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Rooted in International Politics: An Examination of Political Drivers and Effects of of Modern Agricultural Technology

Human beings first emerged as pure hunter-gatherers, chasing their food, both plant and animal, across the landscape. The harnessing of the seed – and the ability to reliably cultivate the seed – transformed human society into a sedentary environment, one from which civilization could flourish. Thus, whomever controlled the seeds held incredible power and authority over the stability of society. Looking ahead to modern day, the ability to reliably cultivate such seeds continues to reign at a level of unrivaled importance. Whereas agricultural technologies of the past, such as irrigation and tractors, have propelled most civilized areas to a general point of food security, high uncertainty of such food security persists in the wake of an exponentially increasing global population combined with a rapidly changing climate system spurred from anthropogenic greenhouse gas emissions. Powerful corporate actors have emerged to support global agriculture under these circumstances, commonly and colloquially referred to as 'Big Agriculture'. The importance of their prominent agricultural technologies have enforced existing power structures between some states and conversely empowered previously less-powerful states. The technologies of pesticides and genetically-modified (GM) pesticide-resistant crops (PRCs) have changed how countries interact with each other due to the mere inescapability of all states' needs to reliably feed their populations.

To appreciate the political actions, consequences, and nature of 'Big Agriculture's impact on international affairs, it is important to start by examining the larger scope of the topic, following seed technology's historical path towards prominence, and moving to an increasingly microscopic view, presenting select case studies of the impact on countries from Argentina to Mali to Haiti. This paper will showcase how pesticides and GM crops have encompassed the identities of both democratic and authoritarian technologies, either empowering or crippling countries' sovereignty. The technologies exist within both technological determinism and social constructivism constructions due to their inherent positioning in political and economic structures.

After demonstrating the state interactions that have been created or upheld by the use of these technologies, this paper will conclude by exploring the next generation of agricultural technology – digital agricultural – and how the power of data control can and will allow Big Agriculture to continue to cement themselves into the same systems of market control by constructing political and economic narratives. The paper ends by calling for the purposeful integration of indigenous knowledge and citizen input with scientific research to formulate sustainable and equitable agricultural technologies.

Emergence Of Big Agriculture & Agricultural Technology

The term 'Big Agriculture' is used to imply that large-scale agricultural corporations are more powerful than they potentially should be. It is commonly used to create a sense of disdain against larger agricultural corporations that have overshadowed the more familiar, family-owned farms with their incredible political and financial power. The term, though, does not have to be viewed in a negative light, but rather can be utilized to consistently emphasize the large-scale power held by such corporate actors. Firms commonly filed into this category include Cargill, ADM, John Deere, CNH Industrial, Syngenta, DuPont, Nutrien, Yara International, BASF, and particularly Monsanto, who continues to be a major player at the heart of past and future advancements and controversies.

Those who identify left of the U.S. political spectrum generally desire greater oversight of the products being developed by these corporate actors out of fear that they are failing to adequately consider public health, safety, and the environment. Those who identify right of the U.S. political spectrum are generally more willing to subscribe to the belief that the agricultural corporations will be naturally governed by market forces to meet the public's needs. In either case, the nature and perspectives on the 'Big Agriculture' actors are important to understand because these firms are the distributors of the politically-charged agricultural technology.

While there are many products that fall into the description of 'agricultural technology', a primary focus across the aisle is on pesticides and genetically modified pesticide-resistant crops, and more specifically, the combination of glyphosate-based pesticides (Roundup at Monsanto) and genetically modified glyphosate-resistant crops (Roundup Ready Crops at Monsanto).

The political integration of Big Agriculture actors like Monsanto does not begin with their selling of agricultural and biotechnology products. Originally, Monsanto was in the business of chemical manufacturing. One of the company's most notable chemical concoctions was utilized by the United States in the Vietnam War in the 1970's, known to most as Agent Orange. Agent Orange was dropped indiscreetly across the forests in Operation Ranch Hand with the intent of defoliating the trees to increase ground visibility and decimating the Vietnam force's food sources. Spraying of the compound additionally resulted in severe unintended consequences related to human and environmental health that still impact the peoples of Vietnam and surrounding countries today (Schecter et al., 2011). Nonetheless, after the war, Monsanto realized that it had the ability to synthesize powerful, non-discrete herbicides, and shifted its focus to the agricultural industry. Roundup, a different compound than Agent Orange, was on the commercial market by 1974 (Duke and Powles, 2008).

Though herbicides were developed to kill weeds and plants that harm food supplies and crops, existing agricultural crops on the market could not survive against the powerful, non-discrete herbicides, for they too were killed by the compound. Thus, a new window in the market emerged: genetically modified pesticide resistant crops. Cross-breeding is the primary method in which stronger crops have historically been created, but it is a method that requires an abundance of time and leaves many factors up to natural variability. Advances in biotechnology and genetics enabled companies like Monsanto to harvest the power of gene-editing, curating genetically-identical crops that are specifically immune to the pesticides applied to them. Farmers who employed these new stronger pesticides in combination with the PRCs found incredible success. The technologies took off in tandem and together painted an incredibly bright future that keenly complimented food security concerns of the 1970's and 1980's.

