data and AI based innovations are also rapidly transforming the operations of agrobusinesses. Augmented reality, voice activated transactions, smart packaging, robotised warehouse management and omni-channel distribution are a few advancements we can point to.[10]

To understand this phenomenon in economic terms; between 2012 and 2017, global investment in digital technologies for food production trebled reaching an impressive 10 billion US dollars.[11] Data-based value propositions have been key to nearly all of these undertakings. We observe two key patterns in the sector: 1.The rise of agritech startups who, fuelled by venture capital, are aspiring to claim a share in the AI market and 2.Traditional giants who have recalibrated their business models through datafication.

When Monsanto acquired the digital agriculture startup, The Climate Corporation, in 2013, it took the first step toward redefining itself as a “data company”. Only a few years later, Bayer acquired Monsanto, expanding its intelligence capital—the latter’s data on soil and cropping with its own knowledge in pharmacogenetics.[12]

Similarly, John Deere’s decision to expand the company’s investment into AI startup Blue River to power the development of unmanned tractors indicates a next wave in agriculture. Deere’s website notes how their future market depends on AI; “As a leader in precision agriculture, John Deere recognises the importance of technology to our customers. Machine learning is an important capability for Deere's future.”[13]

This trend is also observable from the other end. In 2018, Chinese digital company Huawei set up an agricultural Internet of Things Global Joint Innovation Center within the Qingdao Saline-Alkali Tolerant Rice Research and Development Center in China. The centre is working on developing an “Agricultural Fertile Soil Platform” and is focussed on developing smart agriculture solutions through IoT, big data and cloud computing.[14] In the US, Alphabet Inc, Google’s parent company is making investments into startups, such as the Farmers Business Network and Bowery Farms.[15]

In allied sectors, a growing global trend is expected to spur greater digitally enabled value additions in the farm to fork supply chain, with grocery e-tail emerging as an important market segment. Not least are agribusiness giants in the food retail market, such as Kellogs, who have now donned the hat of venture capital funders in a clear bid to capture a share of a digital ecosystem that is transforming consumption habits rapidly.[16]

These are not merely developments in rich countries, but are indicative of a reorganisation of the sector on a global to local scale. ETC group's research has noted that data-based business value propositions have been the driving factor for the rapidly ongoing transnational consolidation in the industrial food supply chain across different verticals, including farm machinery, seeds, agrochemicals and pesticides.[17] Syngenta's multi-million dollar investments in startups in India and Israel are as much part of this wave[18] as are the many big data partnerships being struck in African agricultural markets, such as The Africa Regional Data Cube.[19]

From enhancing crop science breakthroughs to building solutions for effective resource optimisation, it is clear that AI innovations will be the key way forward for global food production, more so in global South nations, where agriculture is still the economic mainstay. But how this innovation tide will be applied and made to work for the benefit of all actors, including small land-holders, women farmers, etc., remains a question and challenge for policy.

In the subsequent sections, we examine current initiatives in AI in Indian agriculture—both private and state-led—and attempt to assess their potential for furthering development. We begin with a brief overview of the state of agriculture in India, the policy thinking of the Indian state on the role of AI in agriculture and key impediments that bear upon its effective adoption and uptake. This is followed by an analysis of private sector trends in the domain. Lastly, the prospects for AI in agriculture are discussed, along with directions for policy. Insights offered in this paper draw from interviews with AI startup founders, digital platform companies, knowledge experts and public officials, along with secondary research. What we attempt here is not exhaustive and is limited to a preliminary scoping of the current outlook for the domain.

2. The Current State of Indian Agriculture

AI in the field of agriculture is seen as a significant focus area for policy. This is perhaps logical, considering that over decades, policy processes have failed to respond to the "agrarian crisis" marked by extreme distress for a majority of farmers in the country.[20]Droughts, clubbed with other factors, including a fall in prices of agricultural produce, low public investment in agriculture and declining agricultural exports, have aggravated this situation.[21]

Grassroots movements have sought to visibilise and draw attention to the issue. In 2017, farmers from the southern state of Tamil Nadu demonstrated in the country's capital over lack of drought relief measures and escalating farmer suicides.[22] The year 2018 saw two "long marches" in which over 50,000 farmers took to the streets to voice their concerns and advocate for the passage of long outstanding sectoral reforms outlined in the MS Swaminathan Report, 2005.[23,]

