PRECISION AGRICULTURE: A COSTLY DISTRACTION FROM REAL CLIMATE SOLUTIONS

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Introduction

Since the 1990s, a handful of food and agriculture corporations and some lawmakers have promoted precision agriculture as the future of farming. This push has been reflected in federal policy, most notably in the 2008 and 2018 Farm Bills, which contained numerous references to increasing the adoption of precision agriculture technologies. Interest in these technologies has continued to expand, with proposals to make precision agriculture even more widespread in US farming.

In the current context of the worsening climate crisis, proponents present precision agriculture as a critical tool in reducing the environmental impact of industrial agriculture, sometimes at the expense of other, more traditional practices and strategies. Although precision agriculture may play a role in transitioning to more sustainable farming systems, it comes with additional socio-economic and environmental costs. It may not address the root causes of the challenges farmers face.

Instead of relying on precision agriculture technologies to solve key challenges our agricultural system is facing today, policymakers should:

1. Prioritize support for practices that are accessible and beneficial to small-scale producers and producers using integrated or agroecological farming methods;
2. Demand greater transparency and oversight of agritech firms promoting precision agriculture technologies;
3. Narrow the definition of the kinds of precision agriculture technologies that can qualify for federal support; and
4. Promote solutions that are proven to increase soil organic carbon and reduce agricultural emissions, without sidelining farmers or farmworkers.

What is Precision Agriculture?

Precision agriculture (PA) is a set of emerging technologies that use data from the Global Positioning System (GPS), sensors, and internet-connected technologies to tailor how fertilizers, pesticides, water, and other inputs are applied on farms. These tools aim to improve efficiency and reduce input use by targeting specific areas within a field—an approach known as site-specific crop management (SSM).[1] Current PA tools include variable-rate technology (VRT), which adjusts inputs based on field conditions, and automated or semi-automated tractors. Farmers can bundle these technologies with each other and with emergent applications (like drones). Some of these technologies only work as part of integrated packages of precision agricultural services sold by large agricultural corporations. However, PA remains loosely defined, and its effectiveness and accessibility vary widely across regions and farm types (see Table 1).

Corporations promoting PA technologies say PA will solve key problems confronting agriculture. First, they suggest that precision agriculture will reduce farmers' use of chemical inputs and scarce water resources by enabling them to apply targeted amounts to specific areas of their fields rather than broad application over the entire field. Second, these corporations suggest that PA will promote more sustainable agriculture through the reduced use of agricultural inputs like pesticides and synthetic fertilizers that contribute to greenhouse gas emissions and can degrade soil health in ways that reduce the soil's ability to sequester carbon. Finally, corporations and lawmakers offer automation as a solution to perceived labor shortages, suggesting that computers and machines can replace labor and boost productivity.

While PA has been helpful for certain subsets of farms and for certain kinds of goals, **on the whole, PA is a false solution that diverts attention and resources away from proven solutions.** These proven solutions include intercropping, agroforestry, silvopasture and integrated pest management, which are more accessible to small and mid-sized farms, especially those led by Black, Indigenous, and other farmers of marginalized groups often excluded from access to expensive, high-tech systems. Precision agriculture is designed to work within industrial monocropping systems at the expense of integrated, organic, and regenerative systems that are more climate-resilient and cost-effective. In fact, greater reliance on precision technologies could worsen core problems in the food system by accelerating land consolidation and giving already-dominant large-scale producers even greater advantages.[2] This deepens economic inequities and threatens the viability of diverse, community-based farming. Moreover, precision agriculture brings its own set of environmental harms that further undermine sustainable agriculture goals.

What's wrong with precision agriculture?

Precision agriculture doesn't actually reduce the use of fertilizer, pesticides, and water.

Corporations promoting precision agriculture as a sustainability solution say it will reduce the use of fertilizers, pesticides, and water. Agricultural soil management (including fertilizer application) comprises over half of all agricultural emissions, creating dead zones, and harming wildlife populations.[3] We desperately need these reductions to meet climate and other ecological goals. But precision agriculture doesn't help us do that.