With the global population projected to continue increasing exponentially, dire predictions of a Multhusian famine were believed to be imminent. The developing world (particularly Africa, South Asia, and Southeast Asia) was an area of concern, for their populations were growing at a much higher rate due to advances in industrialization in these regions (Welch and Graham, 1999). Thus, the Green Revolution, a movement to dramatically increase agricultural productivity, emerged. The Green Revolution was an extraordinary and successful period of increased food crop productivity, with the production of cereal crops tripling while populations had only doubled (Pingali, 2012). The new pesticides and GM crops neatly fit into the rhetoric and goals of the Green Revolution. From their conception, these technologies were heralded in a 'pro-poor, pro-sustainability' light, the keys to long-term agricultural viability across the globe.

Regarding sustainability, countries that grow their own food could theoretically expend fewer resources for importing and transporting foreign agricultural goods – a noteworthy accomplishment since transportation and packaging are considerable producers of emissions (Newell and Taylor, 2018). Genetically modified crops could also be engineered to require fewer resources for growth. Water, fertilizer, and soil usage could all theoretically be reduced with the invention of specific GM crops, allowing for less intensive resource use in countries prone to drought or regions naturally low in soil nutrients. GM crops had the potential to be the beacon for sustainable agriculture, and they were frequently heralded as such (Miller and Conko, 1970). With this marketing schema, the technologies were spread globally and championed by a combination of political factors.

Political Drivers of Agricultural Technology

A basic necessity of a civilization is that it can feed itself. State actors soon took notice of these new agricultural technologies and how they could be used to either feed their own constituents or be grown within their borders to be sold to other states for the same reason. Modern agricultural technology is subsequently driven by and steeped in political activity, rendering it as an inherently political technology.

Economic

Continuing with the ‘pro-poor, pro-sustainability’ rhetoric, agricultural technology goods and servies were expected to be rendered to and requested by political actors. Such rhetoric directly contributed to Big Agriculture’s “focus on markets in developing countries” (Glover, 2010). And with Wall Street investors comparing the developments in agricultural biotechnology to the “discovery of fire”, the identified market was forcefully pursued (Stein, 2005). These buyer/seller relationships between developing/developed countries grew and morphed over time in a strategic fashion.

Before countries were customers of GM crops, they were most likely a recipient of the seeds in the form of a ‘donation’, either directly or indirectly from a Big Agriculture actor. USAID declared in their own documentation that, “aid leads to trade, from which Americans stand to benefit directly”, meaning that U.S. Big Agriculture actors targeted developed countries to ‘help’ first, knowing that they could groom them into customers later on. More specifically, of the 50 largest customers for U.S. agricultural goods, 43 had previously received food assistance in the form of these donations (USAID, 2002). A pipeline of customers was strategically constructed by means of the ‘pro-poor, pro-sustainability’ rhetoric. With new technologies of pesticides and GM crops, the United States would be overflowing with GM soy and corn seeds – and needed large markets to sell them to.

Larger, more prominent states like the U.S. already had access to developing countries’ agricultural markets through nontraditional pathways such as foreign aid. The market for pesticides and GM crops in the developing world was clearly the direction to head in, and its promise of customership was a significant driving force in the proliferation of these technologies. Through this lens, these agricultural technologies have merely served as an amplifier of international political standings, a tool for the authoritative states of the world. More powerful countries continue to find new technological developments to adhere to their image and presence of global dominators, controllers, and leaders. For the United States, this reason, among others, creates a clear case for the enormous support in the form of subsidies given to the domestic agriculture sector to keep their production on the forefront of innovation. Agricultural innovation at large scale practically guarantees developed countries the marketing power of their products over developing countries – a continuation of the ‘mother country’ relationship propagated by colonialism since its inception.

Control over trade markets additionally allowed U.S. Big Agricultural actors to shape how their products were presented to developing countries. The case of Monsanto’s Bt cotton in Burkina Faso, as explained by Luna & Dowd-Uribe (2020), is a prime example. The authors describe how Big Agriculture actors capitalized on the political economy of knowledge production, stating, “pro-GM organizations portrayed Bt cotton in Burkina Faso as an unmitigated success”, yet this claim was drawn from a small number of narrow studies that had methodological flaws. Such studies utilized averages that misconstrued the notable variability in outcome from farmer-to-farmer. Additionally, they often did not take into account the growing method utilized by the farmers when comparing Bt cotton versus conventional farming, among other reporting flaws. Nonetheless, since Big Agricultural actors had such tremendous political sway coming into the Burkina Faso market, they controlled the information that was fed to both the public and to officials. In 2008, the adoption of Bt cotton by the country became the largest introduction of GM crops to Africa in history.

