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Efficiency in U.S. Agriculture: A Decade of Change (2015–2025)

Over the past 10 years, U.S. agriculture has become increasingly **efficient**, producing more food with fewer inputs. This trend is evident when examining key performance indicators (KPIs) – **Labor productivity**, **Technological adoption**, **Resource use efficiency**, **Economic output**, and **Caloric output** – especially for the five most consumed crops in the United States (corn, soybeans, wheat, rice, and sugar crops). Below, we define each KPI and review how it has changed, citing USDA data and research. We then discuss how these trends can guide decision-making for the future of American agriculture.

Labor Productivity and Workforce Changes

Definition: *Labor productivity* in agriculture measures output per unit of labor (per worker or per hour). High labor productivity means farmers produce more crop output with the same or less labor input.

Trends: U.S. farming has achieved dramatic labor efficiency gains over the long term. Total farm output nearly tripled from 1948 to 2017 even as the amount of labor (hours worked) fell by over 80% [1] [2]. In fact, agricultural output per worker grew about **16-fold** (per hour about 17-fold) between 1948 and 2017 [3]. This reflects decades of mechanization and consolidation – for example, bigger tractors, combines, and other equipment replacing manual labor. In the last decade specifically, the decline in farm labor hours has *slowed* (there are fewer workers to shed), but the overall trend of rising output with a smaller workforce continues [2]. Higher *labor quality* has also helped: today's farm operators and workers are more educated and skilled on average, which boosts productivity per worker [4]. The farm labor force has shifted toward fewer, larger operations where one or two people can manage far more acreage than in the past [5].

Example – Corn Harvest: Corn, the nation's largest crop at about 14 billion bushels a year [6], is now mostly harvested by machine. A single combine operator can harvest hundreds of acres that would have required many hands in earlier eras. The result is a huge increase in corn output per labor-hour. Similar labor efficiencies are seen in soybeans (~4 billion bushels/year) [7] and wheat (~1.8 billion bushels/year) [8], which are also highly mechanized. In summary, farmers are **"producing more with fewer inputs"** – including labor – than ever before [9].

Technological Advances and Adoption

Definition: *Technological efficiency* refers to the adoption of innovations – from advanced machinery to improved crop genetics and digital tools – that allow more output from the same resources. Key ag technologies include improved seed varieties, biotechnology (GM crops), precision agriculture (GPS-guided equipment, sensors, data analytics), automation, and improved fertilizers and pesticides.

Trends: Technological progress has been **the primary driver** of productivity growth in U.S. agriculture [10]. Over the past decade, American farmers have widely embraced precision agriculture and other digital tools.

For instance, GPS **auto-steering guidance** on tractors and combines, which was used by only single-digit percentages of farms in the early 2000s, is now employed by about 70% of large-scale farms (and over 50% of midsize farms) as of 2023 [11]. Yield monitors, GPS yield mapping, soil sensors, and variable-rate input applicators have also become common on large farms, enabling farmers to optimize planting density, fertilizer, and irrigation with pinpoint accuracy. Overall, **27% of U.S. crop and livestock farms** had adopted at least one form of precision agriculture by 2022 (up 2 percentage points from 2018) [12]. Farmers cite increased yields, lower input costs, and labor savings as motives for adopting these technologies [13].

At the same time, **biotechnologies** introduced in prior decades (e.g. genetically engineered corn and soybeans) reached very high adoption levels and continued to pay efficiency dividends through the 2010s. Improved crop genetics and traits (such as pest resistance and drought tolerance) have helped raise yields and reduce losses. USDA researchers note that *innovations in crop genetics, better farm management, and precision equipment have together driven total factor productivity upward* [14]. In short, American producers have entered the digital farming era: even traditionally low-tech sectors are seeing automation (for example, robotic milking machines on dairy farms to save labor [15]). This widespread tech adoption on farms large and small has boosted output and reduced waste.

Example – Precision Farming on Corn/Soy: Corn and soybeans (the top U.S. field crops by acreage) have seen especially strong tech uptake. Nearly all U.S. corn and soy acres are planted with genetically engineered seed varieties. On large Midwest grain farms, it's now routine to use GPS-guided planters and harvesters, yield-mapping software, and drones or satellite imagery to monitor crop health. These tools enable fine-tuned decisions that improve efficiency – for example, applying fertilizer only where needed, which raises productivity per acre and prevents overuse. The result has been steady yield gains (corn production has **"been steadily increasing since the 1950s"** due to such improvements [16]) and more stable outputs despite weather variability.

Resource Use Efficiency (Land, Water, and Inputs)

Definition: *Resource use efficiency* refers to the productivity of natural resources (land, water) and inputs (fertilizer, energy) in agriculture. Key metrics include crop yield per acre (land productivity), water use per crop output, and input use intensity (e.g. fertilizer or energy per bushel produced). Improving resource efficiency means getting more output from the same or fewer resources, thereby reducing the environmental footprint per unit of food.