Precarity continues to be a hallmark of the sector, with prospects being particularly bleak for small and marginal producers and women and landless farmers, who comprise a bulk of the population whose livelihoods are tied to agriculture and are today finding themselves edged out of the sector altogether.[24] Unreliable market linkages and access to inputs, fluctuating commodity prices, depressed returns and high indebtedness (exacerbated by a predatory micro-finance industry) are contributing factors that make farming a high risk proposition.[25]

Incomes have been steadily declining since 2011 for farmers and wage-labourers with the average annual income of a farmer estimated to be 77,976 Indian rupees.[26] On the other side, non-farm activities now bring in close to 65 percent of rural household incomes.[27] It is not surprising then that in a survey on the state of Indian agriculture, 76 percent of farmers reported wanting to give up farming.[28]

3. The Rhetoric and Reality on AI for agriculture

An Inter-Ministerial Committee set up to alleviate agrarian distress has outlined an umbrella approach for "Doubling Farmers' Income by 2022", envisioning a proactive role for digital technologies.[29] NITI Aayog, Government of India's think tank, brought out the National Strategy for Artificial Intelligence in June 2018, identifying key priority areas in health care, agriculture, education, smart cities and infrastructure and smart mobility and transportation.[30] In agriculture, enhanced farmers' income, increased farm productivity and reduction of wastage have been identified as targets for AI-led innovations, with a new thrust on "Farming as a Service" (FaaS).[31] The national strategy document notes that "the agriculture sector in India, which forms the bedrock of India's economy, needs multi-layered technology infusion and coordination amongst several stakeholders."

Other industry forecasts have indicated that AI technologies can be used to address notable challenges in the sector including market fluctuations, irregular irrigation, eroding soil health and sub-optimal pesticide use.[32]A study by Accenture for instance, notes that digital farming services are likely to have an impact on close to 70 million Indian farmers by 2020.[33]

The policy rhetoric needs to be contextualised against the reality. Current efforts led by government to integrate advanced AI technologies in agriculture lack in the scope and pace necessary for a digitally-enabled transformation of the sector. Key challenges in this regard are discussed below.

3.1 The Data Problem

Data, the vital ingredient for digital intelligence solutions, remains an underdeveloped resource in India. AI-based modelling in agriculture typically depends on a complex array of data sets, including topography, climate, soil, seed varieties, cropping and input practices, crop diseases and pest management. Traditionally, these data pools have been maintained by public agencies. Also, to provide the backbone for robust algorithmic solutions, data must satisfy several attributes—volume, variety, velocity, veracity, value, exhaustivity, fine grainedness, relationality, etc.[34] However, government data leaves a lot to be desired in this regard.[35] Not only are there gaps in data baselines in the sector, but even where public data sets do exist, they are not made available in the public domain.[36]

If opened up and made usable, government data can be a useful public resource to catalyse innovation. But this is easier said than done. As Ram Dhulipala, who leads the research team for digital agriculture at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) in India, points out, “The problems with agriculture are very localised and contextualised. To find appropriate solutions we need disaggregated data. However, the data from government sources is mostly aggregated. This is a serious gap.”

The data problem has far-reaching consequences for AI development in India. The McKinsey Global Institute indicates that among 19 sectors evaluated in India, the potential value of AI for agriculture was in the bottom tercile.[37] NITI Aayog has also pointed out that a push for AI in agriculture may ultimately be only a lukewarm prospect for the private sector given that, “efforts from private sector may neither be financially optimal nor efficient on a standalone basis.”

This was also underlined in the expert interview undertaken for this research; insurance companies, for instance, have not come forward to adopt schemes such as Pradhan Mantri Fasal Bima Yojana, the state led crop-insurance scheme rolled out in 2018. The dearth of good quality block level data is seen to make it unviable for companies to design suitable insurance products for farmers.[38]

3.2 Absence of a Multi-Sector Data And AI Framework

Despite efforts to articulate a vision for data and AI, there is still no coherent “Data and AI” framework for projects across various departments. The Government of India’s Economic Survey 2019, for example, recognises the critical nature of “data infrastructure” necessary to maintain a competitive edge in the global economy and has underlined the aspiration to build such infrastructure based on “data of, by, and for, the people.”[39] Yet, there is neither a mention of AI, nor any reference to big data, in the agriculture chapter.

