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Agroterrorism, Resilience, and Indoor Farming

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AGROTERRORISM, RESILIENCE, AND INDOOR FARMING

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Agroterrorism poses a significant threat to food supplies and the stability of agricultural markets. The industrialization of agricultural has substantially improved productivity and efficiency, but has also contributed to the sector's declining resilience—the ability to withstand and adapt to stress and change. Consequently, agriculture has become increasingly vulnerable to possible agroterrorist attacks. However, by working to increase biodiversity and minimize the connected and concentrated nature of agricultural production, the industry can lower its vulnerability to attack. Indoor agriculture may be one way to accomplish this goal. This Article describes indoor agriculture, explains the concept of agroterrorism, and explores the potential risk of an agroterrorist attack on the United States. It concludes by suggesting possible ways to increase the resilience of the agricultural industry, particularly through the use of indoor agriculture.

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I. INTRODUCTION

Between December 2003 and January 2004, exports of U.S. beef and related products crashed by 90%.[1] Cash and futures market prices of cattle took a nosedive along with retail beef prices; at the same time, Washington and several other states were shut off from interstate beef exports.[2] Two hundred feedlots were visited by federal authorities, 75,000 cows were investigated, and more than 700 cows were destroyed.[3] The cause of these dramatic numbers? A single, aged dairy cow in Washington was found to have bovine spongiform encephalopathy (BSE), or 'mad cow disease,' on December 23, 2003.[4]

Although BSE is a horrifying, degenerative, and ultimately lethal disease for cows, it is also extremely unlikely to transfer to humans, since transmission would require eating a diseased cow's brain.[5] No other cow was found with BSE in Washington or elsewhere in the United States that year, and in fact, only a handful of other singular cases have been documented since 2003.[6] The panic that stemmed from one sick cow illustrates how even a small and unintended inter-

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[1] Ji Young Park et al., *The State-by-State Economic Impacts of Mad Cow Disease on the United States* 2 (Homeland Sec. Ctr., Working Paper No. 125, 2006), http://research.create.usc.edu/cgi/viewcontent.cgi?article=1078&context=nonpublished_reports [https://perma.cc/86T5-Z7P6] (accessed Dec. 24, 2016).

[2] *Id.*

[3] Matthew Halverson, *Washington's Mad Cow Scare: 10 Years Later*, SEATTLE MET (Jan. 2, 2014), http://www.seattlemet.com/articles/2014/1/2/washington-s-mad-cow-scare-10-years-later-december-2013 [https://perma.cc/P2P8-ATAN] (accessed Dec. 24, 2016).

[4] Jason Henderson, *FAQs About Mad Cow Disease and Its Impacts*, MAIN ST. ECONOMIST 2 (Dec. 2003), https://www.kansascityfed.org/publicat/mse/MSE_1203.pdf [https://perma.cc/EC7L-KAXL] (accessed Dec. 24, 2016).

[5] Park et al., *supra* note 1, at 5.

[6] *Timeline of Mad Cow Disease Outbreaks*, CTR. FOR FOOD SAFETY, http://www.centerforfoodsafety.org/issues/1040/mad-cow-disease/timeline-mad-cow-disease-outbreaks [https://perma.cc/VY6J-8UCP] (accessed Dec. 24, 2016). These cases did not re-

ference with the safety of the U.S. food supply can have dramatic and far-reaching consequences.[7] An intentional attack on the U.S. food supply via agroterrorism could trigger consequences on an even more massive scale.

While agricultural industrialization has radically improved productivity and efficiency, it has also increased the sector's risk of possible terrorist attacks by destroying much of its resilience—or ability to withstand and adapt to stress and change—and making it more vulnerable as a result.[8] The U.S. regulatory structure currently focuses on reducing the risk of agroterrorism by developing response plans and enhancing on-farm surveillance and security.[9] While this is an important part of safeguarding agriculture, it misses the root cause of the increased risk of an attack: the sector's lowered resilience. Instead, the regulatory structure should focus on increasing agriculture's biodiversity and reducing its connectivity and concentration in order to recover its resilience. Indoor agriculture is a small but growing trend that could help realize these goals and substantially reduce the risk of an attack on the entire sector.[10]

This Article seeks to show that the current agricultural system is increasing the risk of agroterrorism, but when used appropriately, indoor agriculture can and should be used to decrease that risk. Part II gives an overview of indoor agriculture, including a description of its major features and some common criticisms. Part III defines agroterrorism and outlines some possible categories of agroterrorists. Part IV evaluates the current risk of an agroterrorist attack on the United States by describing today's agricultural sector and analyzing it through the elements of risk: threat, vulnerability, and consequences. Part V shows that instead of enhancing security or developing response plans to reduce the risk of agroterrorism, industry and regulators should focus on bolstering agriculture's resilience, particularly through the use of indoor agriculture.

II. INDOOR AGRICULTURE

A new type of agriculture has been surfacing over the past decade or so that is hailed largely as a supplementary sustainable food source.[11] The trend is still new and varied enough that it has yet to go by an agreed-upon name—contenders include closed loop systems, con-

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sult in similarly massive reactions since BSE was then better understood and response mechanisms had improved.

[7] These consequences may have an international impact because other countries may be wary about importing diseased food.

[8] Sarah Rotz & Evan D.G. Fraser, *Resilience and the Industrial Food System: Analyzing the Impacts of Agricultural Industrialization on Food System Vulnerability*, 5 J. ENVTL. STUD. & SCI. 459, 460 (2015).

[9] *Id.*

[10] *Id.*

[11] NEWBEAN CAPITAL ET AL., INDOOR CROP PRODUCTION: FEEDING THE FUTURE 8 (Mar. 2015) [hereinafter FEEDING THE FUTURE].

trolled environment agriculture, plant factories, soilless growing, urban agriculture, vertical farming, and indoor agriculture, among others.[12] This Article uses the term *indoor agriculture*, defined as the growing of produce using soilless hydroponic, aeroponic, and aquaponic technologies inside greenhouses, warehouses, and containers.[13] Indoor agriculture ranges from basic greenhouses to fully automated, remotely controlled, clean-room systems.[14] Currently, indoor agriculture in the United States makes up a very small percentage of fruit and vegetable production, almost certainly less than even 1%.[15] Other countries, however, have much larger indoor farming markets—for instance, a quarter of China's vegetables come from indoor farms.[16]

A. Features of Indoor Agriculture

Indoor farms can be built nearly anywhere, from the roofs of buildings, to underground tunnels, to even the South Pole.[17] A plant factory in Japan was built in a location devastated by a 2011 tsunami to "prove that vegetables can be produced anywhere now," according to the company's CEO.[18] In the United States, more than a dozen commercial-scale vertical farms have been built in California, Delaware, New Jersey, Texas, and Wyoming.[19] This number is expected to triple by the end of 2016.[20] Single cities can house a huge variety of indoor farms in myriad locations, including people's homes.[21]

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[12] *Id.*

[13] *Id.*

[14] "Hydroponic systems work by submerging plant roots in a closed-loop recirculating water system filled with dissolved essential minerals and nutrients. Aeroponic systems are similar in concept, delivering water and essential nutrients in a mist to increase water efficiency and expedite plant growth. Aquaponics is a coupling of hydroponic plant growing methods with conventional agriculture." *Id.*

[15] *See id.* at 10.

[16] *An Infographic of China's Indoor Agriculture Industry*, INDOOR.AG, https://indoor.ag/2015/02/infographic-chinas-indoor-agriculture-industry/ [https://perma.cc/3AFA-VPJM] (accessed Dec. 24, 2016).

[17] *5 Reasons the Future of Agriculture Is Indoors*, INDOOR.AG, https://indoor.ag/2014/03/5-reasons-future-agriculture-indoors/ [https://perma.cc/2M6E-5CP6] (accessed Dec. 24, 2016) [hereinafter *5 Reasons*] ("The National Science Foundation has its own hydroponic farm at its station in the South Pole.").

[18] Gloria Dickie, *Q&A: Inside the World's Largest Indoor Farm*, NAT'L GEOGRAPHIC (Jul. 19, 2014), http://news.nationalgeographic.com/news/2014/07/140717-japan-largest-indoor-plant-factory-food/# [https://perma.cc/4KC5-HJ63] (accessed Dec. 24, 2016).

[19] Mark Anderson, *MIT's Food Computer: The Future of Urban Agriculture?*, IEEE SPECTRUM (Jan. 20, 2016), http://spectrum.ieee.org/computing/embedded-systems/mits-food-computer-the-future-of-urban-agriculture [https://perma.cc/VF59-7HZW] (accessed Dec. 24, 2016). Japan currently has 145 vertical farms, Taiwan has 45, and China recently announced it intends to build 20 more. *Id.*

[20] JEFF BIRKBY, VERTICAL FARMING 7 (Jan. 2016), https://attra.ncat.org/attra-pub/download.php?id=512 [https://perma.cc/BF7L-SSN7] (accessed Dec. 24, 2016).

[21] *See* Connie Kim, *Seoul City Government to Activate 1,800 Urban Farms*, ARIRANG (Apr. 18, 2015), http://www.arirang.co.kr/News/News_View.asp?nseq=178734 [https://perma.cc/ZD9C-JT96] (accessed Dec. 24, 2016) (reporting on unused spaces at schools, parks, and apartment rooftops being transformed for urban farming).

Although based on the standard greenhouse, indoor agriculture designs are highly varied and can look very different from those original structures. Sometimes layers of plants will rotate inside glass buildings to catch sunlight; sometimes lighting is entirely artificial.[22] Hydroponic greenhouses grow crops inside using natural sunlight during the day and artificial lighting systems at night and during off-peak seasons.[23] Vertical farms grow crops in layers inside large industrial spaces with hydroponic, aquaponic, or aeroponic equipment, using solely artificial lighting.[24] Container farms are effectively vertical farms made of multiple small units that allow customizable farm sizes.[25] On the whole, indoor farms are highly efficient and productive. For instance, an acre of conventional farmland is 43,560 square feet and yields about the same amount of vegetables, herbs, and fruits as a 36-square-foot vertical farm.[26]

Indoor agriculture relies on new and constantly improving technologies to enhance productivity and efficiency.[27] All indoor farms utilize climate control technology to keep plants at target humidity and temperature levels.[28] Some farms maintain 24/7 LED lighting that renders weather, sunlight, and seasonal variation entirely irrelevant.[29] Lighting wavelengths can be optimized for growing different plants.[30] Greenhouses can hold higher levels of carbon dioxide than ambient air, which increases photosynthesis and consequently plant productivity and vigor.[31] Solutions of micro- and macronutrients can be individualized for growing different types of produce.[32] Often, indoor farming operations also use polarized water because it holds onto more nutrients than rainwater.[33] This increases plant growth rate while helping to reduce bacterial and microbial pathogens.[34] Water is

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[22] *See* FEEDING THE FUTURE, *supra* note 11 (outlining the highly varied structures and systems of indoor agriculture).

[23] *Id.* at 10.

[24] *Id.*

[25] *Id.*; George Dvorsky, *How Vertical Farming Is Revolutionizing the Way We Grow Food*, GIZMODO (May 3, 2016), http://io9.gizmodo.com/how-vertical-farming-is-revolutionizing-the-way-we-grow-1730550597 [https://perma.cc/G9UJ-P53R] (accessed Dec. 24, 2016).

[26] Julia Terruso, *City Council Encourages 'Vertical Farming'*, PHILLY.COM (Apr. 29, 2016), http://www.philly.com/philly/news/politics/20160429_Council_encourages__vertical_farming_.html [https://perma.cc/MG3F-GLYV] (accessed Dec. 24, 2016). For reference, thirty-six square feet is less than 1% of an acre.

[27] FEEDING THE FUTURE, *supra* note 11, at 24.

[28] *Id.*

[29] Terruso, *supra* note 26.

[30] Michaeleen Doucleff, *Vertical 'Pinkhouses:' The Future of Urban Farming?*, NPR (May 21, 2013), http://www.npr.org/sections/thesalt/2013/05/21/185758529/vertical-pinkhouses-the-future-of-urban-farming [https://perma.cc/6K79-9ATC] (accessed Dec. 24, 2016).

[31] Dvorsky, *supra* note 25.

[32] FEEDING THE FUTURE, *supra* note 11, at 8.

[33] Dvorsky, *supra* note 25.

[34] *Id.*

continuously recycled from plant moisture and is not released into the ground or air since the system is enclosed.[35]

Indoor agriculture is also taking advantage of big data. For instance, Dr. Caleb Harper from the MIT Media Lab is currently developing an open source, digitized food-growing system platform.[36] Sensors monitor plant growing conditions and "fine-tune the light exposure, temperature, humidity, carbon-dioxide level, water cycle, and nutrient exposure according to a preset recipe for growing the plant."[37] These recipes are available for free on the platform and can be tweaked and improved by users.[38] Companies can use data collected from each harvest to perfect growing environments and continuously enhance farm efficiency and productivity.[39]

The indoor agriculture trend is in part a response to increasing consumer demand for local produce.[40] This new demand has been brought on somewhat by corporate marketing tactics, but also by a desire for freshness and the perception of healthfulness.[41] Indoor agriculture offers a decentralized supply chain and food produced geographically closer to consumers—for instance, one Nevada indoor farm picks basil at 5:00 AM that can be on tables in a Las Vegas casino restaurant by lunchtime.[42] Indoor agriculture promises freshness since farms can be positioned closer to cities: they are built up rather than out, taking up less ground-space, and can be housed in old warehouses or other buildings that are already close to consumers.[43] Additionally, produce from indoor farms may indeed be healthier; not only does the practice dramatically reduce the use of pesticides and herbi-

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[35] Dickie, *supra* note 18.