Since the 1990s, farmers have increasingly adopted precision agriculture technologies, using them on approximately 50% of U.S. corn and soybean acreage by 2010–2012.[4] But fertilizer use in the US has not gone down over the same period — it has actually increased, with significant year-to-year fluctuations in response to fertilizer and crop prices.[5] Similarly, we have not seen dramatic decreases in pesticide use, with some data showing only slight declines,[6] and other estimates showing increased use.[7] After 30 years of development, many celebrated claims about precision agriculture's ability to reduce inputs remain speculative, and are based on limited field trials, models, or projections. **In short, there are very few reliable studies or evidence that precision agriculture has reduced the use of chemical inputs in real-life applications, which casts doubt on their ability to do so in the future.**[8] By contrast, many studies examine precision agriculture adoption rates among farmers.[9] These studies tend to presume that more adoption will mean more impact. But as the analysis above suggests, there's no hard evidence to believe this.

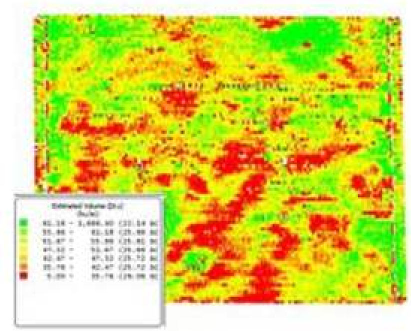
Much of the recent growth in precision agriculture has been in technologies that have very little to do with chemical inputs, including auto-steering and auto-guidance in farm equipment.[10] But even with fairly high adoption rates of yield mapping and increased use of VRT, which was used on between 5%-25% of total U.S. planted acreage for winter wheat, cotton, sorghum, and rice as of 2018, we don't see corresponding downward trends in the use of fertilizers or pesticides.[11]

Precision agriculture can't change the fundamental flaws in our food system. We will continue to require fertilizers as long as we keep growing nitrogen-hungry crops like corn in monocultures. Corn is the most widely planted crop in the US, and it also has the highest nitrogen requirements per acre.[12] Although there are regional differences, climate change is projected to decrease overall corn yields in the US and introduce greater yield variability. Maintaining or increasing the productivity of these crops will necessitate more inputs, especially if PA is used with the primary goal of yield maximization.[13] VRT, yield mapping, and certain other PA technologies can reduce the excess use of fertilizers, pesticides, or water. They don't address core nutrient imbalances in industrial agriculture or move us toward more resilient food and farming systems.

To make meaningful reductions to input use, we need **real solutions** — integrated and biodynamic farming systems guided by the principles of agroecology, Traditional Ecological Knowledge, and/or other holistic and time-tested knowledge systems. These systems reduce emissions and increase carbon sequestration and nutrient availability through companion planting, cover cropping, minimal till, biological forms of pest and weed management, and seed breeding for climate-adapted traits,[14] and thus reduce the reliance on chemical inputs.

Table 1: Examples of precision agriculture technologies

Auto-steer or auto-guidance	Farm equipment that allows partial or complete automation, connected to GPS. Aims to prevent skipping sections of large fields.	 **Photo:** www.futurefarming.com
Drones or UAVs	Devices flown remotely over a field, usually to collect multispectral and thermal imagery that can be used to assess crop and soil health or detect diseases, but can also directly deliver crop inputs (e.g., crop dusting).	 **Photo:** www.irisonboard.com
Robotics	Advanced machinery developed to carry out farm tasks, like weeding, planting cover crops, or collecting on-farm data.	 **Photo:** www.bayer.com

