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19 March 2024

Precision Agriculture: The Benefits, Challenges, and Paths to Adoption

Innovation in the modern world focuses on dreams rather than solutions. For instance, novel systems such as self-driving cars and augmented reality provide little benefit over existing technologies in their day-to-day utility, but they spark excitement in consumers. This obsession over "futuristic" technology robs the general public of benefits from a greater focus on advancement in less glamorous areas. Technological breakthroughs in less publicized industries, such as those in the growing world of precision agriculture (PA), provide great hope for the future of our planet. The "precision" in PA refers to the application of technology, namely sensors and algorithms, to agricultural processes with an intention to increase efficiency and maximize output. Currently, global agricultural systems are failing to meet growing needs. Unless a serious change is made, the number of people living malnourished will only increase, as will tensions between farmers and governments. PA presents itself as the best option to prevent this future.[1]

For modern PA technology, the primary focus is on large-scale monitoring of crop growth. Prevailing innovation in the field deals with different methods of monitoring crops to maximize yield at a low cost. As Shaikh outlines, "The task of monitoring is extremely important in all agricultural applications because often, we need to monitor large areas. Thus, the unmanned vehicles and drones embedded with various sensors (such as camera) facilitate pest detection and crop imaging" (Shaikh, et al). Outside of the sensors on unmanned drones

[1] It should be understood that PA technologies are not strictly intended to replace traditional farming methods. While this is an area some research is going into, this paper will not explore advancement in total automation, as this technology seems the furthest from implementation.

mentioned for large-scale monitoring, Shaikh also breaks down the primary categories of PA sensors that are currently used. The five primary types of sensors identified in use are soil sensors (temperature, moisture, etc.), weather sensors (temperature, pressure, wind, etc.), irrigation sensors (level, pH, etc.), crop sensors (image, pest detector, infrared, etc.), and livestock sensors (feed, GPS, sound, etc.) (Shaikh, et al). Some subset of these sensors is used extensively in all PA systems ranging from single-plant to large-scale farms. After these sensors gather information about the state of the farm, this data must be analyzed.

As discussed by Professors Suresh Neethirajan and Lenny Van Erp-van der Kooij, data science, or "big data", is then called upon to help inform decision-making. As seen within precision livestock farming (PLF), data analytics can be used to help "... inform management about nutritional needs, reproductive status, and declining trends in productivity, that may indicate animal health and welfare issues." (Neethirajan & Kemp). Using only traditional methods, observing these trends and knowing when to make a change is far more difficult, especially on large farms. When PA systems are implemented, their utility comes in boosting the efficiency of farming. In crop growth, this comes through minimizing the amount of crops that die and increasing the rate at which crops can grow, both increasing yield. In PLF, monitoring the health of animals more precisely can help prevent drops in productivity due to illness (or outbreaks of illness). Additionally, the use of sensors for tracking the estrus of female cows to determine the optimal window for a cow to be impregnated can also provide a significant boost in efficiency for dairy cows (Van Erp-van der Kooij).

Outside of common sensors gathering data on soil to promote crop growth and camera usage for large-scale monitoring, another exciting area where innovation could be seen is within thin-film plant wearables (TFPWs). Similarly to wearable technologies used for tracking personal health, these sensors have great potential in monitoring plant health, as Heyu Yin, a postdoctoral scientist at Columbia University, explores. "... TFPWs are of great interest due to their noninvasive and flexible features, which also integrate compliance with irregular plant tissue surfaces. TFPWs are suitable to monitor environmental parameters such as temperature, humidity, and biotic parameters including water potential, displacement/strain of plant tissue, and volatile organic compounds" (Yin, et al). TFPWs are far from the only example of innovation in sensing technology, but they provide insight into how many novel ideas can be found within the push for PA sensors.