[36] *Overview*, MIT MEDIA LAB OPEN AGRIC., http://openag.media.mit.edu/about/ [https://perma.cc/F4QG-XVC4] (accessed Dec. 24, 2016). *See also* Frederic Lardinois, *Agrilyst Raises $1M Seed Round for Its Indoor Agriculture Analytics Service*, TECHCHRUNCH (May 11, 2016), https://techcrunch.com/2016/05/11/agrilyst-raises-1m-seed-round-for-its-indoor-agriculture-analytics-service/ [https://perma.cc/8GZZ-2XCF] (accessed Dec. 24, 2016) (describing how Agrylist, an indoor farming data service company, is launching a version of its service specifically for vegetable producers that "includes workflow management tools, as well as support for tracking inventory and managing nutrients and pests").

[37] Anderson, *supra* note 19.

[38] *Id.*

[39] Joshua Burd, *Future Farm: Indoor Agriculture Is Happening Today in Downtown Newark*, NJ BIZ (Apr. 25, 2016), http://www.njbiz.com/article/20160425/NJBIZ01/304259994/innovation——future-farm-indoor-agriculture-is-happening-today-in-downtown-newark [https://perma.cc/3GMZ-THX4] (accessed Dec. 24, 2016).

[40] Jodean Robbins, *The New Face of Hydroponics*, 32 PRODUCE BUS. 51, 52 (2016).

[41] *See id.*; FEEDING THE FUTURE, *supra* note 11, at 19 (asserting that fresh and local food has better taste, which partly explains consumer demands).

[42] FEEDING THE FUTURE, *supra* note 11, at 19 ("The number of farmers markets has more than doubled over the past decade, providing increased opportunities for consumers to 'buy local.' Small farms tend to favor direct-to-consumer channels as they offer logistic simplicity and higher per-unit margins."); *5 Reasons*, *supra* note 17.

[43] FEEDING THE FUTURE, *supra* note 11, at 41.

cides, but also, at least one study found 50% more vitamin C in tomatoes grown under LED lighting.[44]

Indoor farming producers also advertise the sustainability and precision of indoor farming, which caters to consumers' desire for environmentally-friendly and high-tech practices. Indoor agriculture reduces food waste and labor costs, drastically cuts pesticides, herbicides, and water usage (up to 95% for some farms), renders weather almost irrelevant, and shrinks travel distances and costs.[45] LED lights are cooler than traditional lighting so they can be placed close to plants, which reduces required energy and space.[46] On average, 30–40% percent of lettuce grown outdoors is wasted, compared to less than 3% of lettuce grown at an indoor plant factory in Japan.[47] And although indoor farms are physically smaller, newer farms may be up to seventy-five times more productive and ten times more efficient than conventional farms.[48]

B. Criticism and Response

Critics of indoor agriculture push back against claims of sustainability and the trend's ability to compete economically.[49] The larg-

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[44] Lori Zimmer, *Tomatoes Blasted with LED Lights Have 50 Percent More Vitamin C*, INHABITAT (May 9, 2013), http://inhabitat.com/tomatoes-blasted-with-led-lights-have-50-percent-more-vitamin-c/ [https://perma.cc/KS2M-GTS3] (accessed Dec. 24, 2016). *See also* Heather Platt, *Could the Future of Urban Agriculture Be Located Inside a Vernon Warehouse?*, L.A. WEEKLY (May 10, 2016), http://www.laweekly.com/restaurants/could-the-future-of-urban-agriculture-be-located-inside-a-vernon-warehouse-6896070 [https://perma.cc/62LM-DCPL] (acessed Dec. 24, 2016) (noting higher nutrient content in lettuce grown at an indoor farm in Los Angeles).

[45] J.D. Heyes, *The Future of Farming Will See Robots Replacing Field Workers . . . New Robot-Run Farm Factory Produces 30,000 Heads of Lettuce a Day*, NAT. NEWS (Feb. 2, 2016), http://www.naturalnews.com/052834_robot_workers_sustainable_agriculture_mini_farm_grow_boxes.html [https://perma.cc/KW36-4XJ3] (accessed Dec. 24, 2016); Lorraine Chow, *5 Ways Vertical Farms Are Changing the Way We Grow Feed*, ECOWATCH (Mar. 10, 2015), http://ecowatch.com/2015/03/10/vertical-farms-grow-food/ [https://perma.cc/SLY4-WASZ] (accessed Dec. 24, 2016); *Our Technology*, AEROFARMS, http://aerofarms.com/technology/ [https://perma.cc/D3NG-SPNM] (accessed Dec. 24, 2016).

[46] Doucleff, *supra* note 30.

[47] Dickie, *supra* note 18. "Losses in our food system occur throughout the supply chain. Food is lost on farms; during processing, distribution, and storage; in retail stores and food service operations; and in households for a variety of reasons at each stage." DANA GUNDERS, NAT. RES. DEF. COUNCIL, WASTED: HOW AMERICA IS LOSING UP TO 40 PERCENT OF ITS FOOD FROM FARM TO FORK TO LANDFILL 7 (2012). Produce may not even be harvested because of disease or weather damage, or simply because harvesting it may not cover labor and transportation costs. *Id.*

[48] Burd, *supra* note 39; *Environmental Outlook: The Growth of Large-Scale Indoor Urban Farming* at 11:44:29, NPR: THE DIANE REHM SHOW (Feb. 3, 2016), http://the dianerehmshow.org/shows/2016-02-03/environmental-outlook-the-growth-of-large-scale-indoor-urban-farming [https://perma.cc/9M76-RTRJ] (accessed Dec. 24, 2016).

[49] *See* FEEDING THE FUTURE, *supra* note 11, at 20, 36 (citing common criticisms of the economic viability of indoor agriculture); George Monbiot, *Greens Living in Ivory Towers Now Want to Farm Them Too*, GUARDIAN: ENV'T (Aug. 16, 2010), http://www.theguardian.com/commentisfree/2010/aug/16/green-ivory-towers-farm-skyscrapers [https://

est growing U.S. vertical farm company currently does not turn a profit, and some agricultural experts are skeptical that these types of farms ever could.[50] For one thing, land in rural areas is abundant and cheap compared to the real estate in and around major cities that is sold at a premium.[51] Piled on top of this baseline are costs for development approval, infrastructure, construction, and ongoing sophisticated lighting, irrigation, and retention systems.[52] Keeping lights on sixteen-to-eighteen hours a day is currently an astronomical energy cost, and not exactly the pinnacle of sustainability.[53] It is impossible to beat the $0 price tag of free sunlight used in conventional farming. The world's largest producing vertical farm, based in New Jersey, is being subsidized by the state's government and will cost $39 million for about an acre of square footage dedicated to growing arugula and kale.[54] In comparison, the average price of an acre of farmland in Iowa is less than $8,000.[55]

Still, these criticisms are likely overstated. At least one American company sees an economically viable future for indoor agriculture, and is planning to build twenty-five indoor farms over the next five years.[56] Plus, multiple avenues can help reduce costs. Repurposing abandoned warehouses or other buildings can cut start-up expenses, and company founders expect economies of scale to considerably reduce the price of the emerging technologies.[57] LED bulbs have gone from 20%–68% efficient in the last five years, and are expected to see continued improvements.[58] Additionally, plants will continue to be bred and cultivated more precisely for indoor environments, which could lower costs even

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perma.cc/9RC2-R8AA] (accessed Dec. 24, 2016) (criticizing indoor farming's expense and energy needs).

[50] *See* Chris Clayton, *Urban Farming Goes High-Tech*, PROGRESSIVE FARMER (May 2, 2016), https://www.dtnpf.com/agriculture/web/ag/news/farm-life/article/2016/05/02/aerofarms-seeks-change-model-indoor [https://perma.cc/ZC8X-LTTZ] (accessed Dec. 24, 2016) (asserting that Aerofarms is not yet profitable); BIRKBY, *supra* note 20, at 4 (listing expense and energy issues).

[51] Scott Beyer, *Newark Subsidizes a Crackpot Idea: Vertical Farming*, FORBES (Apr. 9, 2015), http://www.forbes.com/sites/scottbeyer/2015/04/09/newark-subsidizes-a-crackpot-idea-vertical-farming/#35511348784b [https://perma.cc/M7A9-EJZD] (accessed Dec. 24, 2016).

[52] *Id.*

[53] Jeff Wells, *Indoor Farming: Future Takes Root in Abandoned Buildings, Warehouses, Empty Lots and High Rises*, INT'L BUS. TIMES (Aug. 9, 2014), http://www.ibtimes.com/indoor-farming-future-takes-root-abandoned-buildings-warehouses-empty-lots-high-rises-1653412 [https://perma.cc/44MS-HYSS] (accessed Dec. 24, 2016).

[54] Beyer, *supra* note 51.

[55] *Id.* "A few years ago in Vancouver, a company sought to install a massive greenhouse for vertical lettuce production on top of a city-owned parking structure, but failed. Some of it had to do with investors and contracts with the city, but it was also hampered by high startup costs relative to the resulting crop yields. . . . Currently, the Vancouver company is trying to sell their failed $1.5 million greenhouse on craigslist." Dvorsky, *supra* note 25.

[56] Clayton, *supra* note 50.

[57] Burd, *supra* note 39.

[58] *Environmental Outlook*, *supra* note 48, at 11:24.

more.[59] For example, a plant factory can control the root weight of crisp head lettuce so that 92% of the plant's total weight is salable compared to 40% of the same plant grown conventionally.[60] Importantly, many cost comparisons fail to take into account the full cost of conventional farming, and simply compare the price of land to the start-up expenditures, rather than looking at labor, machinery, transportation, storage, and environmental externalities like the cost of air and water pollution on surrounding communities.[61] A leading academic anticipates capital costs will reduce by half over the next five years, making indoor farming much closer to achieving field parity with traditional farms.[62]

Some types of produce are more economically viable than others. Lettuce and leafy greens are well-suited to indoor farming since they are fast-growing (they can mature in less than a month) and can be sent to market quickly.[63] They are the most common type of indoor farm produce right now, though small rooted vegetables are starting trial production.[64] An Indoor Agriculture Convention white paper notes that "[p]rice parity has already been reached for some high-value crops and in certain markets during winter . . . [, and as] technologies continue to advance, the primary cost drivers of the industry—capital equipment, and labor, electricity, and nutrients per harvested plant—will continue to decrease."[65] Still, many believe urban agriculture is unlikely to replace conventional agriculture anytime soon—if ever—because staple crops like wheat, corn, and soybeans are optimized for conventional outdoor growing.[66] Even so, the inventor of aeroponics is currently working to develop large-scale grow systems for wheat.[67]

Furthermore, comparisons often fail to consider existing Asian indoor farms, which have shown economic viability in countries like Japan.[68] Over 75% of Japan's plant factories in 2014 either made a profit

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[59] Wells, *supra* note 53.

[60] PLANT FACTORY: AN INDOOR VERTICAL FARMING SYSTEM FOR EFFICIENT QUALITY FOOD PRODUCTION 24 (Toyoki Kozai et al. eds., 2016).

[61] Telephone Interview with Dickson Despommier, Professor of Pub. Health and Microbiology, Columbia Univ. Med. Ctr., Owner, Vertical Farm Techs. (May 9, 2016) [hereinafter Despommier].

[62] NEWBEAN CAPITAL & LOCAL ROOTS, ROBOTICS AND AUTOMATION IN INDOOR AGRICULTURE 4, 23 (Oct. 2015).

[63] Dickie, *supra* note 18; Laurie Winkless, *Urban Farming: Fad or Futureproof?*, FORBES (Mar. 9, 2016), http://www.forbes.com/sites/lauriewinkless/2016/03/09/urban-farming-fad-or-futureproof/#34dd86f0ead8 [https://perma.cc/K5GA-269F] (accessed Dec. 24, 2016).

[64] PLANT FACTORY, *supra* note 60, at 27. Characteristics of plants suited to indoor agriculture include: short height, growing well under low light intensity and high planting density, high value, a capacity to be improved with environmental control, and around 85% of the plant being salable. *Id.* at 19.

[65] FEEDING THE FUTURE, *supra* note 11, at 48.

[66] Wells, *supra* note 53.

[67] Despommier, *supra* note 61.

[68] Christine Eigenbrod & Nazim Gruda, *Urban Vegetable for Food Security in Cities: A Review*, 15 AGRONOMY FOR SUSTAINABLE DEV. 483, 490 (2015).

or broke even, and the 25% losing money were simply unaware of the "necessity of CO_2 enrichment in an airtight [indoor farm]."[69] Seoul's city government plans to build 1,800 urban gardens inside unused school spaces, rooftops, and other areas by 2018: ideally, every home in the city will be within a ten-minute walk to one of these gardens.[70]

Finally, sustainability concerns about energy usage continue to be addressed as indoor farms are updated and improved—for example, like the new version of vertical farm called the Skyfarm.[71] The prototype is designed with hydro-, aero-, and aquaponic technologies to produce food in urban or nutrient-poor areas, and relies on wind turbines attached to the top for electricity.[72] In 2016, the project won an award for sustainability at the Architectural Review MIPIM Future Projects Awards.[73]

III. AGROTERRORISM

Only since the September 11th attacks has agroterrorism really been recognized by the United States as a national security threat.[74] This Section explores this relatively new concern. First, it defines *agroterrorism* and describes types and characteristics of possible biological agents that could be used against the agricultural sector. Then it discusses possible agroterrorists by reviewing historical actors and likely characteristics for actors today.

A. Defining Agroterrorism

Agroterrorism is a subset of terrorism that directs intentional harm towards the agricultural sector, including both croplands and livestock facilities.[75] Specifically, agroterrorism is "the deliberate introduction of an animal or plant pest with the goal of generating fear, causing economic damage, and/or undermining social stability."[76] Although the definition generally includes the use of chemical, radioac-

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[69] PLANT FACTORY, *supra* note 60, at 26.

