

Machinery

for big ag



MACHINERY FOR BIG AG refers to manufactured equipment used in agriculture. This includes, for example, tractors, haying and harvesting machinery and equipment used for planting, fertilizing, ploughing, cultivating, irrigating and spraying. Today, the world's largest farm equipment companies are gearing up to control digital ag technologies and farm data as their number one strategy for expanding market share. Digitalised agriculture implies other machinery used down on the farm – drones, sensors and devices that run apps, for example – as well as internet connectivity.

Table 1: Sales of the Leading Farm Equipment Companies, 2020

Rank	Company (Headquarters)	Sales 2020, US\$ millions	% Market Share 2020
1.	Deere & Company (USA) ¹	22,325	17.5
2.	Kubota (Japan) ²	14,140	11.0
3.	CNH Industrial (UK/Netherlands) ³	10,916	8.5
4.	AGCO (USA) ⁴	9,150	7.2
5.	CLAAS (Germany) ⁵	4,609	3.6
6.	Mahindra & Mahindra (India) ⁶	2,480	2.0
	Total Top 6	63,620	49.8
7.	Iseki (Japan) ⁷	1,399	1.1
8.	SDF Group (Italy) ⁸	1,307	1.0
9.	Kuhn Group (Switzerland) ⁹	1,164	<1.0
10.	YTO Group (China) ¹⁰	984	<1.0
	Total Top 7 - 10	4,854	<4.1
	Total Top 10	68,474	<53.9
	Worldwide Farm Machinery Sales (est.)¹¹	127,800	

Source: ETC Group, based on company annual reports

According to the Mechanical Engineering Industry Association (VDMA) based in Frankfurt, the worldwide market for agriculture equipment reached US\$128 billion in 2020.

- The top 4 companies account for 44% of the global ag machinery market.
- The top 6 companies account for one half of the global ag machinery market.

In some regions and countries, farm machinery markets are even more consolidated.

For example:

- In the United States, just three companies – Deere, CNH and AGCO – account for more than 90% of high-horsepower tractor sales.¹²
- Mahindra & Mahindra controls more than 40% of India's farm equipment market.¹³

Trends: chew on this

ETC finds that the major trends in the industrial ag machinery market include:

- **Market Volatility**
- **A Push to Automate**
- **Drive to Digitalize Fuelling Ag Machinery Markets**
- **Continuing Battle over Who Owns and Controls Farm Data**
- **Drones Take Flight**

Market Volatility: A Bumpy Ride

In 2020-21, ag machinery markets experienced pandemic-induced volatility. After the cease fire in the China-U.S. trade dispute resulted in growing demand for corn and soybeans, US tractor sales revved up by double-digit percentages.¹⁴ In India, Mahindra & Mahindra saw its June 2021 domestic sales increase by 31% over the previous year,¹⁵ and the European Agricultural Machinery Association reported 25% more tractors registered across Europe in the first six months of 2021 compared to the same period in 2020.¹⁶

But supply chain challenges caused headaches. Big farm machinery manufacturers scrambled to keep up with new orders in 2021¹⁷ due to depleted inventory, shortages in labour and raw materials (including semiconductors¹⁸) and rising freight costs.¹⁹ In May 2021, Deere warned that the chip shortage

posed a significant risk and noted that raw material and freight costs would double for the year.²⁰ Nevertheless, in August, Deere forecast record net income for 2021, double its 2020 figure.²¹ Two months later, 10,000 unionized Deere workers went on strike to protest low wages and inadequate retirement benefits.²²

A Push to Automate

Pandemic-induced lockdowns and restrictions on the cross-border movement of migrant workers led to farm labour shortages, giving the ag equipment sector even more incentive to accelerate a long-promised shift to automation. According to global data platform for intelligence on start-ups, Dealroom, investment in farm robotics/automation start-ups, including vertical and indoor farms, jumped 40% from January to August 2020.²³ In 2020, Kubota unveiled its first completely autonomous tractor – dubbed “the dream tractor”²⁴ – and is now working with start-ups developing technologies for growing/harvesting crops that require a dextrous handling (fruits such as strawberries, apples, grapes, for example)²⁵ – an area the company views as especially ripe for automation.

Governments are supporting automation in agriculture, too. In 2020, the U.K. Research and Innovation agency awarded £2.5 million to a consortium of academic and private sector firms developing the world’s first robotic farm, dubbed “Robot Highways.”²⁶ The project claims that its autonomous tech will enable a 40% reduction in labour and help move the sector toward a carbon zero future.²⁷ In Thailand, the Ministry of Agriculture and Cooperatives established tech-focused subcommittees on Big Data, Smart Agriculture, E-Commerce and Agribusiness.²⁸ The government also developed “TraceThai,” a national, digitalized traceability system that will start with tracking organic foods.²⁹ Industrial agriculture is notorious for exploitation of farm labour and, contrary to companies’ claims, the current push to automate farm equipment threatens to amplify exploitation by increasing worker surveillance, pressures to meet inhumane machine-designated targets and the deskilling of workers.³⁰

Table 2: Selected acquisitions/investments related to automation and precision farming by Big Ag Machinery corporations (2019-2021)

Farm Machinery Company	Acquisition/Investment
Deere & Company	Acquired Bear Flag Robotics for US\$250 million to develop autonomous tractors; ³¹ Deere is collaborating with tech start-ups: Nori (carbon offset platform based on digital recordkeeping), Nvision Ag (data modelling and aerial imaging for corn farmers to manage nitrogen levels), Scanit (early detection of airborne pathogens), and Teleo (turning existing equipment into remote-controlled robots). ³²
CNH Industrial	Acquired precision agriculture pioneer Raven Industries for US\$2.1 billion; ³³ holds minority stake in Augmenta (automates farming operations); ³⁴ minority investment in US-based Monarch Tractors. ³⁵
CLAAS	Holds a minority stake in AgXeed (to build field robots). ³⁶
AGCO	Precision Planting, LLC (subsidiary of AGCO) acquired Headsight, Inc. (precision agriculture harvesting); ³⁷ acquired Farm Robotics and Automation S.L (“Faromatics”), a precision livestock farming company. ³⁸
Kubota	Bought an additional stake in Indian tractor manufacturer Escorts (total 15%); ³⁹ bought stake in Israeli start-up Tevel (flying autonomous fruit-picking robot); ⁴⁰ collaboration with Aurea Imaging (autonomous orchard and vineyard farming).
Mahindra & Mahindra	Acquired stake in Resson, a predictive data analytics company (other investors include Monsanto Growth Ventures and McCain Foods); ⁴¹ acquired a stake in Swiss agritech firm Gamaya (hyperspectral imaging, AI and machine learning algorithms). ⁴²