Years later in 2016, Burkina Faso opted out of Bt cotton completely and all at once. The country's farmers complained of millions of dollars lost because the Bt cotton lint quality was far inferior to conventional cotton. This key attribute of lint quality was interestingly absent from the data showcased by Big Agriculture actors in regards to Burkina Faso's success story.

The data for Bt cotton in Burkina Faso was obtained, managed, and extrapolated from by Big Agriculture actors themselves. Controlling the data, and thus the common knowledge, allowed them to control the narrative surrounding GM crops in Burkina Faso and eventually the rest of Africa. The data was used to construct and promote Burkina Faso's 'success story', so much so that it led to government and agricultural leaders from 17 African countries being invited to "Seeing is Believing" tours organized by Monsanto and the biotechnology company, International Service for the Acquisition of Agri-Biotech Application (ISAAA). At these tours, the visitors were shown statistics and results from the studies discussed above which had partially incorrect information.

Existing economic structures allowed Big Agriculture actors like Monsanto to take advantage of the trust given to them by developing countries. Economic motivations lead to exaggerations and misleading statements in reports on the success of GM crops, allowing Big Agriculture actors to open the door for themselves to more developing countries. Controlling the economic decisions allowed Big Agriculture to have definitive power over the data, and thus the common knowledge on GMO crops. In a blending of economic and political power, scientific misinterpretations, and purposeful facades, controlling the data related to pesticides and GM crops propelled the expansion of these technologies in developing countries.

Legislative

In addition to consistent economic backing and a guaranteed market, on the more judicial side of the aisle debates over intellectual property historically tend to favor Big Agriculture in developed countries. This frequently leads to developed countries additionally supporting Big Agriculture's intellectual property claims due to less arguing power. Support from the courts also bolsters the proliferation of GM crops and is an incredibly motivating factor for Big Agriculture actors to keep producing them.

The traditional seed market sold its products as a one-time investment. After the first round of crops grew, the resulting seeds could be harvested at no extra cost to the farmer in a process referred to as 'seed saving'. The next generation of crops could be grown from there. Big Agriculture, having put extensive effort and years of resources into newly-proliferated GM seeds, was not excited to enter the same market that had existed for seeds all throughout time. Instead, Big Agriculture actors sought to bring an entirely new seed market to the table that would render their GM seeds more valuable – and, importantly, more necessary to buy again and again.

Producers of GM seeds claimed that their seeds were a patentable product containing novel innovations: inventions that should be strictly protected by law. Big Agriculture actors, Monsanto in particular, systematically lobbied to enact both plant patents and utility patents for the GM crop products. Moran (2014) explains that,

> *"A plant patent gives individuals protection against others duplicating their breed asexually, selling the plant in whole or in part, or importing the variety from a foreign country. Meanwhile,*

> *a utility patent covers not only the plant itself and its descendants, but also its method of production and the uses of the plant… While the requirements for a utility patent are stricter, both types of patents last for 20 years in this rapidly changing field."*

The private agricultural sector pushed U.S. intellectual property (IP) rights in the direction of a "stringent patent regime for genetically modified seeds" (Stein, 2005). The developments in IP rights serve to protect agricultural corporations' GM technologies and encourage the corporations to continue innovating without fear of losing their products' market edge. It was a definitive movement of the U.S. legal system in support of these agricultural technologies and their importance.

Although these IP rights were determined within U.S. legal systems, their message and legislative impact did not stay locked within the confines of the American border. Due to extensive influence in international markets, "the United States is the world leader in the development of intellectual property rights" (Stein, 2005) and leverages IP extensively in trade. The mere existence of a law to protect intellectual property rights on plant varieties likely set path dependency forces in motion (Filomeno, 2013). Other powerful countries, who also sought to encourage biotechnology development and ownership within their borders, followed in the footsteps of the U.S. and commonly adapted the plant and utility patents.

Many developing countries, influenced and persuaded by their seed providers (the developed countries), also frequently followed suit. Their motivations were generally different, for they did not tend to agree out of principle but mainly due to a lack of voice on the subject and in international markets. Often, these states were a part of free trade agreements with the U.S. (Nadal and Wise, 2004).

The most definitive piece of legislation was the 1970 Plant Variety Protection Act (PVPA). This document provided protection for sexual reproduction in plants, including seed germination for seventeen years (Stein, 2005). Although countries on a national level tended to go along with these developments, individual farmers were not on board. This new system, of having to pay a company for the seeds one collected on one's own farm through labor and intelligence, was entirely counter-intuitive to the system of farming that had existed since the dawn of civilization: seed saving. The Food and Agriculture Organization of the United Nations reports that seeds saved by and exchanged among farmers account for up to 80-90% of all seeds in developing countries (Mosoti and Gobena, 2007). Big Agricultural companies required that farmers sign documentation that legally restricted them from saving the genetically modified seeds from their own crops to plant in upcoming seasons (Herring, 2007).

