

**Animal Farm: agriculture from an investor's perspective**

Our soft landing thesis is still alive as of mid-May. While US Q1 GDP is now tracking just 1.4% due to headwinds from inventories and trade, Q2 is tracking 3.4% with domestic final sales projected to rise at 2.7%. While CPI measures did a U-turn this year (see inflation monitor above), labor market indicators are softening. One or two Fed cuts still seem reasonable for 2024. I'm more concerned with the risk of weaker growth than the risk of rising inflation. New orders less inventories is our preferred leading indicator, and it weakened recently in the US. More on the growth picture and the commercial real estate drag in June.

With spring planting season having arrived in Zone 7<sup>1</sup>, it's a good time to review **agriculture from an investor's perspective**. Topics include food price inflation in the wake of Russia's invasion of Ukraine; public and private equity investments in agriculture; farmland ownership and drivers of farmland returns; seed bio-engineering designed to reduce consumption of fertilizer, fungicide and water; and satellite data on the immense agricultural damage occurring in Gaza. The Appendix looks at the avian flu's impact on agriculture and the food supply.

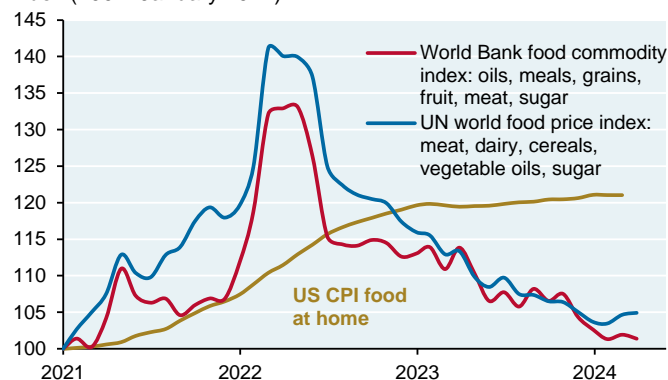
**Food inflation: food commodity prices declining but consumer food price inflation includes more than that**

I've written before about the temporary impact of wars and other geopolitical conflict on equities. The same can be said for the impact of Russia's invasion of Ukraine on certain global food prices. As shown in the first chart, food price indexes have declined sharply from peak levels, mostly a reflection of declining prices for corn, wheat, vegetable oils and dairy (livestock prices have remained more stable).

**In contrast, US "food at home" inflation has not declined alongside falling commodity prices.** The reason: this index measures prices to the consumer (not the farmer) and incorporates labor costs, production costs including fertilizer and energy, and localized factors such as weather and avian flu outbreaks. As per the Kansas City Fed<sup>2</sup>, for every \$1 spent on food at the supermarket, wholesale and retail trade account for 40 cents and food processing accounts for another 25 cents; the cost of farm production only accounts for 15 cents of each \$1. Changes in income, meat consumption and at-home food consumption, all of which rose during the pandemic, were bigger drivers of rising food prices to US consumers in 2022 than rising commodity prices. In addition to these factors, the FTC reports that grocery store profit margins remain higher than pre-pandemic levels<sup>3</sup>.

**Changes in food prices**

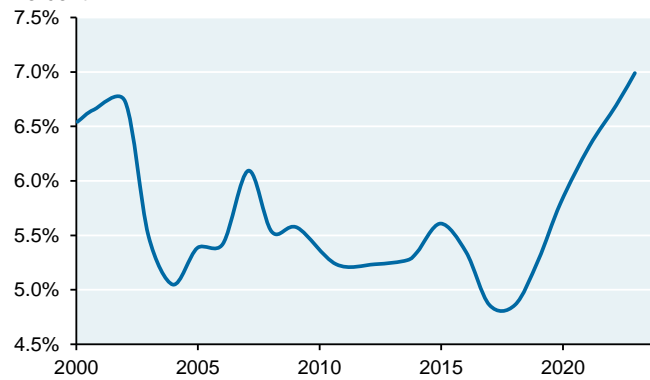
Index (100 = January 2021)



Source: Bloomberg, JPMAM, April 2024

**US grocery stores profit margin**

Percent



Source: "Feeding America in a Time of Crisis", FTC, March 2024

<sup>1</sup> I grow tomatoes, cucumbers, peppers, lettuce, figs and a variety of herbs. My unit costs are extraordinarily high. Vegetable beds are raised and fenced due to all the deer. If you're an accomplished bow hunter, you can sit up in the treehouse and cull the deer for me from October 1 to January 31.