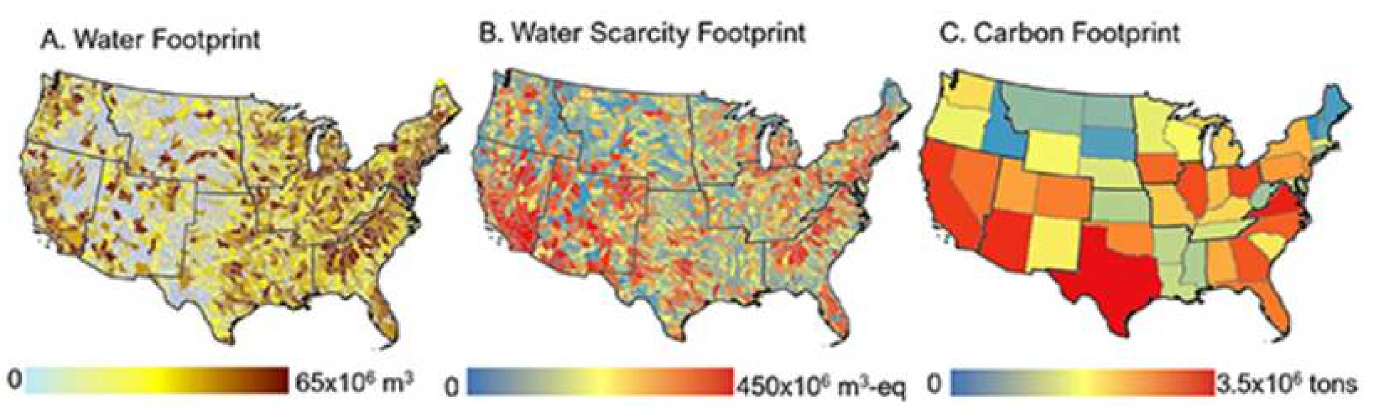
Artificial Intelligence and machine learning	An advanced stage of automation where algorithms make decisions. Can be paired with other PA technologies to manage crop inputs or make planting decisions.	
Variable Rate Technology Yield mapping and monitoring	Farm equipment programmed to use remote sensing imagery and other farm data sources to develop maps of field variability and then deliver tailored amounts of inputs to different parts of a field.	 **Photo:** www.researchgate.net
Yield mapping and monitoring	Technology that uses GPS data and data collected from farm equipment to create yield maps for farmers to use in making decisions about when to sow, fertilize, or harvest.	 **Photo:** upload.wikimedia.org
Soil sensors	Sensors in the soil that can record moisture or compression, and report that data to an internet-connected device or software for use in assessing irrigation needs.	 **Photo:** https://potatoes.news
Internet of Things	Refers to a network of internet-connected objects that record and store data across devices. Can include many things on this list, including robots, drones, and sensors.	

Precision agriculture has environmental costs.

Policymakers need to account for the environmental and social costs that accompany the production and use of some precision agriculture technologies.

Many precision agriculture technologies rely heavily on Internet-connected devices and energy-intensive operations, including Artificial Intelligence (AI). As such, they come with additional resource consumption and emissions, reflecting the environmental footprint of the wider Information Communications Technology (ICT) sector as a whole. In 2020, the global ICT sector used 4% of global electricity and contributed 1.4% of global emissions.[15] This is a small increase from 2010, because of increasing energy efficiency and use of renewable energy, but there is still cause for concern. First, the ICT sector's emissions are outpacing the decarbonization trajectory outlined by the International Telecommunications Union,[16] which aims to align the greenhouse gas emissions for the information and communication technology sectors with the UNFCCC Paris Agreement and the IPCC Special Report: Global Warming of 1.5°C. Second, user devices accounted for over half of the sector's emissions, and these are projected to continue increasing.[17] In particular, precision agriculture and Internet of Things (IoT)—which refers to a network of physical devices embedded with electronics, software, and network connectivity that enable these objects to collect and exchange data—in farming will expand the emissions in this category by adding more user devices.[18] The rapid uptake of AI in agriculture and more widely will add to the energy burden.[19]

The immense amounts of data generated through Internet-connected devices, applications, and platforms are stored and processed on servers in massive data centers. In addition to basic operating electricity, these machines also require a significant amounts of electricity and water to avoid overheating.[20] As of 2022, the 2,600 data centers in the US were among the top 10 water users in the country's commercial and industrial sectors. Many of these data centers are clustered around Dallas, the San Francisco Bay Area, and Los Angeles and in watersheds already affected by debilitating droughts and water stress.[21] [22]



The direct and indirect environmental impacts associated with data center operation across the continental United States. (source: Md Abu Bakar Siddik, Arman Shehabi, and Landon Marston)

Additionally, the growth of Internet-connected devices has increased demand for mined minerals and metals to produce their component parts. Some of the most widely publicized materials include coltan, used in mobile device capacitors and mined in the Democratic Republic of Congo by child laborers and people enslaved by militia groups; lithium, widely used in various precision agriculture technologies, rechargeable batteries, and renewable energy applications; copper, used as a conductor in electronic devices; and rare earths, used in computer chips.[23] In addition to their emissions, water pollution, and other environmental impacts, these types of mining are also associated with labor exploitation and the degradation of Indigenous peoples' lands.[24]

All of these factors suggest that precision agriculture should be understood and assumed to have additional environmental and social costs. These costs should be weighed against any environmental benefits from precision agriculture, which—as the previous section suggested—should be more rigorously assessed.