Globally, individual farmers were highly unwilling to comply with these demands from Big Agriculture, despite what their national government had decided on the matter. In both India and Brazil, countries that heavily rely on growing GM cotton and soy crops, respectively, Herring (2007) highlights how farmers found methods to circumvent international legislative bans on seed-saving. Seeds were pirated in locally-based 'stealth seed' networks, directly in violation and defiance of the seed proprietary obligations forced upon farmers that used transgenic crops. These acts of resistance by farmers did not go unnoticed, but they also did not have the farmers' intended impact. Instead, these under-the-table activities lead Big Agriculture to develop more stringent methods of seed-saving restriction: terminator seed technology (Klepek, 2012).

Developments in bioengineering meant that Big Agriculture could develop seeds that purposefully could not reproduce after one generation, leaving the buyer of the seed with no chance to save and replant seeds for the next season. In May 1998, Monsanto gained access to a "U.S. patent on a sterile-seed 'genetic use restriction technology' (GURT) that would render genetically modified plants infertile", allowing them to develop terminator seeds (Glover, 2010). Terminator seeds were a physical embodiment of the seed-saving restrictions created above but without any room for individual disobedience. The new technology would leave farmers no other choice but to buy the next generation of seeds from their Big Agriculture supplier each and every subsequent season.

The terminator sterility gene being granted IP protection to Monsanto was an enormous statement in the discussion regarding ownerships and genetic technology. It raised international flags on how Big Agriculture actors could enforce patent rights across state boundaries and across existing IP documentation since there was and is no explicit international law on the subject. Historically, U.S. law has been on the side of Big Agriculture, but the U.S. has yet to be entirely successful in persuading other state actors across the globe.

An entirely economic pursuit, the development of terminator seeds forgot to account for the tangled and incredibly important concepts of sovereignty and the relationship of food to such sovereignty. Although terminator technologies have yet to make a commercial debut, due to enormous global pushback, their mere possibility of existence have shaped state actors' response to the idea of exploitative agricultural market strategies. For many countries, the terminator technology was a step too far away from sovereignty. In Brazil, licensing for its agricultural research centers was at one point altered such that farmers were explicitly granted the 'right to save seeds for their own use in subsequent seasons, thereby prohibiting Monsanto from introducing the 'terminator gene''. The documentation also declared that the agreements serve to "reduce dependency of Brazilian farmers on multinational corporations" (Jepson 2002). With these internal documents, Brazil responded to Big Agriculture's pending oversight with regulation of its own, building barriers against impending agricultural technologies before they could exploit Brazilian farmers. Sovereignty over their Brazilian crop seeds was defined as a norm worth upholding in the wake of expanding agricultural technologies.

Overall, legislative protection of transgenic seeds as intellectual property has been a clear propellant of these agricultural technologies, but it has not gone without pushback from consumers of the technologies.

Reliance

The economic and legislative storylines above paint a picture of reliance. More specifically, the resulting image is the strategic approach of Big Agricultural actors to construct a relationship of reliance between themselves and less powerful countries' agricultural needs. Although agricultural reliance on these technologies is of course an effect, it serves the purpose as a driver of the technology as well. A self-fulfilling cycle is proliferated through the expansion of these technologies, with pesticides being the main offender. To grasp the full situation, the longstanding relationship between weeds and agriculture must be revisited.

Now, weeds are nothing new to farmers. They are the original enemy. Weed-controlling technology has evolved throughout human history and glyphosate pesticides are merely the newest chapter in that story. Farmers buy glyphosate pesticides from Big Agriculture actors to help them solve their weed problems. For the first couple rounds of use the pesticides are incredibly effective, wiping out most everything in their path. Due to the nature of evolution, however, the effectiveness of the pesticides dwindles as the use increases. In the world of plant biology, weeds are categorized as 'opportunistic' species. They grow quickly, are hardy, and do not require abundant resources to thrive. Most importantly, they reproduce with great multitude and rapidity. Having these features allows weeds to adapt throughout generations and continue to survive in the conditions they find themselves in. Therefore, individual weed plants that survive the original pesticide application and manage to remain undetected are able to reproduce, replant, and create a new generation of pesticide-resistant weeds. The pesticide-application cycle begins yet again.

Evolution is thus the enemy of weed-destroying technologies but the best friend of the sellers of these technologies. One method that farmers use to combat this natural cycle is to simply increase their usage of the pesticide (Benbrook, 2016). Some weeds may have light resistance to glyphosate but are not able to survive the pesticide in extraordinarily large amounts. Using more pesticides requires the farmers to buy more pesticides, naturally. Another method utilized by farmers is to apply the same measured amount of pesticide but with a more potent, updated version of the product. In this method, farmers are required to buy a new version of the pesticide, still adding to the bottom line of Big Agriculture.

Either way, non-organic farmers find themselves at a point of no return with pesticide use and must continue buying some form of the product from the Big Agriculture actor. It is no surprise that no pesticide has ever been sprayed so widely around the globe as glyphosate (Duke and Powles, 2008). The same story follows suit with GM crops, for as pesticide use and potency increases, the GM crops must be altered to remain resistant to the pesticide application technology.