Drive to Digitalize Fuelling Ag Machinery Markets

“We are transforming from a machinery company into a smart technology company.” – Martin Kremmer, director ETIC, John Deere European Technology Center⁴³

“...[E]nvironmental narratives are legitimizing a digital transition in the food system that might otherwise raise critical questions about issues such as data sovereignty, increased surveillance and corporate control over farming practices.” – Louisa Prause, Sarah Hackfort and Margit Lindgren writing in *Agriculture and Human Value*⁴⁴

For all agriculture sectors – from livestock breeding and ranching to industrial farming – data is itself a precious commodity, which some have dubbed “the new soil” and others “the new cash crop.”⁴⁵ The farm equipment sector is no exception, and digitalization is driving the growth strategies of all the major companies.⁴⁶ (IHS Markit estimates that the global digital farming market was worth US\$5-7 billion in 2020 – less than 5% of the total farm equipment market – but is forecast to increase to US\$15 billion by 2027.⁴⁷)

With heaps of data on soil quality, weather, input levels – such as seeds, pesticides and fertilizers – farm equipment makers have refashioned themselves into tech companies.⁴⁸ Agricultural machinery now also implies drones,

sensors and robots equipped with artificial intelligence (AI) and/or machine learning capabilities to target individual plants or plots, with the promise of “precision” – just the right amount of water or fertilizer or pesticide: good for the crop, good for the environment and good for the farmer’s bottom line, go the claims. Deere & Company now employs more software engineers than mechanical engineers.⁴⁹

In reality, precision ag’s claims to save time, money and labour stand on shaky ground due to unequal digital access, a narrow focus on a few commercial crops, inaccurate GPS systems, sensors and other hardware and software components – especially algorithms – and the inability of these technologies to gauge complex farm realities, practices and micro-climates.⁵⁰

“Precision farming” can imply multiple technologies, including:

Robots for weeding,⁵¹ fruit and vegetable picking, irrigation, and spraying pesticides;

- **Drones** to scan soil fertility, to monitor crop health, to apply pesticides, herbicides and fertilizers, and even to plant seeds;⁵²
- **Sensors** (hyperspectral, multispectral, thermal and LiDAR) that capture information that may not be visible to the naked eye, such as soil moisture, plant stress levels, presence of weeds, or pests;
- **Data analytics** to process the gathered data in order to give recommendations on how, where and when to irrigate, apply pesticides and fertilizers;
- **Satellite imagery** to assess yields, crop damage, growth rates;⁵³
- **GPS (Global Positioning System) and BeiDou Navigation Satellite System (BDS)** for on-farm navigation of machinery;
- **Cloud providers**, making possible storage and processing of massive datasets;
- **Internet connectivity**, which underpins all the other technologies.

Ag machinery companies, together with agrochemical and seed industry firms, have successfully propelled the narrative that precision agriculture is the key to productivity, sustainability and climate resilience. Working hand-in-hand with industry, many national governments, philanthro-capitalists (e.g., the Bill & Melinda Gates Foundation) and the Consultative Group on International Agricultural Research (CGIAR, which has received more than US\$1 billion from the Gates Foundation⁵⁴) have embraced the drive to digitalize the global South and peasant agriculture.⁵⁵

Global collaborations, like the Agricultural Innovation Mission for Climate (AIM for Climate) launched at the UN’s 2021 Climate Conference (COP26) by the U.S. and U.A.E., are pushing “climate-smart agriculture,” advocating

for more investments in ag tech and on-farm data collection, and continuing extractive agriculture.⁵⁶ Even public sector techno-optimists are endorsing digital ag for the global South with scant empirical evidence of how these technologies may impact peasant farming communities.⁵⁷ In her budget speech for the financial year 2022-23, the Finance Minister of India declared that the “use of ‘Kisan Drones’ will be promoted for crop assessment, digitization of land records, spraying of insecticides, and nutrients.”⁵⁸ In the words of researcher Glenn Davis Stone, “there is significant movement towards surveillance-based, decision-appropriating technologies being developed and deployed for peasants in the global South.”⁵⁹

Some academics warn that the ability to “harvest new data sources” from peasant farmers will amplify the global land grab.⁶⁰ They explain that the extraction of previously-inaccessible, farm-level micro-data will allow better assessments of profit potential, thus accelerating land grabs in the global South.⁶¹

Table 3: Selected digital agriculture platforms of farm equipment manufacturers and inter-sector collaborations