Precision Agriculture and the Jevons Paradox

The Jevons Paradox states that in the long term, increased resource efficiency can lead to an increase in resource consumption, rather than decreasing it.[25] The Jevons Paradox (also known in economics as a rebound effect) has been observed and debated in various sectors, including energy-efficient cars and refrigerators.[26] **As it pertains to precision agriculture, we can anticipate that greater uptake of PA (and its broadening to include more AI and IoT) will, increase consumption of water, energy, and materials by data centers and individual devices.** Because PA contributes to further farm consolidation[27] and operates most effectively with industrial systems and at large scales, it will likely also increase the extent and environmental impact of industrial agriculture and monocropping.

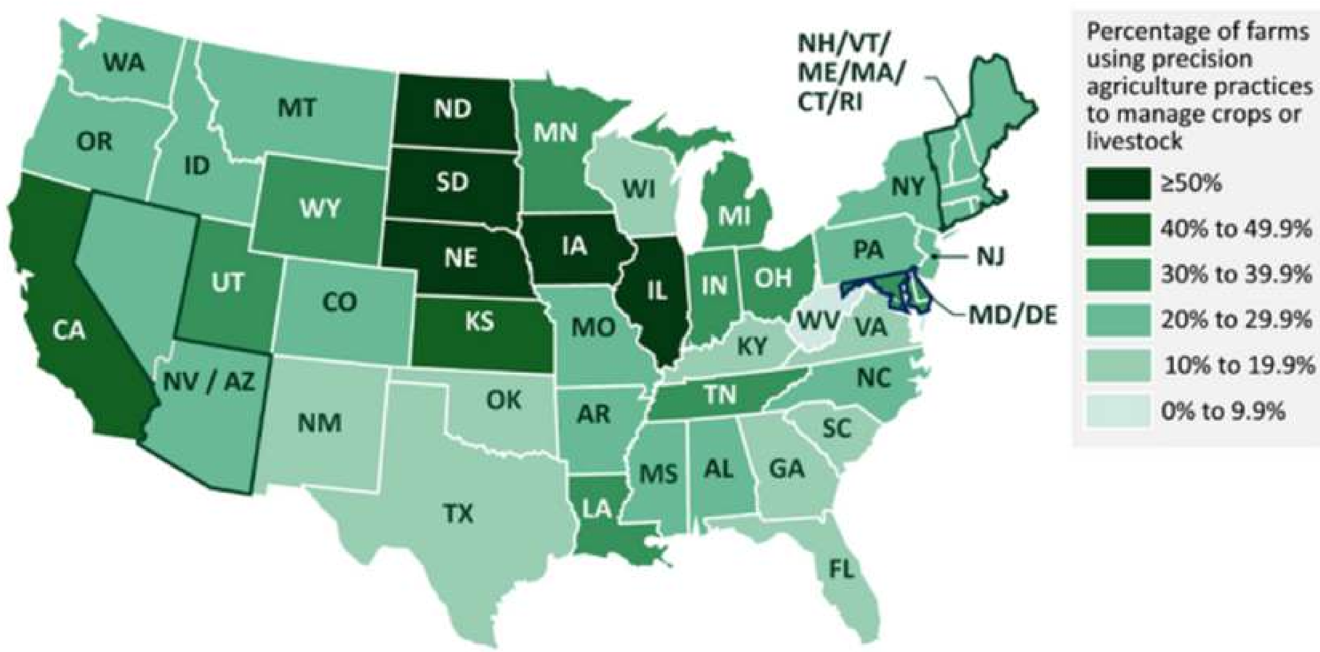
Precision agriculture is often inaccessible or unprofitable for small or diversified farmers, contributing to consolidation and inequality.