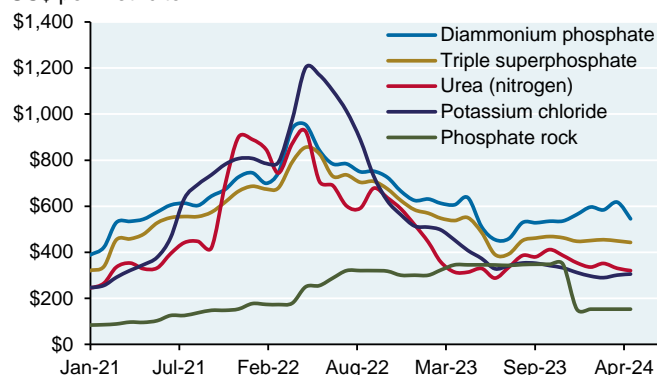
<sup>2</sup> "Commodity Prices Have Limited Influence on US Food Inflation", Kansas City Fed, September 23, 2022

<sup>3</sup> "Feeding America in a Time of Crisis", FTC, March 21, 2024

**More evidence of agricultural price normalization.** Fertilizer prices have declined back to early 2021 levels, and global fertilizer exports have reversed ~50% of the decline which took place in 2022. This is a consequence of some countries increasing production when Russian/Chinese fertilizer supplies fell, and the benefit of declining natural gas prices. When fertilizer prices spiked, some analysts feared that global farmers would reduce fertilizer application which would lead to food shortages; however, this did not take place on a global basis. Using urea imports as a proxy for fertilizer application, US fertilizer use rose from 2020-2022, remained flat in Europe and declined in India, Argentina and other developing countries<sup>4</sup>. **The world is often more resilient than feared.**

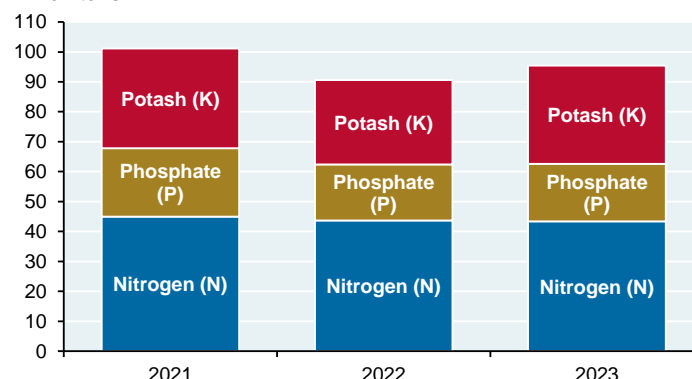
#### Global prices for fertilizers

US\$ per metric ton



#### Global fertilizer exports

Million tons

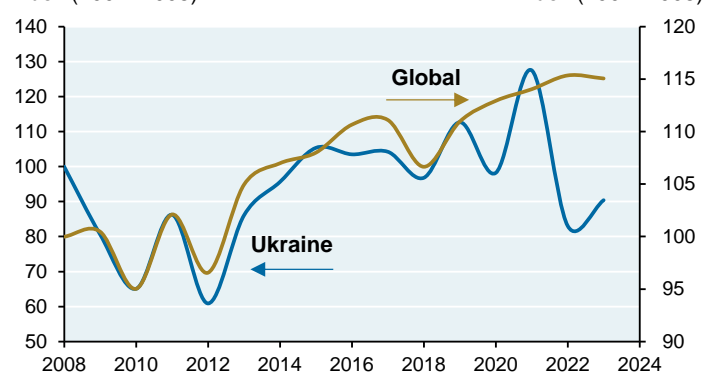


**Ukrainian production of corn and wheat fell by ~35% in 2022 vs 2021, but as with fertilizer, other countries increased production.** As shown below, global wheat production remained stable as Canada, Russia, Brazil and Kazakhstan increased output to offset Ukraine's decline. The impact on global corn production in 2022 was larger, but has risen back to prewar levels as China, the US, Brazil and Argentina increased corn production in 2023. On oilseeds, global and Ukraine production were barely impacted at all in 2022.

**While global production hasn't changed much, Ukraine's agricultural base has been devastated by Russia's invasion:** roughly one-third of Ukraine's territory is now contaminated with toxic elements such as lead, cadmium, arsenic and mercury leaching from ammunition and weapons into the soil<sup>5</sup>. Forests totaling 9,300 acres have been burned, rivers have been polluted, wildlife has been decimated and land mines have been scattered across 67,000 square miles<sup>6</sup>. And it may get worse: the WSJ reports that Ukraine's interception rate of Russian missiles has fallen to 30% from 83% a year ago.