The use of GM crops can increase the use of pesticides as well. Farmers have no need to be conservative, careful, or strategic in their application of pesticides if the crops they plant are resistant to its effects. Before GM PRCs were utilized, farmers had to spray pesticides only before or after crops were planted to avoid contact with the actual crop itself. With GM PRCs, "glyphosate [can] be sprayed 1-3 times or more after the crop [has] emerged" to give the farmer more weed-control assurance throughout the growing season (Benbrook, 2016). One exception to this phenomenon is the invention of GM crops that are naturally pest-resistant, meaning that no pesticides are needed for their propagation.

This cyclic cat-and-mouse game between farmers and evolving weeds sets the stage for a market that grows itself. The pesticide product creates reliance. Once Big Agriculture actors are able to physically and metaphorically plant their seeds within a country's borders, future reliance on their technology is difficult to escape from. Thus, Big Agriculture actors expend an enormous amount of political and economic resources to get their foot into the door of countries' agricultural sectors, and the success they reap from these endeavors only serves to fuel future ones. There are few one-time customers of these technologies, giving Big Agriculture incredible power over the consumers of their products on a state-by-state level.

Political Effects of Agricultural Technologies

In addition to pesticide and GM crop development being supported and propagated by political factors, the implementation of these technologies deeply affects state actors and the relationships between them. Being inherently political, these technologies have created deep ripples in the schemas of normative behavior, international lobbying, trade, and the notion of sovereignty itself.

Norms

Before delving into the complex way these technologies have shaped interactions between state actors, it is important to peer inside the state actors themselves and the decisions they had to make in the wake of these emerging technologies. In particular, GM crops forced states across the globe to define new norms – and the decisions are not trivial. The decision to accept or reject pesticides or GM crops in any fashion impacts the protection of smaller and mid-scale farmers for the rest of the state's future. Pesticides and GM crop technologies are tailored to the needs of large-scale farming and mainly stand to increase their profitability. Their benefits to smaller scale farms are not nearly as noticeable.

Although pesticides and GM crops are simply commodities bought and sold, they can change the social and economic landscape when introduced to a state. Will the technologies disproportionately profit some farmers more than others? How will the state's consumers react? Can consumers purchase the products from other countries, while farmers cannot grow the product within the country? Are the crop's products comparable throughout the supply chain?

Can the soil and resources of the region adapt sufficiently and sustainably? Pesticides and GM crops are representative of a new era of agriculture with many questions, some less-answerable than others, but all tying into some sort of normative belief regarding 'how things should be'.

Other prominent technologies, such as nuclear weapons and genetic engineering for human embryos, demand stark, definitive norms related to morality and expensive and intensive infrastructure, and have their norms defined by both individual states and international organizations. The agricultural technologies in question, on the other hand, do not have a strict international set of laws dictating their usage, in favor or in opposition. GM crop innovations additionally do not receive the same time-sensitive attention as the other technologies mentioned above. For instance, the first time that farmers' rights regarding plant genetics were explicitly mentioned by the United Nations Food and Agriculture Organization (UN FAO) was in 2007, 13 years after the first genetically-altered grown crop, the Flavr Savr tomato, was commercially sold (FAO, 2007, Lemaux, 2008).

While the UN FAO's current International Treaty on Plant Genetic Resources for Food and Agriculture mentions farmers rights, sustainability, and benefit sharing system, the language is vague, fails to discern due dates, and offers no repercussion against states that do not follow the proposed actions. The door is consequently left open to each state to decide where they stand on the spectrum of both pesticide utilization and GM crop propagation and consumption.

Furthermore, norms are often defined by the more powerful, developed countries in the field. The United States and EU generally occupy these roles but are entirely divided on their stances on GM crops. Whereas the EU is staunchly anti-GMO, the United States is one of the biggest proponents of the technologies. The two entities' lack of unison opens the door to developing countries to cement their own normative stances – or to potentially choose sides between the U.S. and EU. A notable third actor has emerged in the GM revolution as well: Asia. China, a pro-GMO state, offers a new market for many countries who previously supplied European nations with agricultural goods but can no longer due to the EU's anti-GMO policies (Katovich, 2012). Even more, states can choose to not side with any major state actor and insteads integrate elements from multiple regulatory approaches. They can forge a policy that is uniquely their own, a development that has created "substantial regulatory diversity in the South" (Falkner and Gupta, 2008).

External international pressure aside, a significant difficulty of states defining norms was that there was originally little evidence to show the long term effects of pesticides and GM crops. Although the technologies were touted in an entirely positive light of efficiency by their Big Agriculture manufacturers, their social, environmental, and economic repercussions were unknown, particularly in less powerful states. Combining the opportunity to not be entirely influenced by the U.S. or EU with the ambiguity of the impacts of the new agricultural technology lead developing states to handle this norm-forming process in differing manners, weighing citizens or science more than the other.