The need for PA is most clearly seen through the failures of our current agricultural systems to meet food needs across the map. As Yin puts it, "With around 820 million people across the globe being undernourished and a 34% projected growth of world population by 2050—corresponding to a 60% increase in food demand—there is a compelling need to utilize advanced technologies in the agriculture sector to increase agricultural productivity and reduce food losses to guarantee food security" (Yin, et al). These levels of hunger (and the outlook for the future) present a pressing need for change. Agricultural productivity can be significantly boosted by PA technology through continuous monitoring of crops and livestock and thorough analysis of the data this monitoring provides. Similarly, food losses can be reduced by the use of sensors providing information on the health of individual plants and with others providing info on pests. These factors work hand-in-hand to provide an agricultural system that yields an output coming closer to global needs for nourishment.

In addition to sensing, further innovation can be anticipated on the software side. One common buzzword within technology in recent years has been the "blockchain". Though mostly used in contexts of NFTs (non-fungible tokens) during their peak, the application of blockchain technology to PA seems to be much more appealing, as Neethirajan explains. “A particular advantage of blockchain technology is that information is shared across a peer network rather than under the control and custody of a single person or group. In the event of a livestock disease outbreak, farmers from around the globe could securely input and access disease data, actively helping to control the outbreak or prepare farmers for an outbreak they expect to reach their farm” (Neethirajan & Kemp). The issue with getting this technology to reach its full potential lies in the lack of standardization currently seen within PA.

Although many exciting technologies currently exist in PA, getting these technologies to be more widely adopted and accessible is a key step that must be taken. Standardization could go a long way in helping precision agriculture become more widely adopted. When combined with existing hesitance over PA technologies, issues in compatibility between different products that work into a PA system could be enough to cause farmers to dismiss the technology (Shaikh). For the adoption of these technologies to be made simpler for lower budget farming, Professor Martin Bosompem suggests a shift in the focus on PA technology: “... the focus should be on affordable technology adapted to small scale mostly manual agriculture... Affordability can be enhanced by encouraging entrepreneurs to offer PA services, instead of expecting small scale farmers to invest in technology” (Bosompem). With Bosompem’s research taking place on cocoa farming in Ghana, the barriers to entry for usage of PA technology are of greater concern than many large farms in the US that most research has focused on.

Despite the benefits of PA, the effects of this innovation on the most involved people in farming must be considered. Farming has been a mainstay of human life for millennia, and developments in farming have been vital in increasing the availability of foodstuffs and other goods at lower prices. With such a longstanding history, farmers are hesitant to adopt expensive

PA technologies when the benefit may not be immediately apparent. In Bosompem's research on challenges to the implementation of PA in Ghana, he found that "... [farmer socio-demographic characteristics] emerged as the most important challenge that needed to be surmounted... These characteristics are aged farmers, low education level of farmers, lack of computer knowledge, negative attitude towards new technologies…" (Bosompem). Some of these drawbacks can be mitigated by a closer relationship between companies wishing to implement PA technologies and the farmers whose livelihoods they will affect.

Outside of drawbacks having to do with a lack of knowledge of the technology, many PA technologies that companies strive to implement now have prohibitive costs or significant constraints. For example, Yin's research shows the constraints of a relatively inexpensive NFC (near field communication)-tag, stating that "The soil moisture sensing platform used an NFC-tag to harvest energy from nearby cell phones to power the sensor. The magnetic field generated by a smartphone is stable enough to power up the battery-less NFC-tag for moisture measurement and data transmission. However, the power level of NFC can only ensure a communication distance of ≈3 m which requires the power source, such as smartphones, to be close enough to the sensor, limiting its broader applications" (Yin, et al). Despite the advantage of the simplicity of a system using a tiny NFC-tag embedded with a microchip containing information on soil moisture, the issue comes in spreading this to a large scale: the lack of range prevents a low-cost option like this from being a solution. The best balance seems to be found in what Bosompem suggested: barriers to entry being lowered by companies working directly with farmers rather than farmers having to purchase and configure systems themselves. In addition, a focus on aiding farmers rather than on replacing their utility is necessary to guarantee the willingness of farmers to support the technology.