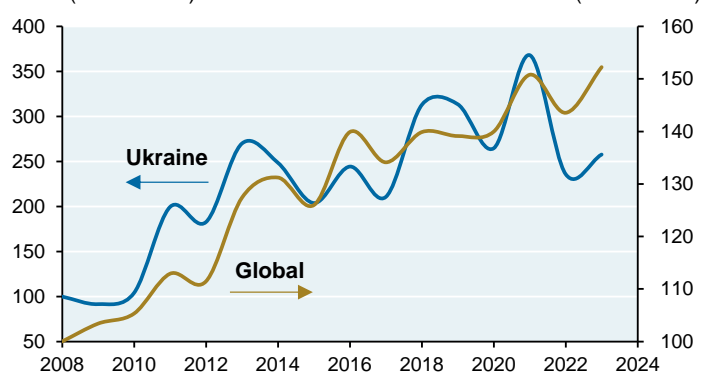
#### Production of wheat

Index (100 = 2008)



#### Production of corn

Index (100 = 2008)



<sup>4</sup> "Who's afraid of high fertilizer prices", International Food Price Research Institute, March 21, 2024

<sup>5</sup> Dr Olena Melnyk, ETH Zurich and Sumy National Agrarian University

<sup>6</sup> "After Two Years of War, Ukraine Sees Deepening Environmental Wound", Yale Environment 360, Feb 23, 2024

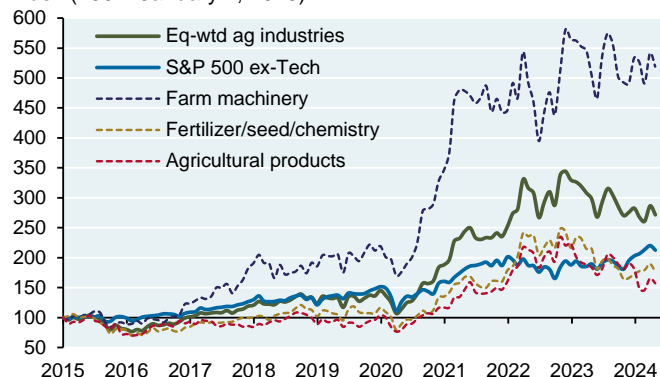
**Public market equity investments in agriculture<sup>7</sup>**

There are seven large cap US agricultural stocks in three industries: farm machinery (Deere); fertilizer, seed and chemistry (Mosaic, CF Industries, FMC Corp and Corteva); and agricultural products (Archer Daniels Midland, Bunge Global). An equal-weighted basket of these industries outperformed the S&P 500 ex-tech index since 2015; this is mostly a function of a surge in Deere stock in 2021. As shown on the right, agricultural industries trade at lower P/Es after a surge in 2020-2021. Rising unsold inventories of tractors/combines and falling projections for net farm income shown on the next page indicate substantial cyclical pressures on agribusiness, which may explain why current industry P/Es are below average.

Over the medium term, **positive farm drivers** include crop demand from renewable diesel/aviation fuel demand, and rising demand for US agricultural exports. **Drags** include premiums for “green” fertilizer (green hydrogen > green ammonia > green nitrogen fertilizer), a shift from diesel to more costly electrified farm equipment and increased ESG tracking/reporting standards imposed by wholesale customers. In a scenario consistent with decarbonization and net zero compliance, the Buckeye Institute estimated in February 2024 that corn farm operating expenses could rise by as much as 34%. It will also be important to monitor potential impacts of weight loss drugs on demand for cereals, sugar and affected other crops.

**Agriculture returns vs S&P 500 ex-Tech**

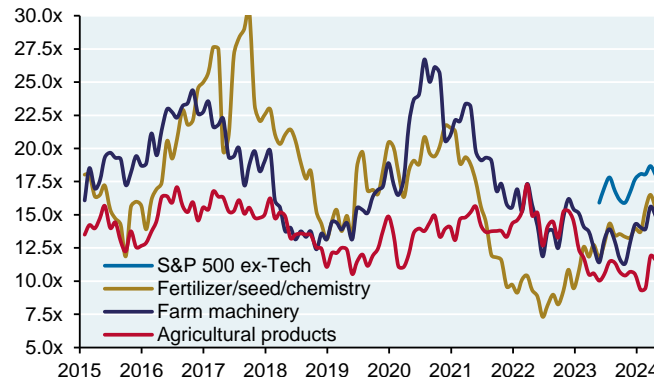
Index (100 = January 1, 2015)



Source: Bloomberg, JPMAM, May 2024

**Agriculture and S&P 500 ex-Tech P/E ratios**

Forward P/E ratio



Source: Bloomberg, JPMAM, May 2024

**What about agriculture exposure via non-US equities, US REITs and commodity futures?** The last chart shows performance of the three US agriculture industries in green; a global agriculture equity index in gold; two US small cap farmland REITs in blue; and a ladderred agriculture and livestock futures total return index in red. Over the time period shown US agriculture stocks outperformed all of them, and also outperformed the S&P 500 Packaged Foods index comprised of companies mentioned in footnote #7.

