

## Sustainability

# Feeding the future: How climate and agriculture intersect

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### Key takeaways

- The global population, which is expected to grow by an additional ~2 billion people by 2050, will require the global agriculture industry to produce more food in the next 3-4 decades than was produced in the last 8,000 years (source: World Wildlife Foundation).
- Meanwhile, the ramifications of climate change - from rising temperatures, more frequent droughts, declining soil quality, crop damage from disasters, and surging pest populations - are profound.
- We discuss several focus areas of sustainability in agriculture, and break down how agriculture technology (AgTech) solutions can play a pivotal role in enhancing efficiency, addressing pain points, and reducing the environmental footprint within the agricultural sector.

### Agriculture's \$50B climate crisis

Across the globe, the impact of climate change is multifaceted. The UN warns that climate change is set to expose up to 80 million more people worldwide to hunger by 2050. And in the United States, the ramifications of climate change – from rising temperatures, more frequent droughts, declining soil quality, crop damage from disasters, and surging pest populations – are profound. These issues already incur substantial costs for the US crop agriculture industry, accounting for approximately \$20 billion annually which is about 8% of total US crop revenues.

Severe droughts and floods have historically caused 15-30% drops in corn yield in the US versus the year prior and account for nearly all of the current crop losses caused by weather disasters (source: USDA, American Farm Bureau Federation). By midcentury, the southern and midwestern states are poised to be the hardest hit according to BofA Global Research, with more frequent droughts expected. At the same time, warmer winters will facilitate invasive pests, leading to a potential increase in destruction of 50% of wheat and 30% of maize, according to University of Washington research. These factors are estimated to cause annual losses of ~\$50 billion, including \$5 billion in direct crop losses and \$40 billion in societal costs tied to food security and safety.

As farmers consider adapting their farming practices to mitigate the impacts of climate change, US crop insurance costs are set to rise by +4-22%, and costs could rise even higher (+10-37%) if they do not adapt (source: USDA). However, in the years ahead, agriculture technology (AgTech) solutions can play a pivotal role in enhancing efficiency, addressing pain points, and reducing the environmental footprint within the agricultural sector.

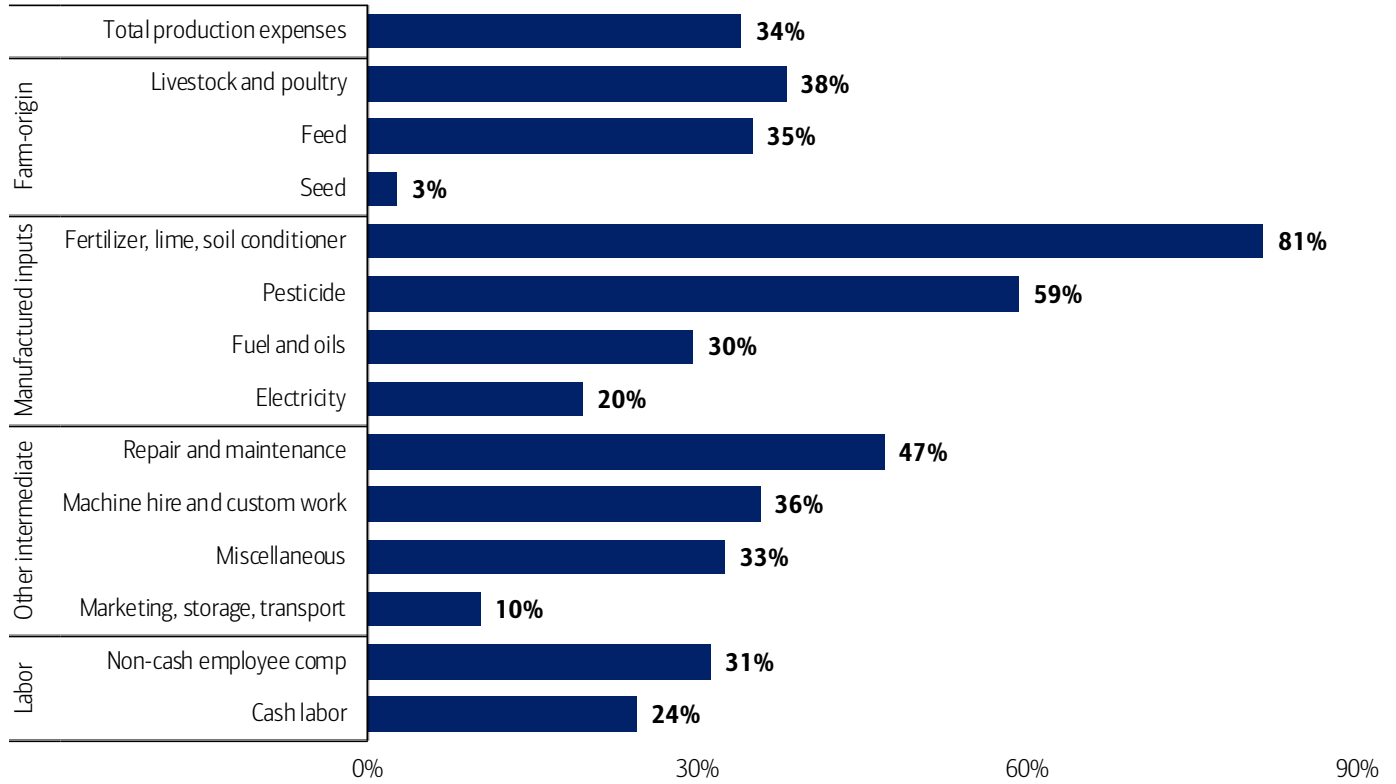
### Rising costs are affecting the entire food supply chain