Despite the constraints, investment in PA could help increase profits for individual farmers, which could help ease tensions between farmers and governments that have recently boiled over. As Tanno and Liakos discuss, farmers across Europe are currently protesting increasing costs of production as well as an increase in “cheap agricultural imports from Ukraine, including grain, sugar and meat” (Liakos). Farmers are finding it harder to profit off of their livelihoods as a result. Their frustration is compounded by the constraints imposed on farmers by the European Green Deal, which attempts to reduce emissions by taxing farmers for pesticide use and CO_2 output while simultaneously removing existing tax write-offs. Though protests have yielded some concessions by lawmakers, the root of the problem must be addressed, which PA can help with. Farmers are crucial to maintaining societal function through their control over agricultural output, and imposing restrictions on farmers that rule existing practices to be illegal merely builds resentment. If governments invest in the deployment of PA technologies, which can increase efficiency and reduce emissions without harming the long-term profits of farmers, both governments and farmers will see long-term success. Though the buy-in costs for large systems are high, governments have the power to mitigate this issue.

Building on Bosompem’s suggestion, governments could also step in to help aid in the adoption of PA. As seen in the EU, there is an ongoing push for emissions to be reduced to help slow the damaging effects of climate change, seen best through their goal to reach net zero emissions by 2050 (Liakos). Considering the prevalence of similar goals in governments worldwide, aiding the adoption of PA technologies as part of this agenda seems to be a logical solution. Organizations such as the USDA National Institute of Food and Agriculture provide significant funding to PA projects, but this support for implementation should be brought to greater levels to contribute to adoption by farmers. Specifically, government organizations could work directly with companies and farmers, providing tax credits as an incentive, similarly to existing credits for the adoption of solar. This option would take the economic strain off of both the PA companies and individual farmers, making this an ideal option if room can be made within the government budget.

The implementation of precision agriculture is vital to guaranteeing a viable, well-lived future for people around the world. The agricultural industry has a massive impact on the lives of everyone on the planet, and the failures made to this point have contributed to great losses. As Bosompem states, “By 1990, poor agricultural practices had contributed to degradation of 38% of the roughly 1.5 billion hectares of global arable land” (Bosompem). Innovation in PA technologies could help slow this degradation by using sensors for more precise use of fertilizers and pesticides, watering of plants, and feeding of animals. While the challenges to PA mean the technology will be delayed in adoption, the innovations in the field spark hope that efficiency can be increased enough that consumers see costs go down massively for agricultural goods. Ideally, this should be done in a way that maximizes the agency of individual farmers to lessen the ideological shift PA poses, which can be helped massively by investment by companies and governments.

Works Cited:

Bosompem, Martin. “Potential Challenges to Precision Agriculture Technologies Development in Ghana: Scientists’ and Cocoa Extension Agents’ Perspectives.” *Precision Agriculture*, vol. 22, no. 5, Oct. 2021, pp. 1578–600. *Springer Link*, https://doi.org/10.1007/s11119-021-09801-2.

Liakos, Chris, and Sophie Tanno. “Farmers’ Protests Have Erupted across Europe. Here’s Why.” *CNN*, 3 Feb. 2024, https://www.cnn.com/2024/02/03/europe/europe-farmers-protests-explainer-intl.

Neethirajan, Suresh, and Bas Kemp. “Digital Livestock Farming.” *Sensing and Bio-Sensing Research*, vol. 32, June 2021, p. 100408. *ScienceDirect*, https://doi.org/10.1016/j.sbsr.2021.100408.

Shaikh, Faisal Karim, et al. “Recent Trends in Internet-of-Things-Enabled Sensor Technologies for Smart Agriculture.” *IEEE Internet of Things Journal*, vol. 9, no. 23, Dec. 2022, pp. 23583–98. *IEEE Xplore*, https://doi.org/10.1109/JIOT.2022.3210154.

Van Erp-van der Kooij, E., editor. *Precision Technology and Sensor Applications for Livestock Farming and Companion Animals*. Wageningen Academic Publishers, 2021.

Yin, Heyu, et al. “Soil Sensors and Plant Wearables for Smart and Precision Agriculture.” *Advanced Materials*, vol. 33, no. 20, May 2021, p. 2007764. *DOI.org (Crossref)*, https://doi.org/10.1002/adma.202007764.