**Stock of unsold US farm equipment**

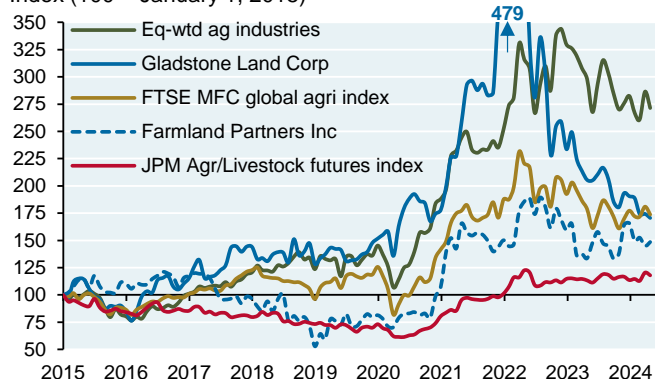
Monthly inventory of unsold machinery, thousands



Source: Sandhills Global, March 2024

**US agriculture returns: stocks vs REITs and commodities**

Index (100 = January 1, 2015)



Source: Bloomberg, JPMAM, May 2024

<sup>7</sup> Our focus here is on crop farming and industries that service/support them, rather than on egg/meat and other packaged food production (Tyson Foods, Pilgrim's Pride, Hormel Foods, BRF SA, etc)

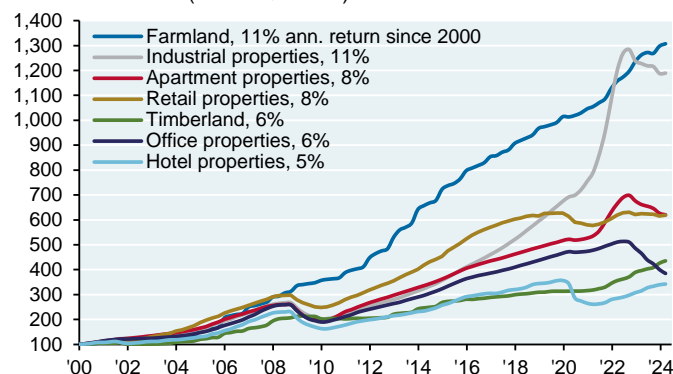
## Private investments in farmland

NCREIF publishes returns for a range of privately owned real assets. As shown below, their Farmland Index is at the top with annualized returns of 11% and volatility of 6.5% (just 4.3% since 2007). Returns are split 50/50 between operating income and capital appreciation; the universe includes farms dedicated to annual and permanent crops. What do I make of NCREIF data? First, farmland assets used in NCREIF appraisals are a very small fraction of US farmland values (see table). The reason: institutional ownership of farmland is only 4%<sup>8</sup>; the rest is owned by small, medium and large families. Second, farmland transaction volumes are very low relative to assets; as a result, NCREIF farmland returns are more driven by appraisals than other real assets. And third, NCREIF values farmland and timberland using a discounted cash flow approach which produces more “smoothed” results than the “multiple of cash flow” approach used for commercial real estate.

**Bottom line: farmland has likely increased in value (in part due to falling interest rates since the late 1990’s), but NCREIF farmland total returns may not be reflective of the median farm owner experience. I would not get carried away with mean-variance comparisons of NCREIF farmland returns to other assets.**

### Unleveraged real asset returns since 2000

Total return index (100 = Q4 1999)



Source: Bloomberg, NCREIF, JPMAM, Q1 2024

### Appraised value of NCREIF real assets vs asset size

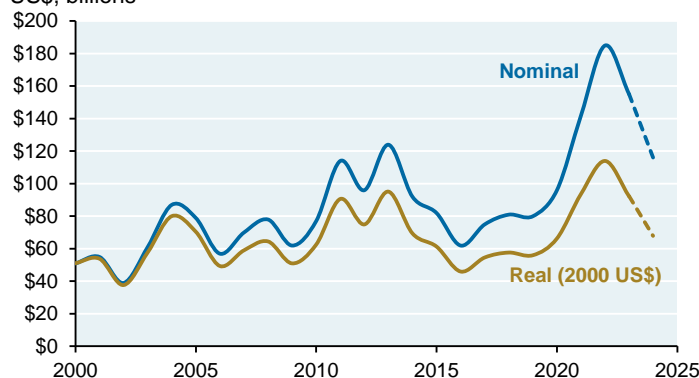
Asset Class	NCREIF universe (US\$ billions)	Total universe (US\$ billions)	NCREIF share
Industrial	\$292	\$2,400	12.2%
Apartment	\$239	\$3,800	6.3%
Office	\$179	\$3,200	5.6%
Retail	\$118	\$2,900	4.1%
Timberland	\$27	\$266	10.2%
Farmland	\$16	\$3,500	0.5%
Hotel	\$3	\$160	2.2%

Source: NCREIF, NAREIT, Ag America, JPMAM, May 2024

The USDA also computes income and appreciation data, covering both crop and livestock operations. In nominal terms, USDA net farm income rose by 4.5% per year from 2000-2023, which is 2% in real terms. This compares to 6.1% nominal growth in S&P 500 net income over that period. From a cyclical perspective, the USDA projects a sharp decline in net farm income in 2024 vs 2022. The USDA’s estimated capital appreciation is similar to NCREIF data at 4%-5% per year from 2009-2023.