Severe weather events, high input costs, and challenged supply have played a key role in US food price inflation. Rising natural gas and coal prices led to production cutbacks in ammonia (a key input for nitrogen-based fertilizers) in Europe and China, while Belarus and Russia sanctions have created nitrogen and potassium supply shortages. And this summer's extreme heat and droughts in the Mediterranean—which are becoming more frequent due to climate change—have caused a record spike in wholesale olive oil prices that will be passed onto US consumers (source: Scientific American).

Labor costs have also increased significantly. Farm labor markets have become tighter with 40% of new agriculture jobs left unfilled each year in the US (source: Purdue University). As a result, farmers have had to offer better pay to attract and maintain workers. In fact, inflation-adjusted agricultural wage growth has outpaced that of non-agricultural wages by 11ppt between 2000 and 2022 (source: USDA). Overall, these labor shortages have had several impacts including reduced output (revenues) to increased food waste – approximately one-third of edible produce remains unharvested, according to Santa Clara University.

**Exhibit 1: Change in nominal production expenses (excluding operator dwellings), 2023F vs 2018**

US farm production expenses have gone up a whopping 34% in the last 5 years



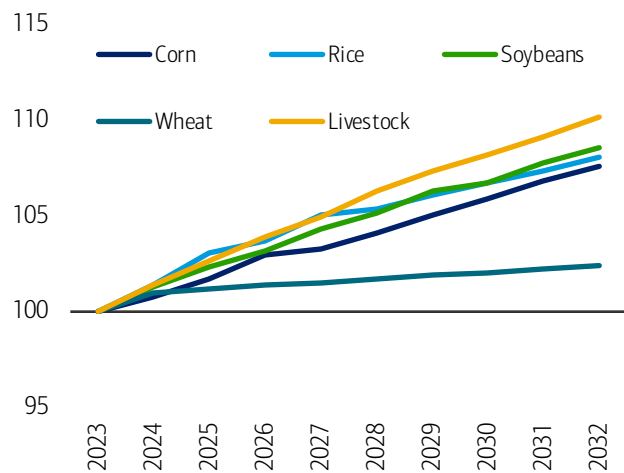
Source: USDA, BofA Global Research

**At the same time, growing demand will require boosting food production**

Recent price spikes and localized scarcities, together with growing populations and food consumption, underscore the need to boost food production in the coming decades. Domestic demand for the US' major crops and livestock is expected to grow between 2-10% over the next decade (Exhibit 2) Increasing consumption of meat, which requires >4x more acreage than a vegetarian diet, will further increase the demand pressure on feed crops (Exhibit 3; source: The Economist).