The absence of a coherent “Data and AI” framework also translates into policy ambiguities about private access to public data. While the NITI Aayog strategy paper does conceptualise a National AI Marketplace, including for annotated data, what seems to be missing is the normative thinking about checks and balances for data access and use.

An official from the Department of Biotechnology, which leads FarmerZone,[40] a public-private agricultural data portal, stressed the importance of such norms in digital intelligence solutions, observing how precision farming and predictive farming solutions to enhance farm productivity and improve input practices requires a data and intelligence backbone that is publicly owned and managed in a transparent and scrutable way. She cautioned that “without private sector accountability, we may be left in a situation where private companies are designing their own AI-based modelling solutions which push their own products.”

3.3 Lack of Integration between Agriculture Reform and AI Policy

Policy approaches like "Doubling Farmers' Income by 2020" have sought to tackle legacy issues in agriculture without seeking any synergies with data and AI policies on agriculture. Similarly, digital technology initiatives such as the Electronic National Market (e-NAM) platform for agro-commodities that provides digital assaying and grading and online payment options for commodity auctions, all of which comprise important sources of data, have not yet integrated a strong data-centric vision.

Part of the problem arises in the liberalisation of the agriculture sector itself. New measures such as the Model Contract Farming Act of 2018, for example, look to ease and liberalise contract farming practices by diluting the roles of traditional markets and market regulators, instead seeking to integrate farmers directly with the market, especially, agro-industries.[41] Agricultural trade in the coming years is hence likely to steadily bypass the various state Agricultural Produce Market Committees (APMCs). While the relative merits of this transition for mitigation of market and price risks for the farmer are still to be assessed, these trends certainly present concerns for the availability of public data sets in agricultural commodity trade. With the APMCs increasingly disintermediated from the supply chain, the e-NAM system embedded in the APMC architecture will also be bypassed and hence, a vital node of potential data capture at scale for public innovation will be lost. Market liberalisation in agricultural trade and direct procurement by companies will also mean the risk of farm-based data and data about input practices becoming privatised by default.

3.4 Gaps in Public AI Research

Another major policy challenge is the general state of AI research in the country. Current R&D initiatives remain concentrated in elite institutions in India, such as the Indian Institutes of Technology (IITs) and that too among a closely knit pool of 50 to 75 principal researchers. While the country ranks third globally in bringing out high quality research publications in AI, its impact factor trails far behind world leaders such as China.[42] The number and relative quality of scholars in the space, resource and administrative bottlenecks, siloed research approaches in the academy, combined with poor computing infrastructure and lack of annotated quality data, have been noted as major pain points impeding AI research in India. The doubling of the Digital India budget to 477 million US dollars in 2018 with a view to expand AI research is a welcome first step, but addressing institutional weaknesses will remain a larger challenge.[43] It is also unclear how public agriculture universities and research institutions will benefit from this allocation. The prospects at least for the immediate future therefore seem to be rather bleak for public AI innovations in agriculture.

4. Private Sector Trends

In the private sector context in India, the AI phenomenon is nascent, with many of the cutting edge global advances still in the realm of aspiration. But all signs suggest that this is not to be the case for long. "Agri-food tech", a broad term used to refer to a range of digitally-driven innovations in the global food and agriculture industry, both upstream (biotechnology, farm management, farm robotics & equipment, bioenergy & biomaterials, agribusiness marketplaces, etc.) and downstream (online restaurants, e-grocery, restaurant marketplaces, etc.), is a rapidly growing area in India.[44] There is a notable rise in B2C (business to consumer) and B2B (business to business) marketplaces and digital platforms.[45]

Between 2013–17, India saw investments in over 558 deals in agri-food tech totalling 1.66 billion US dollars. This accounts for approximately 10 percent of global activity in the domain during the same period. In fact, in 2018, India saw the biggest deal in the sector, with the food delivery app, Swiggy, receiving over 1 billion US dollars in funding, moving the country up to the third place in investment geographies for agri-food tech. Given that India's large consumer base has dictated the flow of innovation in other industries, such as telecom, downstream investments shaped by consumer preferences are poised to trigger a fork-to-farm, reverse ripple effect.

