The Environmental Benefits of Precision Agriculture in the United States

Executive summary and details

AEM Association of Equipment Manufacturers

ASA American Soybean Association

CropLife America

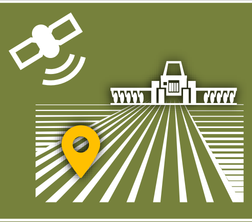
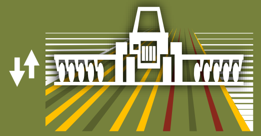
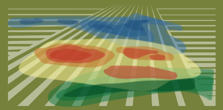
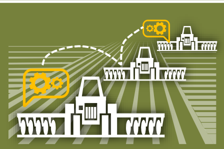
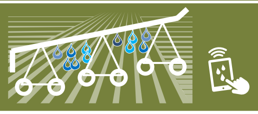
National Corn Growers Association

OBJECTIVE

The overarching objective for this project is to

quantify the environmental benefits of precision agriculture (P.A.) in the United States.

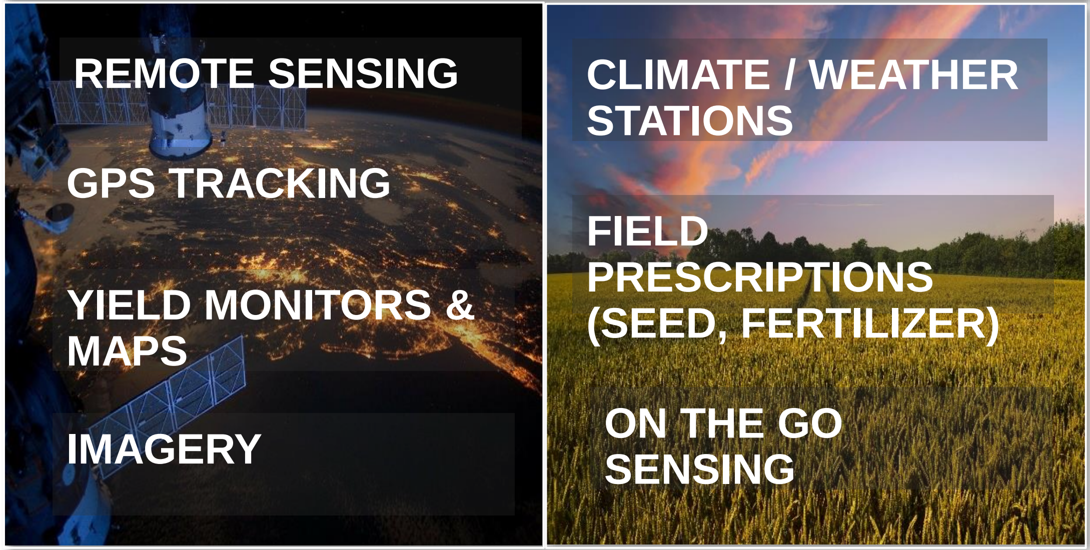
Five key precision agriculture (P.A.) technology areas were identified for this study

P.A.TECHNOLOGY AREA	DEFINITION	TECHNOLOGIES ANALYZED
 AUTO GUIDANCE	Auto-steer uses GPS signals to automatically control the tractor in seeding, spraying, fertilizer application and harvesting, reducing overlap of farming operations and leading to substantial fuel savings.	▪ Auto steering
 MACHINE SECTION CONTROL	Machine section control technology turns planter, fertilizer or sprayer sections on or off in rows that have been previously seeded/sprayed, or at headland turns, point rows and waterways.	▪ Tillage drag/depth control ▪ Planting row, depth, down pressure control ▪ Fertilizer row control ▪ Spraying row control
 VARIABLE RATE	Variable rate technology uses sensors or preprogrammed maps to determine seeding, fertilizer, crop protection application rates. Supporting technologies include variable rate controllers, GPS, yield monitors, crop sensors and soil sensors.	▪ Variable rate planting ▪ Variable rate fertilization ▪ Variable rate spraying, including UAV (drone) applications
 MACHINE & FLEET ANALYTICS	Real time monitoring of equipment, providing information like GPS location, equipment idling, traffic control and route suggestions.	▪ Fleet analytics ▪ Telematics
 PRECISION IRRIGATION	Ability to switch on/off apply and different amounts of water to different areas of the field. *Focused on center pivots.*	▪ Sensor driven center pivots ▪ Lower energy precision application