### US net farm income

US\$, billions



Source: USDA ERS, JPMAM, February 2024

**What explains declining USDA projections of 2024 net farm income vs elevated 2022 levels?** Rising production expenses combined with falling prices for crops and livestock. Some details:

- 20%-25% projected price declines for soybeans, cotton corn and hogs; larger % declines for dairy and poultry
- 5%-10% projected increases in the cost of labor, herbicides, seeds, repairs and livestock feed and a 38% projected increase in interest costs

Sources: USDA Net Farm Income reports, Sept 7 2023 and Feb 7, 2024

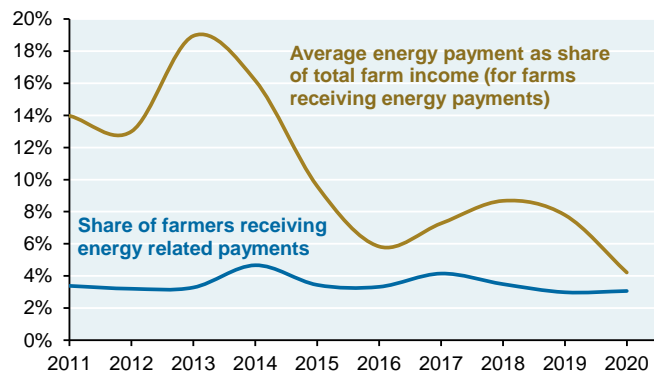
<sup>8</sup> While institutional ownership of farmland used for *crops* is very low, factory farming of *livestock* is highly concentrated and institutionalized: 70% of cattle, 98% of pigs, 99% of turkeys, 98% of egg-laying chickens and 99% of broiler chickens are bred and processed on such factory farms.

**What about energy payments to farmers that are not included in net farm income cited above?**

In April 2024, the USDA published a report on energy payments to farmers resulting from leases or royalties from natural gas, oil and wind production<sup>9</sup>. As of 2020, 3.1% of farmers received energy-related payments, and these payments comprised 4% of total farm income (crop/livestock production value plus gov't payments plus energy payments). Note: both charts refer only to the universe of farms receiving some energy payments.

**Energy payments to farm operators**

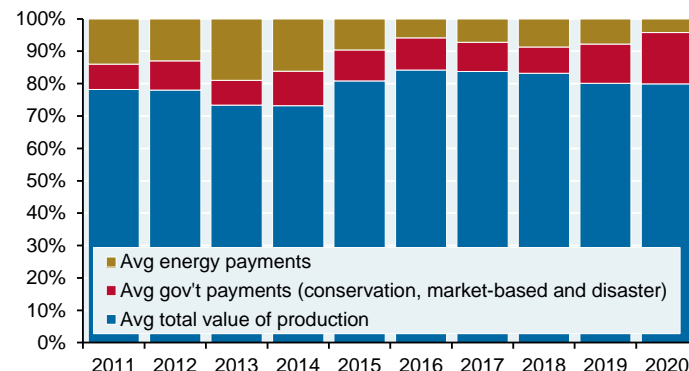
Percent



Source: USDA, JPMAM, 2024

**Breakdown of US total farm income**

Percent



Source: USDA, JPMAM, 2024

**Who owns American farms and forests?**

On foreign entities owning forestland, cropland or pastureland:

- Foreign entities own just 3.4% of US forests and farms. This figure is 3x higher than in 1981
- Of all foreign holders, the largest are entities in Canada (31%), the Netherlands (12%), Italy (7%), the UK (6%) and Germany (6%)
- Acreage owned by Chinese entities is less than 1% at 350,000 acres, down slightly from its level in 2021. Of this amount, the largest parcel was purchased in Texas with the investor's intention of building a wind farm on it, a project which was denied since state laws ban foreigners from accessing the Texas grid

On the domestic ownership of US cropland and pastureland:

