**Undoing Environmental Damage with Digital Agriculture**

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined using the Honor Guidelines for Thesis-Related Assignments

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## Introduction

The globe is on the brink of another agricultural revolution. The previous agricultural revolution, the Green Revolution of the 1960–1970 s, laid the groundwork for applying newly discovered knowledge in science and chemistry to increase crop output. The science-first approach to farming led the world to the conventional practices used in the modern era of agriculture: the widespread use of nitrogen and phosphate fertilizers, deforestation, and the rise of ultra-corporatization of food production. These practices initially saw waves of success – higher crop yield, shorter growth duration, and lower food prices all led to a global scale adoption of green revolution practices (John et al., 2001). Interestingly, though, farmers today are beginning to face new problems. Tighter profit margins and lower crop yield. The initial response was to follow convention; pump more fertilizer, increase irrigation, and pressure the land to push out every bit of potential growth year-round. But the trend is only continuing; our land continues to produce weaker crops and farmers are seeing fewer returns. The chemistry and scientific discoveries of the 20$^{th}$ century have come to their limits. Modern research is unveiling that the challenges our farmers now face are only a symptom of much deeper issues. Agricultural pollution and soil degradation can be contributed exclusively to the practices we adopted during the green revolution and the consequences will be faced by the entire world.

The failures of conventional farming techniques have pushed the world toward a new agricultural revolution. To deal with the blowback of the world's old practices, farmers are turning their backs to over-cultivation and excess chemical usage and are now looking toward engineers to develop analytical solutions to solve the world's agricultural problems. Titled the Digital Agricultural Revolution, the coming wave of agricultural technology is centered around diligently tracking resource usage, collecting data, and using models to optimize harvests most efficiently. The following three primary drivers enable the Digital Revolution: the availability of robotics and sensor technology, data analytics with artificial intelligence, and blockchain tech. These forces add new levels of precision to change the way farmers produce and sell their food. Higher precision results in less pollution, higher yield, and less waste. With the rise in the human population, it is estimated that the world must produce 60% more food to feed the projected 9.3 billion humans by 2050 (United Nations, n.d.). Now more than ever, is imperative that the agricultural industry adopt digital farming practices. Agricultural leaders must focus their efforts on working closely with engineers to continue to develop technology that will lead to a future of sustainable food production.

**The Price of the Green Revolution**

The green revolution has standardized practices that resulted in negative long-term contributions to food production by polluting the environment and degrading agricultural soil. Agricultural pollution is the contamination of the environment and surrounding ecosystems by biotic and abiotic byproducts resulting from farming practices. Land and resource management decisions can greatly affect the pollution of farmlands and the surrounding environment (Lindwall, 2019). The use of chemical fertilizers for raising crops was once the solution to increasing food production but has since cost the damage to surrounding environments and health risks to humans.

Nitrogen is a key component in plant growth, thus nitrogen-containing fertilizers have been applied in heavy quantities by farmers. But crops use only about 50% of the nitrogen from fertilizers (Hirel et al., 2011). The remaining nitrogen is washed out of the soil as run-off and ends up in surrounding waterways where it contaminates drinking water and fuels unwanted growth of microorganisms, algae, and plants. For aquatic ecosystems, this biological growth consumes abnormal amounts of dissolved oxygen, leaving behind dead zones where other aquatic species cannot thrive. Unwanted blooms also release toxins into the atmosphere. Nitrous oxide is a greenhouse gas with a warming potential three hundred times that of carbon dioxide; it is a gaseous byproduct formed by certain microorganisms' consumption of nitrogen from fertilizers. Nitrogen runoff also poses severe health risks to humans. The National Institutes of Health claims that "excessive nitrogen is linked to cancers, reproductive impacts, hypothyroidism, and methemoglobinemia" (Lenox, 2021).

One of the greatest dangers conventional farming poses to humans, however, is the blow back being experienced from polluting the soil. Soil degradation is a form of agricultural pollution characterized by the decline in soil fertility and soil structure due to changes in the physical, chemical, and biological quality of soil. Deforestation, intensive cultivation, and over usage of chemical fertilizers can all result in soil degradation (Begum, 2021). Degraded soil lacks the nutrients, water, and biodiversity that naturally exist in the environment. The consequences are pertinent to food production – degraded soil either produces inferior quality crops or does not yield crops at all. For humans, this could mean a future of wide-spread malnourishment and starvation. A report by the United Nations University estimates that 52% of the world's agricultural land is considered moderately or severely degraded (ScienceDaily, 2015). Our species will not be able to meet food production goals without restoring the degraded land and protecting our current agricultural land. An increased presence of technology to monitor, track, and facilitate food production is the best path to sustainability and increases yields.

**Smart Agriculture**

The digital agriculture revolution leverages smart technology to optimize crop efficiency by being as precise as possible with resource usage. The biggest technological force behind the newly deployed smart farming products is the technology of the Internet of Things (IoT). IoT refers to a system of interconnected devices embedded with sensors and software that work together to collect data and communicate in real-time. Farmers are employing a myriad of connected devices to monitor their land and perform large-scale analysis. Soil sensors are among the most popular options – a network of sensors can be deployed on a field to monitor key soil nutrients, crop health, and other important metrics. IoT has the power to be a platform for communicating across multiple devices so a single technology is rarely used. Drones have increased in popularity in agriculture as a tool for monitoring crops and even delivering fertilizers, pesticides, etc. using imaging and computer vision.