In the case of Mali, the state heavily considered the direct opinions of its people in deciding norms for national GMO technology, particularly relating to Bt cotton. In January 2006, the government created a space for farmers from a range of farm sizes to learn about, discuss, and recommend policy implementations regarding Bt cotton. The event was called the ECID, Espace Citoyen d'Interpellation Démocratique (Citizen's Space for Democratic Deliberation), and after multiple days of information and conversation, the 45 invited farmer-jurors "unanimously rejected the introduction of GMOs to Mali" (Pimbert and Barry, 2021). In response to the ECID's results, the Mali government initially delayed and then eventually decided against GMO cultivation approval legislation. This was the beginning of Mali's norm of protecting the interests of traditional farming over GMO integration. Now Mali is instead a part of the UN's

Integrated Pest and Production Management system where farmers aim to retain yields while eliminating chemical pesticides on their cotton fields (FAO, 2021).

Other states chose to take a more scientific approach to justify their normative approach to pesticides and GM crops. Brazil, a current lead grower of GM crops, created multiple internal research groups and regulatory organizations to scientifically evaluate the environmental, economic, and human safety of such crops (Velini et al., 2017). Despite negative pressure from the public, Brazil defined its norms based on research that sufficiently showed the safety and viability of GM crops in its own country. As a physical declaration of this norm, there are over 200 institutions engaged in GMO activities that have been granted a Biosafety Quality Certificate in Brazil (Mendonça-Hagler et al., 2008).

International Lobbying

In additional contrast to technologies like nuclear and human embryo genetic engineering, a state's stances on pesticide and GMOs are relatively flexible. Proponents of GMOs and anti-GMO actors alike recognize this malleability and consistently put pressure on states to change their normative approaches. Often, even after states define their initial normative stance on GMO integration, the state is subject to international lobbying aiming to sway the norms and alter related domestic policy. The results of these lobbying interactions can either strengthen existing power structures or serve to challenge the international status quo regarding developed and developing countries.

Mexico is familiar with this progression as the U.S.'s closest southern neighbor. When NAFTA opened the door to free trade across the U.S.-Mexico borders, U.S. maize farmers pushed their products into Mexican markets. Mexican officials were cautious about the impact of GM crops on small farmers and subsequently decided to solely permit GM crops for consumption, not for production, within the border (Nadal & Wise, 2004). However, in 2001, a group of researchers found many samples of GM maize planted in Mexico (Quist & Chapela, 2001). They concluded that the GM crops were a result of cross-contamination, a mere accidental but highly likely result of U.S.-originated GM crops being sold within Mexico. The loss of Mexican maize's genetic integrity was a source of alarm and caused outcry, for maize is a central and foundational crop to Mexican culture (Newell, 2009, Katovich, 2012).

The idea of banning glyphosate and GM crops began floating around Mexican politics. CropLife, an agricultural lobbying group in the U.S. composed of representatives from Monsanto and other Big Agriculture actors, began lobbying the U.S. Trade Representative's ambassador, declaring that Mexico's actions were "incompatible with Mexico's obligations under [U.S.-Mexico free trade agreements]" (Novak, 2020).

After grappling with this twisting dilemma of IP laws and farmers' rights for two decades, in early 2021 Mexican officials released a statement declaring the banning of glyphosate pesticides and GM corn. Since their decision, Big Agriculture actors were quick to file for an injunction in Mexican courts to stop the mandated phaseout of glyphosate (Wise, 2021). Mexico's norms are now being lobbied against by proponents of pesticides and GM crops. Their decision to renounce the agricultural technologies and double-down on their own domestic maize production is a significant rejection of long-standing power dynamics between the U.S. and Mexico.

Sovereignty

When a state permits the sale or purchase of technologies, they have two pathways on how to interact with them. A state can either become a grower of the crops to other states or a state can become a consumer of the crops from other states. Since reliable agricultural produce is critical to the wellbeing of a state, the role a state chooses can directly impact the state's sovereignty, or at least the perception of their sovereignty.

There are some previously less powerful states who have emerged as opportunistic victors by choosing to become exporters of GM crops. These states have redefined their roles as leaders in the global perception, rather than remaining dependent on historically more powerful countries. Whereas many countries followed the common narrative of seeing GM crops as a route to food security within their own borders, others view GM crops through their economic potential on the global market.

Argentina is a prime example of a successful GM grower nation. Nearly all of Argentina's GM crops are for export and even more specifically for animal feed. Opinions on pesticide use and GM crop technologies are hot topics in South America, so the government was wary of introducing GM crops to internal markets. Nonetheless, Argentinian officials realized the potential of the technology and calculated that profits from exporting GM crops could serve as economic fuel for tackling Argentinian poverty (Newell, 2009). The South American state has found high levels of economic success through this plan, particularly because it has not adhered to Monsanto's IPR requests. Despite intense and frequent attempts by Monsanto to overcome Argentina's dissent, including "suspending its R&D activities in Argentina and filing a lawsuit against exporters of Argentine soybean products in Europe", Argentina has upheld its legislation that fails to grant any IP protection to GM seeds (Filomeno, 2013).