Precision agriculture technologies have extremely high acquisition costs and often are not very affordable, profitable, or practical for small-scale or less well-resourced farmers.[28] According to data from 2019, USDA's Economic Research Service estimated that less than 25% of small farms used yield maps, soil maps, VRT, and/or guidance systems, compared to half of large row crop farms.[29] Small-scale farms likely won't be able to incur enough cost savings or yield increases from most PA technologies to make them profitable, even with federal funding support and reduced prices over time. By contrast, larger farms can take advantage of economies of scale, spreading the costs of the expensive equipment over more acreage and thereby reducing the cost per acre. In addition to prohibitive costs, some PA technologies are difficult or complicated to use, limiting adoption among small-scale and family farmers.[30]

Because of long-standing structural racism in agriculture—including discriminatory lending practices, unequal access to land and credit, and exclusion from federal programs—Black, Indigenous, and other farmers of color are more likely to operate smaller farms with fewer financial resources.[31] Precision agriculture, as it is currently designed and deployed, accelerates the exclusion of these farmers by reinforcing barriers they already face: high costs, technological complexity, and a poor fit with the diversified and regenerative practices they are more likely to use.

Meanwhile, larger farms will likely see increased profitability from PA technologies, further consolidating their land access and market power. In 2013, a USDA Economic Research Service study suggested that precision agriculture could ultimately contribute to increased farm consolidation, by privileging larger farmers through cost savings and profits.[32] The largest farms, which are overwhelmingly dominated by white farmers and men,[33] will likely benefit most from the reduced labor and input costs afforded by PA technologies, with a few exceptions.[34]

Use of precision agriculture practices by U.S. farms, June 2022–June 2023



Source: GAO summary of data reported in 2023 by the U.S. Department of Agriculture; Map Resources (map). | GAO-24-105962

Map source and link: https://www.gao.gov/products/gao-24-105962

PA is currently best suited for industrial agriculture and monocropping of key commodity crops, systems which are predominantly used by large corporations. **By contrast, many small farmers and farmers of color grow crops USDA characterizes as "specialty" crops, like vegetables and fruits, and tend to use regenerative practices, which PA tools do not adequately support.**

Therefore, farmers who have diversified crop operations will likely not be able to benefit from these investments, since precision agriculture is designed to work within large industrial and monocropping systems of key commodity crops, like corn and soybeans.[35] For farmers using intercropping, crop rotation, or even monocropping of non-commodity crops, precision agriculture tools can be inaccurate and give unreliable assessments — for example, estimating vegetable crop yields incorrectly or incorrectly applying algorithms trained to assess staple crops' plant health and fungicide needs to non-staple crops.[36]

Policymakers often assume that we can solve unequal adoption rates by increased diffusion and accessibility — if we simply help small farmers get precision agriculture technology by offering financial support or by increasing rural internet access, then they'll be able to realize the benefits. But this assumes the core problem is access, not design. **Precision agriculture is not a neutral technology waiting to be equitably distributed — it is a tool developed within and for industrial systems that exclude most small farmers and farmers of color.** In some cases, latecomers or those for whom technologies are not adapted do not enjoy the same advantages or profit increases — and in fact may be run out of business.[37]

The 2022 Census of Agriculture shows that **farmland is increasingly consolidated into fewer and larger farms,** with 228,495 farms (10.7%) lost since 2002.[38] More recently, from 2017 to 2022, the number of farms in the US decreased by 6.9%, with over 142,000 farms lost. Farms reporting at least one Black producer have been hardest hit, with a decrease of between 8% and 13% (depending on the figures used).[39] As of 2024, the largest farms, with over $1 million in sales, are only 6% of farms but own over 35% of farmland.[40]

Without structural changes to how agricultural policy benefits small farmers and farmers of color over large corporations, investing public dollars in **PA will only deepen inequality and increase land ownership, production, and profit consolidation.**

*Many rural communities across the country have weak internet infrastructure. Some precision agriculture-focused marker bills introduced in Congress propose to increase broadband access, which is a commendable goal in itself. Some of these initiatives are expressly supported by corporations like John Deere, which seek to expand markets for precision agriculture.[41] However, leveling the playing field and making the technology more accessible in this respect will not resolve some fundamental tensions around precision agriculture's suitability or profitability for small-scale and diversified farmers.

Precision agriculture can undermine workers.

In seeking to address labor challenges in agriculture, policymakers must ensure that solutions uplift workers—not replace them.