Trends: American agriculture has achieved **higher yields on less land** and is working to produce "more crop per drop" of water and inputs. Over the last decade, total U.S. farmland area has remained roughly constant or even declined slightly, yet crop outputs grew – indicating rising yield per acre. For example, average corn yield hit new highs in recent years (regularly 170+ bushels/acre, versus ~150 a decade ago), continuing a long upward trend [16]. Similarly, soybean yields have trended upward, reflecting better varieties and practices. According to USDA analysis, *global* productivity gains have led to **fewer natural resources used per unit of output** on average [17] – and the U.S. exemplifies this, with less land and labor needed per bushel of grain than ever before.

Water use efficiency is an increasing focus, especially in irrigation-dependent regions. The USDA Natural Resources Conservation Service (NRCS) has been helping farmers implement water-saving practices, recognizing that producers must "do more with less water" as water supplies tighten [18]. Techniques like **drip irrigation, efficient sprinklers, and irrigation scheduling** have expanded. For instance, when a

Montana grain farmer upgraded from flood irrigation to a pipeline sprinkler system, he was able to **use half the water** he used before, yet irrigate his crops in a fraction of the time [19]. Conservation practices such as **cover cropping** and **no-till farming** are also more widely adopted now; these improve soil structure and moisture retention, reducing runoff and the need for excess irrigation [20] [21]. According to the latest USDA irrigation survey, total farm water withdrawals in 2023 were slightly *below* those in 2018, even though farm output rose in that period [22] – evidence that water productivity is improving.

Fertilizer and energy inputs have seen mixed trends. Farmers have intensified input use in some cases (to push yields), but precision agriculture helps **reduce excess fertilizer or fuel use** by targeting applications. The result is that input use per unit output has not grown in proportion to yields. In fact, since 1948 the use of labor and land dropped dramatically while intermediate inputs like fertilizer increased only modestly, so overall input use was nearly flat while output surged [23]. This means each bushel of grain today embodies far fewer resources than decades ago. Modern corn, for example, uses fertilizer and water more efficiently thanks to both genetic improvements and management: more of the applied nutrients are converted into grain, and less water is lost to evaporation or runoff due to improved practices.

Example – Rice and Water: Rice farming, which is water-intensive, has benefited from improved resource efficiency. The U.S. is a major rice exporter, with concentrated production in Arkansas, California, and a few other states [24]. Over the past decade, many rice growers adopted laser leveling of fields and alternate wetting and drying irrigation techniques to reduce water use. These methods cut water consumption per acre while maintaining high yields. Backed by USDA programs, rice farmers are proving that even a traditionally flood-irrigated crop can be grown with less water without sacrificing output – a crucial adaptation as aquifer levels decline in some regions.

Economic Productivity and Output Growth

Definition: The *economic efficiency* of agriculture can be captured by **Total Factor Productivity (TFP)** – the ratio of total outputs to total inputs. If TFP rises, it means farmers are getting more output from the combined inputs of land, labor, capital, and materials. Economic efficiency also relates to farm profitability (producing at lower cost per unit) and the sector's competitiveness in markets.

Trends: Productivity data from USDA's Economic Research Service show that **productivity improvements have been the main engine of U.S. agricultural growth** [14]. From 2011 to 2021, total farm output continued to grow annually while total inputs used (land, labor, capital, chemicals, etc.) barely increased – even *decreasing* in some recent years [25]. The latest decade saw a slight slowdown in the rate of productivity growth compared to earlier decades (a pattern observed globally as well [26]), but the overall trend remains positive. Between 1948 and 2021, U.S. farm output grew ~1.46% per year on average, with TFP contributing about +1.49% per year to that (while input use change was about –0.03% per year) [27] [14]. In other words, virtually all output growth has come from being **more efficient**, not from using more land or labor. In fact, reductions in labor and land inputs *slightly outweighed* the growth in inputs like fertilizer, meaning farmers achieved higher production with **fewer overall inputs** over time [28] [9].

For farmers, higher efficiency often translates to lower production cost per unit and better margins (assuming commodity prices do not fall equally). On a national scale, rising agricultural productivity has economic benefits: *"Improved agricultural productivity means the U.S. agricultural sector can compete more effectively with global competitors without reducing farm profits. At the same time, land and labor can shift to other sectors of the economy. Finally, improved agricultural productivity may benefit consumers in the form of* *lower prices."* [29] . Indeed, inflation-adjusted food prices have trended downward or remained moderate in part due to productivity gains. Americans spend a historically low share of their income on food, thanks in no small part to efficient U.S. crop production.