Farmers in Argentina are able to save seeds without paying Monsanto for every planting, leading to an unofficial estimate of 70-80% of seeds being 'illegally' planted (Newell, 2009). Through these methods of self-preservation, Argentina has risen to be the second largest producer and exporter of GM crops, accounting for 23 percent of global production (James, 2006). It cemented itself as a key global agricultural player by pushing off demands from the U.S. and its Big Agriculture actors wanting to protect IPR of GM crops. And more interestingly, it has defined its role in the international agricultural community as a 'feeder' of other countries.

On the other side of the aisle, some states have become heavily reliant on other states to fulfill their need for GM crops. Requiring another entity to provide these often staple crops, such as corn, wheat, soy, rice, and cotton, is potentially threatening to the state's sovereignty since the crops serve as a base for much of society's needs and sustenance.

Haiti is a country that stumbles with agricultural sovereignty and relies heavily on imported food to sustain its population. The majority of Haitian-produced food is grown on small lands by peasant farmers using indigenous techniques (Garth, 2013). The productivity of such farming is not high enough to support the Haitiain country alone, leading to much of Haiti's food supply being imported from foreign countries. Such importation only contributes to the cycle of less domestically-grown food being bought, leaving Haitian farmers with an increasingly smaller market. This has clearly been the case of Haiti's relationship with 'Miami Rice'. Since the inception of GM crops in the U.S., Bell (2013) explains:

> *"...rice grown in such places as Arkansas and California and shipped by boat to Haiti could be sold cheaper than rice actually grown in Haiti. As a result, Haiti's domestically produced rice supply fell from 47 percent in 1998 to 15 percent in 2008.18 "Miami" being interchangeable with "United States" to many a Haitian, the import was quickly nicknamed "Miami rice."*

Haiti's hyper-reliance on imported food additionally exposes the state to price jumps during global food crises (Mazzeo, 2009). In developing countries such as Haiti, where the system of government is less stable, public infrastructure is less reliable, and GDP is lower, the lack of surety in the state's food supply can be disruptive for the population and can result in civil unrest, erupting in the form of riots during 2008 food shortages (NBC, 2008).

These agricultural power dynamics are potentially made even more dangerous in the wake of climate change. If crop supplies begin to become unstable, states with access to staple GM crops will be able to charge whatever they please for their products, challenging the notion of sovereignty for states which cannot produce their own crops. Having to rely on another nation for food reinforces existing unequal dynamics between existing powerful and less powerful states. On the other hand, for states like Argentina, becoming the provider of food for other nations creates external dependencies and can reinvent existing international power relations. Pesticides and GM crops have both bolstered and reconceived longstanding forces of international influence.

The Next Generation of Agricultural Technology

As with most of the modern world, agriculture is moving into the digital age. Digital agriculture describes the most modern computer-based agricultural technologies, including big data, smart farming, and precision agriculture. These are all individually related to, but not directly definitive of, the similar developments in agricultural technology of machinery automation. Whereas physical farming machinery becomes increasingly automated to reduce the burden on individual human labor within the harvesting and tending processes of agriculture, digital agriculture capitalizes on the data stored by these devices and the ability to control them in an optimized manner.

Digital agriculture technology consists of software; lines and lines of code ingesting data from satellites, agricultural machinery and sensors deployed in the crop fields, inventory records, and more; running the data through complex algorithms; and delivering advice to farmers on how to proceed. The algorithms are designed to solve optimization problems such as how and when to water different breeds of crops, controlling fertilizer utilization, managing risks, predicting yields, and finding the optimal datetimes to plant, tend, and harvest. They are created from a combination of intense environmental models that utilize large-scale data storage. As with the formerly discussed technologies of pesticides and GM crops, digital agriculture technology aims to increase crop yield while requiring fewer input resources.

The marketing of digital agriculture has also echoed that of its agricultural technology predecessors, making use of the 'pro-poor, pro-sustainability' rhetoric. It makes sense because the same Big Agriculture firms that sell pesticides and GM seeds are developing digital agriculture platforms. Proponents of digital agriculture proclaim that its optimization abilities will help farmers in developing countries achieve much higher levels of production, allowing the states to become more agriculturally self-sufficient while preserving more of their natural environment (Lajoie-O'Malley, 2020). Despite these claims, digital agriculture has many more attributes that point to it cementing less powerful countries firmly into their current status and restricting their sovereignty.

Architecturally, digital agriculture depends on cloud computing and the Internet of Things (IoT) connectivity of 'smart' farming sensors and technologies. The infrastructure requirements inherently cater to more developed, technologically advanced states that have IT resources, reliable bandwidth, and experts to support the architecture. States that already bring these attributes to the table will be able to scale digital agriculture more efficiently and amass the benefits that it brings far before less technologically developed states. This disparity in digital infrastructure will widen the gap between the producing ability of developed and developing countries. A likely possibility is a similar outcome to 'Miami Rice' in Haiti, where the surplus of foreign grown crops drives crop import prices down, driving domestic crop production down. The cycle of reliance is strengthened through a new technology (Bell, 2013).