Deere & Company	
Digital Ag Platform	Deere Operations Centre (farm management)
Some components	JD link (data transfer); John Deere Mobile Weather; Ag Logic (remote work management); Field and Water Management
Interoperability; Digital Ag collaborations	U.S. Agency for International Development, Corteva, John Deere and Global Communities work on precision ag in Zambia; data integration agreement between E-luminate, Golden Harvest’s (Syngenta’s corn and soybean seeds) digital ag platform and Deere Operations Center; ⁶² Deere, CLAAS, CNH Industrial and 365FarmNet formed a data interface project called Data-Connect that will enable farmers operating machinery from different cooperating brands to view and exchange machine data; ⁶³ partnered with Volocopter to develop an agricultural drone (VoloDrone) for agrochemical spraying
AGCO	
Digital Platform	Fuse; FendtONE (operating system) by Fendt (AGCO subsidiary)
Some components	AGCO Connect (machine focused telemetry software, yield monitoring system; AccuBoom (targeted spraying); Climate FieldView app (agronomy decision and visualization)
Digital Ag Collaborations	AGCO partnership with Climate FieldView; AGCO entered into a collaboration with Robert Bosch GmbH, BASF Digital Farming and Raven Industries Inc. to work on targeted spraying technology ⁶⁴
Kubota	
Digital Ag Platform	KSAS (Kubota Smart Agri System), cloud-based agricultural management support service
Some components	Plans to include fertilizer application, chemical spraying, and business support system ⁶⁵
Collaborations	Partnered with US Chipmaker Nvidia to develop self-driving farm tractors; ⁶⁶ partnered with Aurea Imaging for “crop intelligence” for fruit growers; ⁶⁷ Japanese subsidiary of Mahindra & Mahindra collaborated with Kubota for joint IoT solutions, OEM supply arrangements; ⁶⁸ collaborated with Microsoft to shift to its Azure cloud services; part of AGROS, collaboration between Wageningen University & Research and 26 private partners, including BASF

CLAAS

Digital Ag Platforms	CLAAS Connect; 365FarmNet (CLAAS Subsidiary); CLAAS E-Systems (CLAAS Subsidiary)
Some Components	CLAAS Telematics, BASF AgSolutions Finder (pesticide measures), Agopressure by Michelin (Components of 365FarmNet)
Collaborations	Bayer, CLAAS collaborate to expand Climate FieldView digital farming platform

CNH Industrial

Digital Ag Platforms	AGXTEND
Some components	CropXplorer (uses sensors for nitrogen application and other uses); FarmXtend (provides sensor-based detailed agronomic recommendations); SoilXplorer (soil sensors); NIRXact (Near Infrared sensors providing recommendations for application)
Collaborations	CNH Industrial partnered with AGCO, Bayer, Jacto, Nokia, Solinftec, TIM and Trimble under ConectarAGRO to push precision farming in Brazil; CNH Industrial, Accenture and Microsoft for increasing CNH's digital capabilities; ⁶⁹ partnered with DroneDeploy to deliver a packaged deal of a DJI drone/camera and the company's software for plant health analysis

Mahindra & Mahindra

Digital Ag Platforms	Krish-E (India); DigiSense 4G
Some components	Soil mapping, drone spraying, pest management
Collaborations	Mahindra & Mahindra's Japanese subsidiary, Mitsubishi Mahindra Agricultural Machinery Company and Kubota announced collaboration for Japanese domestic operations

Continuing Battle over Who Owns and Controls Data

The legal ownership of data collected on-farm is murky at best.⁷⁰ Deere, for example, has famously argued that when a farmer buys one of the company's tractors, they receive a "license to operate the vehicle" but they are not the owner of the equipment, the software embedded in it or the data generated by the equipment.⁷¹ By asserting themselves as the ultimate data-owners, farm equipment manufacturers seek to retain control of a product that itself has enormous value. This is also evident in the partnerships between the big agrochemical/seed companies and farm equipment manufacturers (see Table 3). These collaborations involve the sale or exchange of data, which are analysed to deliver prescriptions to the farmer – for example, which seeds to plant on which plot of land or the application rates of other inputs. The company that controls farm data is positioned to use its farm management platform to link the farmer to preferred products (i.e., its own and those of its partners). The immediate goal is to optimize sales on the company's platform. In the longer term, the ag machinery/tech firms are positioned to further usurp farmer autonomy and decision-making by creating technology lock-ins. For example, in order to qualify for credit or to meet food safety standards, farmers could be compelled to adopt particular precision ag technologies and products.⁷²

Additionally – and relatedly – equipment repair services are a profitable revenue stream for farm machinery manufacturers. Companies like Deere say

it's illegal for farmers or independent technicians to tinker with embedded software, which is considered proprietary. Equipment repairs are time consuming and costly for farmers, and waiting for a company-approved technician to show up at harvest time can mean tens of thousands of dollars in lost income. The “Right to Repair” movements across the world are fighting against manufacturers like Deere (as well as Apple and Tesla) that want to prevent farmers/consumers from fixing the products they've bought. Anti-trust researchers believe that Deere's aggressive attack on the right to repair demonstrates the company's attempt to monopolise the market for digital agricultural information.⁷³ In July 2021, the Biden administration took steps to push back on the manufacturers' anti-competitive repair restrictions in the U.S., but the new rules are still being written.⁷⁴

Drones Take Flight: Bedrock of Digital Ag is in the Sky

*“I am the eye in the sky
Looking at you
I can read your mind...”* – from “Eye in the Sky,”
lyrics by Eric Woolfson, Alan Parsons

Cameras and other sensors attached to drones function as the eyes of the digital ag-machine bundle. Sensors can map terrain and capture detailed images of farmland, and drones can shoot seeds in the ground and spray chemicals on crops. In some cases, drones are being used in “precision ranching” to track cattle and monitor health.⁷⁵ The leading farm equipment manufacturers have become drone devotees, especially through collaborations with other, drone-centred companies: Deere & Company has partnered with Volocopter to develop a drone (VoloDrone) for agrochemical spraying;⁷⁶ CNH Industrial teamed up with DroneDeploy to deliver a packaged deal of a DJI drone/camera plus DroneDeploy software to assess plant health analysis (with the capability to zoom in to “inches above the plants”);⁷⁷ and Kubota has recently invested in fruit-picking drone company Tevel.⁷⁸

Seeds and agrochemical companies, too – Bayer, Corteva AgriScience and BASF, for example – are partnering with (mostly private) drone hardware manufacturing companies like DJI (the largest seller that accounts for about 70% of the drone market),⁷⁹ XAG⁸⁰ and Delair⁸¹ (see Table 4). AGCO manufactures its own drones while Mahindra & Mahindra is expected to launch ag-drones soon after getting conditional permission from the Civil Aviation Ministry of India to conduct drone-based agricultural trials and precision spraying on paddy and hot pepper crops in Telangana and Andhra Pradesh, respectively.⁸²

Whose ag-drone software will dominate has not yet become clear: Slanrange,⁸³ Taranis,⁸⁴ PrecisionHawk,⁸⁵ FarmLens (owned by AgEagle) and Climate Corporation (owned by Bayer) all sell programs that analyze agricultural data to provide input recommendations to farmers.