Corporations explicitly promote precision agriculture as labor-saving technologies. For example, John Deere promotes its autonomous tractor, which can cost up to $800,000, by stating that “[i]t can work long days and even nights, with or without an operator in the seat” and asking “Would an extra worker come in handy? One that's never late. One that won't mind working all night.” [42]

Corporations are not only touting automated machines designed for farm sectors that are already highly mechanized, like field crop production (which employs only 13% of farmworkers) but are also developing and promoting robotics and other technologies for more labor-intensive types of farming, such as fruit and vegetable production.[43] Only a few farmworkers would be needed to operate these types of machines, and this would likely require additional training programs, for which some farmworkers may be ineligible.[44]

Historical precedents: The impacts of automation on tomato pickers and dockworkers

Based on historical precedents, we can expect the increased adoption of precision agriculture to be correlated with job loss. Although there are numerous examples of this throughout the history of technology, two salient cases from the 20th century are the introduction of the tomato harvester and the containerization revolution in the shipping industry.

Over the 1940s and 50s, researchers at the University of California, Davis developed a mechanical tomato harvester to address labor issues and shortages.[45] In 1964 the Bracero program ended, reducing the availability of farm labor and making growers more dependent on the available labor pool. At the same time, the Civil Rights Act increased protections for seasonal workers, and a number of farmworker unions were forming and striking for better pay and treatment in California. In this context, the tomato harvester was rapidly taken up to replace the need for workers. By the late 1970s, 32,000 jobs in the tomato industry had been lost.[46] In addition, the harvesters were only compatible with and affordable on large farms; as such, the industry became increasingly consolidated, from 4,000 tomato growers in the early 1960s to closer to 600 in 1973 (a decline of 85%).

Similar patterns played out in the shipping industry. In the 1950s, the introduction of shipping containers dramatically increased productivity, allowing for shipments to be unloaded much faster. But this resulted in huge job losses — up to 90% of dockworkers in New York's ports lost their jobs, and the same pattern played out in other cities across the US and elsewhere.[47] In the decades since, unionized dockworkers have gone on strike numerous times to protest automation and containerization and attempt to protect job security (including in October 2024).[48]

Some economists and policymakers assume that displaced workers will simply find jobs in other sectors, or will move into better paying jobs operating new technologies. They also tend to examine these patterns in the aggregate and find that job losses in one sector do not necessarily translate to higher unemployment overall. However, it is likely that displaced agricultural workers will not be able to easily find employment in job markets that increasingly require specialized skillsets compatible with new technologies.[49]

Precision agriculture can erode and undermine farmers' knowledge about their crops and land.

Corporations and policymakers pushing for precision agriculture assume that the knowledge gained through PA technologies is inherently superior to farmers' knowledge about their land, seeds, soils, and production and that PA will improve decision-making and outcomes. There are a few problems with these assumptions:

1) PA technologies can be fairly imprecise, particularly for farms growing nontraditional crops, and can introduce algorithmic biases.[50]

2) Over-reliance on PA technologies can disconnect farmers from their field operations and undermine their own knowledge and skills. This creates a lock-in effect and introduces sources of vulnerability, in the event of technology failures or changing weather and climate conditions.[51] Since many PA technologies are proprietary, there is some concern that this will create dependencies on particular corporations and platforms to be able to continue to access or store data in usable formats, or that farmers switching agricultural technology providers (ATPs) could be considered in breach of contract.[52]

More widely, this contributes to a deskilling of farming, with advice and decision-making largely coming to farmers through corporate-owned technologies and algorithms programmed by these corporations. **Deskilling means that farmers need to rely more and more on corporate advice and tools, leading to corporations further controlling our food and farming systems.**

Precision agriculture raises concerns over farmers' privacy and data security, and exposes our food system to cyber attacks.

The drive for more data benefits agritech corporations more than farmers. As PA technology adoption rates increase, ATPs can collect more information that directly benefits them in a few ways:

> **1. They use the data to make recommendations to farmers about their own products.** For example, Bayer's Climate Corporation aggregates data from farm equipment sensors, weather stations, and other sources. Then it uses machine learning algorithms to market and recommend inputs to farmers (many of which are presumably produced and sold by Bayer, one of the largest agricultural and pharmaceutical corporations in the world). Bayer's Climate FieldView — a big data analytics platform for farmers — offers decision support tools, which often involve advising farmers to purchase Bayer's agrochemicals.[53]

2. They may sell the data to third parties. Bayer's Climate FieldView privacy statement states a number of conditions under which data could be shared with other entities, including those with whom Bayer partners, although they note that they have not sold the data on to other third parties unless agreed to by farmers.[54] However, many use agreements are very complex, and there may be instances where farmers have opted in to their data being sold without realizing it.