[70] Kim, *supra* note 21.

[71] *Overview: Skyfarm*, ROGERS STIRK HARBOUR & PARTNERS, http://www.rsh-p.com/projects/skyfarm/ [https://perma.cc/F6P9-FRUM] (accessed Dec. 24, 2016).

[72] *Id.*

[73] *Skyfarm Wins Sustainability Award at MIPIM*, ROGERS STIRK HARBOUR & PARTNERS (Mar. 16, 2016), http://www.rsh-p.com/news/2016/skyfarm-wins-ar-mipim-sustainability-prize/ [https://perma.cc/XG2W-GXPG] (accessed Dec. 24, 2016).

[74] JIM MONKE, CONG. RESEARCH SERV., RL32521, AGROTERRORISM: THREATS AND PREPAREDNESS (2007).

[75] EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION, EPPO INFORMATION ON PLANT HEALTH ASPECTS OF BIOTERRORISM: THREATS AND PREPAREDNESS (Sept. 2007) [hereinafter EPPO]. The term *agroterrorism* was only added to the Oxford English Dictionary in 2006, defined as "activity intended to damage a country's agriculture, *esp*. the use of a biological agent against crops, livestock, etc., in order to disrupt or infect the food supply." James Gleick, *Cyber Neologoliferation*, N.Y. TIMES MAG. (Nov. 5, 2006), http://www.nytimes.com/2006/11/05/magazine/05cyber.html [https://perma.cc/A6GT-6YEM] (accessed Dec. 24, 2016).

[76] EPPO, *supra* note 75.

tive, nuclear, or explosive agents, this Article will mostly focus on biological agroterrorism.[77] It is virtually impossible to list all the possible methods of attack an agroterrorist could use; the agricultural system has multiple points of entry, many different agents or weapons could be used, and endless routes of infection, disease spread, and other harms exist.[78]

1. Types of Biological Agroterrorism Agents

Biological agroterrorism generally involves some kind of dissemination vehicle to spread viruses, bacteria, toxins, or other harmful agents that infect or kill humans, livestock, or crops.[79] An attack could involve well-known biological weapons like bacillus anthracis (anthrax) or foot-and-mouth disease (FMD), but it can also include use of higher-order animals like poisonous snakes or activities like polluting water supplies with dead animals.[80] For agroterrorism, pathogens—bacteria, viruses, or other microorganisms—are mostly considered in the context of dissemination among livestock or croplands.[81]

The Animal and Plant Health Inspection Service (APHIS) developed a list of biological agents and toxins that have "the potential to pose a severe threat to agricultural production or food products."[82] Some of these agents, like FMD virus or lumpy skin disease virus, affect multiple animal species.[83] While FMD is not considered a direct threat to human health and often does not outright kill animals, it has

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[77] MONKE, *supra* note 74, at 7.

[78] Helen S. Lawrence, *Potential Agroterrorism Vulnerabilities in American Agriculture*, GEO. MASON U. 10 (2011), http://0-search.proquest.com.gull.georgetown.edu/docview/851549872?accountid=36339 (accessed Nov. 27, 2016).

[79] *See* Orlando Cenciarelli et al., *Bioweapons and Bioterrorism: A Review of History and Biological Agents*, 6 DEF. S&T TECH. BULL. 111, 111 (2013) (explaining that biological warfare has historically been defined "as the intentional use of microorganisms, and toxins . . . to produce diseases and deaths among humans, livestock and crops . . . [and requires] the presence of . . . one or more pathogens . . . and a vehicle for their dissemination"); *Bioterrorism Overview*, CDC, http://emergency.cdc.gov/bioterrorism/overview.asp [https://perma.cc/2349-R6DS] (updated Feb. 12, 2007) (accessed Dec. 24, 2016) (defining *bioterrorism* as a "deliberate release of viruses, bacteria, or other germs (agents) used to cause illness or death in people, animals, or plants").

[80] W. Seth Carus, *The History of Biological Weapons Use*, 13 HEALTH SECURITY 219, 220 (2015). Some agents that are technically 'biological' and could be used as 'weapons' are not typically considered 'biological weapons.' For instance, trying to spread locusts into enemy territory would fall into this category, although if they spread disease, the insects would then probably be considered biological weapons. *Id.* ("Insects are also excluded as weapons, unless used as a vector to spread a pathogen.").

[81] David F. Grieco, *Closing the Barn Door: Interagency Approaches to Reduce Agroterrorism Threats*, 6 INTERAGENCY J. 28, 28 (Spring 2015).

[82] MONKE, *supra* note 74, at 44–45; 9 C.F.R. § 121.3(a)–(f) (2014) (listing "biological agents and toxins [that] have the potential to pose a severe threat to animal health or to animal products"). APHIS is part of the USDA and its mission is "to protect the health and value of American agriculture and natural resources." *About APHIS*, APHIS (Aug. 3, 2015), https://www.aphis.usda.gov/aphis/banner/aboutaphis [https://perma.cc/AV47-BQQK] (accessed Dec. 24, 2016).

[83] MONKE, *supra* note 74, at 45.

been called the most dangerous disease for livestock because of its characteristics: it is highly infectious among multiple species, renders livestock unable to eat, drink, or walk, and causes painful blisters that can destroy hooves.[84] Other agents affect only one type of animal, like BSE or rinderpest virus for cows, or classical swine fever virus for pigs.[85]

Some agents are also harmful to humans. APHIS-listed agents that overlap with the Centers for Disease Control and Prevention's (CDC) list of agents posing risk to human health include anthrax, rift valley fever virus, and eight others.[86] These agents can be extremely dangerous. Anthrax, for instance, has a 75% human fatality rate when it infects the respiratory tract and can survive in soil for up to 200 years.[87]

APHIS also lists agents and toxins that pose a severe threat to plants or plant products.[88] These viruses, bacteria, or fungi can cause widespread losses of important crops like potatoes, rice, corn, and citrus, with the potential for substantial economic damage.[89] They can cause diseases like brown rot, potato wart, and citrus greening, among others.[90] Unlike diseases for animals, eradicating the most contagious plant pathogens has rarely been attempted; farmers instead rely on managing diseases at a low incidence or severity.[91]

2. Characteristics of Biological Agroterrorism Agents

Biological agents can be appealing weapons largely because of their useful characteristics. Importantly, most can easily multiply within and move between hosts, which creates unpredictable spreading and disease transmission.[92] For instance, animals infected with FMD shed huge amounts of the virus that easily infect other animals either by direct contact or at a distance by contaminating water and

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[84] Roger Breeze, *Agroterrorism: Betting Far More Than the Farm*, 2 BIOSECURITY & BIOTERRORISM 251, 251–52 (2004).

[85] MONKE, *supra* note 74, at 45. "BSE, or 'mad cow disease,' is considered dangerous enough to be a select agent, even though mad cow disease is less likely to be a terrorist's choice than other diseases. With BSE, infection is not certain, symptoms take years to manifest, and the disease may not be detected—all making credit for an attack more doubtful." *Id.* at 46.

[86] 9 C.F.R. § 121.4(b) (2014). The World Organisation for Animal Health (OIE) describes some of these diseases, and others, with its Technical Disease Cards. *Technical Disease Cards*, WORLD ORG. ANIMAL HEALTH, http://www.oie.int/animal-health-in-the-world/technical-disease-cards/ [https://perma.cc/ADH7-ZZJS] (accessed Dec. 24, 2016).

[87] Cenciarelli et al., *supra* note 79, at 119–20 (citing ECP Yuen, *Biological Warfare: The Facts*, 8 H.K. J. EMERGENCY MED. 232, 234 (2001)).

[88] *See* 7 C.F.R. § 331.3 (2014) ("[T]he Administrator has determined that the biological agents and toxins listed in this section have the potential to pose a severe threat to plant health or to plant products.").

[89] MONKE, *supra* note 74, at 46–47.

[90] *Id.* at 47.

[91] L.V. Madden & M. Wheelis, *The Threat of Plant Pathogens As Weapons Against U.S. Crops*, 41 ANN. REV. PHYTOPATHOLOGY 155, 159 (2003).

[92] Cenciarelli et al., *supra* note 79, at 112.

feed; it can even be spread "for many miles in atmospheric plumes of aerosol droplets."[93] Furthermore, most agents are invisible and therefore cannot be identified until after spreading begins.[94] This lag time can allow an agent to become established and spread before farmers even begin to respond.

B. Possible Agroterrorists

1. Historical Agroterrorism

Historically, non-state actors have used agroterrorism in only a few instances, but these attacks illustrate the wide breadth of motive and method.[95] In 1952 for instance, a Kenyan national liberation group called the 'Mau Mau' poisoned cattle at a British mission station to further its effort to end British colonial rule.[96] Thirty-three years later, an attack involved Mexican contract workers whose job it was to eradicate screwworm near the border of the United States.[97] Concerned about protecting their jobs, the workers deliberately spread the insect among livestock in the area.[98] In 1997, Israeli settlers in the Gaza Strip destroyed 17,000 metric tons of Palestinian grapes using pesticides.[99] Non-state actors have also made documented agroterrorism threats in Sri Lanka, Australia, Uganda, and the United States.[100]

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[93] Breeze, *supra* note 84, at 252.

[94] Cenciarelli et al., *supra* note 79, at 111.

[95] Haralampos Keremidis et al., *Historical Perspective on Agroterrorism: Lessons Learned from 1945 to 2012*, 11 BIOSECURITY & BIOTERRORISM s17, s22 (2013). This article is limited to terrorist attacks by non-state actors, although state actors have also developed agricultural biological weaponry, including "Canada (1939–1969), France (1922–1928, 1934–1940, and 1947–1972), Japan (1930–1945), Germany (1923–1945), the United Kingdom (1940–1964), the Soviet Union (1928–1992), Iraq (1974–1991), South Africa (1981–1995), Hungary (1936–1944 and 1945–1989), and the United States (1942–1969), to name just a few." *Id.* at s18.

[96] *Id.* at s21.

[97] *Id.*

[98] *Id.*

[99] JIM MONKE, CONG. RESEARCH SERV., RL32521, AGROTERRORISM: THREATS AND PREPAREDNESS 5–6 (2004).

[100] *Agroterrorism Incidents*, GOOGLE MAPS, https://www.google.com/maps/d/u/0/viewer?mid=ZJMDYRQ7xfXI.khqBD06gzwRI&hl=EN_US [https://perma.cc/W4VZ-RTS9] (accessed Dec. 24, 2016). One U.S. example of agroterrorism involves food contamination rather than a threat or attack on a farm or livestock facility. In 1984, a cult in The Dalles, Oregon, contaminated multiple salad bars with salmonella in a dry-run attempt to temporarily reduce the voting population in the county. The cult planned to contaminate the county's water supply close to an election, allowing their members who were running for county commissioner and sheriff's office positions to then be elected when voters failed to turn out. The water contamination never occurred, but more than 750 people got sick from the salad bar dry run. *25 Years to Oregon Salmonella Bioterrorism*, HOMELAND SECURITY NEWS WIRE (Oct. 7, 2009), http://www.homelandsecuritynewswire.com/25-years-oregon-salmonella-bioterrorism [https://perma.cc/QAD8-C2FC] (accessed Dec. 24, 2016). *See also What Are Some Examples of Agroterrorism?*, EXTENSION (Apr. 26, 2010), http://articles.extension.org/pages/37146/what-are-some-examples-of-agroterrorism [https://perma.cc/HC76-SDLN] (accessed Dec. 24, 2016) (describing agroterrorism attacks in Wisconsion).

2. Categories of Possible Agroterrorists Today

A 2005 Department of Justice report outlines several categories of possible agroterrorists.[101] These categories include international terrorist groups such as al-Qaeda; economic opportunists who may want to use a deadly virus outbreak to manipulate markets for personal gain; domestic terrorists such as an unbalanced person, disgruntled employee, apocalyptic sect, or person wanting to harm the government; and militant animal rights activists who may believe an attack is warranted to end the use of animals for food.[102] Though not a result of a terrorist attack, a 1970 outbreak of leaf blight on corn shows how lucrative a single outbreak of disease can be for just a few individuals.[103] As the blight spread, the media took notice, and the weekend headline "Corn Market in Turmoil" shattered trading records the following Monday.[104] Three days later, future prices of corn jumped thirty cents per bushel—an enormous amount considering the millions of bushels traded.[105] One corn trader made a $500,000 profit in a single month, amounting to over $3 million today.[106]

Fears of an attack on the U.S. agricultural sector are not unfounded. In 2002, a Navy SEAL team found hundreds of concerning documents during a raid of a known al-Qaeda storehouse in caves in eastern Afghanistan.[107] The storehouse contained a collection of American science journals; USDA papers; lists of livestock pathogens like FMD, hog cholera, and rinderpest; and lists of crop diseases like soybean rust and rice blight.[108] The team also found training documents for using the pathogens on U.S. farms.[109] Though the attacks never came to pass, the episode demonstrates the possibility of future agroterrorist threats to the U.S. agricultural system.

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101 TERRY KNOWLES ET AL., DEFINING LAW ENFORCEMENT'S ROLE IN PROTECTING AMERICAN AGRICULTURE FROM AGROTERRORISM 24 (2005).

102 *Id.*; *see* Keremidis et. al., *supra* note 95, at s19 ("The 4 categorized bioterrorist groups might have different motives for using biological weapons[,] . . . but the common thread is their willingness to use biological weapons to effect changes in society.").