Table 4: Partnerships between Drone Manufacturers, Ag Input Companies and other actors

Drone company	Partnerships
XAG (China)	XAG partnered with Bayer and Alibaba Rural Taobao to form the “Sustainable Farming Programme” in China focused on digital ag; ⁸⁶ with Bayer to commercialize digital farming technology in Southeast Asia & Pakistan (SEAP); ⁸⁷ with Federal University of Paraná (UFPR), Brazil and Timber to plant trees; ⁸⁸ with The National Centre for Precision Farming, Harper Adams University, U.K. to develop drones and robotics for UK and European farmers ⁸⁹
AgEagle Aerial Systems (USA)	BASF ’s xarvio FIELD MANAGER integrated with AgEagle’s senseFly’s eBee X fixed-wing drone platform; ⁹⁰ (AgEagle acquired senseFly from Parrot in 2021 ⁹¹)
DJI (China)	With Syngenta Japan to promote ag drones in Japan; ⁹² CNH Industrial and DroneDeploy sell a packaged deal of a DJI drone/camera plus software for plant health analysis; an agreement with Syngenta Korea to be its sole drone partner, and to promote jointly aerial pesticide application in South Korea; ⁹³ Corteva owns a fleet of 400 DJI drones ⁹⁴

Unsurprisingly, Big Tech has already beefed up its involvement in digital agriculture. Gartner, a technology-focused consultancy, calculates that spending on cloud services will reach nearly 10% of all corporate spending on information technology in 2021, while Andreessen Horowitz, a venture-capital firm, estimates that many tech start-ups already spend 80% of their revenues on cloud services.⁹⁵ The proliferation of digital ag companies is a gold mine for Big Tech, which will sell cloud services to enable massive volumes of agriculture-related data to be stored and processed. BASF⁹⁶ and Bayer⁹⁷ use Amazon Web Services (AWS) to process and analyse data on their digital platforms while Syngenta, Corteva Agriscience and BASF use Google Cloud services (via their collaborations with DroneDeploy⁹⁸ and Taranis⁹⁹). The cloud services market is tightly consolidated: AWS held 41% of the cloud services market in 2020, and the top five cloud service providers accounted for 80% of the market.¹⁰⁰ More than half of Amazon’s operating income comes from AWS.¹⁰¹