3. They use the data to train and improve their machine learning and AI algorithms, much like OpenAI and Microsoft have used published work without consent to train generative AIs (for which they are facing lawsuits).[55] Because farmers do sign contracts and licensing agreements when purchasing PA technologies or software, there is some degree of consent. However, the benefits are unequal, and consent may not be fully informed. Farmers may not have a full picture of how data will be used and will not be compensated for corporate use of their data to improve marketing strategies or products.

There is also some concern that corporations, in collaboration with other institutions like large banks, could use the data to unduly influence commodity pricing and speculation, land valuation, or loan agreements. This could further jeopardize farmers' incomes, livelihoods, and access to land. Complex end-user license agreements grant data ownership to agritech corporations, enabling them to compile very detailed maps of land productivity, yields, and other characteristics that could be used to distort markets and hurt farmers.[56]

> "In many cases, these EULAs [end user license agreements] will include phrases such as: "the grower grants (the service provider) a perpetual worldwide license to the use of any data stored in the system.""
>
> — Testimony by Billy Tiller, founder of Grower Information Services Cooperative (GiSC) and a 4th generation farmer in West Texas, before the House Agriculture Subcommittee on General Farm Commodities and Risk Management, July 13, 2017[57]

Lastly, PA technology is vulnerable to cyber attacks, and can be weaponized by adversarial governments and others interested in disrupting and/or exploiting our food system. **In 2023, food and ag businesses reported 167 ransomware attacks that disrupted our food systems.**[58] Many of these attacks had large impacts, such as the ransomware attack on meatpacking giant JBS by a Russian-based group in 2021 that caused the company to shut down for multiple days and led to a large ransom payment.[59]

Precision agriculture isn't a good use of taxpayer dollars.

Every taxpayer dollar invested in agriculture should build the future of farmers, not the bottom lines of Bayer, Microsoft, and John Deere. Public investments should meet the real needs of farmers, not create guaranteed markets for corporate products that have little proven benefit to the environment or rural communities.

For policymakers concerned about federal spending, precision agriculture is not an efficient use of public funds. Businesses developing precision agriculture products have easy access to private venture capital, with investments in ag tech amounting to over $11 billion in 2021.[60] Corporations like Bayer and Microsoft are already experiencing significant boosts to their revenues from precision agriculture applications, cloud services, artificial intelligence, and big data. These contributions are only expected to grow.[61] Similarly, some analysts predict that precision agriculture will drive three-quarters of John Deere's sales growth in the coming years.[62] Taxpayer dollars should not be used to increase the profits of multinational corporations; they should be used to strengthen rural communities and support our farmers. Instead of subsidizing market growth for food and ag corporations that are already incredibly profitable with taxpayer dollars, the federal government should support small and mid-sized farmers who are employing real solutions on their farms — solutions that prioritize stewardship of land, resilience to climate change, and vibrant rural economies.

Agritech corporations sell precision agriculture as new and innovative, often describing it as a "disruptive" technology that will revolutionize agriculture.[63] In reality, this is just a marketing ploy. New developments in AI and robotics are merely spinoffs of existing forms of precision agriculture that have been around for decades. During this time, corporations have been frustrated by disappointing adoption rates among farmers, and there's been very little evidence that precision agriculture in real-world on-farm applications can deliver the kinds of impacts on yields or input use that have been shown in limited field trials.[64] Rather than revolutionizing farming, precision agriculture often reinforces the same industrial systems that concentrate wealth and power in the hands of a few corporations, while leaving most farmers behind. When federal funding is used to expand precision agriculture approaches, this merely bankrolls and subsidizes corporate efforts to create markets for new and not-so-revolutionary products, rather than addressing farmers' real-world needs.