Currently, the following dominant trends are observed in the AI-agritech space in India (including but not restricted to agri-food tech).

4.1 Traditional Players Move Towards Datafication

In keeping with global trends, the digital space in Indian agriculture is seeing companies from the agribusiness end enter the fray. Mahindra, which is the biggest tractor company in India with multiple verticals in the farm-to-fork supply chain, has been integrating digital intelligence into its business models. It has acquired startups, such as the agri-rental platform Trringo, launched its own advisory services platform, and its tractors are now IoT enabled.[46] The company's Information Technology Services division, Tech Mahindra, is also developing AI solutions for agriculture. Godrej Agrovet, a diversified agro-company, has introduced a smart app to capture market intelligence and enhance its data-based decision making abilities. United Phosphorous Limited (UPL), India's largest agrochemical company, has collaborated with Microsoft on a Pest Risk Prediction API through which farmers receive automated calls with predictive insights on pest infestation.[47]

4.2 Tech Giants Collaborate with Governments

Digital companies have made forays into the agriculture and AI space via public private partnerships with state agencies and governments. For instance, IBM Watson's IoT platform has been deployed in many states, in collaboration with the NITI Aayog. The technology, which uses a "data fusion" approach, combines remote sensing data from The Weather Company, an IBM concern, along with satellite and field data from sensors, to provide localised and actionable advisory services, including an AI crop yield prediction model.[48] Similarly, Microsoft has been expanding into digital agriculture in a big way. Collaborations with the Government of Andhra Pradesh on a Zero Budget Natural Farming Programme and with the Government of Karnataka on building a predictive pricing model are some examples in this regard.[49]

4.3 AI Startups Navigate an Uphill Path

A 2018 report by FICCI observes that nationally, 366 agri-based startups came up between 2013 to 2017, with more than 50 percent of these coming up in 2015 and 2016.[50] However, when we examine the range of agritech startups in India, the number of initiatives that are primarily AI driven are very few. Many startups have incorporated AI-based value additions to their current platform-based models, but AI is not their unique value proposition. For instance, NinjaCart is an example of a hyper-local market linkage platform that intermediates transactions between horticultural farmers and small and mid-tier green grocers in cities. The company received 35 million US dollars in Series B funding from Syngenta and Accel US and 100 million US dollars in Series C funding from Tiger Global.[51]It is planning to go full throttle and expand its in-house data science capabilities.

As part of primary research for this paper, four AI startups working in this field were interviewed. A brief snapshot of their work (See Table (1)) and details of their AI solutions are provided here.

Table 1. AI agritech startups in India: An overview

Startup	What it does?	How the AI works?	Funding
Intello Labs	Intello labs is an AI-based commodity testing solution that uses image recognition technology and deep learning algorithms to provide agri-commodity grading. Currently, the company offers testing and grading of wheat, corn, tomato, soy bean, potato and onion. Intello began with a pilot project with the Government of Rajasthan on wheat and grain testing and today works with a wide variety major FMCG, retail and e-commerce companies such as Reliance, Amazon and Big Basket.	Computer vision (image recognition technology) and deep learning techniques are used to train algorithms with sample data of different commodities. An in-house annotator tool sifts through data (supplied from the client end, generated in-house, or sourced from third party private companies) to then build intelligence around commodities.	Seeded by angel investors. Raised seed 2 million US dollars in seed funding from Nexus ventures and Omnivore
Fasal	Fasal offers Climate Smart Precision Agriculture Solutions and works directly with farmers as well as big companies such as, Grover Zampa Vineyards. Fasal's 'Smart Agriculture Solution Kit' allows for monitoring and optimising environmental and climatic parameters in agriculture, vineyards, greenhouses, etc. in real-time.	IoT sensors deployed in farms take periodic readings and feed them into a network. Analytics is performed upon this data.	Earlier incubated at NASSCOM's IoT Centre of Excellence; received seed funding from Zeroth, a Hong Kong based AI startup in 2018 (120,000 US dollars)
Aarav	AUS is an enterprise drone mapping and	Drone mapping is used to collect	Incubated at