**Exhibit 2: Projected increase in US domestic use (disappearance) of corn, soybeans, wheat, and livestock from 2023-2032, indexed to 2023 values**

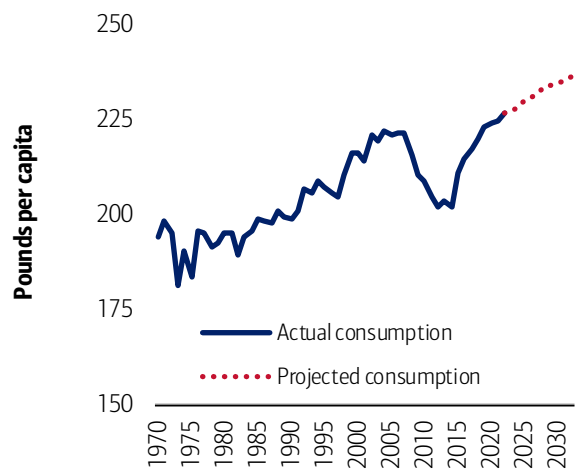
Rising demand for key US crops and livestock



Source: BofA Global Research, USDA Agricultural Projections to 2032 (published 2023). Livestock includes beef, chicken, pork, and turkey.

**Exhibit 3: Annual per-capita consumption of red meat and poultry in the US (retail weight in pounds), historical values from 1970-2022 and projected values from 2023-2032**

Growing US meat consumption will increase demand for feed crops

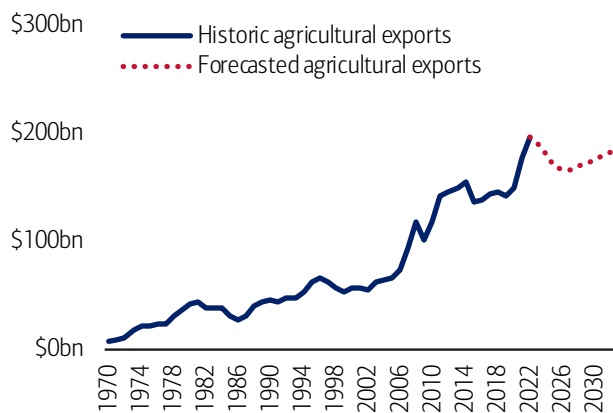


Source: USDA Economic Research Service Livestock, Dairy, and Poultry Outlook

And the US agricultural sector exports more than 20% of the value of its production, meaning that the sector will be impacted by the growing global population and increased demand for diversified diets and protein (source: USDA). The global population, which is expected to grow by an additional ~2 billion people by 2050 (Exhibit 5), will require the global agriculture industry to produce more food in the next 3-4 decades than was produced in the last 8,000 years (source: World Wildlife Foundation).

**Exhibit 4: US agricultural exports in bn USD, historical values from 1970-2022 and forecasted values from 2023-2032**

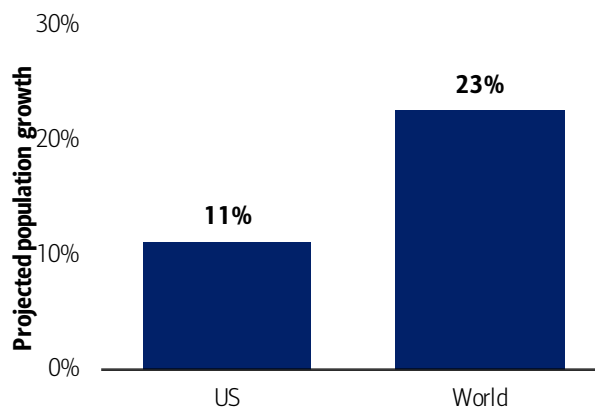
US ag exports expected to remain strong over the next decade, although off 2022's record high



Source: USDA Economic Research Service (ERS)