How we get to the future: Many technologies **enable** precision agriculture

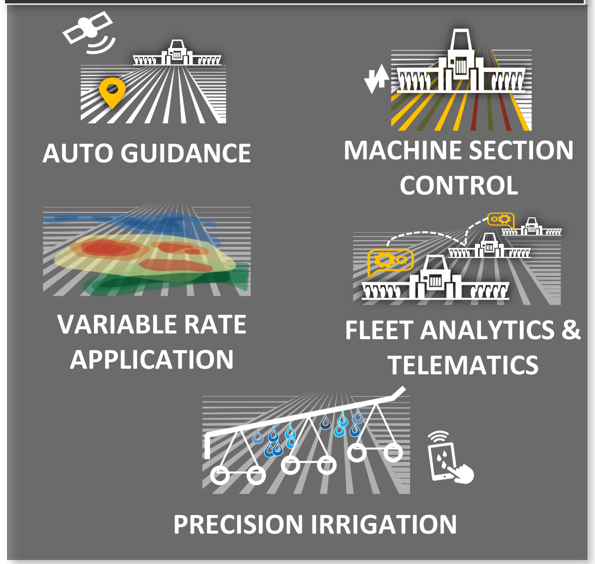
Enablers

AG TECHNOLOGY



Impacts measured

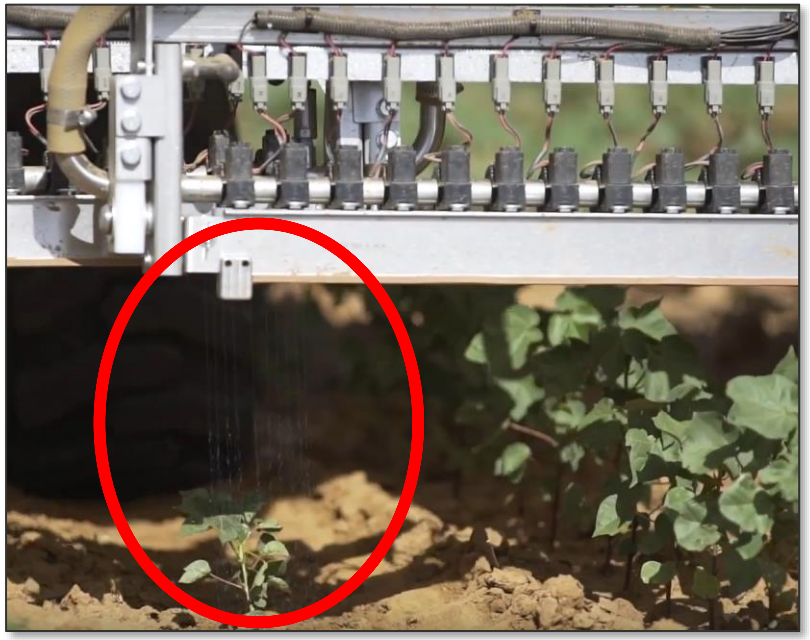
PRECISION AG TECH



*Enabling technologies such as **yield mapping** and **soil sampling** were included indirectly within the "execution" of precision ag tech. The environmental benefits of the precision ag technologies are only achievable with accurate and routine use of enabling technologies.*

What is NOT in this study: Emerging technologies or other tools of modern ag, i.e. seed traits

SEE and TREAT WEED CONTROL



Targeted spraying mechanisms from OEMs and startups are beginning to enter the marketplace. Early estimates show that initial savings from herbicide application can be up to 90% **per pass**. Yet, questions remain as to the long-term effectiveness, as residual action on weeds is a major source of control.