Startup	What it does?	How the AI works?	Funding
Unmanned Systems (AUS)	analytics company that offers mapping and imaging and analytics services. It is empanelled with many state governments in India as part of their surveying and mapping efforts for different undertakings and has also worked with contract farming and seed companies.	and process data. Analytical layers are then applied based on the needs of the client for specific intelligence.	IIT-Kanpur; raised seed funding in 2016 and 2018 (amount undisclosed)
Agricx	Agricx offers AI based grading and certification software for cold storage companies and traders. The company uses its grade determination algorithm to assay commodities such as potatoes, rice, pigeon pea and chocolate.	Image recognition technology is used to assess commodities and grade them. Layers of information—source of commodity, date of procurement and quality parameters—can be tagged to the process, based on client needs.	Series A funding from Ankur Capital & CIIE (500,000 US dollars)

The many hot deals currently being struck in the sector seem to point to a rosy outlook for AI in agriculture. However, what our field work with startups tells us is that larger market dynamics present many constraints, limiting the AI potential.

a. Consumer/client, rather than farmers, the starting point of innovation

Current industry trends tell us that startups in the agri-value chain are deeply concentrated in the e-grocery/retail end or in the midstream segment for market linkages and value added innovations. These include assaying and grading, certification and standards development, optimisation of logistics, all in the B2B (business to business) segment, where startups can work with other actors in more controlled environments and expect assured returns.

The focus on B2B or the client end, rather than on farms and farmers, is owing to the following reasons:

- **A highly fragmented agricultural market, which makes the last mile unattractive, with high resource intensity needed to on-board farmers.** This was cited as a common reason for bypassing the farmer segment. M Ramakrishnan, COO at Intello Labs, opined that a business-to-farmer model could always only “excel in isolated pockets”. Achieving scale, he added, was an issue in this model given that “when you are selling to the farmer, the cost of field sales are pretty high and you need to employ a large number of people to reach out to villages.”

  The resource intensity in implementing last mile solutions becomes a deterrent in building AI solutions that directly target farmers. For instance, Agricx which works on grading solutions for businesses is launching a free Do-It-Yourself (DIY) app for farmers that helps them grade their produce through their phones. Saurabh Kumar, co-founder of the company, says that the service is for “anybody who wants a base level app, which will give them a rough idea of exactly what the quality [of the commodity] is.” While Agricx is open to working with other actors who can innovate through the farmer app, being a lean company, it does not see itself taking on the role of field-based intermediation.

- **The challenges of monetising stand-alone, farm-end AI solutions.** Convincing farmers to ‘buy in’ and pay for digital services and solutions is a very difficult sell. Dhulipala from ICRISAT explained why shaping farm-based decisions and nudging farmer behaviour does not always result in a payout; “If you want startups or private guys to come into this space, obviously they need to have some idea about how they are going to make revenue, but farmers are never going to pay a fee.”

  Startups therefore choose to focus on segments like supply chain simplification, direct market linkages, etc., where there is revenue visibility. Bigger companies in the agritech space on the other hand are able to offer AI-based personalised advisories, bundling this with sale of inputs such as seeds or procurement of produce for retail. Dhulipala notes how, “Big e-commerce platforms have stronger revenue visibility. They sell seeds that otherwise cost 100 Indian rupees for 80 Indian rupees. The farmer is anyway receiving an instant benefit and so, out of the 20 Indian rupees he saves, he can be charged a small commission for the advisory.”