**Exhibit 5: Projected population growth (%) for the US and world, 2023 to 2053**

By 2053, there will be 37 million more mouths to feed in the US and 1.8 billion more globally



Source: BofA Global Research, US Congressional Budget Office (CBO) 2023 population projections, United Nations Department of Economic and Social Affairs 2022 World Population Prospects

**Food security, health, and environmental challenges**

As climate change exacerbates yield reductions, it threatens global food security, potentially placing 80 million more people at risk of hunger (source: UN). Growing food demand intensifies these risks and underscores health and safety concerns. Additionally, in the US, 34 million people—including 5 million children—live in food-insecure households, costing the US healthcare system at least \$160 billion annually (source: USDA, Bread for the World Institute). Food insecurity can lead to chronic diseases, causing affected families to spend ~20% more on healthcare (source: Health Affairs). In total, food security, health, and safety issues cost the US health care system over \$220 billion each year (source: Bread for the World Institute, USDA, Attina et al., 2016).

**Increasing pests, foodborne illness put food safety at risk**

Environmentally, agriculture is a significant contributor to challenges like biodiversity loss (see: [Biodiversity means business](#)) and extensive pesticide use, which exceeds 1 billion pounds annually in the US. As climate change increases the range and appetite of pests, pesticide use is expected to rise (source: EPA). In fact, the wide use of crop chemicals (and a declining rate of introduction of new active ingredients) has led to more than 500 species of pests to develop some level of pesticide resistance, which has increased the risk of lower yields and crop failure (source: Michigan State University).

A warmer climate also makes plants more susceptible to fungal infections, which is expected to increase mycotoxins (toxins from fungi) in foods and the prevalence of foodborne illness, which currently costs the US ~\$20 billion annually in healthcare expenditures and lost wages (source: USDA).

**Agriculture has a significant environmental impact**

As the need to produce more food becomes increasingly urgent, there is also a growing awareness of the complex relationship between agriculture and the environment. Greenhouse gas (GHG) emissions, biodiversity loss through deforestation, pesticide usage, and irrigation practices exert significant environmental impacts.

In fact, agriculture is responsible for 11% of US GHG emissions, primarily via nitrous oxide and methane, which is >25x more potent as a greenhouse gas than CO2. And 70% of agriculture’s methane emissions come from livestock, who release the gas as part of their digestion process, while soil management practices contribute to ~95% of the sector’s nitrous oxide emissions (source: US Environmental Protection Agency [EPA]).

The expansion of agriculture has also had consequences on global biodiversity. It has led to the conversion of natural habitats into farmland, resulting in significant losses in plant and animal species. Additionally, pesticide use, with >1 billion pounds used annually in the United States (source: EPA), poses risks to ecosystems and pollinators.

## AgTech: Feeding more, polluting less

Innovations in agriculture technology (AgTech) can help to address these multifaceted issues including environmental sustainability, food security, food safety, and farmworker health & safety by increasing efficiency and reducing input costs. We discuss several focus areas of sustainability in agriculture and break down how AgTech is shaping a new farming landscape.

Economies of scale from increased adoption of AgTech solutions may bring down costs and enable necessary advancements in efficiency. Precision agriculture (precision ag) uses fuel, labor, and inputs more efficiently. How? Genetic modifications can make crops more resistant and increase yields. Bacteria-sourced nitrogen can reduce the use of synthetic nitrogen fertilizer and resulting nitrogen oxide emissions. Indoor agriculture can protect yields from extreme temperatures. For field crops like maize and wheat, which can't feasibly be farmed indoors, digital and precision ag could be the salve.

### AgTech can address labor & supply chain issues

Amid the US' agricultural labor shortage, AgTech can reduce labor requirements by 30-40% according to BofA Global Research. Improving tractors with automated guidance and vision can avoid damaging crops and reduce driver fatigue, which is important given that shifts are commonly more than 16 hours per day (source: CES). Automated machinery could also help reduce workers' exposure to heat and pesticides. For example, yield and georeferenced soil maps can decrease labor hours per bushel by 35%, while variable rate technologies can decrease labor hours per bushel by 28% (source: USDA; Schimmelpfennig, 2016).