SMART COMBINES

Smart combines improve the ability of the operator to automate adjustments usually made by skilled operators. A typical smart combine uses cameras and sensors to detect changes in crop conditions so combine adjustments can be made automatically and maintain optimal performance.

Source: Blue River Technologies

Five key environmental benefits were identified to be quantified as a result of P.A. technology adoption

	Productivity	Fertilizer Use	Herbicide Use	Fossil Fuel Use	Water Use
Direct Outcomes *(quantified)*	▪ Yield benefit from accurate spacing (pass-to-pass, end/point rows) and population rate	▪ Optimization of fertilizer applications (reduced overlap, avoid skips, best placement and rate of inputs)	▪ Optimization of herbicide applications (reduced overlap, avoided skips, best placement and rate of inputs)	▪ Fuel savings from fewer field passes, variable depth of tillage, and/or more efficient harvest	▪ Application of water avoided due to remote shutoff of center pivots, along with selective application
Indirect Outcomes	▪ Avoid unproductive/ preserved land from being in production ▪ Reduced soil compaction	▪ Improved water quality (reduced nutrient runoff) ▪ Improved soil health ▪ Net GHG reduction (including in production of inputs)	▪ Improved soil health, and reduced erosion through less tillage ▪ Net GHG reduction (including in production of inputs) ▪ Improved water quality ▪ Reduced weed resistance development	▪ Net GHG reduction	▪ Improved water quality through reduced runoff ▪ Less energy use by running pumps fewer hours

The **crops** studied included a range of row crops, broad acre non-row crops, roots and tubers, and forage

Row crops	**Broad Acre** (Non-Row) **Crops**	**Roots & Tubers**	**Forage***
Corn	Wheat	Tubers	Hay
Soybeans	Sorghum	Sugarbeets	Alfalfa
Cotton			
Peanuts			

This study focused on crop production, leaving downstream impacts of precision technologies on animal agriculture for future study

*Only hay and alfalfa acres west of the Rockies were considered for P.A. use

A model was built for each of the five environmental benefits, capturing data and contributions from each of the relevant P.A. technology areas