b. Startups face tough competition from big corporations

Rhetoric about enterprising startups being able to rapidly innovate and disrupt the market does not quite pan out. Even in the midstream segment where business value propositions are clearer, there is overall scepticism about new-to-field initiatives. Companies looking for AI solutions are also likely to bet on established tech players rather than startups. Early adopters are a rarity in the agriculture industry, and startups need to put in a lot of work to win business. Time to market for products and services can be anywhere between six months to a year, with smaller players simply not able to make the leap to mobilise the resources needed**.**

c. The AI Disjunct in Make in India

Given that AI is a capital intensive undertaking requiring high-tech hardware devices and machinery, much of which is currently not available domestically needs to be imported. The high import duty on IoT devices, which was until recently at 30 percent, and on other hardware was noted as a cost that smaller players find difficult to off-set, especially if they are targeting farmers as in the case of Fasal, an IoT startup that works with horticulture farmers. “We want to sell it [the IoT kit] for 90 Indian rupees, but because of taxes we have to sell it for 140 Indian rupees,and every 10 Indian rupees increase, decreases exponentially the number of farmers who can buy [the service],” pointed out company founder, Shailendra Tiwari.

If import duties are prohibitive on the one hand, high-tech manufacturing has also not taken off in a big way despite policies such as Make in India. This particularly applies to manufacturing of drones, which are critical digital intelligence tools for agriculture innovation. Vipul Singh, who heads Aarav Unmanned Systems, believes that past a certain scale, he will have little choice but to outsource manufacturing of drones to China. He reckons that "most of the essential components like high efficiency miniature brushless motors, lithium polymer or lithium ion batteries, etc., are not at all manufactured in India... Also, making drones is a multidisciplinary activity, which requires precise synchronisation among different stakeholders just like the automotive industry. The current drone industry in India is very scattered and small scale, with not much fundamental level technology development."

d. It's all about the data roadblock

As previously discussed, the rickety data infrastructure in India has meant that many startups have had to actively engage in the task of creating data baselines and pools. This becomes essential to enhance their value proposition and strengthen platform performance, whether that be through production of multi spectral data sets through drone mapping, climate and soil data through IoT networks of sensors and chips, annotated data through image recognition or building predictive pricing models through time series data. Intello Labs, for instance, currently sends out people to various locations, including to APMC *mandis* (market places), to collect data through photographing commodities and feeding it in through smart phones. These resource intensive efforts carried out by small and mid-sized startups are less amenable to building complex AI solutions that demand large volumes of highly diverse data sets.

5. Implications for AI in Agriculture

What the scoping study points to is that despite policy aspirations, the roadmap for AI in agriculture in India is still mired in data deficits coming from legacy systems and lack of incentives for farmer-centric data innovations. With a lot of players—from small startups, to mid-sized domestic companies and large transnational corporations (TNCs)—in the fray, current trends reflect challenges for disruptive innovations that can transform farming practices for greater livelihood sustainability. Business opportunities in the midstream segment seem to drive AI innovations, even as big players—traditional and digital—are investing in longer term, resource intensive strategies to build datasets. Based on this scoping study, we infer the following issues and implications for the future of AI in Indian agriculture.

5.1 Lack of Appropriate Public Intervention for Domestic Innovation

The lack of public data pools has a direct bearing on the fledgling startup ecosystem and the prospects for AI innovation in agriculture. On the one hand, this forecloses possibilities for public interest innovation. On the other, capture of the data marketplace by big corporations ends up reducing the overall competitiveness of the sector, creating entry barriers for smaller players. Further, governance mechanisms to ensure data protection and create the checks and balances to prevent misuse of public data sets and public interest concerns in private partnerships are not yet developed. Support for domestic startups seems to rely mainly on incubators and startup contests, with no comprehensive strategy to expand the manufacturing base necessary for cutting edge AI. The lack of support for public R&D is yet another factor discouraging domestic innovation. Today, India's competitive position in AI is lower than countries like China and Israel, where development of AI technologies has received considerable public investment.

5.2 Trends towards Consolidation, End-To-End Control and Loss of Local Autonomy

While startups are able to work on AI-enabled innovations at higher levels of the value chain, they are ill-equipped to respond to the structural problems of agriculture in India. AI solutions that can expand and respond to static and dynamic knowledge needs of farmers and improve their farm-based practices and decisions are driven by larger and more entrenched players such as Bayer-Monsanto and Walmart-Flipkart. These companies engaged, or looking to engage directly, with farmers in the precision agriculture segment can afford resource intensive investments to consolidate the value chain. They can exercise complete control of the inputs or procurement segment and thus co-opt farmers into a marketised agricultural paradigm. This does bring some gains to farmers, but ultimately leads to corporatised takeover of agriculture, diminishing farmer autonomy over livelihoods.