103 *See Corn Disease Panics Stock Market, U.S. President*, WEBGROWER.COM, http://www.webgrower.com/information/corn_panic.html [https://perma.cc/5Z7A-P38A] (updated July 30, 2016) (accessed Dec. 24, 2016) (explaining how the outbreak of leaf blight in corn resulted in steep price rises in corn trading).

104 *Id.*

105 *Id.*

106 *Id.*

107 Jesse Hirsch, *Food (In)security: Are Farms the Next Terrorist Target?*, MOD. FARMER (Dec. 16, 2013), http://modernfarmer.com/2013/12/food-insecurity-farms-next-terrorist-target/ [https://perma.cc/5TZT-FTXS] (accessed Dec. 24, 2016).

108 *Id.*

109 *Id.*; *Agroterrorism: The Threat to America's Breadbasket: Hearing Before the Comm. on Govt'l Affairs*, 108th Cong. 2 (2003) (statement of Susan M. Collins) [hereinafter *Breadbasket*] ("The Poisoner's Handbook, an underground pamphlet published here in the United States that provides detailed instructions on how to make powerful plant, animal, and human poisons from easily obtained ingredients and how to disseminate them[,] . . . was found in Afghanistan in the hands of a group known to support al-Qaeda.").

IV. RISK OF AN AGROTERRORIST ATTACK ON THE UNITED STATES

This Section will analyze the risk of an agroterrorist attack on the United States by first describing the current state of the agricultural sector, and then examining three elements of risk: the threat of an attack, the vulnerability of the system, and the possible consequences of a successful attack. Overall, the risk of an attack is probably somewhat low because the threat—especially the intent portion of the analysis—is also likely quite low.[110] However, industrialization has weakened the agricultural sector's resilience, thereby increasing its vulnerability, the potential consequences of an attack, and the overall risk of agroterrorism.[111] As industrialization progresses, this risk will arguably continue to climb unless fundamental changes are made to the agricultural system.

A. State of the United States Agricultural System

Agriculture and its related industries are hugely important to the American economy today. In 2014, the industry made up 4.8% of the United States' gross domestic product, around $835 billion.[112] Almost 10% of employment was related to agriculture, accounting for 17.3 million full- and part-time jobs.[113] Over half of the United States' 2.3 billion acres is used for agricultural production, including cropland, pasture, and grazed forestland.[114]

1. Changes to the Agricultural Sector

Beginning in the mid-1900s, agricultural productivity in the United States skyrocketed—between 1948 and 2011, crop and livestock productivity grew by 163% and 130%, respectively.[115] As part of this boost, farms scaled up and consolidated. The agricultural work force halved and the number of individual farms dropped from a peak of around 6.8 million in 1935 to around 2 million by the 1970s, where it

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110 PETER CHALK, RAND NAT'L DEF. RES. INST., HITTING AMERICA'S SOFT UNDERBELLY: THE POTENTIAL THREAT OF DELIBERATE BIOLOGICAL ATTACKS AGAINST THE U.S. AGRICULTURAL AND FOOD INDUSTRY 15 (2004).

111 *See* Rotz & Fraser, *supra* note 8, at 467. ("[T]he North American food system is now, more than ever before, displaying certain characteristics of a . . . system . . . vulnerable to external shocks such as those caused by . . . contamination.").

112 *Ag and Food Statistics: Charting the Essentials*, ECON. RES. SERV., USDA, http://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/ [https://perma.cc/F8HB-EMVS] (updated Oct. 11, 2016) (accessed Dec. 24, 2016) [hereinafter *Ag and Food Statistics*]. This includes sectors "related to agriculture—forestry, fishing, and related activities; food, beverages, and tobacco products; textiles, apparel, and leather products; food service and drinking places [that] rely on agricultural inputs in order to contribute added value to the economy." *Id.*

113 *Id.* The bulk of these jobs were for food services and drinking places. *Id.*

114 *Ag and Food Statistics*, *supra* note 112.

115 SUN LING WANG ET AL., USDA, AGRICULTURAL PRODUCTIVITY GROWTH IN THE UNITED STATES: MEASUREMENT, TRENDS, AND DRIVERS 6 (2015).

has generally remained.[116] Farming operations now average 430 acres, about three times larger than farms in 1935.[117] In 2007, 9% of U.S. farms accounted for 80% of total sales.[118]

This surge in productivity and scale has been attributed mainly to industrialization stemming from electrification, improved machinery, chemical inputs, plant and animal breeding, and governmental agricultural policies.[119] As a result, the American agricultural sector has become considerably more concentrated and connected, and much less biodiverse over the past sixty years or so.[120] These changes have contributed to declines in agricultural resilience, defined as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, . . . and the capacity to adapt to stress and change."[121]

2. Livestock

Today, the traditionally small, family-owned animal farms have largely been replaced with enormous livestock production facilities called Concentrated Animal Feeding Operations (CAFOs).[122] These feedlots contain hundreds, thousands, or hundreds of thousands of animals that live in crowded warehouses and are bred almost exclusively for rapid and extreme growth.[123] CAFOs developed because their economies of scale and closer, formal links between livestock providers and processors increase productivity and lower costs for consumers.[124] In

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116 PAUL K. CONKIN, A REVOLUTION DOWN ON THE FARM: THE TRANSFORMATION OF AMERICAN AGRICULTURE SINCE 1929 98 (2008); *Ag and Food Statistics*, *supra* note 112.

117 *Ag and Food Statistics*, *supra* note 112.

118 *U.S. Farms—Large and Small*, ECON. RES. SERV., USDA, https://www.ers.usda.gov/webdocs/publications/eib48/10596_page6.pdf [https://perma.cc/4B3Y-J5JE] (accessed Dec. 24, 2016).

119 CONKIN, *supra* note 116, at 99.

120 Rotz & Fraser, *supra* note 8, at 462, 464, 467. Biodiversity is used here as the "level of species richness that is functionally effective for the given system." *Id.* at 460.

121 *Id.* at 460, 468 (quoting Nathan L. Engle et al., *Towards a Resilience Indicator Framework for Making Climate-Change Adaptation Decisions*, 19 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 1295 (2014)).

122 *See* CARRIE HRIBAR, NAT'L ASS'N OF LOCAL BOARDS OF HEALTH, UNDERSTANDING CONCENTRATED ANIMAL FEEDING OPERATIONS AND THEIR IMPACT ON COMMUNITIES (2010) (noting that livestock farming has significantly transformed in the past few decades from small, family-owned farms to large concentrated animal feeding operations); 40 C.F.R. § 122.23(b) (2012) (defining concentrated animal feeding operations). The terms *CAFO*, *feedlot*, and *factory farm* are used interchangeably throughout this Article.

123 *See* CTR. FOR FOOD SAFETY, AMERICA'S SECRET ANIMAL DRUG PROBLEM: HOW LACK OF TRANSPARENCY IS ENDANGERING HUMAN HEALTH AND ANIMAL WELFARE 2 (Sept. 2015), http://www.centerforfoodsafety.org/files/animal_drug_final_63173.pdf [https://perma.cc/H46C-UVJ8] (accessed Dec. 24, 2016) ("[A]nimals are industrially bred for rapid growth and high output and are tightly crammed, caged, and sometimes even chained or tethered.").

124 James M. MacDonald & William D. McBride, *The Transformation of U.S. Livestock Agriculture: Scale, Efficiency, and Risks*, 43 USDA ECON. INFO. BULL., at iii (2009).

2005, for instance, dairy farms with 1,000 cows or more had average costs 15% below dairy farms with 500–900 cows, and 35% below those with 100–199 cows.[125]

Because CAFOs are often overcrowded, dirty, and poorly ventilated, the animals raised in them are more vulnerable to disease.[126] To remedy the issue, farmers enrich animal feed with a cocktail of hormones, additives, and low-level doses of antibiotics to keep livestock from getting sick.[127] Consistent low-level antibiotic use is viewed as economical: farmers do not have to make expensive improvements to CAFO conditions, and its use increases an animal's weight gain per unit of feed.[128] However, it also allows animals with weaker immune systems to live, pass these weak traits on to their offspring, which eventually increases the susceptibility of entire herds of animals to a variety of diseases.[129]

Another industrial practice, selective breeding, also maximizes livestock productivity by concentrating on production features rather than improving animal health. For instance, hens can now produce around 300 eggs per year, cows deliver more than 10,000 liters of milk in a single lactation period, and chickens reach slaughtering weight after just five weeks of intensive raising.[130] Enhanced performance is targeted towards increasing salable parts of the animal such as muscle size or milk production, and minimizing energy consumption of other bodily functions, such as the immune system.[131] As a result, animals are highly reliant on specific environments, cannot easily fight infections, and are increasingly genetically homogeneous.[132]

Livestock farming sectors tend to concentrate in specific locations around the United States. Cattle are mostly located in the middle of

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125 *Id.*

126 *See* FOOD & WATER WATCH, FACTORY FARM NATION: HOW AMERICA TURNED ITS LIVESTOCK FARMS INTO FACTORIES (2010) ("Crowded, unsanitary conditions leave animals susceptible to disease . . . .").

127 *See id.* (stating that the conditions in CAFOs making animals more vulnerable to disease also drive the use of antibiotics and hormone treatments).

128 *Prescription for Trouble: Using Antibiotics to Fatten Livestock*, UNION CONCERNED SCIENTISTS, http://www.ucsusa.org/food_and_agriculture/our-failing-food-system/industrial-agriculture/prescription-for-trouble.html [https://perma.cc/YM9P-CBZM] (accessed Dec. 24, 2016).

129 Jonathan Knutson, *FDA's New Prescription: Veterinarians Must Give Oversight on Drug Use*, AGWEEK (Nov. 30, 2015), http://www.agweek.com/news/north-dakota/3892847-fdas-new-prescription-veterinarians-must-give-oversight-drug-use [https://perma.cc/E4KS-YY76] (accessed Dec. 24, 2016).

130 Anita Idel, *Livestock Production and Food Security in a Context of Climate Change, and Environmental and Health Challenges*, U.N. TRADE & ENV'T REV. 138, 145 (2013).

131 *Id.* at 145.

132 *See id.* at 146 (stating that the current practices of industrial livestock production are causing a loss of genetic diversity and increasing animals' vulnerability to pests and infectous diseases).

the country and California.[133] Hog production is clustered in North Carolina, Iowa, and several other Midwestern states.[134] Chicken farming is located in the South and California, and dairy is produced around the edges of the country, but especially in California and Wisconsin.[135]

3. Cropland

The growing and harvesting of crops has also seen dramatic change over the past century. In the early 1900s, farmers planted crops over large areas and spent significant amounts of time in fields, allowing them to readily recognize plant diseases and other threats.[136] More than half of the U.S. population lived in rural areas, and the small, diversified farms there employed close to half of the U.S. workforce.[137]

By the twenty-first century, however, small numbers of enormous and specialized farms with fewer farmworkers who spent far less time in fields were the norm.[138] Animal and human labor was largely replaced by tractors and other machinery.[139] Productivity and yields increased with advancements in plant breeding and the development of inexpensive chemical fertilizers and pesticides.[140] Vertical integration—the merging of two businesses operating at different stages of production—and "development of special-use, high-value commodities" contributed to upsurges in farm specialization and scale.[141]

Industrialized farming and genetic modification of crops has promoted monocultures—"the practice of growing single crops intensively on a very large scale"—and contributed to declines in biodiversity.[142]

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[133] *Factory Farm Map*, FOOD & WATER WATCH, http://www.factoryfarmmap.org/#animal:hogs;location:US;year:2012 [https://perma.cc/N7RW-B5NP] (accessed Dec. 24, 2016).

[134] *Id.*

[135] *Id.*

[136] Lawrence, *supra* note 78, at 4.

[137] Carolyn Dimitri et al., *The 20th Century Transformation of U.S. Agriculture and Farm Policy*, 3 USDA ECON. INFO. BULL. 2 (2005), https://www.ers.usda.gov/webdocs/publications/eib3/13566_eib3_1_.pdf [https://perma.cc/2YTX-CGKU] (accessed Dec. . 24, 2016).

[138] *Id.* at 2.

[139] *Id.* at 2, 6.

[140] *Id.* at 6.

[141] *Id.* at 7.

[142] *Industrial Agriculture: The Outdated, Unsustainable System that Dominates U.S. Food Production*, UNION CONCERNED SCIENTISTS, http://www.ucsusa.org/our-work/food-agriculture/our-failing-food-system/industrial-agriculture [https://perma.cc/E6FW-7TKD] (accessed Dec. 24, 2016); Deniza Gertsberg, *Loss of Biodiversity and Genetically Modified Crops*, GMO J. (June 17, 2011), http://gmo-journal.com/2011/06/17/loss-of-biodiversity-and-genetically-modified-crops/ (accessed Dec. 24, 2016) ("[I]ndustrial forms of agriculture, with emphasis on large-scale monoculture crop production, have a negative impact on biodiversity."). Paradoxically, effective crop breeding and genetic engineering to improve resilience, taste, texture, and other valued characteristics depend on biodiversity. THE WORLDWATCH INSTITUTE, STATE OF THE WORLD 2005: REDEFINING

This reduced biodiversity has made crops more vulnerable to new pests and pathogens (other than those that genetic engineering protects against), and has negatively impacted surrounding ecosystems and environments.[143] A well-known example of the weakness of monocultures is the Irish potato famine of the late 1840s, when large areas of uniform potato crops became diseased, leading to overwhelming losses.[144] Monocultures have been further encouraged by outdated Farm Bill rules prohibiting farmers who grow commodity crops (such as soy, corn, or wheat) from also growing fruits and vegetables, as well as by free-trade mechanisms.[145]

Crops also tend to concentrate in specific regions. The largest commodity crops grown in the United States are corn, soybeans, wheat, and cotton, and are mostly located in the Midwest.[146] Corn, the largest of the four, is produced principally in Iowa, with much of it going to animal feed, ethanol, and high fructose corn syrup.[147] California is responsible for most of the produce consumed in the United States: the California Central Valley alone produces two-thirds of the nation's produce and 80% of the world's almonds.[148]

GLOBAL SECURITY 66 (2005) [hereinafter REDEFINING GLOBAL SECURITY]. Efforts towards conserving biodiversity can be seen in the 1,300 seed gene banks around the world, housing around 6 million population samples. P. E. Rajasekharan, *Gene Banking for* Ex Situ *Conservation of Plant Genetic Resources*, *in* PLANT BIOLOGY & BIOTECHNOLOGY 445 (Bir Bahadur et al. eds., 2015).