- Small family farms account for 45% of all farmland; mid-size and large family farms account for another 51%; non-family (corporate or institutionally owned) farmland represent the remaining 4%. In 2023, a bill was proposed but not yet passed in Congress to restrict corporations, multi-layered subsidiaries, pension funds and investment funds from purchasing and leasing land while also receiving USDA subsidies (which could severely curtail institutional investment given the importance of USDA subsidies)
- Another sign of the "family-owned" nature of US farms: ~50% is inherited or purchased from a relative. And: 90% of owners have no intention of selling, and of the 10% that do, only 20% of that amount intend to sell to a non-relative. Eventually, some will face a selling decision anyway: according to the USDA, ~400 million acres of farmland is projected to change hands in the next decade
- Despite what you read on Twitter (which a recent article in Foreign Policy Magazine describes as a "sewer of disinformation"), Bill Gates owns a very small percentage of US farmland. Gates' 270,000 acres acquired from pension funds and insurance companies represent 0.03% of all US farmland
- One notable comparison: institutional ownership of single-family homes is 5%, but the pressing political issue is that institutional ownership of rented single-family homes has risen to 26%

Sources: American Farm Bureau, USDA, Foreign Policy, Joint Center for Housing Studies at Harvard

<sup>9</sup> "The Role of Commercial Energy Payments in Agricultural Producer Income", USDA, April 2024



## The intersection of machine learning and agriculture

The typical farm application of fertilizer, pesticides, fungicides and water are not as optimized as you might think. On fertilizer, only around half the amounts often applied are taken up by plants; the rest is wasted, leaching into waterways or broken down by microbes in the soil<sup>10</sup>. These runoff sources result in powerful GHG emissions since nitrogen in unabsorbed fertilizer turns into nitrous oxide, which is 300x more powerful as a GHG agent than CO<sub>2</sub>. GHG emissions from nitrogen runoff are only part of fertilizer's overall GHG footprint; another major component is natural gas combusted to make ammonia for nitrogen fertilizer<sup>11</sup>.

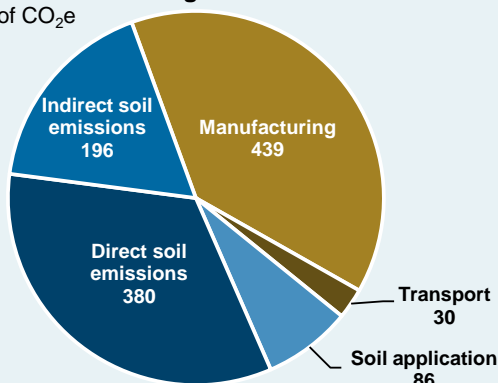
As for fungicides, only 22% of farmers use them and when they do, they're generally used blindly on all crops. In contrast, roughly 70% of crops would benefit from fungicides, but only need them in targeted applications instead of constant use.

**InnerPlant aims to improve crop management by genetically engineering plant DNA to emit fluorescent biomarkers when stressed due to fungal infections, insect infestation, inadequate fertilizer or not enough water.** Their first USDA-approved product: soy seeds that respond to fungal infection; FDA approval is still pending. Its fertilizer biomarkers distinguish between inadequate phosphorous, potassium and nitrogen (the latter being more important for corn than soy which typically does not receive nitrogen fertilizer).

InnerPlant's fluorescent signals are designed to be visible by satellites, drones and tractors which communicate the need for remedial steps. These are potentially powerful signals since its biomarkers are designed to emit distress signals 2-4 weeks *before* visible symptoms are otherwise noticeable. The ultimate goal: reduced waste of fertilizer, fungicide, pesticide and water, and increased yields by delivering crop inputs only when needed and not randomly or constantly. Biomarker sensors represent another step in a long line of agricultural productivity improvements, some of which are shown on the right<sup>12</sup>.

### Global emissions from nitrogen fertilizers

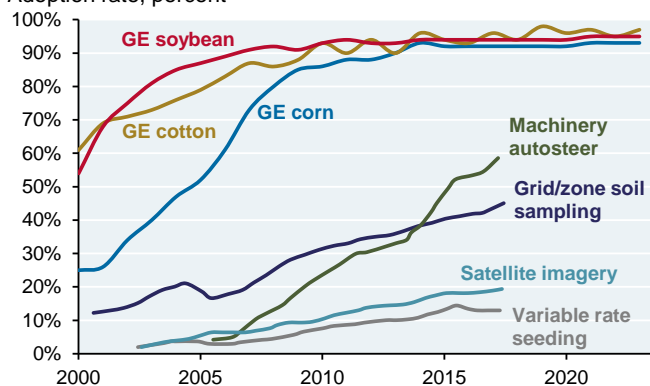
Million tonnes of CO<sub>2</sub>e



Source: "Greenhouse gas emissions from global production and use of nitrogen synthetic fertilisers in agriculture", Scientific Reports, August 2022

### Genetic and precision agriculture

Adoption rate, percent



Source: UC Davis, USDA, 2023. GE = genetically engineered

**InnerPlant deploys AI and machine learning at numerous points in its detection-to-action system.** In order to design and develop signaling crops, InnerPlant uses ML to process large amounts of genomic data to learn which pieces of DNA accurately and specifically indicate targeted stress. InnerPlant also uses AI/ML in data processing to disentangle fluorescent signals from background sunlight in satellite, drone and tractor detection. The signaling crops generate a high-quality dataset combined with additional data streams such as weather, topography, disease pathology and crop physiology to provide training data for AI/ML prediction models.