Additionally, such arrangements also give corporate players an unfair "knowledge premium" (a first mover advantage with strong IP protections), locking in developing countries and their farmers into a relationship of dependence. Not only does the path for domestic innovation become foreclosed, but local knowledge systems may also be appropriated through micro-surveillance or discarded altogether in favour of end-to-end integrated solutions.

Currently, local knowledge practices such as development of germ plasm and seed keeping are at tremendous risk of being decimated by predatory IP regimes favouring big corporations.[52] The pre–digital history of patent wars in India around regional commodities such as basmati and turmeric have exhibited the ease with which the ownership of local knowledge systems and intellectual resources of communities can be thrown into question.[53] With vast quantities of gene sequencing data of agricultural produce now available on the cloud and companies being able to model seed science from anywhere, local knowledge faces an imminent threat of appropriation through AI.

Developments such as Walmart's decision to integrate AI as value added input services in its contract farming arrangements in India therefore need to be closely watched.[54] While it is anyone's guess what the outcomes of such trends will be, we can only look to similar developments in other markets to see what the future may hold for the small Indian farmer in the datafied world of agriculture. Similar to what is unfolding in India, retail end demands have been driving particular food production trends in Vietnam, New Zealand, Australia and Indonesia. Kartini Samon from GRAIN, a non-profit working with small farmers in the global South notes that, through farm-to-fork consolidation, e-commerce giants establish end-to-end control over entire supply chains of agricultural commodities. Independent farmers lose their bargaining power and the entire agriculture sector becomes completely consumer-driven. Marginal and small farmers tend to be edged out as there is no room for small-scale operations. This has serious gender implications for women's livelihoods, given that most small holdings in the Asia-Pacific region are managed by women.

AI-based solutions can also amplify social differences and inequality. Consider the advent of fintech in agriculture and the associated role of credit-based scoring systems in determining farmers' access to stable finances. As exclusive gatekeepers and arbitrators of access to resources, data-driven decision making models could easily edge out marginal players who the AI system deems unworthy.

5.3 PPPs as a Route to Entrenchment of Digital Giants

Current models in PPPs, such as the NITI Aayog-IBM partnership or the proposed collaboration between the Government of Andhra Pradesh and Alibaba, seem to raise questions about the role of big digital players in the AI ecosystem. It is not yet clear how these partnership arrangements will be governed in public interest so as to deter private value capture by big companies and can protect marginalised constituencies. This ambiguity can be a slippery slope towards monopolistic practices and unregulated data control by powerful corporations, leaving other actors in a highly skewed playing field.

The Zero Budget Natural Farming initiative of the state of Andhra Pradesh is a case in point. The project, which has many components of digital integration, involves global financial institutions, banks and funds and is currently backed by massive state guarantees, against the advice of the Reserve Bank of India (RBI) (given that this may artificially push up the viability of projects).[55] Although the professed aim of the project targets marginal producers, quite paradoxically, the financial and digital arrangements open up possibilities for greater corporate control of agriculture and run antithetical to the interests of farmers and their livelihoods.

6. Directions for Policy

The current AI-driven knowledge framework in agriculture is yet to redeem the long-standing problems of Indian agriculture. What we need therefore is an umbrella policy on AI and agriculture, built on the first principle of long term sustainability of agricultural livelihoods, that can work to guarantee rewarding and stable livelihoods for marginal producers, women farmers, landless farmers, co-operatives and Farmer Producer Companies (FPOs). AI technologies must work to sustain diverse and locally relevant practices of agriculture that not only learn from local knowledge systems, but also respect and promote the traditional knowledge commons. An AI ecosytem in agriculture must encourage innovation at the edges—enabling entrepreneurs and SMEs to innovate along the entire value chain. Within a comprehensive policy framework on AI and agriculture, interconnected strategies and actions need to be initiated by multiple nodes in the government. Some suggestions in this regard are offered below.