143 Gertsberg, *supra* note 142.

144 BIODIVERSITY INT'L, THE ROLE OF CROP GENETIC DIVERSITY IN THE AGRICULTURAL PRODUCTION SYSTEM TO REDUCE PEST AND DISEASE DAMAGE (Devra R. Jarvis et al. eds., 2011).

145 *See* Natasha Geiling, *California's Drought Could Upend America's Entire Food System*, THINKPROGRESS (May 5, 2015), http://thinkprogress.org/climate/2015/05/05/3646965/california-drought-and-agriculture-explainer/ [https://perma.cc/8LDA-M6GP] (accessed Dec. 24, 2016) [hereinafter *California's Drought*] ("From 1996 until the most recent version of the Farm Bill, farmers that grew commodity crops like corn and soy were actually prohibited from also growing specialty crops like fruits and vegetables on their land. Anyone who grew a specialty crop on land meant for subsidized commodity crops would have to forfeit their subsidy and pay a penalty equal to the market value of whatever specialty crop they grew, a policy that did little to discourage farmers in the Midwest from becoming large producers of one or two commodity crops."); Rotz & Fraser, *supra* note 8, at 463 ("In fact, free-trade mechanisms have led to further farm-scale specialization . . . because factors such as the promotion of agrochemical use, single crop machinery, crop-based financial loans, and pressure from both governments and agribusinesses to achieve economies of scale, all directly influenced the trend toward specialization and remain intact under market liberalization.").

146 USDA, LONG-TERM PROJECTIONS 28 (Feb. 2016), https://www.ers.usda.gov/webdocs/publications/oce20161/56729_oce-2016-1.pdf [https://perma.cc/J9FS-JXBY] (accessed Dec. 24, 2016).

147 *Corn for All Purposes*, NAT'L AGRIC. STAT. SERV., USDA, https://www.nass.usda.gov/Charts_and_Maps/Crops_County/pdf/CR-PL15-RGBChor.pdf [https://perma.cc/VSR5-BEE8] (accessed Sept. 16, 2016); *see* Geiling, *supra* note 145 (noting Iowa's steady replacement of diverse crops with large operations growing corn or soy).

148 Geiling, *supra* note 145. California produces 84% of the United States' peaches, 94% of the broccoli, and 99% of the artichokes. It is also responsible for huge quantities of tomatoes, lettuce, celery, and carrots. *Id.*

B. Risk of an Agroterrorist Attack on the United States

Tommy Thompson, the former secretary of the U.S. Department of Health and Human Services, is often quoted from his 2004 resignation speech as saying, "For the life of me, I cannot understand why the terrorists have not attacked our food supply because it is so easy to do."[149] How reasonable is this assertion? Three metrics underpin an analysis of agroterrorism risk: "the threat to a target, the target's vulnerability to the threat, and the consequences should the target be successfully attacked."[150] Each of these elements will be considered individually in the context of an agroterrorist attack in the next few Sections. The United States probably faces a relatively low risk of agroterrorism since the threat of an attack is low. However, the risk is increasing as agriculture further industrializes and in doing so, heightens the sector's vulnerability and potential consequences of an attack.

1. Threat

There is a threat to the U.S. agricultural system when a person or organization has both the capability and intent to damage it.[151] Overall, the threat of agroterrorism is likely low: although attacking the sector would be relatively simple, agroterrorism lacks "a single, highly visible point of focus for the media," which is a primary concern for many acts of terrorism.[152]

a. Capability

Biological agroterrorism has been called low-tech and high-impact, and could be a cheap, simple way to cause widespread damage.[153] For instance, any harmful biological agents can be found in the environment, rather than having to be created in a lab.[154] The highly infec-

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[149] One must question whether making this public statement was at all advisable. *Protecting the U.S. Food Supply from Agroterrorism*, HOMELAND SECURITY NEWS WIRE (Nov. 12, 2014), http://www.homelandsecuritynewswire.com/dr20141112-protecting-the-u-s-food-supply-from-agroterrorism [https://perma.cc/NM5Z-LC8R] (accessed Dec. 24, 2016).

[150] HENRY H. WILLIS ET AL., RAND CENTER FOR TERRORISM AND RISK MANAGEMENT POLICY, ESTIMATING TERRORISM RISK, at xvi (2005).

[151] *Id.*

[152] PETER CHALK, RAND NATIONAL DEFENSE RESEARCH INSTITUTE, RESEARCH BRIEF: AGROTERRORISM—WHAT IS THE THREAT AND WHAT CAN BE DONE ABOUT IT? 2 (2003).

[153] Keremidis et al., *supra* note 95, at s20. "[D]espite heightened vigilance, farms are still seen as a weak link in the 'farm-to-table continuum,' according to the 184-page DHS report 'Food and Agriculture Sector-Specific Plan,' published in 2010. Some larger farms have ramped up security—electronic alarms, security gate check-ins, et cetera—but that's far from the industry standard. Many cattle ranchers still maintain pretty old-fashioned security: lock and key and a watchful eye. And when it comes to slipping in an unknown pathogen, you wouldn't need a huge security breach. A Kleenex tainted with FMD drifting into a dairy barn, or a dusting of wheat rust falling from the sky, could do the job." Hirsch, *supra* note 107.

[154] For example, animal toxins like African milk bush plant are common to particular areas in Kenya, and since most plant diseases have not been eradicated, they can be

tious FMD virus is prevalent in South America and could be smuggled into the United States in "manure stuck to the bottom of a shoe, for example."[155] Detecting smuggled agents like this is unlikely because airports and borders do not check individuals or luggage for disease samples, livestock are not usually vaccinated against many of the worst pathogens, and agents can be highly resilient over long time periods.[156] Furthermore, many pathogens that are lethal or contagious in plants or animals are not harmful to humans, allowing for easy transport, handling, and dissemination.[157]

Even more complex agroterrorist attacks are also likely quite achievable today. Open-source scientific literature is widely accessible via the web, and the physical resources necessary for manufacturing large quantities of some agents can be found in a regular science lab or are readily available to the scientific community for more sophisticated manufacturing.[158] Many of these agents can be produced in just a few days or even hours.[159]

Additionally, the expertise, equipment, and materials required for a comprehensive attack are not particularly suspicious or difficult to procure since they are legitimately used by agricultural, pharmaceutical, and medical industries.[160] For example, a microbiologist researching at Kyoto University led an attempt to disperse anthrax and botulinum in Tokyo in the 1990s.[161] Although the attack was ultimately unsuccessful, the group was able to produce the toxins by freely purchasing necessary equipment, "including a coil-method heat exchanger, pump motor, vinyl chloride pipes, air filtration media, molecular modeling software, and lasers."[162] Botulinum toxin is legitimately used to treat conditions like migraine headaches, chronic lower back

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found relatively easily in different crops around the world. Keremidis et. al, *supra* note 95, at s21.

155 CHALK, *supra* note 110, at 15.

156 *Id.*

157 *Id.* at 16. For instance, classical swine fever, African swine fever, rinderpest virus, and peste des petits ruminants all have high mortality rates but cannot be spread between animals and humans.

158 Joseph W. Foxell, Jr., *Current Trends in Agroterrorism (Antilivestock, Anticrop, and Antisoil Bioagricultural Terrorism) and Their Potential Impact on Food Security*, 24 STUD. CONFLICT & TERRORISM 107, 109 (2001); Mark Polyak, *The Threat of Agroterrorism: Economics of Bioterrorism*, 5 GEO. J. INT'L AFF. 31, 32–33 (2004). The Poisoner's Handbook, for instance, is an underground book that was supposedly written by an American to attack America's agricultural sector and is widely available and easily located. MATTHEW RICHERT, PROTECTING THE AGRICULTURAL INFRASTRUCTURE 38 (2015). *See also Breadbasket*, *supra* note 109, at 1 (discussing the presence of the Poisoner's Handbook in Afghanistan).

159 Foxell, *supra* note 158, at 109.

160 *Id.*

161 Polyak, *supra* note 158.

162 *Id.*

pain, strokes, and cerebral palsy, making its production less suspicious.[163]

Finally, large quantities of an agent may not be necessary for an attack if the only goal is to cause massive panic or fear—just a few cases of a highly contagious disease like FMD could interrupt months of animal production and exports.[164] For these smaller attacks, labs are unnecessary since material scraped from another already diseased animal could be sufficient.[165] For example, a relatively unsophisticated terrorist could easily bring FMD material into the United States, break into an un-surveilled hog CAFO, and infect multiple animals.[166] Pigs have an especially long incubation period, or time between infection and onset of symptoms.[167] They typically begin shedding the virus seven-to-ten days *before* symptoms are visible, and so combined with a CAFO's low ratio of workers to animal, spread of the disease could be extremely rapid and take a long time to detect.[168] A USDA model of disease transmission estimates viruses like FMD could spread to twenty-five states in just five days.[169]

b. Intent

The intent element probably reduces the threat of agroterrorism.[170] Although an attack on the agricultural sector could lead to significant consequences, it lacks "a single point of reference for the media to focus on," rendering it too dry for a terrorist hoping for high drama.[171] Although effects could be costly and long-lasting, agroterrorism probably would not elicit the desired panic or fear that, say, a September 11th-style suicide bombing would.[172] Escalation theory—"which holds that in order to maintain credibility terrorist groups must demonstrate a continued ability to . . . maintain[ ] a consistent, if not escalating, level of violence"—supports this premise for already well-known terrorist groups.[173] Other factors reducing the intent ele-

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163 Stephen S. Arnon et al., *Botulinum Toxin As a Biological Weapon*, 285 J. AM. MED. ASS'N. 1059, 1059–60 (2001).

164 Mark Wheelis et al., *Biological Attack on Agriculture: Low-Tech, High Impact Bioterrorism*, 52 BIOSCIENCE 569, 571–72 (2002).

165 *Id.*

166 *Id.*

167 *Disease Development*, BOUNDLESS, https://www.boundless.com/microbiology/textbooks/boundless-microbiology-textbook/epidemiology-10/disease-patterns-132/disease-development-675-10799/ [https://perma.cc/TX98-K66V] (accessed Dec. 24, 2016).

168 CHALK, *supra* note 110, at 17.

169 *Id.*

170 TERRENCE K. KELLY ET AL., RAND SCI. & TECH., THE OFFICE OF SCIENCE AND TECHNOLOGY POLICY BLUE RIBBON PANEL ON THE THREAT OF BIOLOGICAL TERRORISM DIRECTED AGAINST LIVESTOCK 144 (2004).

171 *Id.*

172 KNOWLES ET AL., *supra* note 101, at 32.

173 Aeneas R. Gooding, Agricultural Terrorism (Agroterror) and Escalation Theory, at v (Dec. 2007) (unpublished postgraduate thesis, Naval Postgraduate School) (on file with the Naval Postgraduate School and Homeland Security Digital Library).

ment include low risk of human fatalities, delayed impacts, ease of confusion with natural outbreaks, and the relatively low population of suitable attack areas.[174] It is unsurprising then that so far only two documented cases exist involving terrorists using pathogenic agents to infect livestock or contaminate produce.[175]

2. Vulnerability

Vulnerability measures "the probability that an attack of a given type will be successful once it has been launched."[176] Overall, the American agricultural sector is probably quite vulnerable to an attack. Industrialization has led to upsurges in farm size and integration across sectors and geographical boundaries. In turn, this has increased concentration and connectivity and decreased biodiversity, each of which weaken the sector's resilience and make it more vulnerable to widespread consequences in the event of an attack.[177]

a. Loss of Biodiversity

Biodiversity enhances ecosystem stability because components that seem redundant at one time enable organisms to withstand and recover from new and different disturbances.[178] Diversified crop systems are demonstrably more capable of "withstand[ing] pest outbreaks, price instabilities (as the farmer has different kinds of crops to sell and eat), and weather perturbations than more specialized systems."[179] In an agroterrorism context, biodiverse systems have more plants and animals resistant to disease, which could slow spreading of an agent and allow farmers and the government more time to respond.

Unfortunately, both livestock and crops are seeing dramatic reductions in biodiversity as agriculture has industrialized. Livestock breeding has generated high-producing, but homogenous animals, increasing the likelihood of an introduced disease wiping out a facility's entire animal population.[180] Antibiotic-resistant 'superbugs' have evolved in response to intensive farming practices like consistent low-

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174 CHALK, *supra* note 110, at 28.

175 *Id.*

176 WILLIS ET AL., *supra* note 150, at 8.

177 One study summarizes industrialization this way: "At the root of our critique, therefore, is a concern that de-regulated market forces (made possible through numerous re-regulations established to benefit capital) have created incentives that have traded off short-term productivity against long-term resilience." Rotz & Fraser, *supra* note 8, at 468.

178 Miguel A. Altieri, *Strengthening Resilience of Farming Systems: A Prerequisite for Sustainable Agricultural Production*, U.N. TRADE & ENV'T REV. 56, 56–57 (2013).