Example – Corn Belt Efficiency: In the Corn Belt states, large family farms dominate grain production and are among the most economically efficient. They benefit from economies of scale and high-tech inputs. As a result, these farms can produce corn and soy at a lower cost per bushel than smaller, less-equipped farms. The economic efficiency is reflected in the fact that large-scale family farms (with $1 million+ gross income) account for nearly half of U.S. farm production by value [30] [31] – they have grown by being more productive and economically viable. For the nation, this means an abundant supply of staple crops for domestic use and export, reinforcing the U.S. role as a competitive agricultural exporter.

Caloric Output and Crop Yields

Definition: The *caloric efficiency/output* KPI looks at the food energy produced by agriculture – essentially how many calories of food are generated per unit of input or land. It also relates to the contribution of major crops to the diet. In simple terms, we can consider the total **caloric yield** (calories per acre) of crops and how that has changed, as well as what share of the American diet is supplied by these key crops.

Trends: The five crops highlighted (corn, soybeans, wheat, rice, and sugar crops) form the backbone of the American food supply in terms of calories. **Corn**, while largely used for animal feed and industrial uses, also indirectly contributes calories via meat, corn sweeteners (high fructose corn syrup), and corn products. **Wheat** is the largest source of direct grain calories (e.g. bread, pasta) in the American diet. **Soybeans** contribute through soybean oil (the most used cooking oil) and as feed for animal protein. **Rice** is a staple grain for many consumers and an export crop. **Sugar crops** (sugar beets and sugarcane) and corn (for corn syrup) supply the vast quantities of sweeteners Americans consume. The U.S. is one of the world's largest consumers of caloric sweeteners [32] , and wheat and corn-based products remain daily diet staples.

Over the past decade, **caloric output per acre** has risen as yields increased. For example, an acre of U.S. corn in 2020 produced roughly 15 million kilocalories of edible grain (corn grain is about 3600 kcal per kg), which is up from perhaps ~13 million a decade earlier – a substantial gain in potential food energy. Similar gains are seen in wheat and rice yields translating to more calories of food per acre. Advances in crop breeding and agronomy thus directly enhance the food (and feed) energy available. On a per capita basis, the U.S. food system supplies more than enough calories: about 2,500+ kcal per person per day are available in the food supply, slightly down from 2000 but still above dietary needs [33] . Notably, **around 70% of those calories come from plant-based foods**, with grains being the single largest contributor (approximately 580 kcal per person per day in 2010 came from grains) [33] . Added fats/oils (mostly from soy, corn, canola) contributed about 500 kcal per person, and added sugars about 360 kcal, in recent estimates [33] [34] . This underscores that *the efficiency and output of these major crops directly affect national food security and nutrition*. As their yields improve, the U.S. can feed more people with the same land – or free up land for other uses or for export crops.

It's also worth noting that improved efficiency has environmental and nutritional implications. Higher caloric output on less land can spare land for conservation. Meanwhile, an abundant calorie supply has kept basic food commodity prices low, though it also enabled the proliferation of cheap sugars and oils in the diet (contributing to dietary challenges). These are areas where future decision-making may balance pure caloric efficiency with health and sustainability goals.

Example – Feeding Power of U.S. Corn: U.S. corn yields illustrate caloric efficiency well. Corn is calorie-dense; most U.S. corn becomes livestock feed, but that ultimately translates to calories in meat, dairy, and eggs. With corn yields rising about 1-2 bushels per acre per year [35], each acre's calorie output keeps growing. If one acre of corn (~175 bushels) can feed several cattle or produce thousands of gallons of ethanol plus sweetener, this shows how a small land area now yields enormous energy. The increase in corn caloric productivity over the last 10 years helps ensure ample feed for livestock and ingredients for processed foods and biofuel, all with a smaller resource footprint. Similar statements can be made for wheat (more loaves of bread per acre than 10 years ago) and for soy (more oil and protein per acre). In short, American farms are extracting more calories of nourishment per acre and per input, which bodes well for meeting food demand as population grows.

Guiding Future Agricultural Decisions

Understanding these KPI trends is crucial for planning the future of U.S. agriculture. Here are ways these insights can guide decision-making:

- **Investing in Innovation and R&D:** The data show that technological innovation has been the main driver of efficiency gains [10]. To sustain productivity growth (which has shown signs of slowing), continued investment in agricultural research, extension services, and innovation is needed. USDA and policymakers should prioritize R&D in areas like precision agriculture, plant breeding (e.g. drought-resistant or higher-yield crops), automation/robotics, and sustainable farming methods. Innovation will be key to feed a growing population under climate and resource constraints.

- **Workforce and Labor Strategy:** With labor use declining and an older, smaller farm workforce, future strategies should address labor availability and skills. This may involve promoting agri-tech education and training for the next generation of farmers to maintain high **human capital** in farming [4]. It also suggests immigration and labor policies should ensure an adequate supply of farm labor where mechanization isn't feasible (e.g. for certain fruit/vegetable harvesting). Furthermore, since labor productivity is high, we can focus on **labor-saving technologies** for remaining bottlenecks – for example, supporting the development of robotic fruit pickers or weeders to improve efficiency in labor-intensive specialty crops, similar to how row-crop farms mechanized.