Notes

- 1 Deere & Company news release, “Deere Reports Net Income of \$757 Million for Fourth Quarter, \$2.751 Billion for Year,” n.d.: https://s22.q4cdn.com/253594569/files/doc_financials/2020/q4/4Q_2020_News-Release-and-Financials.pdf, p. 19.
- 2 Kubota Report 2021: https://www.kubota.com/ir/financial/integrated/data/digest2021_11.pdf.
- 3 CNH Industrial Annual Report 2020, p. 41: https://www1.cnhindustrial.com/en-us/investor_relations/financial_information/annual_reports/CNH_Industrial_Annual_EU_report_2020_final.pdf.
- 4 AGCO Annual Report, p. 106: <https://investors.agcocorp.com/static-files/dde17fd9-4fca-4bbo-b77a-baf80115f3bd>.
- 5 CLAAS 2020 Annual Report, p. 36: <https://www.claas-group.com/blueprint/servlet/blob/2375836/obfd21a9e422155e73c-2284c9b7ee053/annual-report-2020-data.pdf>.
- 6 Mahindra & Mahindra Integrated Annual Report 2020, p. 282: <https://www.mahindra.com/resources/investor-reports/FY21/Annual-Reports/MM-Annual-Report-2020-21.pdf>.
- 7 Iseki (Japan) Annual Report, June 2021, p. 5: https://www.iseki.co.jp/english/csr/report/pdf/iseki_report2021.pdf.
- 8 SDF Group, Annual Report 2020: https://issuu.com/sdf-group/docs/sdf_annual_2020_single_en_issuu.
- 9 See Kuhn website: <https://www.kuhn.com/en/about-kuhn>.
- 10 YTO Group (China), 2020 Annual Report of the First Tractor Company Ltd, p. 318: <https://www1.hkxnews.hk/listedco/listcomnews/sehk/2021/0422/2021042200929.pdf>.
- 11 According to the Mechanical Engineering Industry Association (VDMA), the value of worldwide agriculture equipment sales was US\$127.8 billion.
- 12 High horsepower tractors are used for row crop production, such as corn. See Jacob Bunge and Bob Tita, “Biden Order Takes Aim at Tractor Repair,” *Wall Street Journal*, 10 July 2021: https://www.wsj.com/articles/biden-order-takes-aim-at-tractor-repair-11625914801?st=53rcklwwf55dl4i&reflink=desktopwebshare_permalink.
- 13 Sonia Shenoy and Surabhi Upadhyay, “M&M eyeing price hike in November; says company’s tractor market share at 40% plus,” 02 November 2021: <https://www.cnbctv18.com/auto/mm-eyeing-price-hike-in-november-says-companys-tractor-market-share-at-40-plus-11318782.htm>.
- 14 Scott Carpenter, “How Ag Giant John Deere Has Plowed Through The Pandemic,” *Forbes*, 26 October 2020: <https://www.forbes.com/sites/scottcarpenter/2020/10/26/john-deere-plows-through-pandemic-on-government-payments-to-farmers-and-late-crop-price-surge/?sh=7642bdcd3a47>.
- 15 Mahindra & Mahindra, “Mahindra’s Farm Equipment Sector Sells 46875 Units in India during June 2021,” 01 July 2021: <https://www.mahindra.com/news-room/press-release/mahindras-farm-equipment-sector-sells-46875-units-in-india-during-june-2021>.
- 16 CEMA press release, “Covid-19 impacts 2020 tractor registrations, first 2021 semester confirms recovery despite supply chain challenges,” 30 September 2021: https://www.cema-agri.org/images/publications/press_releases/2021-09-30_Economic_Press_Release_Tractor_Registrations_2020_and_1st_semester_2021.pdf.
- 17 Noah Wicks, “Farm equipment dealers struggle to keep lots stocked amid supply chain troubles,” *Agri-Pulse*, 07 July 2021: <https://www.agri-pulse.com/articles/16095-farm-equipment-dealers-struggle-to-keep-lots-stocked-due-to-high-demand-supply-chain-issues>.
- 18 IANS, “Ford joins top automakers to halt production due to semiconductor shortage,” *Business Standard*, 11 January 2021: https://www.business-standard.com/article/international/ford-joins-top-automakers-to-halt-production-due-to-semiconductor-shortage-12101100337_1.html.
- 19 Cindy Wang, Enda Curran, and Bloomberg, “Why the world supply chain crunch keeps getting worse,” *Fortune*, 26 August 2021: <https://fortune.com/2021/08/26/world-supply-chain-crunch-getting-worse-shipping-delta-variant/>. “The cost of sending a container from Asia to Europe is about 10 times higher than in May 2020, while the cost from Shanghai to Los Angeles has grown more than sixfold, according to the Drewry World Container Index.”
- 20 Shreyasee Raj and Rajesh Kumar Singh, “Deere raises earnings forecast, flags production risks,” *Reuters*, 21 May 2021: <https://www.reuters.com/business/deere-raises-forecast-profit-more-than-doubles-equipment-demand-2021-05-21/>.
- 21 John Deere, “Deere Reports Third Quarter Net Income of \$1.667 Billion,” 20 August 2020: <https://www.deere.com/en/our-company/news-and-announcements/news-releases/2021/corporate/third-quarter-earnings/>.
- 22 The strike ended in November 2021 with a contract approved by Deere and Co. workers but it exposed deteriorating workers’ rights in the U.S. the last decade. See Michael Sainato, “Over 10,000 John Deere workers strike over ‘years’ of poor treatment,” 14 October 2021: <https://www.theguardian.com/us-news/2021/oct/14/john-deere-workers-strike-contract-union>.
- 23 Emiko Terazono, “Farm robots given Covid-19 boost,” *Financial Times*, 30 August 2020: <https://www.ft.com/content/ob394693-137b-40a4-992b-ob742202e4e1>.
- 24 Kubota news release, “Kubota unveils a ‘dream tractor,’” 15 January 2020: <https://www.kubota.com/news/2020/20200115-1.html>.
- 25 John Seabrook, “The Age of Robot Farmers,” *New York Times*, 15 April 2019: <https://www.newyorker.com/magazine/2019/04/15/the-age-of-robot-farmers>.
- 26 University of Reading (UK) news release, “Reading role in the world’s first robotic farm project,” 17 July 2020: <https://archive.reading.ac.uk/news-events/2020/July/pr844759.html>.
- 27 University of Reading (UK) news release, “Reading role in the world’s first robotic farm project,” 17 July 2020: <https://archive.reading.ac.uk/news-events/2020/July/pr844759.html>.
- 28 Pearly Neo, “Thailand’s hi-tech food future: Government pledges to step up transformation of food and agri sector,” *FoodNavigator Asia*, 18 April 2022: <https://www.foodnavigator-asia.com/Article/2022/04/18/thailand-pledges-to-step-up-transformation-of-food-and-agri-sector>.
- 29 Pearly Neo, “Digitising Thailand’s food chain: National traceability system to focus on organic products first – government insights,” *FoodNavigator Asia*, 23 December 2020: <https://www.foodnavigator-asia.com/Article/2020/12/23/Digitising-Thailand-s-food-chain-National-traceability-system-to-focus-on-organic-products-first-government-insights>.
- 30 See, for example: ETC Group, “Did you know that the digitalization of agriculture could affect farmers’ rights?,” 09 December 2021: <https://www.etcgroup.org/content/did-you-know-digitalization-agriculture-could-affect-farmers-rights>.