<sup>10</sup> "Fertilizer and climate change", MIT, Manthiram et al, July 2021

<sup>11</sup> Agriculture emissions are 10% of US GHG emissions; agricultural emissions are split roughly 50/50 between livestock and crops (EPA)

<sup>12</sup> "Innovation, growth and structural change in American Agriculture", Alston et al, UC Davis, 2020

## Agricultural damage in Gaza and Israel

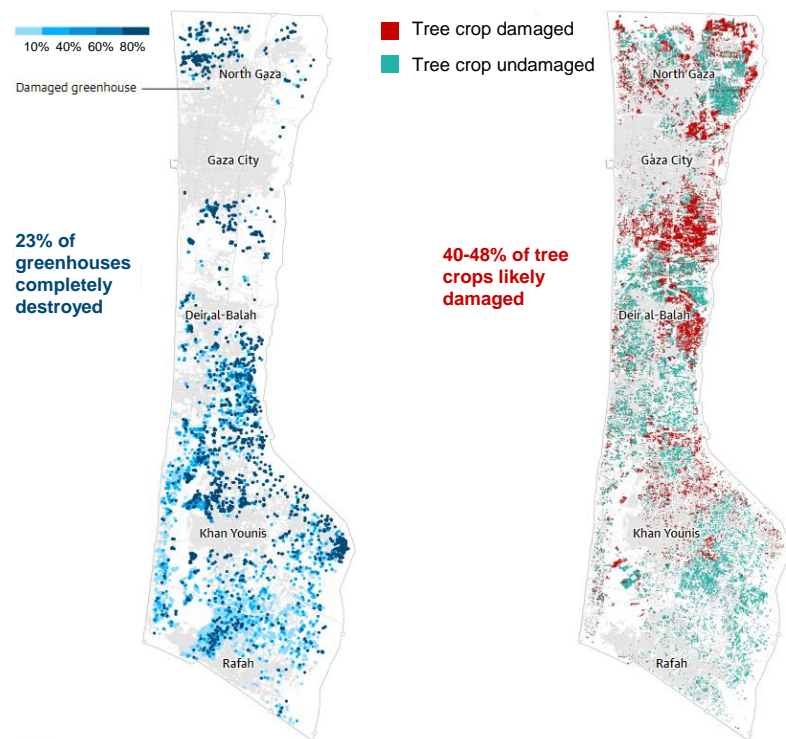
In our energy paper, we discussed distributed solar power in Gaza and its potential to meet electricity demand once the 55%-65% of buildings that have been damaged or destroyed are rebuilt. Another necessary Gaza reconstruction project detected by satellite imagery: **replanting and resuscitation of damaged tree crops**. As shown below<sup>13</sup>, almost half of Gaza's tree crops (mostly olives and fruit/nut orchards) have been damaged due to airstrikes and bulldozers; in Northern Gaza, damage could reach 70%. In addition, ~25% of greenhouses have been destroyed with another 40% damaged and likely unusable.

As for agricultural land, 35%-45% has been destroyed across the Gaza strip<sup>14</sup>. Damage includes 90% of Gaza's 6,500 poultry farms, 149 sheep farms, 5 cattle farms, 20 dairy farms and fish farms along the coast due to bulldozing<sup>15</sup>. This damage is compounded by ~50% of all water infrastructure having been damaged, as well as extensive damage to energy infrastructure required for irrigation and food refrigeration<sup>16</sup>.

In Israel, many farming communities were abandoned and turned into ghost towns<sup>17</sup> after the Hamas attacks. On October 7, Hamas forces destroyed food and water dispensers on Israeli poultry farms, leading to the death and decomposition of 300,000 chickens. Hamas forces also destroyed farmland, livestock, plants, orchards, greenhouses, barns and irrigation/filtration infrastructure in the western Negev which produces 70% of the country's vegetables and 20% of its fruit.

### Damage to individual greenhouses and tree crops in Gaza

Damage due to direct impact of war, satellite imagery at 3-meter resolution



Before 2023, Gaza contained 170 square km of agricultural land, 47% of Gaza's total land area; 35%-45% of the agricultural land has been destroyed according to satellite analysis. Some of these areas have been converted into military earthworks (fortifications).

When the war ends, soil remediation (including microorganisms needed for viable crops) is expected to take around five years. After that, citrus groves will need three to five years from the time of planting to start bearing fruit, while olives will require five to seven years. Longer remediation periods would be needed for areas affected by white phosphorous.