- **Encouraging Technology Adoption for All Farm Sizes:** The data indicate large farms have adopted precision technology at far higher rates than small farms [36] [37]. To avoid a digital divide, USDA can guide programs (cost-share, technical assistance) to help small and mid-size farms access these efficiency-boosting tools. This could involve expanding extension education on precision ag, subsidizing precision equipment for family farms, and demonstrating the ROI of technology adoption. By increasing adoption across the board, the entire sector's efficiency can rise. In addition, since many benefits of technology relate to reducing inputs (fertilizer, fuel) and environmental impact, broad adoption supports sustainability goals as well.

- **Resource Sustainability and Climate Resilience:** Gains in resource efficiency must continue if agriculture is to be sustainable. Water scarcity and soil health are critical concerns for the next decade. Decision-makers should strengthen conservation initiatives (like NRCS programs) that have proven effective in saving water and soil [38] [19]. For instance, greater incentives for drip irrigation, soil moisture monitoring, and drought-tolerant crop varieties can help farmers maintain yields with less water. Similarly, encouraging practices like no-till and cover cropping builds resilience by improving soil structure and carbon content, which in turn boosts long-term productivity. The last 10 years show these practices catching on; future policy can accelerate this by linking farm support payments to conservation outcomes or expanding cost-share for equipment that enables reduced tillage, etc. Ultimately, conserving resources per unit of output is both economically and environmentally prudent – it ensures farms remain productive in the face of climate change and resource limits.

- **Economic Viability and Farm Income:** The efficiency improvements have allowed more output with fewer inputs, but farm income can still be volatile (as seen with swings in commodity prices and input costs in the 2010s and early 2020s). Policymakers should use the knowledge that productivity is the main growth engine to shape supportive policies – for example, crop insurance and risk management tools can safeguard efficient producers against bad luck (droughts, floods), ensuring they stay in business to keep contributing to the food supply. Additionally, since large farms drive a big share of output [31], maintaining competitive markets and preventing monopolistic practices in input industries (seeds, machinery) will help farms of all sizes access innovations at fair prices. Supporting cooperative models or financing for technology could help smaller farms remain economically viable and efficient. In short, **efficiency metrics inform where to bolster the farm economy** – be it through supporting innovation adoption or through safety nets during downturns – to keep productivity on its upward trajectory without sacrificing farm profitability.

- **Nutrition and Food Security Planning:** The caloric output data shows that a few crops (corn, wheat, soy, rice, sugar) dominate the calorie supply. This has pros and cons for future planning. On one hand, it's efficient to produce staple calories with high-yield crops; on the other, dietary diversification and nutrition are important. Decision-makers might use this information to **balance productivity with nutrition** by encouraging fruit and vegetable production (which has not seen the same dramatic efficiency gains and can be labor-intensive). From a food security standpoint, the U.S. clearly produces enough aggregate calories; the focus for the future might shift to producing *higher quality* calories (proteins, vitamins) efficiently and distributing them accessibly. Additionally, knowing that Americans consume large quantities of sugar and oil (calories which are abundant due to corn, soy, sugar crops) [33] can guide public health-oriented agricultural decisions. For example, incentives for growers to plant more specialty crops or whole grains could improve nutritional outcomes without greatly sacrificing efficiency, given the surpluses in staple calories.

- **Climate Change Adaptation:** While not explicitly covered in the above KPIs, climate considerations are implicit in resource efficiency and technology use. Future decisions should leverage the past decade's efficiency gains to tackle climate challenges. This means doubling down on practices that reduce greenhouse gas emissions per unit of food (such as precision fertilizer use to cut nitrous oxide emissions, or improved manure management in livestock). It also means breeding and adopting crop varieties that can maintain high yields under heat or irregular weather. Essentially, **maintaining efficiency gains in the face of climate stress** will be a top priority. The USDA can guide this by funding climate-smart agriculture programs and ensuring that the productivity improvements of the last 10 years are not lost to more extreme conditions.

In conclusion, the past decade's data on labor, technology, resource use, economic, and caloric efficiency in U.S. agriculture tell a story of remarkable progress. American farmers are producing more food with fewer people, less land, and in some cases less water, enabled by better technology and knowledge. These trends provide a roadmap for the future: continue fostering innovation, spread modern practices to all farmers, and sustain the natural resource base. By doing so, the U.S. can remain a leader in agricultural productivity and food security. As the USDA and other stakeholders plan ahead, these KPIs serve as benchmarks of success and areas requiring attention – ensuring that the efficiency gains translate into a resilient, profitable, and sustainable food system for America.

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