179 Rotz & Fraser, *supra* note 8, at 462.

180 NATO SCI. FOR PEACE & SECURITY PROGRAMME, CROP BIOSECURITY: ASSURING OUR GLOBAL FOOD SUPPLY 4 (Maria Lodovica Gullino et al. eds., 2008) [hereinafter NATO CROP]. "During the last century 1,000 breeds—about 15 percent of the world's cattle and poultry breeds—have disappeared, and about 300 of these losses occurred in the last 15 years. The problem has been greatest in industrial countries, where factory farming has been most intense." REDEFINING GLOBAL SECURITY, *supra* note 142, at 65.

level dosing of antibiotics to animals in CAFOs.[181] These superbugs have become an attractive biological weapon as they are increasingly difficult to treat and livestock becomes more and more vulnerable to disease

Industrialization has shifted crops into specialized monocultures where disease could spread swiftly and decimate agricultural yields.[182] Large-scale equipment, fertilizers, and pesticides have created giant, tightly packed fields of genetically similar crops that vastly increase the likelihood of total crop loss.[183] Additionally, farmers are essentially powerless in modern markets that concentrate in the hands of a few—"private standards adopted collectively by this small set of powerful companies" force producers across the country to grow the exact same things, leading to extreme declines in diversity.[184]

A 1970s outbreak of southern leaf blight on the U.S. corn crop illustrates problems inherent in homogenous crops.[185] The blight, a fungus marked by black and purple smears on corn leaves and ears, wiped out around 50% of yields simply because over 80% of the U.S. corn crop contained an identical susceptibility gene.[186] Scientists had to travel to a remote area in Mexico to find genetically diverse corn with a resistant gene and crossbreed it with the U.S. variety.[187] This homogeneity is not specific to corn; alarmingly, "[s]ince the beginning of the last century, 75 percent of the genetic diversity of agricultural crops has been lost."[188]

b. Increasing Concentration and Connectivity

The increase in agricultural concentration and connectivity further weakens the system's resilience. Intensive factory farms housing thousands of animals with weak immune systems in extremely close proximity create ideal conditions for disease spread.[189] Once an animal is diseased, farm operators may be unaware of the problem un-

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181 CHALK, *supra* note 110, at 9.

182 NATO CROP, *supra* note 180, at 4.

183 RICHARD GRECO, AGROTERRORISM AND THE CORN MONOCULTURE IN THE UNITED STATES 5–6, 12 (2012) ("[B]iodiversity falls since certain types of corn are more efficient with the fertilizers and pesticides available and produce increased yield . . . . Thus genetic diversity falls as one or few species of corn rise above the others in usefulness.").

184 Rotz & Fraser, *supra* note 8, at 463.

185 REDEFINING GLOBAL SECURITY, *supra* note 142, at 65.

186 *Id.*

187 *Id.* at 66. Today corn is the highest produced crop in the United States. NAT'L AGRIC. STATISTICS SERV., USDA, CROP PRODUCTION 2015 SUMMARY 81 (Jan. 2016), http://www.usda.gov/nass/PUBS/TODAYRPT/cropan16.pdf [https://perma.cc/NUQ7-G8MX] (accessed Dec. 24, 2016).

188 REDEFINING GLOBAL SECURITY, *supra* note 142, at 64.

189 CHALK, *supra* note 110, at 8; Aaron S. Bernstein, *Biological Diversity and Public Health*, 35 ANN. REV. PUB. HEALTH 153, 160 (2014) ("Crowding pigs, especially when they are genetically homogenous, may increase the potential for influenza viruses to infect them, just as plant monocultures may be more vulnerable to crop pests and pathogens. Once pigs in a CAFO become infected, influenza viruses may swap strands of genetic material.").

til a substantial portion of the herd is sick simply because the sheer number of animals per worker makes monitoring for disease so difficult.[190] Compounding this problem is the fact that it is against a farmer's interests to report outbreaks: doing so could result in the destruction of an entire herd or other severe economic consequences.[191] The infection of just one facility could have a dramatic impact on food supply since CAFOs now house such large numbers of livestock.[192]

Once animals reach a certain weight, they are moved from CAFOs to large-scale and concentrated slaughtering, processing, and distribution operations that allow significant contamination among facilities.[193] Just transportation alone of these animals "circumvents natural barriers that could slow pathogenic dissemination," and contributes to the spread of disease through commingling in trucks.[194] Rapid travel over huge distances could exacerbate the spread of contagious diseases when animals contact each other before symptoms present.[195] If animals become sick from an unusual or foreign pathogen, veterinarians and scientists could take a long time to recognize or identify unfamiliar symptoms.[196] For livestock diseases with long incubation periods that can jump the species barrier to infect humans, consequences of an outbreak could be catastrophic.[197]

On the other hand, CAFOs are indoor facilities that can be secured with locks and video surveillance. In contrast, crops are planted close together on thousands of acres of open but connected fields and pastures.[198] Such huge expanses of land are difficult to secure and can be prime targets for destroying large quantities of food at once.[199] Because of the low surveillance of cropland, extensive lag times between introduction of a pathogen and disease discovery are likely, possibly on the order of months or even years.[200] Sometimes cropland spreads across U.S. borders, further opening possible entryways for attack.[201]

The consolidated layout of American agriculture production across the country is also concerning. Since most industries are concentrated

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190 REDEFINING GLOBAL SECURITY, *supra* note 142, at 67.

191 *See* INST. OF MED. & NAT'L RESEARCH COUNCIL, SUSTAINING GLOBAL SURVEILLANCE AND RESPONSE TO EMERGING ZOONOTIC DISEASES 165, 168 (Gerald T. Keusch et al. eds., 2009).

192 *Id.* at 104; Foxell, *supra* note 158, at 111.

193 MONKE, *supra* note 99, at 1.

194 *Id.*

195 CHALK, *supra* note 110, at 8.

196 MONKE, *supra* note 99, at 1.

197 The spread of bird flu offers one example. "A National Academy of Sciences report says that while the deadly bird flu virus, H5N1, began in wild birds, it developed its power to spread because of the cramped conditions of Asian factory farms. It is factory farming and the international poultry trade that are largely responsible for the spread of bird flu." CHARLES PERROW, THE NEXT CATASTROPHE: REDUCING OUR VULNERABILITIES TO NATURAL, INDUSTRIAL, AND TERRORIST DISASTERS 298–99 (2007).

198 MONKE, *supra* note 99, at 1.

199 *Id.*

200 Madden & Wheelis, *supra* note 91, at 158.

201 Wheelis et al., *supra* note 164, at 572.

in particular regions, an agroterrorist would need fewer pathogens to strategically attack areas critical to, say, a particular animal.[202] Targeting sectors this way could decimate large portions of the livestock industry.[203] Although croplands are more geographically dispersed—the 'Corn Belt,' for instance, ranges from Iowa, Indiana, most of Illinois, and parts of Kansas to Missouri, Nebraska, South Dakota, Minnesota, Ohio, and Wisconsin—California's particular domination of the fruit and vegetable industry is alarming.[204] California's depleting groundwater and drought conditions have already shown problems inherent in regional farming and the vulnerability that comes from failing to grow diverse crops across the nation.[205]

While vertical integration of the livestock and crop industries tends to cut costs, it also increases the potential for exposure to dangerous pathogens.[206] Producers, shippers, processors, and even retailers are often owned by a single company, which means "a breach in any part of the system could conceivably affect the entire system, resulting in widespread exposure of consumers to tainted produce and massive financial loss to the company."[207]

c. Other Factors Increasing Vulnerability

Cyber attacks are another concern as the agricultural system increasingly depends on computers, technology, and the internet.[208] Farmers rely more heavily on data today than ever before as new farm-management services generate planting recommendations based on past crop yields and soil content.[209] Industrial farmers use satellite-guided machinery and algorithm software to determine planting patterns.[210] Adding this extra avenue of attack further increases system

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202 Foxell, *supra* note 158, at 110.

203 *Id.*

204 Geiling, *supra* note 145.

205 *Id.* ("'When you look at the California drought maps, it's a scary thing,' Craig Chase, who leads the Leopold Center for Sustainable Agriculture's Marketing and Food Systems Initiative at Iowa State University, told ThinkProgress. 'We're all wondering where the food that we want to eat is going to come from. Is it going to come from another state inside the U.S.? Is it going to come from abroad? Or are we going to grow it ourselves?'").

206 Ekaterina Arabska & Ivanka Shopova, Assuring Food Security in Agricultural Production in the Republic of Bulgaria Under the Conditions of General Globalization, *in* NATO SCI. FOR PEACE & SECURITY SERIES—D: INFORMATION AND COMMUNICATION SECURITY: COMPREHENSIVE APPROACH AS "SINE QUA NON" FOR CRITICAL INFRASTRUCTURE PROTECTION 156 (Denis Caleta & Vesela Radovic eds., 2014).

207 *Id.* at 156.

208 FDA ET AL., FOOD AND AGRICULTURE SECTOR-SPECIFIC PLAN 6 (2015), http://www.fda.gov/downloads/Food/FoodDefense/FoodDefensePrograms/UCM483872.pdf [https://perma.cc/2KPH-BUYB] (accessed Dec. 24, 2016).

209 *U.S. Farming Sector Increasingly Vulnerable to Cyberattacks*, HOMELAND SECURITY NEWS WIRE (Feb. 20, 2015), http://www.homelandsecuritynewswire.com/dr20150220-u-s-farming-sector-increasingly-vulnerable-to-cyberattacks [https://perma.cc/4B6P-GRW4] (accessed Dec. 24, 2016).

210 *Id.*

vulnerabilities: hacking could leave farmers unable to make good decisions, deliberately destroy crops through over-application of pesticides, or allow terrorists to use a producer's own drones to scope out a target prior to an attack.[211]

Other factors affecting vulnerability include minimal surveillance and on-farm security, the difficulty of monitoring access and egress roads, and the regular employment of unscreened, seasonal workers.[212] Additionally, the expansiveness of cropland enables multiple vehicles of attack, such as crop dusters, drones, unmanned ground vehicles like tractors or sprayers, projectiles of infectious pathogens, irrigation contamination, infected pollinating insects, and low-flying airplanes, among others.[213]

3. Consequences

An agroterrorist attack properly carried out could have a host of extremely undesirable consequences, although even a substantial outbreak of disease in U.S. crops or livestock almost certainly would not cause famine.[214] Still, human health and safety could be in serious jeopardy, depending on the type of biological agent used.[215] More likely, the most substantial effects would be economic. Once a disease outbreak is identified, infected (and potentially infected) livestock and crops would have to be destroyed, costing money from both the loss of production and the eradication.[216] Even a small event could prompt restrictions from other countries concerned about importing infected meat or produce.[217] While consumers would likely shift away from purchasing targeted types of produce or meat, demand for other foods would rise to fill the gap.[218] Tourism and its attendant economic benefits would likely fall in areas near an outbreak.[219]

Agroterrorism would also negatively impact consumer satisfaction. Confidence in the American food system and the government would drop following an attack as critics point fingers and painful images of diseased animals or crops spread.[220] Eradication efforts could include extensive culling of both diseased and non-diseased ani-

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211 Market Research Store, *Agricultural Drone Market Is $494 Million Anticipated to Reach $3.69 Billion by 2022*, NEWSMAKER (May 3, 2016), http://www.newsmaker.com.au/news/52899/agricultural-drone-market-is-494-million-anticipated-to-reach-369-billion-by-2022 [https://perma.cc/3RQV-TRVM] (accessed Dec. 23, 2016).

212 KNOWLES ET AL., *supra* note 101, at 49; Dean Olson, *Agroterrorism: Threats to America's Economy and Food Supply*, 81 FBI L. ENFORCEMENT BULL. 1, 6 (Feb. 2012).

213 Lawrence, *supra* note 78, at 4; Foxell, *supra* note 158, at 107; Christina Cooper, *Cybersecurity in Food and Agriculture*, *in* PROTECTING OUR FUTURE, VOLUME II: EDUCATING A CYBERSECURITY WORKFORCE 69 (2015).

214 Wheelis et al., *supra* note 164, at 570.

215 MONKE, *supra* note 74, at 2.

216 *Id.* at 8.

217 NATO CROP, *supra* note 180, at 5.

218 MONKE, *supra* note 99, at 6.

219 *Id.* at 7.

220 *Id.* at 6; CHALK, *supra* note 110, at 22.

mals that may be vigorously opposed at least by some animal rights groups, if not the general public.[221] Once slaughtered, animal carcasses would have to be incinerated or put in landfills, which could generate public outrage from environmentalists and others.[222] As the president of Kansas State University put it: "The vision of National Guard troops having to machine-gun tens of thousands of diseased cattle in Kansas' feedlots doesn't present a pretty picture."[223]

Agroterrorism is still terrorism: one of its major purposes is to instill fear and anxiety in large numbers of people.[224] According to a study by RAND, "terrorists could use this state of public anxiety to their advantage to create a general atmosphere of fear without having to actually carry out indiscriminate civilian-oriented attacks that could both incur mass reprisals and alienate actual and/or potential support."[225] This is especially true for attacks resulting in human deaths, no matter how few.[226]

Examples of natural disease outbreaks shed light on possible effects that could stem from an agroterrorist attack.[227] One such example is found in the 2001 outbreak of FMD in the United Kingdom.[228] Between February 20 and September 30 of that year, instances of FMD skyrocketed from 57 to over 2,000 confirmed cases.[229] The outbreak spread throughout the United Kingdom and into Ireland, France, and the Netherlands.[230] Unfortunately, "[c]ontingency planning had not allowed for the rapid dispersal of diseased animals and the failure to understand the pattern of animal movements rendered the initial attempts at disease control hopelessly ineffective, thereby heightening the crisis."[231] An estimated 10 million animals were slaughtered, and the cited economic costs range from $10.7 billion to $11.7 billion (£5.8 billion to £6.3 billion).[232] Around a third of the costs were direct payments to farmers for compensation.[233] Seventy percent of farms in the originating county were subject to complete or partial

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221 MONKE, *supra* note 99, at 6; CHALK, *supra* note 110, at 22.