- 31 Joseph White, "Deere, Bear Flag aim to automate tractors as 'fast as possible,'" *Reuters*, 06 August 2021: <https://www.reuters.com/technology/deere-bear-flag-aim-automate-tractors-fast-possible-2021-08-05/>.
- 32 PR Newswire, "Deere adds new companies to its 2021 Start-up Collaborator program," 27 January 2021: <https://www.prnewswire.com/news-releases/deere-adds-new-companies-to-its-2021-startup-collaborator-program-301216232.html>.
- 33 CNH Industrial, "CNH Industrial to acquire Raven Industries, enhancing precision agriculture capabilities and scale," 21 June 2021: <https://media.cnhindustrial.com/EUROPE/CNH-INDUSTRIAL-CORPORATE/cnh-industrial-to-acquire-raven-industries--enhancing-precision-agriculture-capabilities-and-scale/s/8cdo82be-4e36-44fo-a6ea-bfe897740e79>.
- 34 Anthony James, "CNH Industrial takes stake in Augmenta to offer intelligent crop spraying," *Food and Farming Technology*, 26 March 2021: <https://www.foodandfarmingtechnology.com/news/agricultural-machinery/cnh-industrial-takes-stake-in-augmenta-to-offer-intelligent-crop-spraying.html>.
- 35 CNH Industrial, "CNH Industrial completes minority investment in Monarch Tractor," 02 March 2021: <https://media.cnhindustrial.com/EUROPE/CNH-INDUSTRIAL-CORPORATE/cnh-industrial-completes-minority-investment-in-monarch-tractor/s/65225ee6-b1a5-4f56-84fe-13c7986dbd64>.
- 36 CLAAS Group, "CLAAS cooperates with start-up AgXeed and acquires minority shareholding," 12 May 2021: <https://www.claas-group.com/press-releases/claas-cooperates-with-start-up-agxeed-and-acquires-minority-shareholding/2483284>.
- 37 AGCO, "Precision Planting Agrees To Acquire Headsight Business," 04 August 2021: <https://news.agcocorp.com/news/precision-planting-agrees-to-acquire-headsight-business>.
- 38 <https://news.agcocorp.com/news/agco-acquires-faromatics-a-precision-livestock-farming-company>.
- 39 Press Trust of India, "Kubota Corp to acquire additional 5.9% stake in Escorts for Rs 1,873 crore," 18 November 2021: https://www.business-standard.com/article/companies/kubota-corp-to-acquire-additional-5-9-stake-in-escorts-for-rs-1-873-crore-12111800645_1.html
- 40 Kubota, "Kubota Invests In Tevel, The Leader Of Flying Autonomous Fruit-Picking Robots," n.d.: <https://ke.kubota-eu.com/blog/news/kubota-invests-in-tevel-the-leader-of-flying-autonomous-fruit-picking-robots/#agriculture>
- 41 Resson, "Mahindra & Mahindra Joins McCain Foods and Monsanto Growth Ventures As Strategic Partners in New Brunswick-Based Resson," 8 May 2018: <https://www.mccain.com/information-centre/news/mahindra-mahindra-joins-mccain-foods-as-strategic-partners-in-new-brunswick-based-resson/>.
- 42 Mahindra, "Mahindra enters into Strategic Alliance with Switzerland-based Gamaya," 14 June 2019: <https://www.mahindra.com/news-room/press-release/mahindra-enters-into-strategic-alliance-with-switzerland-based-gamaya>
- 43 Laurie Bedord, "John Deere Transforming From A Machinery Company To A Smart Technology Company," *Successful Farming*, 11 October 2019: <https://www.agriculture.com/news/technology/john-deere-unveils-farm-of-the-future>.
- 44 Louisa Prause, Sarah Hackfort and Margit Lindgren, "Digitalization and the third food regime," *Agriculture and Human Values* (2021): <https://doi.org/10.1007/s10460-020-10161-2>.
- 45 Alistair Fraser, "Land grab/data grab: precision agriculture and its new horizons," *The Journal of Peasant Studies*, 2019: DOI : 10.1080/03066150.2017.1415887.
- 46 Esri & The Science of Where Podcast, "John Deere: How Data Science Drives Business Growth," 24 January 2020: <https://www.esri.com/about/newsroom/podcast/john-deere-how-data-science-drives-business-growth/>.
- 47 IHS Markit, "Digital Farming and Robotics 2021," 2021. See <https://ihsmarkit.com/info/0821/digital-farming-robotics-2021.html>.
- 48 Scott Carpenter, "Access To Big Data Turns Farm Machine Makers Into Tech Firms," *Forbes*, 31 December 2020: <https://www.forbes.com/sites/scottcarpenter/2021/12/31/access-to-big-data-turns-farm-machine-makers-into-tech-firms/?sh=73afbfe7e47>.
- 49 Nilay Patel, "John Deere Turned Tractors into Computers — What's Next? CTO Jahmy Hindman on farming, data, and right to repair," *The Verge*, 15 June 2021: <https://www.theverge.com/22533735/john-deere-cto-hindman-decoder-interview-right-to-repair-tractors>.
- 50 Oane Visser, Sarah Ruth Sippel, Louis Thiemann, "Imprecision farming? Examining the (in)accuracy and risks of digital agriculture," *Journal of Rural Studies*, 28 July 2020: <https://doi.org/10.1016/j.jrurstud.2021.07.024>.
- 51 Donna Lu, "Robot with pincers can detect and remove weeds without harming crops," *New Scientist*, 29 April 2020: <https://www.newscientist.com/article/2241741-robot-with-pincers-can-detect-and-remove-weeds-without-harming-crops/>.
- 52 See, for example, DroneSeed, a re-forestation start-up: <https://droneseed.com/#about-us>.
- 53 Nick Measures, "How satellite imagery is helping precision agriculture grow to new heights," *Eco-Business*, 02 March 2021: <https://www.eco-business.com/news/how-satellite-imagery-is-helping-precision-agriculture-grow-to-new-heights/>.
- 54 Bill & Melinda Gates Foundation news release, "Bill & Melinda Gates Foundation Pledges \$315 million to Support Innovations That Help Smallholder Farmers Adapt to Climate Threats," 02 November 2021: <https://www.gatesfoundation.org/ideas/media-center/press-releases/2021/11/gates-foundation-pledges-315-million-smallholder-farmers-cgiar-climate-change>.
- 55 ETC Group, "Did you know that the digitalization of agriculture could affect farmers' rights?," 09 Dec 2021: <https://www.etcgroup.org/content/did-you-know-digitalization-agriculture-could-affect-farmers-rights>. See also: Glenn Davis Stone, "Surveillance agriculture and peasant autonomy," *Journal of Agrarian Change*, 2022, pages 1–24: <https://doi.org/10.1111/joac.12470>.
- 56 AIM for Climate is supported by 41 countries and more than 100 entities including Big Ag companies, universities, and corporate-linked entities. See AIM for Climate website: <https://www.aimforclimate.org/>. See also, ETC Group, "As big oil states plan to promote energy-hungry agtech as a 'climate solution' at COP26, it's time to question their AIM," 28 October 2021: <https://www.etcgroup.org/content/big-oil-states-plan-promote-energy-hungry-agtech-climate-solution-cop26-its-time-question>.
- 57 Glenn Davis Stone, "Surveillance agriculture and peasant autonomy," *Journal of Agrarian Change*, 2022, pp. 1–24: <https://doi.org/10.1111/joac.12470>.