Bias is another area of concern within the digital agriculture platform. Most methods of large-scale farming modernly used are relatively unsustainable. Large-scale farms rely heavily on mono-cropping, fertilizer application, and pesticide use – each of which cause detriment to the environment through soil depletion, eutrophication, and polluting water with chemicals, respectively. If this sort of farm structure is the primary source of data that digital agriculture devices are running on, the models are biased and subsequently poorly set up farmers for long term success.

The bias is further complicated since the farmers' data is owned by the profit-seeking Big Agriculture firms. Whereas intellectual property rights can be difficult to enforce in the case of GM seeds, data can be harnessed from digital agriculture systems and used by the Big Agriculture actors as easily as a farmer simply checks a box at the bottom of a Terms & Conditions agreement (Carbonell, 2016). Farmers have voiced concern over the misuse of their personal data that they have to sign over to use the software (Regan, 2019). In many cases, farmers are not even permitted to view the data that their own farm generates, as it becomes property of the digital agriculture company (Kosior, 2019). The entire process bears resemblance to Big Agriculture's attempt at erasing the practice of seed-saving. Farmers who use these digital technologies do not have any legal access to the data they create – the same data that is sent back to Big Agriculture servers to strengthen models and feed Big Agriculture's systems – just as they were not allowed the autonomy over the seeds produced from GM crops.

Digital agriculture allows Big Agriculture actors the ability to know exactly what each farm they service needs, how much of each product, when the shipments are needed, and more, enabling them with the ability to market their products with striking accuracy and pre-formed knowledge about each individual customer. Although entirely speculative, the technology theoretically also allows Big Agriculture to bias their models to inform farmers that they need to purchase more supplies than the farmer needs to (Cobby 2020). The danger in proprietary algorithms is that no one but the creators of the system would know if the algorithm was taking advantage of farmers in this way, and farmers may not trust the modelled outputs for this reason (Rotz et al., 2013). States with more advanced data protection laws may be able to circumvent some of these requirements, but the prospects are unlikely. Such action would require an abundance of resources and fortitude to reject the political lobbying of Big Agriculture, similar to Argentina's continuous rejection of Monsanto's anti-seed saving policy (Filomeno, 2013).

The future of digital agriculture is rife with inequalities of power, knowledge, and ownership that favor the hands of Big Agriculture and more technologically adept states. But this is nothing new. Although digital agricultural technologies consist of an entirely different medium than their previous counterparts, they only serve to reflect and reinvent existing power structures. Yet, often what follows the insurgency of authoritarian technology is an inverse democratic version of the same technology, for the two methods of control are in constant struggle against each other. Although developments are far from official, Hackfort (2021) declares that there are independent actors that seek to democratize the playing field:

> *"Coders and famers are collaborating to develop platforms for knowledge sharing and mutual learning alternatives and using them to advance alternative visions of agriculture."*

The agricultural future that secures sovereignty, food security, and environmental health is one that increasingly seeks to wholly integrate the ideas of agroecology and indigenous knowledge with cutting edge, proven scientific results. That is clear. What is less clear is if digital agriculture will be the technological platform for which this convergence of ideological thinking will happen.

The confluence of these conflicting ideologies is more than necessary. With climate change already altering expected crop patterns globally, farmers will need help adapting to novel seasons and conditions (Walthall et al., 2012). Reliable software and models will be key to agricultural longevity, creating an enormous dependency on the legitimacy of the networks and infrastructures of digital agriculture products. Food sovereignty is in jeopardy without adequate and fair technologies. It is simply in the interest of every actor – corporate, public, and consumer – to advocate for worthy, equitable, and sustainable agriculture technologies, for the actors who control the seeds hold incredible power and authority.

Conclusion

Pesticides and GM crops are the past few decades' most politically influenced and influential agriculture technologies on an international scale. Their widespread use can be attributed to a variety of political-economic, legislative, and control-driven factors that have primarily aimed to fortify structures between historically powerful and less powerful states, despite claiming to be humanitarian in nature. Their political impact, however, dances along the spectrum of democratic and authoritarian. Because these technologies are part of dynamic economic, political, and environmental systems, their introduction to global agriculture encouraged some developing nations to make decisions that delineate themselves as self-reliant, or at least not entirely reliant on more powerful nations. Food security has also challenged states to weigh options of how they feed their citizens and whether GM crops are included – with the prospect of sovereignty laying in the balance.

The rise of digital agriculture technology serves as an amplification of the international political developments started during the spread of pesticides and GM crops. However, the infrastructure, data privacy procedures, and economic incentives embedded within digital agriculture will potentially make it more difficult for less powerful states to advocate for themselves. To ensure adequate, equitable, and sustainable global agricultural production, Big Agriculture's products should integrate agroecology principles and prioritize the protection of individual farmers.

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