Furthermore, federal funding for precision agriculture can reinforce patterns of inequality in access to loans and grants, unless very specific stipulations are written into legislation. **Among farmers, precision agriculture primarily benefits large-scale operators,[65] who also tend to have more access to traditional banking and financing mechanisms.** At the same time, small and mid-size farmers struggle to get private or federal funding to purchase operating equipment, access or retain farmland, and implement climate-resilient practices. Federal programs like EQIP and CSP are consistently over-subscribed, with the majority of applicants turned away.[66] In these circumstances, the priority should be to ensure that more people can access these programs and implement climate-resilient practices, rather than opening up additional support for PA — often to the benefit of industrial producers who are already more able to afford and profit from these technologies. Redirecting taxpayer support to expand these proven programs would ensure that more farmers, not just the largest and wealthiest, can survive, adapt, and thrive.

Many other input-saving practices are a fraction of the cost of many precision agriculture technologies. For example, it would cost between $30,000 and $50,000 for an average-sized corn farm in the US to plant nitrogen-fixing winter cover crops like hairy vetch to reduce the need for fertilizers in the following season, compared to between $150,000 and $250,000 for VRT systems (on top of the cost of fertilizers themselves).[67]

In addition, some introduced legislation would enable producers to get EQIP and CSP funding for any precision agriculture technology, including technologies (like GPS or autosteer) that have very little impact on emissions or input use. Some proposals would also allow precision agriculture to qualify for supplemental payments under CSP, rather than simply as a regular enhancement.[68] This is all despite PA's questionable impact on emissions, carbon sequestration, and water conservation (as discussed previously).

At a time when public trust in government spending is fragile, Congress should make it clear that farm program dollars are intended to support the people working the land, not tech giants and their shareholders. Taxpayer money should go towards practices that can benefit everyone, not just tech corporations and the largest farms.

Recommendations:

Instead of relying on precision agriculture to solve our agricultural challenges and bankroll the bottom lines of agritech corporations, policymakers should:

- **Increase federal support and incentives for practices that reduce input use** through deeper transformation of farming systems, including but not limited to agroforestry and silvopasture, cover crops, integrated crop, and livestock production;
- **Prioritize the practices above**, and others that are utilized by and beneficial to small-scale producers and producers using integrated, traditional, or agroecological farming methods;
- **Ensure that carbon stocks remain in the soil** by incentivizing the use of organic or regenerative practices;
- **Engage in greater oversight of agritech firms selling precision agriculture technologies**, including data ownership and privacy and monitoring of uses by third parties; [69]
- **Define precision agriculture more narrowly** and specify that any funding earmarked for climate-smart agriculture be limited only to specific precision agriculture technologies that have demonstrated real-world and evidence-based impacts on emissions reduction and/or soil organic carbon;
- **Block legislation** allowing broadly-defined precision agriculture technologies to qualify for supplemental payments under the Conservation Stewardship Program;
- **Bar large producers** using precision agriculture technologies from accessing federal subsidies or payments, in order to level the playing field and not compound economic advantages for the largest farms;
- **More strongly value farm labor with better pay and workplace protections**, while supporting farm prices to allow for higher labor costs (without passing on these costs to consumers) — for example, by factoring fair labor treatment and costs into subsidy programs, increasing payments and incentives for collective ownership and farm cooperatives, withholding federal payments from operations with bad labor practices, and more directly intervening in oversupply problems to boost commodity prices.

More broadly, precision agricultural technologies can and should be responsive to farmer and community needs, ideally developed from the ground up, in contrast to many technologies for which agritech corporations are now trying to create markets among farmers (including through government subsidies). We should emphasize and promote agricultural technology providers that are collectively owned and operated, and whose data policies reflect this.

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7. Donald Atwood and Claire Paisley-Jones (2017) Pesticides Industry Sales and Usage 2008 - 2012, US Environmental Protection Agency; Benbrook, C.M. (2012) Impacts of genetically engineered crops on pesticide use in the U.S. -- the first sixteen years. *Environ Sci Eur* 24, 24.

8. Two notable exceptions are worth mentioning. Yost et al. (2017) conducted a decade-long study of a precision agriculture project in Missouri, which found reduced temporal variability in yields (which may also be explained by other parts of the project) but said little about any impacts on input requirements. See M.A. Yost et al. (2017) Long-term impact of a precision agriculture system on grain crop production, *Precision Agriculture* 18: 823–842. Additionally, an industry-funded study cited fertilizer and water reductions in the single digits, but the data is highly unreliable, as the study did not include any information on the methodology (including data sources or scope), was not published or peer-reviewed in any reputable journals, and has been released publicly only as a PowerPoint.

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