Source: He Yin (Kent State), The Guardian graphic, 2024

<sup>13</sup> Professor He Yin at Kent State analyzed satellite imagery that uses machine learning to identify three square meter tree crops and greenhouses and their level of damage. Yin uses Meta's "Segment Anything" model which relies on high resolution Planet Skysat imagery

<sup>14</sup> "Long-lasting devastation to livelihoods from damage to agricultural lands in Gaza", IFPRI, Feb 2024; similar findings of 35%-45% agricultural land damage are reported by UNOSAT and Forensic Architecture

<sup>15</sup> "Overview of damage to agricultural land & infrastructure due to the conflict in Gaza Strip", UN FAO, Jan 2024

<sup>16</sup> "Israel's offensive is destroying Gaza's ability to grow its own food", Washington Post, May 3, 2024

<sup>17</sup> Reuters, March 27, 2024; NPR, December 24, 2023; WSJ, February 20, 2024

**Appendix: the avian flu's impact (H5N1) on livestock and the food supply**

**Overview.** H5N1 spreads among wild aquatic birds and is then passed to domesticated animals. The highly pathogenic strains result in 90%-100% poultry mortality rates within 48 hours. H5N1 has led to the death or culling of 82 million poultry livestock and \$2-\$3 billion in losses (when the disease is found, the entire flock is slaughtered). For context, the US poultry industry produces more than 9 billion chickens and turkeys each year. H5N1 has also spread to US cattle (36 herds in 9 states); farmers report reduced milk production in infected cattle, although the impact on milk supply has been limited so far and most infected cows do not develop severe symptoms or die. The global implications of H5N1 could be substantial now that poultry has surpassed pigs in terms of global consumption.

**Mutations and spread.** In the past, outbreaks subsided when wild bird migrations ended, but now it appears that H5N1 might be a year-round threat. The WHO warns that outbreaks among other mammals (cattle, skunks, bears, foxes) could increase the virus' ability to circulate more easily among humans. So far, H5N1 in infected cows looks similar to the avian version, but scientists need to monitor how the virus might adapt when spreading from cow to cow. Humans have no pre-existing immunity to H5 viruses, only for H1 and H3.

**Vaccines and trade.** In the US, bird vaccines are applied to prevent diseases like fowlpox but not for avian flu. Some industry analysts believe that trade is the reason: the US exports \$6 billion of poultry per year and many bilateral trade agreements explicitly do not allow bird flu vaccination. The USDA has reportedly tested five H5N1 candidates with some demonstrating near 100% success. In some countries, bird flu vaccines have had only mixed success (China, Egypt, Mexico) while in others they have been more effective (France, Hong Kong).

**Milk supply and precautions.** The FDA was unable to grow an active H5N1 virus from virus fragments found in pasteurized milk, which means that the virus could not replicate. The FDA cautions against drinking unpasteurized milk, recommends keeping pets away from livestock and recommends the use of PPE equipment when working with livestock.

**Agriculture economics.** The Department of Agriculture paid farmers \$500 mm last year for chickens and turkeys they were forced to kill. The USDA livestock indemnity program, part of a farm bill passed by Congress in 2018, pays farmers 75% of the value of animals lost to disease or natural disasters. Since 2022 the program has distributed more than \$1 billion to affected farmers.

**US CPI inflation: eggs**

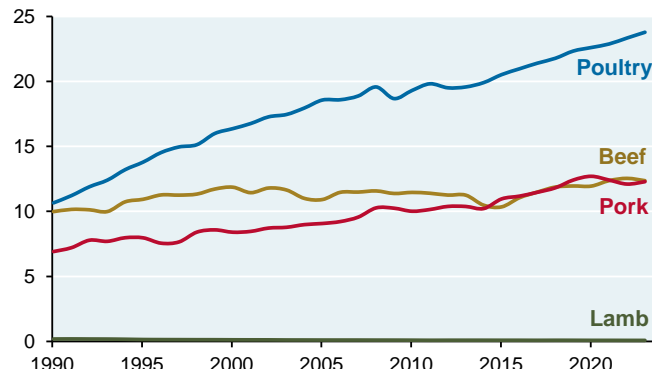
Index (100 = 2008)



Source: Bloomberg, JPMAM, March 2024

**US meat production**

Million metric tons



Source: OECD Food and Agriculture Organization, JPMAM, 2023



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While our internally managed strategies generally align well with our forward-looking views, and we are familiar with the investment processes as well as the risk and compliance philosophy of the firm, it is important to note that J.P. Morgan receives more overall fees when internally managed strategies are included. We offer the option of choosing to exclude J.P. Morgan managed strategies (other than cash and liquidity products) in certain portfolios.

The Six Circles Funds are U.S.-registered mutual funds managed by J.P. Morgan and sub-advised by third parties. Although considered internally managed strategies, JPMC does not retain a fee for fund management or other fund services.

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