6.1 Building Data Infrastructure and Public Goods for Agriculture

Sustained investment for the creation of data infrastructure in the field of agriculture is urgently needed to catalyse research, innovation and application. This includes interventions for digitising existing sources of data and providing open data and APIs on various aspects, including agricultural *mandis* (markets), weather, soil, seeds, etc. Global initiatives like the Platform for Big Data in Agriculture may be useful models to consider, adapt and refine, in this regard.[56] NITI Aayog has also put forth the idea of an annotated national data marketplace, which can serve as a common resource for researchers, private actors and government agencies to innovate upon.

The “AI for all” dictum professed by the government implies measures for a new knowledge culture around data that translates into stronger institutional support and actionable information for the last person in the value chain. Simple and relevant advisory services in local languages based on AI-based models can strengthen local agricultural practices. The Farmer Zone project initiated by the Department of Biotechnology to increase farm productivity and improve input practices in potato cultivation is a useful pilot that can yield many insights in both data management and for suitable replication and localisation across many other crops.

A national data marketplace also requires to be rooted in laws that respect privacy and provide safeguards for personal data protection and collective rights of farming communities to their data.

6.2 Enhancing R&D for Localised AI innovation

Investments needs to be made into furthering research and development in the field, with a focus on multiple and decentralised capacity building for incubation, acceleration, industry connections, mentoring, etc.

- Dedicated incubators and startups focussing on the field need to be promoted. One such initiative is the National Association of Software and Services Companies(NASSCOM) Center of Excellence (CoE) for AI and IoT in India located in Bengaluru.[57] The CoE is part of the Digital India initiative, and as a “deep tech innovation ecosystem” involves startups, innovators, enterprises and the government, with a dedicated cluster on agritech. The NASSCOM CoE has incubated one of the biggest agritech AI companies, Cropin, which is currently working on a “smart farm” platform.[58] ICRISAT, which also runs an in-house incubator, I-HUB, works to support startups in digital agriculture and provides the much needed research inputs.[59]

- Pilot projects involving diverse actors, such as small startups, FPOs, agricultural universities and regional engineering institutes need to be implemented to create an environment of small-scale innovation and localised intervention.
- Hardware self reliance for AI-related needs must be fostered through appropriate manufacturing policies and incentives that also account for expensive, high-end infrastructure, such as Graphical Processor Units (GPUs) used in image recognition.
- Policies need to focus on upgrading extension services and training field personnel to implement public AI solutions at the farm level. Schemes such as MUDRA should support FPOs to build internal data and AI capacities relevant to their business proposition, while mobilising public data sets to generate localised, real time data towards AI solutions. Low-cost IoT kits for real-time data collection can be distributed to farmers. This will help bridge data gaps and enrich the data ecosystem. Farmers and producers can also be trained and incentivised to use these kits and deposit data into a common data repository over which they enjoy clearly defined rights of access and use.

6.3 Countering Data-Driven Monopolisation

For countries, such as India, which have huge swaths of population directly dependent on agricultural livelihoods, countering corporate capture of the agricultural data ecosystem is a key priority. Policies should address vertical integration and anti-trust overtures by big companies in the sector and put in place mandatory data sharing requirements for private sector actors. Additionally, for public-private arrangements, the state must develop transparent frameworks to ensure that the value derived is equitably distributed among the partners and that public sector stake and ownership over the data, source code and algorithms are clearly established. Further, public audits of the AI in such consortia need to be undertaken as due process.

6.4 Fostering Alternative Community Data Models

Data governance models need to allow synergies and complementarities among public, private and community agencies towards localised farming innovations. For instance, a unique aspect to Fasal's work is their recognition of farmers' rights to the data collected as part of their operations. Farmers co-own the data and also receive a share of any value that is monetised from the data. Similarly, the American Farm Bureau Federation in its policy for farm data use and processing explicitly establishes farmers' rights over data collected on their lands, invoking a rights framework to protect community interests in the data. In other cases, social enterprises that support farmers have successfully demonstrated the gains of communitisation of data through ethical data brokerage practices. Examples include EkGaon, a technology solution provider which operates in central India and Vrutti, which works with farmers in South India to secure fair prices for them in commodity markets. Public data models need to co-exist with others where local communities and farmer organisations manage and benefit from data about their own farms and farming practices.

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