- 58 In India, *Kisan* refers to a farmer. See, Government of India, “Budget 2022-2023 Speech of Nirmala Sitharaman Minister of Finance,” 01 February 2022: https://www.indiabudget.gov.in/doc/budget_speech.pdf.
- 59 Glenn Davis Stone, “Surveillance agriculture and peasant autonomy,” *Journal of Agrarian Change*, 2022, pp. 1–24: <https://doi.org/10.1111/joac.12470>.
- 60 Alistair Fraser, “Land grab/data grab: precision agriculture and its new horizons,” *The Journal of Peasant Studies*, 2019: 46:5, 893-912, DOI: 10.1080/03066150.2017.1415887.
- 61 Alistair Fraser, “Land grab/data grab: precision agriculture and its new horizons,” *The Journal of Peasant Studies*, 2019: 46:5, 893-912, DOI: 10.1080/03066150.2017.1415887.
- 62 PR Newswire, “Golden Harvest connects with John Deere Operations Center for farmer-focused data integration,” 27 August 2019: <https://www.prnewswire.com/news-releases/golden-harvest-connects-with-john-deere-operations-center-for-farmer-focused-data-integration-300907996.html>.
- 63 John Deere, “John Deere, CLAAS, CNH Industrial and 365FarmNet form DataConnect,” 05 November 2019: <https://www.deere.com/en/our-company/news-and-announcements/news-releases/2019/agriculture/2019-nov05-dataconnect/>.
- 64 Anonymous, “AGCO, Raven, Bosch and BASF Digital Solutions Form Targeted Spraying Technology Collaboration,” *Farm Equipment*, 28 May 2021: <https://www.farm-equipment.com/articles/19413-agco-raven-bosch-and-basf-digital-solutions-form-targeted-spraying-technology-collaboration>.
- 65 Kubota, “Kubota Smart Agri System,”: <https://www.kubota.com/innovation/smartagri/index.html>
- 66 Kosuke Toshi, “Kubota taps Nvidia tech for smart-farming autonomous tractors,” *Nikkei Asia*, 07 October 2020: <https://asia.nikkei.com/Business/Technology/Kubota-taps-Nvidia-tech-for-smart-farming-autonomous-tractors>.
- 67 Kubota, “Kubota And Aurea Imaging Partner To Drive Autonomous Orchard Innovations,” 24 April 2020: <https://ke.kubota-eu.com/blog/news/strategic-partnership-announcement-kubota-and-aurea-imaging-partner-to-drive-autonomous-orchard-innovations/#agriculture>.
- 68 Anonymous, “M&M’s Japan subsidiary collaborates with Kubota,” *Hindu Business Line*, 31 March 2021: <https://www.thehindubusinessline.com/companies/mms-japan-subsidiary-collaborates-with-kubota/article34205864.ece>.
- 69 Accenture, “CNH Industrial, Accenture and Microsoft Collaborate to Develop Connected Industrial Vehicles,” 01 December 2020: <https://newsroom.accenture.com/news/cnh-industrial-accenture-and-microsoft-collaborate-to-develop-connected-industrial-vehicles.htm>.
- 70 Scott Carpenter, “Access To Big Data Turns Farm Machine Makers Into Tech Firms,” *Forbes*, 31 December 2020: <https://www.forbes.com/sites/scottcarpenter/2021/12/31/access-to-big-data-turns-farm-machine-makers-into-tech-firms/?sh=73afbfb7e47>. Several studies and/or surveys focus on concerns that farmers have about sharing data. See, for example, Jody L. Ferris, “Data Privacy and Protection in the Agriculture Industry: Is Federal Regulation Necessary?” *The Minnesota Journal of Law, Science & Technology*, Vol.18, Issue 1, 2017, pp. 309-342, especially pp. 315-317. Available at: <https://scholarship.law.umn.edu/mjlst/vol18/iss1/6>.
- 71 See Kyle Wiens, “We Can’t Let John Deere Destroy the Very Idea of Ownership,” *Wired*, 21 April 2015: <https://www.wired.com/2015/04/dmca-ownership-john-deere/>.
- 72 Louisa Prause, Sarah Hackfort and Margit Lindgren, “Digitalization and the third food regime,” *Agriculture and Human Values* (2021): <https://doi.org/10.1007/s10460-020-10161-2>
- 73 Kathleen Day, “Monopoly Power: Are new antitrust measures needed to restore competitive balance?” *CQ Researcher*, 03 December 2021: <https://library.cqpress.com/cqresearcher/document.php?id=cqresrre2021120300>.
- 74 Kyle Wiens, “The Biden administration thinks you should be allowed to fix the things you buy,” *Washington Post*, 13 July 2021: <https://www.washingtonpost.com/outlook/2021/07/13/biden-ftc-right-to-repair/>.
- 75 See DJI’s website: <https://enterprise.dji.com/news/detail/dji-drones-adopted-for-precision-ranching>.
- 76 Darrell Etherington, “Volocopter and John Deere team up for a crop-spraying autonomous agricultural drone,” *TechCrunch*, 07 November 2019: <https://techcrunch.com/2019/11/07/volocopter-and-john-deere-team-up-for-a-crop-spraying-autonomous-agricultural-drone/>.
- 77 Anonymous, “DroneDeploy Selected by CNH Industrial for Intuitive New Drone System Targeting Ag Customers,” *Techcrunch*, 16 February 2017: <https://finance.yahoo.com/news/dronedeploy-selected-cnh-industrial-intuitive-170000134.html>.
- 78 Kubota blog, “Kubota invests in Tevel, the leader of flying autonomous fruit-picking robots,” n. d.: <https://ke.kubota-eu.com/blog/news/kubota-invests-in-tevel-the-leader-of-flying-autonomous-fruit-picking-robots/#agriculture>.
- 79 DJI Agriculture, “Cooperative Upgrade! DJI Agriculture Signs a Smart Agriculture Partnership Agreement with Syngenta Japan,” 10 October 2019: <https://ag.dji.com/newsroom/dji-ag-news-en-cooperative>. See also, David Benowitz, “Corteva Deploys Largest Ag Drone Fleet in the World,” *DJI Enterprise*, 25 February 2019: <https://enterprise-insights.dji.com/user-stories/corteva-deploys-largest-ag-drone-fleet-in-the-world>.
- 80 XAG, “Bayer and XAG collaborate to bring digital farming technology to smallholder farmers in Southeast Asia & Pakistan,” 19 March 2020: <https://www.xa.com/en/news/official/xag/77>.
- 81 BASF, “Delair and BASF collaborate to accelerate research for agricultural solutions,” 17 March 2020: <https://www.basf.com/global/en/media/news-releases/2020/03/p-20-144.html>.
- 82 Ministry of Civil Aviation, Government of India, “Conditional exemption from Unmanned Aircraft System (UAS) Rules, 2021 to Mahindra and Mahindra (M&M) Ltd. for conducting drone-based agricultural trials and precision spraying on paddy and hot pepper crop in the state of Telangana and Andhra Pradesh respectively,” 13 August 2021: <https://www.civilaviation.gov.in/sites/default/files/Conditional-exemption-to-Mahindra-and-Mahindra-for-drone-operations-13-Aug-2021.pdf>.
- 83 Muthukumar Kumar, “Helping farmers move from analog to digital farming with drones and remote sensing,” *Geoawesomeness*, 15 January 2019: <https://geoawesomeness.com/helping-farmers-move-from-analog-to-digital-farming-with-drones-and-remote-sensing/>.
- 84 ADAMA, “ADAMA and Taranis Collaborate to Offer Farmers End-to-End Precision Agriculture Solution,” 12 September 2019: <https://www.adama.com/en/449/adama-and-taranis-collaborate-to-offer-farmers-end-to-end-precision-agriculture-solution>.
- 85 PrecisionHawk, “We’ve closed \$75 million of funding—here’s how we’ll use it,” 24 January 2018: <https://www.precisionhawk.com/blog/media/topic/weved-closed-75-million-funding-heres-well-use>