Plus, indoor farming can shorten supply chains. Controlled farming environments (like vertical farming) help reduce reliance on imports by creating a local produce supply. Locally grown food may have greater nutritional value, as the shorter transport distances mean it doesn't have to be picked as early or treated to maintain freshness (source: White House).

### Seeds are critical to crop yields

Bioengineering in AgTech can create more productive seed varieties. Controlled farming environments can protect yields from the severe weather patterns associated with climate change and optimize the growing environment to improve yields. For example, controlled farming can grow 62 crops of pea shoots per year versus just three crops on a traditional farm and ~20 crops in a typical greenhouse (Source: Growing Underground). Genetic modification and gene editing technologies can future-proof yields, e.g., by making crop varieties more drought- and heat-resistant. And beyond food security, higher yields can also support biodiversity, as deforestation pressures are lower when farmers can produce more food on the same land.

### Biologicals provide crop protection

While the term 'biologicals' can broadly refer to the use of bacteria to produce compounds of interest, they can also provide crop protection. Biologicals can provide pesticidal activity (herbicides, insecticides, fungicides, etc.), which are metabolic pathways in natural occurring bacteria – as opposed to the use of legacy synthetic chemicals. AgTech companies are developing biologicals not necessarily for their efficacy, but rather their favorable sustainability profile.

### Bacteria-sourced nitrogen cuts carbon

The nitrogen production industry accounts for 1-2% of global CO2 emissions, while the application of synthetic nitrogen fertilizer is a large source of nitrous oxide emissions. The feedstock to produce synthetic ammonia is either natural gas or coal, with most of the carbon emitted from the process as CO2.

The biological pathway to produce ammonia developed from an evolutionary standpoint as a symbiotic relationship between certain groups of plants (e.g., legumes like soybeans) and these naturally occurring bacteria. Significant energy is required for this reaction, and thus the bacteria receive an energy source from the plant and in return produce the ammonia for the plant. While this biologic pathway is not new, it has only been recently evaluated as a potential add-on technology for non-legume crops like corn and wheat. Given the energy requirements, these bacteria have the ability to detect nitrogen in the surroundings, which causes the ammonia-producing pathway to shut down.

### Cover crops add to sustainability profile

While the concept of cover crops – crops that are planted over the winter, after the fall harvest – is not new, advances in gene editing have allowed for great progress in this field – a key for sustainable agriculture. Due to adverse weather conditions, cover crops have limited time to grow and are usually unable to reach full growth before the next planting season begins and are thus discarded. So why do farmers plant cover crops? Because they offer soil management benefits including soil and nutrient retention. However, they historically have been an additional expense for farmers.

Many companies are working on developing winter cover crops that can actually be harvested, thus having a positive contribution to farmers' income. This is largely possible due to gene editing of these plants, allowing them to mature faster and have higher yields.

Beyond the ability to harvest and sell cover crops, farmers have an additional incentive to use these crops. As carbon credit market is being developed in the US, with large agriculture companies working with farmers to implement more sustainable farming practices and measure their carbon sequestration benefits. The rationale here is to measure how much farmers are able

to reduce their carbon emissions, and create the appropriate documentation, such that carbon credits can be pooled together and then sold.

### **Precision ag creates efficiency**

In the US, less than 20% of all farms are mid-to-large sized farms. However, mid-to-large size farms comprise of most of the total farm acreage across the country. Historically, Precision ag products are focused on large farms but retrofit solution can address the other 80%+ of farms by enabling used or old machines to be updated with the latest technology on these small farms. Retrofit provides a cost-effective solution for farmers to experience the latest technology by lowering the upfront cost of purchasing a new original equipment manufacturer (OEM) product.

Data analytics tools are being developed to reduce and make more efficient use of crop inputs. Precision ag provides innovation solutions (e.g., sense & act technology, autonomous features) that address pain points facing the farmer (labor, input inflation, etc.) in a world where food security is center stage. Over time, precision ag is likely to yield more value per equipment unit as farmers plant and harvest every year.

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