222 MONKE, *supra* note 99, at 6–7; CHALK, *supra* note 110, at 22.

223 KNOWLES ET AL., *supra* note 101, at 14–15.

224 *Id.* at 31.

225 CHALK, *supra* note 110, at 25.

226 *Id.*

227 NATO CROP, *supra* note 180, at 5.

228 *Foot-and-Mouth Outbreak of 2001*, BBC NEWS (Feb. 18, 2011), http://www.bbc.com/news/uk-england-12483017 [https://perma.cc/3HYF-Z25W] (accessed Dec. 24, 2016).

229 DUSTIN L. PENDELL ET AL., THE ECONOMIC IMPACTS OF A FOOT-AND-MOUTH DISEASE OUTBREAK: A REGIONAL ANALYSIS 3 (2007).

230 *Id.* at 3–4.

231 DAVID CAMPBELL & ROBERT LEE, CULLING BY NUMBERS: BLACKBOARD ECONOMICS AND FOOT AND MOUTH DISEASE CONTROL 1 (2002), http://www.fmd.brass.cf.ac.uk/culling.pdf [https://perma.cc/96PP-9W2M] (accessed Dec. 24, 2016).

232 *Id.* at 1, 12; PENDELL ET AL., *supra* note 229, at 4.

233 CAMPBELL & LEE, *supra* note 231, at 13.

culls of their livestock.[234] Neighbors endured the sights, smells, and sounds of animal slaughter and disposal, while television broadcasts covered the events daily.[235] One study on the human social and health impacts of the outbreak in Cumbria County summarized the effects of the disaster:

> The trauma of losing generations of work in building up pedigree herds and flocks at a stroke; the effect on rural businesses threatened by the economic impacts of restricting livestock and human movement; the social impacts of closing auction marts, cancelling seasonal rural social events and isolating 'infected premises' (which means isolating human beings); the public health concerns of carcass disposal methods including landfill, mass burial and burning on pyres; all these may have health and social consequences.[236]

V. MOVING FORWARD

To reduce the risk of an agroterrorist attack, the agricultural sector must considerably improve its resilience. Overall, improving resilience would effectively diminish every element of agroterrorism risk. It would lower the sector's vulnerability—or probability an attack would be successful—while at the same time minimize consequences and reduce the threat by making an attack less attractive. As discussed above, the sector's resilience can be improved by increasing biodiversity and decreasing its concentration and connectivity.

This Section first very briefly reviews the regulatory regime surrounding agroterrorism. It then describes what should be done to improve the resilience of the current agricultural sector, and notes the difficulty of achieving these changes. Finally, it shows how indoor agriculture can supplement the conventional farming system to improve the sector's overall resilience, thereby lowering the risk of agroterrorism.

A. Brief Overview of the Regulatory Regime

The widespread fear and panic following the September 11th attacks pushed the government to identify possible weaknesses in U.S. security, including in the agricultural sector.[237] The Department of Homeland Security (DHS) was established in response to these fears, followed soon after by congressional enactment of the Bioterrorism Act of 2002.[238] This Act sought to "strengthen and enhance food safety and

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[234] MAGGIE MORT ET AL., THE HEALTH AND SOCIAL CONSEQUENCES OF THE 2001 FOOT & MOUTH DISEASE EPIDEMIC IN NORTH CUMBRIA 10–11 (2004), http://www.esds.ac.uk/doc/5407%5Cmrdoc%5Cpdf%5C5407finalreport.pdf [https://perma.cc/5X9B-EV8L] (accessed Dec. 24, 2016).

[235] *Id.* at 11.

[236] *Id.* at 14.

[237] MONKE, *supra* note 74.

[238] Public Health Security and Bioterrorism Preparedness and Response Act of 2002, Pub. L. No. 107-188, 116 Stat. 594 (codified in scattered sections of 7, 18, 21, 29, 38, 42

security," and provided the USDA and FDA more authority to undertake food defense initiatives.[239] Since then, multiple plans, frameworks, and presidential directives have all touched on agroterrorism.[240]

Even so, no industry-specific regulatory requirements exist for food defense or to address the root causes of vulnerability—loss of biodiversity and increased connectivity.[241] The FDA is currently working on a final rule, however, that would at least require food facilities to address the threat of terrorism by implementing strategies to minimize the vulnerabilities of specific processes, like "bulk liquid receiving and loading."[242]

The most relevant authority for addressing agroterrorism is Homeland Security Presidential Directive 9 (HSPD-9), which develops a national policy for defending the food and agriculture system against terrorism and other emergencies.[243] Under this and several other authorities, the DHS, FDA, and USDA developed the 2015 Food and Agriculture Sector-Specific Plan (SSP), a comprehensive guide for the agricultural sector to improve security and resilience.[244] This guide recognizes that under the current agricultural system, preventing every threat or agent is probably not achievable.[245] Rather than considering system-wide changes, however, the SSP emphasizes the importance of early pathogen recognition and nationally coordinated

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and 47 U.S.C.); FDA ET AL., CRIMINAL INVESTIGATION HANDBOOK FOR AGROTERRORISM 3 (July 2008).

239 U.S. GOV'T ACCOUNTABILITY OFFICE, GAO-04-588T, FEDERAL FOOD SAFETY AND SECURITY SYSTEM: FUNDAMENTAL RESTRUCTURING IS NEEDED TO ADDRESS FRAGMENTATION AND OVERLAP 4 (Mar. 30, 2004) (Statement of Lawrence J. Dyckman, Director Natural Resources and Environment). The Bioterrorism Act, among other authorities, allows USDA "to restrict the importation, exportation, and interstate movement of plants, animals, plant and animal products, and plant and animal pathogens." FDA ET. AL., *supra* note 208, at 53.

240 FDA ET AL., *supra* note 208, at vii. Other authorities include the *National Infrastructure Protection Plan 2013: Partnering for Critical Infrastructure Security and Resilience*; *Presidential Policy Directive 21: Critical Infrastructure Security and Resilience*; *Executive Order 13636: Improving Critical Infrastructure Cybersecurity*; and *Presidential Policy Directive 8: National Preparedness*. *Id.* at vi–vii.

241 USDA, FSIS AS A PUBLIC HEALTH REGULATORY AGENCY: HOMELAND FOOD DEFENSE MODULE 12 (Aug. 4, 2015) (noting that the USDA's Food Safety and Inspection Service at least "encourages the private industry to develop and implement food defense plans aimed at minimizing their risk of a food terrorism incident").

242 Mitigation Strategies to Protect Food Against Intentional Adulteration, 78 Fed. Reg. 78,014 (proposed Dec. 24, 2013) (to be codified at 21 C.F.R. § 121).

243 HOMELAND SECURITY PRESIDENTIAL DIRECTIVE 9: DEFENSE OF THE UNITED STATES AGRICULTURE AND FOOD (Jan. 30, 2004). This directive seeks to protect the agricultural sector from terrorist attacks by establishing protection requirements, developing early warning capabilities for threat recognition, enhancing product screening, enhancing response and recovery procedures, and "mitigating vulnerabilities at critical production and processing nodes," which is the only element that could be construed to require reductions in connectivity or increases in biodiversity. *Id.*

244 FDA ET AL., *supra* note 208, at 1.

245 *Id.* at 25.

disease surveillance programs.[246] The plan's priorities for improving resilience also fail to recognize underlying vulnerability issues, and instead seek to simply expand laboratory systems, integrate information sharing, improve cybersecurity, and resolve decontamination issues like livestock disposal.[247]

Generally, the government's scheme for reducing the risk of agroterrorism focuses on developing response plans or increasing surveillance, but ignores problems inherent in the industrialization of agriculture. While these focuses are important, improving the agricultural sector's resilience will have a much greater effect by reducing the overall risk of an attack.

B. Increasing Resilience of the Current Agricultural Sector

Although "it is not feasible to be specifically prepared or have all the scientific tools for every contingency or threat to agriculture," this should not be the goal.[248] Instead, the agricultural sector should focus on improving its resilience, which can be accomplished by spreading everything out and making everything smaller.

CAFOs and other types of highly concentrated animal farming should be eliminated and replaced with more traditional animal husbandry, where livestock must rely on their immune systems—rather than on cocktails of antibiotics and hormones—to survive. Facilities should house fewer animals and be spread across the country, rather than concentrated in certain states and regions. Producers should halt the practice of indiscriminate cross-breeding and move towards small-scale production that supports local genetic diversity, a "prerequisite for adaptation in the face of future challenges."[249] These changes would increase the sector's resilience by making animals hardier and more genetically diverse, which can help stop or at least slow the spread of disease. Furthermore, spreading livestock around the country would reduce the number of miles they are transported, thereby minimizing the potential for viral spreading.

For crops, monocultures should also be eliminated or at least reduced. Farms should increase crop varieties and rotations, cover crops (crops grown for protection and enrichment of soil), perennial plants, and fallowing (leaving land unused for a period of time), and use any other techniques that, like these, have been shown to increase biodiversity.[250] Planting different crops in deliberate patterns can also

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246 *Id.* In fact, instead of discussing industrialization as a cause of low biodiversity that weakens resilience, the SSP blames biodiversity loss on climate change. *Id.* at 6.

247 *Id.* at 40.

248 Madden & Wheelis, *supra* note 91, at 164.

249 *Genetic Diversity of Livestock Can Help Feed a Hotter, Harsher World*, FAO, (Jan. 27, 2016), http://www.fao.org/news/story/en/item/380661/icode/ [https://perma.cc/LB6B-TH78] (accessed Dec. 24, 2016).

250 *Farming for Success in the 21st Century: Increasing Biodiversity*, CAL. CLIMATE & AGRIC. NETWORK, http://calclimateag.org/wp-content/uploads/2013/04/BIodiversity-Fact-Sheet.pdf [https://perma.cc/CA8V-787E] (accessed Dec. 24, 2016).

form buffer zones to slow the spread of a disease. Though modern science is still learning why methods like these so successfully improve resilience, indigenous people have been using such practices for centuries.[251] Unlike livestock facilities, however, cropland is dependent on weather and climate, so it cannot be as easily spread nationally. This is where indoor farming can have a substantial impact on resilience.

Achieving these goals would require substantial overhauls of a highly entrenched system. Conveniently, groups concerned with other interests, like animal welfare, human health, and environmental ills, would likely support many of these changes. For example, there are many proponents of banning or at least drastically reducing the extreme use of antibiotics in livestock because of human health concerns.[252] In fact, California just recently banned livestock use of antibiotics that are medically important for people.[253] When Denmark introduced such a ban in 1998, farmers had to implement changes like "cleaning more frequently, increasing facility ventilation, allowing more space for animal movement, [and] vaccinating animals."[254] Although not drastic, even these small changes can improve the resilience of livestock facilities by spreading animals out and improving their immune systems. Furthermore, indoor farming should be promoted as an attractive way to improve the sector's resilience while giving conventional farming time to catch up.

Disadvantages remain to this approach for improving resilience. First, it is unlikely these changes can be made quickly.[255] Industrial agriculture emerged because there are market benefits to concentration and monoculture.[256] Most notably, industrialization has dramatically reduced the price of food for consumers and kept these prices predictable.[257] Monoculture crops have been bred for farmer profitability: they are "convenient to grow with good yields, good store-shelf appeal, and long shelf life (which allows them to be transported a greater distance)."[258] Because of its high productivity, industrial agriculture

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[251] Bernstein, *supra* note 189, at 158.

[252] *See* Nathalie Prescott, *Antibiotics: It's What's for Dinner*, 28 GEO. ENVTL. L. REV. 307, 312 (2016).

[253] CAL. FOOD & AGRIC. CODE § 14400 (West 2015).

[254] Prescott, *supra* note 252, at 312.

[255] Amy Mayer, *Can Midwest Farmers Fight Monoculture and Grow New Crops?*, KCUR (Apr. 4, 2016), http://kcur.org/post/can-midwest-farmers-fight-monoculture-and-grow-new-crops#stream/0 [https://perma.cc/WA28-AKDF] (accessed Dec. 24, 2016).

[256] *See, e.g.*, Andrew McGuire, *Ecological Theories, Meta-Analysis, and the Benefits of Monocultures*, WASH. ST. U. CTR. SUSTAINING AGRIC. AND NAT. RES. (May 26, 2015), http://csanr.wsu.edu/theories-meta-analysis-monocultures/ [https://perma.cc/4LV4-EH25] (accessed Dec. 24, 2016) (discussing the benefits of monocultures including increased yields).

[257] Bryan Walsh, *Getting Real About the High Price of Cheap Food*, TIME (Aug. 21, 2009), http://content.time.com/time/magazine/article/0,9171,1917726,00.html [https://perma.cc/52YF-R6GC] (updated Aug. 20, 2009) (accessed Dec. 24, 2016).

[258] Steven Novella, *Monoculture*, THE NESS: NEUROLOGICA BLOG (Mar. 4, 2014), http://theness.com/neurologicablog/index.php/monoculture/ [https://perma.cc/424U-7U5V] (accessed Dec. 24, 2016).

has also limited the expansion of farming acreage into forests or other wild areas since less land is necessary to produce the same amount of food.[259]

Indoor agriculture, however, can help improve resilience while also maintaining similar market benefits, described in more detail below. For instance, crop breeding for farmer productivity can sometimes come at the expense of other valuable traits like nutrient density or produce variety.[260] In contrast, indoor agriculture can prioritize these traits instead of those related to surviving pest outbreaks or droughts.[261] It can also minimize encroachment on wild areas since indoor farms can be built up and inside city limits.[262] Also, as technology improves and indoor agriculture becomes more widespread, the trend's associated costs will decline and become more competitive with industrial farming.[263] Even if spreading farms out and making them smaller unavoidably raises costs, these costs would still be worth it for improved resilience of the sector overall.