The real power held by IoT is the capability for automated analysis with Artificial Intelligence (AI). AIs are being built to conglomerate the data to build an action plan that the farmers can respond with. The large amount of data allows for highly precise recommendations to be made, such as localized treatment of crops. Previously, farmers would indiscriminately lay down fertilizers, pesticides, irrigation, etc., which of course would cost resources and resulted in environmental pollution. The technology deployed today, however, uses models to specify the exact location in need of treatment and even specifically the types and quantities of treatment based on the current sensor readings. Current simulation models can take the information provided by the sensors and climate data and provide the exact inputs needed for the field to produce the desired crop yields, such as maximized profit (Gundersen, 2022). This impact reduces cost, decreases harmful pollution caused by over-treatment, as well as prevents over production that could lead to waste.

The usefulness of IoT in agriculture is already being realized, and it is only expected to grow. In 2021, the agricultural IoT market was worth 11.4 billion USD, and is predicted to be worth 18.1

billion by 2026 (Market Research Firm, 2021). This expected growth of IoT farming is warranted because its effectiveness is already being proven. A study in Thailand explored the effectiveness of three different rice patty cultivating techniques to measure the water usage and rice production. After normalizing the water consumption based on the rice output, it was discovered that the IoT-based approach was 40.29% and 29.22% more efficient compared to the other two methods (Laphatphakkhanut et al., 2021). It is clear that IoT devices are benefitting farming by producing a higher crop yield for lower resource cost. Farming at a higher efficiency means an overall reduction in the harmful products that have been going into the soil while simultaneously increasing food production for the growing demand.

**Blockchain in Farming**

Blockchain has evolved to be used for more than just cryptocurrency. It has the power to provide traceability in food production, which helps farmers seek demand, helps protect consumers, and helps reduce food waste. Blockchain is a decentralized database that allows for traceable and transparent transactions. Rather than being held by a centralized owner, blockchains are stored identically by many nodes across an entire network. In agriculture, this means that data about an item of food can be traced by anyone. This including tracing the transactions food takes before reaching the consumer and even connecting a food product’s growth information such as location and crop health. For consumers, this provides a brand-new level of transparency. Consumers will be able to make choices based on their purchasing preferences, which has the potential to push the market in a direction of producing crops with safer and more sustainable methods. For farmers, however, a mass-transparent view of food transactions gives farmers precise knowledge of food demand. This allows farmers to better plan their harvests to minimize wasted food that goes unpurchased. Less wasted food of course means fewer wasted resources going into producing that food. Blockchain is another tool in the digital agriculture revolution that will further disrupt the harmful practices to the environment and help get more food to consumers.

**Profit Over Conservation**

Just as the promise of profit had driven the harmful practices of the green revolution to run rampant, there is always the potential for the digital revolution to establish new methods of harm. The fundamental schism between conservationists and farmers is that the most profitable methods of farming do not always align with the most sustainable practices. The issue though, is that the new agricultural models used to predict crop growth can be highly tuned to maximize profit at the expense of sustainability. AI is an unexplored frontier in agriculture, the technology has not yet had the time to fully mature. An AI could propose a suggestion that it recognizes as beneficial to profit but could cause more harm to the environment. Therefore, it is important to always keep farmers and sustainability experts in the loop of the design process. Engineers building tech for the digital revolution should not lose sight of why this agricultural revolution is necessary in the first place and should therefore always be looking through the lens of a sustainability first approach.

**Power Dynamics of Digital Agriculture**

A benefit of increasing the use of technological equipment in farming is the interest brought to agriculture by new investors previously not engaged in the industry. Large tech companies, such as IBM, have begun investing capital into farmers now that they have some expertise on the matter. However, the farms that stand the most to gain from investments by tech firms are the big farms. Large farms will attract investors more than small farms because they already have the capital to deal with the overhauls brought by the digital revolution. Large-scale farms have the manpower to instate smart devices into their farming, as well as more equipment that helps them take most advantage of digital farming. Furthermore, many small farms in rural communities lack high-speed internet access, which is crucial for connecting a plethora of IoT devices. Small farmers who cannot figure out the recent technology or do not have the resources to take advantage of digital agriculture face threat from the larger agricultural giants who might leave them behind. For those focused on sustainability, this issue presents a conflict of interest. While digital technology has the benefit of pushing large farms to reduce harm in their methods, it has the power to punish small farms, many of which have already been practicing sustainable or organic farming for years. The digital revolution will not reach its full potential unless small farmers also receive investment.

**Conclusion**

The world must change its perspective to recognize that sustainability is a means to long-term profit to meet the food needs of a growing human population. Sustaining the earth's ecosystem prevents damage to agricultural land, which in turn allows more food to be produced. Minimizing the chemicals that are pumped into the soil, namely, nitrogen and phosphate fertilizers, will reduce harm two-fold. Not only will the pollution from agricultural runoff decrease, but also agriculture will face less blow-back from harming the soil's natural ecosystem. The technologies of the digital revolution will have significant leverage on harm reduction to the ecosystem. Deploying the tools of precision agriculture will allow farmers to better control what goes in and what comes out of their land. While being more efficient with agricultural resources is clearly beneficial from a financial perspective in the immediate present, hopefully industry experts carry this sentiment and see that long-term sustainability is also in their financial interest.

Just like any major historical upheaval, the digital revolution will become exactly what engineers make of it. If approached from the lens of sustainability, this agricultural revolution can start undoing the wrongs of the green agricultural revolution.

## Resources


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