- 86** XAG News, “Bayer × XAG × Alibaba Rural Taobao Jointly Unveil ‘Sustainable Farming Programme,’” 28 June 2018: <https://www.xa.com/en/news/official/xag/14> .
- 87** Bayer press release, “Bayer and XAG collaborate to bring digital farming technology to smallholder farmers in Southeast Asia & Pakistan,” 26 February 2020: <https://media.bayer.com/baynews/baynews.nsf/id/Bayer-XAG-collaborate-bring-digital-farming-technology-smallholder-farmers-Southeast-Asia-Pakistan> .
- 88** XAG News, “Brazil Introduces Agricultural Drones from XAG to Plant Trees,” 29 January 2022: <https://www.xa.com/en/news/official/xag/150> .
- 89** XAG News, “XAG & Harper Adams University Developed Strategic Partnership in the UK,” 09 July 2018: <https://www.xa.com/en/news/official/xag/16> .
- 90** senseFly news release, “xarvio Digital Farming Solutions by BASF Selects eBee X Fixed-Wing Drones for Digital Crop Management in Brazil,” 29 October 2019: <https://www.sensefly.com/2019/10/29/xarvio-digital-farming-solutions-basf-selects-ebee-x-fixed-wing-drones/> .
- 91** Tracy Cozzens, “UAV company AgEagle to acquire senseFly from Parrot,” 19 October 2021: <https://www.gpsworld.com/uav-company-ageagle-to-acquire-sensefly-from-parrot/> .
- 92** DJI Brand News, “Cooperative Upgrade! DJI Agriculture Signs a Smart Agriculture Partnership Agreement with Syngenta Japan,” 10 October 2019: <https://ag.dji.com/newsroom/dji-ag-news-en-cooperative> .
- 93** DJI Brand News, “Further Cooperative Upgrade! DJI Agriculture Signs an Exclusive Agreement with Syngenta Korea,” 20 February 2020: <https://ag.dji.com/newsroom/dji-ag-news-syngenta-korea> .
- 94** David Benowitz, “Corteva Agriscience Deploys 400+ DJI Drones and DroneDeploy Software,” 25 February 2019: <https://enterprise-insights.dji.com/user-stories/corteva-deploys-largest-ag-drone-fleet-in-the-world> .
- 95** Anon., “The battle of the computing clouds is intensifying,” *The Economist*, 18 December 2021: <https://www.economist.com/business/the-battle-of-the-computing-clouds-is-intensifying/21806813>
- 96** Thomas Schilling of BASF quoted on AWS website, “BASF Digital Farming Enables Hyper-Localized Decision-Making on AWS,” n. d.: <https://aws.amazon.com/solutions/case-studies/basf-digital-farming/>.
- 97** Peri Subrahmanya, “Bayer Crop Science Drives Innovation in Precision Agriculture Using AWS IoT,” n. d.: <https://aws.amazon.com/solutions/case-studies/bayer-cropscience/> .
- 98** SADA website, “SADA helps DroneDeploy take flight with Google Cloud,” n. d.: <https://sada.com/insights/customer-story/sada-helps-dronedeploy-take-flight-with-google-cloud/> .
- 99** Google Cloud website, “Taranis: Helping farmers to feed the planet with cutting-edge drone imaging and AI,” n. d.: <https://cloud.google.com/customers/taranis>.
- 100** Gartner press release, “Gartner Says Worldwide IaaS Public Cloud Services Market Grew 40.7% in 2020,” 28 June 2021: <https://www.gartner.com/en/newsroom/press-releases/2021-06-28-gartner-says-worldwide-iaas-public-cloud-services-market-grew-40-7-percent-in-2020> .
- 101** Jordan Novet, “Amazon cloud revenue growth accelerates to 37% in Q2,” CNBC, 29 July 2021: <https://www.cnbc.com/2021/07/29/aws-earnings-q2-2021.html> .