C. Using Indoor Agriculture to Increase Resilience of the Agricultural Sector

Indoor agriculture can and should be used to improve the resilience of the agricultural sector, but only insofar as it does not simply become an indoor replication of the vast monoculture croplands inherent in industrial agriculture. Using indoor agriculture to improve resilience could lower the vulnerability of the sector overall to an agroterrorist attack.

1. Possible Strengths of Indoor Agriculture

Indoor agriculture has the potential to reduce vulnerabilities in the food supply.[264] First, the nature of an indoor farm as an enclosed building with a locked door makes breaking into a facility unidentified or undetected to infect produce much more difficult. Some indoor farms require 'clean-room' environments, where workers must wear special

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259 McGuire, *supra* note 256.

260 Novella, *supra* note 258.

261 *See* Kevin Gray, *Traditional Agriculture Has Bought the Farm*, POPULAR SCI. (Sept. 22, 2015), http://www.popsci.com/farms-grow-up-thanks-to-technology [https://perma.cc/BM9F-SWBQ] (accessed Dec. 24, 2016) ("When plants sit directly beneath such specially tuned LEDs, they . . . grow outward in dense leaves, which optimizes nutrient density and means less growing time.").

262 *See* Dickson Despommier, *The Rise of Vertical Farms*, SCI. AM., Oct. 2009, at 84 (discussing the positive effects of vertical farming). *See also Vertical Take-Off*, FRESH PRODUCE J., Jan. 28, 2011, at 62 ("When farms are successfully moved to cities, we can convert significant amounts of farmland back into whatever ecosystem was there originally, simply by leaving it alone.").

263 *See* FEEDING THE FUTURE, *supra* note 11, at 24 ("New integrations of these systems continue to raise yields, increase growing efficiencies, and lower costs associated with indoor crop production.").

264 *Id.* at 32.

gloves, hats, and uniforms, adding a layer of security.[265] Any additional steps required for an attack to be successful lowers the probability of an attack, since "[t]he more accessible a site the more likely it will be a target."[266]

Second, if a pathogen did enter the food supply, "indoor systems are often able to track individual plant variables throughout the growth cycle, allowing farmers to quickly identify the source of contamination and isolate any affected products."[267] Indoor facilities could hire specialized employees like microbiologists who can spot and diagnose diseased plants. The mere fact that produce is grown inside and in smaller batches could limit diseased plants to just that facility and eliminate spread associated with wind or drift.[268] Furthermore, indoor farms inherently support biodiversity since they can easily grow many different types of produce. The geographical closeness of farms to consumers would also reduce the spread of disease—compared to conventional farm locations hundreds of miles outside urban areas, for instance, the New Jersey indoor farm AeroFarms will grow greens only fifteen miles outside of Manhattan, where it plans to sell its produce.[269]

The widespread use of technology and automation will likely provide security as well as points of vulnerability. In the first place, a cyber-agroterrorist attack would not be particularly dramatic since it would not involve frightening pathogens or theatrical bombings. Instead, it would present more as a minor economic loss via a shut down water system or electrical connection.[270] This in itself would be a deterrent for attacking via computer. Additionally, there is vast potential for highly secure agro-technology systems.[271] As technologies develop, they will become more complex and require more sophistication to hack into and damage. Technology can also reduce risks to indoor farm employees: fewer on-site employees are necessary and security cameras could monitor and spot suspicious individuals physically coming in or out of facilities.

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265 *Id.*

266 USDA, *supra* note 241, at 6.

267 FEEDING THE FUTURE, *supra* note 11, at 32.

268 *See* Kathryn McConnell, *Vertical Farms Grow Food by Growing Up, Not Out*, U.S. DEP'T ST. (July 1, 2008), http://iipdigital.usembassy.gov/st/english/article/2008/06/20080630192325akllennoccm0.5946161.html [https://perma.cc/3JDJ-EHBL] (accessed Dec. 24, 2016) ("The controlled environments would prevent the airborne spread of pests and diseases . . . .").

269 Leanna Garfield, *Inside the World's Largest Vertical Farm, Where Plants Stack 30 Feet High*, TECH INSIDER (Mar. 15, 2016), http://www.techinsider.io/inside-aerofarms-the-worlds-largest-vertical-farm-2016-3 [https://perma.cc/ZT6S-EQGR] (accessed Dec. 24, 2016).

270 *See* Robert Norton, *Agroterrorism—Is the Threat Real?*, SE. FARM PRESS (Oct. 30, 2014), http://southeastfarmpress.com/government/agroterrorism-threat-real [https://perma.cc/NJS9-TCTS] (accessed Dec. 24, 2016) (describing the likelihood of an agroterrorist attack and the methods agroterrorists would likely use).

271 Cooper, *supra* note 213, at 70.

In the event of an agroterrorist attack against a conventional farm, a robust indoor agriculture sector actually bolsters the resilience of the overall food supply because of its potential for product diversity and quick production and distribution.[272] Weather and climate are irrelevant for indoor farming, allowing a variety of produce to be grown almost anywhere in any season.[273] Single regions—like the California Central Valley—would no longer be responsible for growing 80% of a certain type of produce.[274] Indoor farms are also highly variable and adaptable—ranging from refrigerator-sized home aquaponic systems, to enclosed greenhouses on rooftops, to multi-story, stand-alone commercial facilities—and ideally, cities would utilize numerous, diverse farms all over.[275] An attack against one indoor farm, or even several in the same state, could never wipe out an entire crop variety in the United States. Indoor farming would "augment the food chain to create a diverse, distributed system more resilient to supply shocks and better prepared to meet the demands of a growing population."[276]

2. Possible Weaknesses of Indoor Agriculture

Indoor agriculture does raise new concerns about the possibility of different types of agroterrorism. Vertical farming in particular is more vulnerable than conventional farming to a one-time bomb strike since the target is much more consolidated. This type of attack could embody a terrorist's desire for drama and fear-mongering above long-term economic harms. Even so, human harm would be limited to the surrounding area, rather than sickening wide swaths of people through food. Additionally, indoor farms still tend to be relatively small, and this type of attack makes more sense targeting highly populated buildings rather than produce facilities.

Moreover, technology and automation tend to be used for indoor agriculture at much greater levels than in conventional farms.[277] For instance, a fully automated plant factory is slated for a 2017 startup near Kyoto, Japan and will be worked entirely by robots.[278] Since much of an indoor farm's required labor can be mechanized and remote monitoring and control systems are not unusual, indoor agriculture farmers can be very removed from crops and therefore from spotting

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[272] FEEDING THE FUTURE, *supra* note 11, at 48.

[273] *Advantages of Vertical Farming*, VERTICAL FARM SYS., http://www.verticalfarms.com.au/advantages-vertical-farming [https://perma.cc/EFG2-NVMR] (accessed Dec. 24, 2016).

[274] Geiling, *supra* note 145.

[275] Despommier, *supra* note 61.

[276] FEEDING THE FUTURE, *supra* note 11, at 48.

[277] *See id.* at 24–27 (describing the technologies involved in indoor agriculture).

[278] Leanna Garfield, *The World's First Robot-Run Farm Will Harvest 30,000 Heads of Lettuce Daily*, TECH INSIDER (Jan. 27, 2016), http://www.techinsider.io/spreads-robot-farm-will-open-soon-2016-1 [https://perma.cc/CC2J-QXFB] (accessed Dec. 24, 2016).

disease.[279] Additionally, these producers may not come from traditional farming backgrounds, making them less able to notice or diagnose diseases, especially if they do not suspect an intentional outbreak. Automation could overlook diseased plants and then unwittingly distribute them to consumers. An easy fix to this problem would be to hire a qualified expert to personally oversee plant health.

Technology and agricultural data networks also come with a host of cybersecurity concerns.[280] The addition of technological infrastructure could allow a cyber-terrorist access to multiple "single points of failure" since indoor farms are "dependen[t] on other critical infrastructures including water, power, dams, chemical, and transportation."[281] A cyber agroterrorist attack has the benefit of concealment, low cost, and low risk, boiled down to the click of a button that could destroy, say, 30,000 heads of lettuce in seconds.[282] Additionally, the sheer pace of technological innovation makes keeping up with security needs increasingly difficult.[283]

Of more long-term concern, indoor agriculture could go the same way as conventional farming by scaling up and homogenizing.[284] Already, experts are imagining mile-long indoor farm facilities in desert areas like Nevada that could supply wheat for huge numbers of consumers.[285] Economies of scale may prove difficult to avoid for indoor farming in the same way they were for conventional practices, which would lead to similar declines in resilience.

3. How to Expand Indoor Agriculture in the United States

Indoor agriculture is a small but burgeoning market. Already, a variety of stakeholders are enthusiastic about its expansion, including universities, governments, and investors.[286] Indoor farming is viewed as much less risky for investors than conventional farming because harvests are not reliant on unpredictable weather patterns and can offer a year-round product.[287] Investment in indoor agriculture has

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279 MARC OSHIMA, AEROFARMS 8 (2016), http://www.usda.gov/oce/forum/2016_speeches/Oshima.pdf [https://perma.cc/AP72-ANWT] (accessed Dec. 24, 2016).

280 Cooper, *supra* note 213.

281 *Id.* at 68.

282 *Id.*

283 *Id.* at 69.

284 *See* Idel, *supra* note 130, at 155 ("Farms should not be factories–they should not be places of large-scale production halls; instead they should be highly integrated, living systems where every part of the system plays a crucial role in the functioning of the system as a whole.").

285 Despommier, *supra* note 61.

286 FEEDING THE FUTURE, *supra* note 11, at 3; *see, e.g.*, B. David Vosburg, *How to Invest in Leafy-Green Indoor Agriculture*, GLOBAL AGINVESTING (Feb. 24, 2016), http://www.globalaginvesting.com/news/blogdetail?contentid=6534 [https://perma.cc/9KJE-DJ43] (accessed Dec. 24, 2016) (discussing factors investors should consider when investing in indoor agriculture companies).

287 BIRKBY, *supra* note 20, at 4; *see, e.g.*, Adele Peters, *Meet the Startup That Wants to Make Vertical Farming Mainstream*, CO.EXIST (Apr. 7, 2015, 8:48 AM), https://

been increasing in recent years: between 2011 and 2014, venture capitalists invested $52 million in the sector, with 60% of that in 2014 alone.[288] Still, indoor farming is relatively new and must confront challenging economics as producers test out what works and what does not.[289]

The public sector could help to expedite growth of the industry at local and federal levels. Local governments can clarify regulations and zoning for indoor agriculture, incentivize indoor crop production by offering underutilized space at a discount for producers, and assist in negotiating long-term rates with utility providers.[290] The federal government could extend funding programs to new producers or create new programs for the indoor agriculture sector like low-interest loan services or something similar.[291] Already, indoor farmers are eligible for several grants and incentives under federal agricultural, energy, and new technology programs.[292] If funding beyond these programs is not an option, the government should at least clarify how indoor agriculture fits into the organic label and require the USDA to begin tracking helpful indoor farming data the same way it does for conventional farms.[293]

Universities also hold a critical role for indoor farming as "[a]cademia has undoubtedly been the driving force behind many technical advances in the indoor agriculture field."[294] Additional collaboration with industry members could further allow smaller players that otherwise could not afford it to become involved in research and development.[295]

Even if local and federal governments did nothing more to advance the indoor agriculture industry, excitement and novelty will likely continue fueling its expansion at a rate that will almost certainly outstrip an overhaul of conventional farming. As technology continues to mature and costs fall, indoor agriculture will become more economically viable, and investment opportunities will swell.

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www.fastcoexist.com/3043850/meet-the-startup-that-wants-to-make-vertical-farming-mainstream [https://perma.cc/ATP6-XSBW] (accessed Dec. 24, 2016) (giving an example of a company which raised $30 million).

288 FEEDING THE FUTURE, *supra* note 11, at 36.

289 *See* Ruth Simon, *Farming Gets High Tech in Bid to Offer Locally Grown Produce*, WALL ST. J. (Apr. 13, 2016, 3:49 PM), http://www.wsj.com/articles/farming-gets-high-tech-in-bid-to-offer-locally-grown-produce-1460576984 [https://perma.cc/H86H-R82F] (accessed Dec. 24, 2016) ("BrightFarms Inc. last year pulled the plug on a planned greenhouse in Washington, D.C., 10 months into the process of getting permits, and earlier exited an effort to develop a rooftop farm in Brooklyn, New York. FarmedHere LLC, which operates a farm in a former box factory outside Chicago, shut down for six months last August to revamp its strategy.").

290 FEEDING THE FUTURE, *supra* note 11, at 40.

291 *Id.* at 40–41.

292 *Id.* at 42.

293 *Id.* at 40–41. Ideally this would include at least production, pricing, and volume data.

294 *Id.* at 41.

295 *Id.*

VI. CONCLUSION

Industrialization of the agricultural system has increased the risk of an agroterrorist attack on the United States by reducing its resilience. The sector must increase its biodiversity and de-concentrate in order to restore that resilience and thereby lower the risk of agroterrorism. Although indoor agriculture is in its infancy, it can and should be used to further these goals along with more fundamental changes to conventional farming. Government and especially the private sector will be instrumental for expanding the indoor farming market, which should be used to improve agriculture's resilience in the face of an agroterrorist attack.