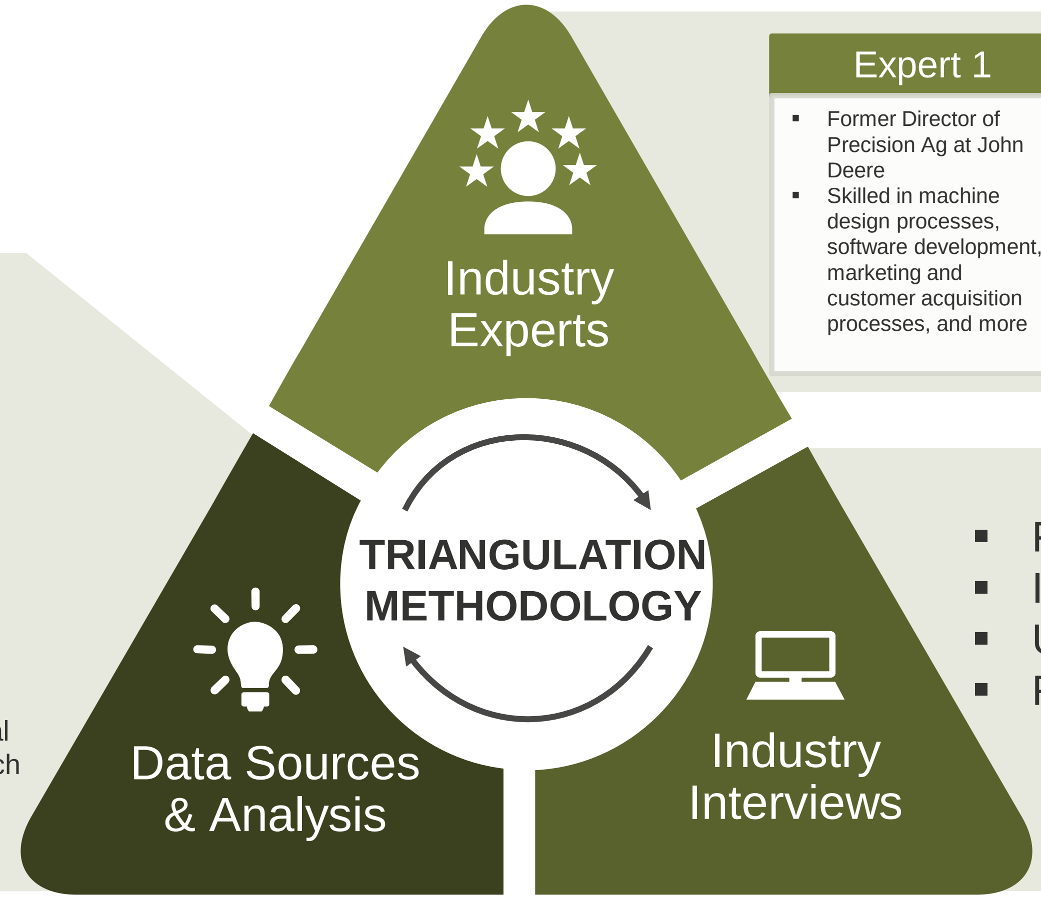
P.A. TECHNOLOGY	How Environmental Benefit is Achieved	ENVIRONMENTAL BENEFITS: Productivity	Fertilizer Use	Herbicide Use	Fossil Fuel Use	Water Use
Auto Guidance	Reduced overlap + avoided skips for field passes with tillage, planters, sprayers, and harvesters	Academic literature utilized; Industry experts utilized	Academic literature utilized; Industry experts utilized	Academic literature utilized; Industry experts utilized	Academic literature utilized; Industry experts utilized	Incomplete information to reliably quantify
Section Control	Optimized placement of seed / fertilizer / crop protection. Optimized down pressure + depth control to gain machine + fuel efficiencies	Academic literature utilized; Industry experts utilized	Academic literature utilized; Industry experts utilized	Academic literature utilized; Industry experts utilized	Incomplete information to reliably quantify	Incomplete information to reliably quantify
Variable Rate	Optimized rate of seed / fertilizer / crop protection applications	Academic literature utilized; Industry experts utilized	Academic literature utilized; Industry experts utilized	Academic literature utilized; Industry experts utilized	Incomplete information to reliably quantify	Incomplete information to reliably quantify
Machine & Fleet Analytics	Improved fuel efficiency from machine optimization	Incomplete information to reliably quantify	Incomplete information to reliably quantify	Incomplete information to reliably quantify	Academic literature utilized; Industry experts utilized	Incomplete information to reliably quantify
Precision Irrigation	Improved water use efficiency	Incomplete information to reliably quantify	Incomplete information to reliably quantify	Incomplete information to reliably quantify	Incomplete information to reliably quantify	Academic literature utilized; Industry experts utilized

Academic literature utilized *Industry experts utilized* *Incomplete information to reliably quantify*

Each of these five environmental benefits **directly links** to two or more of USDA's three sustainability pillars

USDA PILLARS	Environmental Benefits: Productivity	Fertilizer Use	Herbicide Use	Fossil Fuel Savings	Water Use
DIRECT ENVIRONMENTAL BENEFIT		✓	✓	✓	✓
PRODUCTIVITY (YIELD) BENEFIT	✓	✓	✓		
FARMER ECONOMIC BENEFIT	✓	✓	✓	✓	✓

To align on reasonable assumptions for the benefits for each technology, the study utilized the **triangulation** of numerous data sources and industry experts



Expert 1

- Former Director of Precision Ag at John Deere
- Skilled in machine design processes, software development, marketing and customer acquisition processes, and more

Expert 2

- Former Director of Marketing – Precision Agriculture and Construction at CNH
- Skilled at exploring innovative ways to increase agronomic production & sustainability through precision ag

Expert 3

- Former President and CEO of CropLife
- Chairman, Board of Advisors, Farm Journal
- Leader in agricultural strategy services and entrepreneurial investment

Data Sources & Analysis

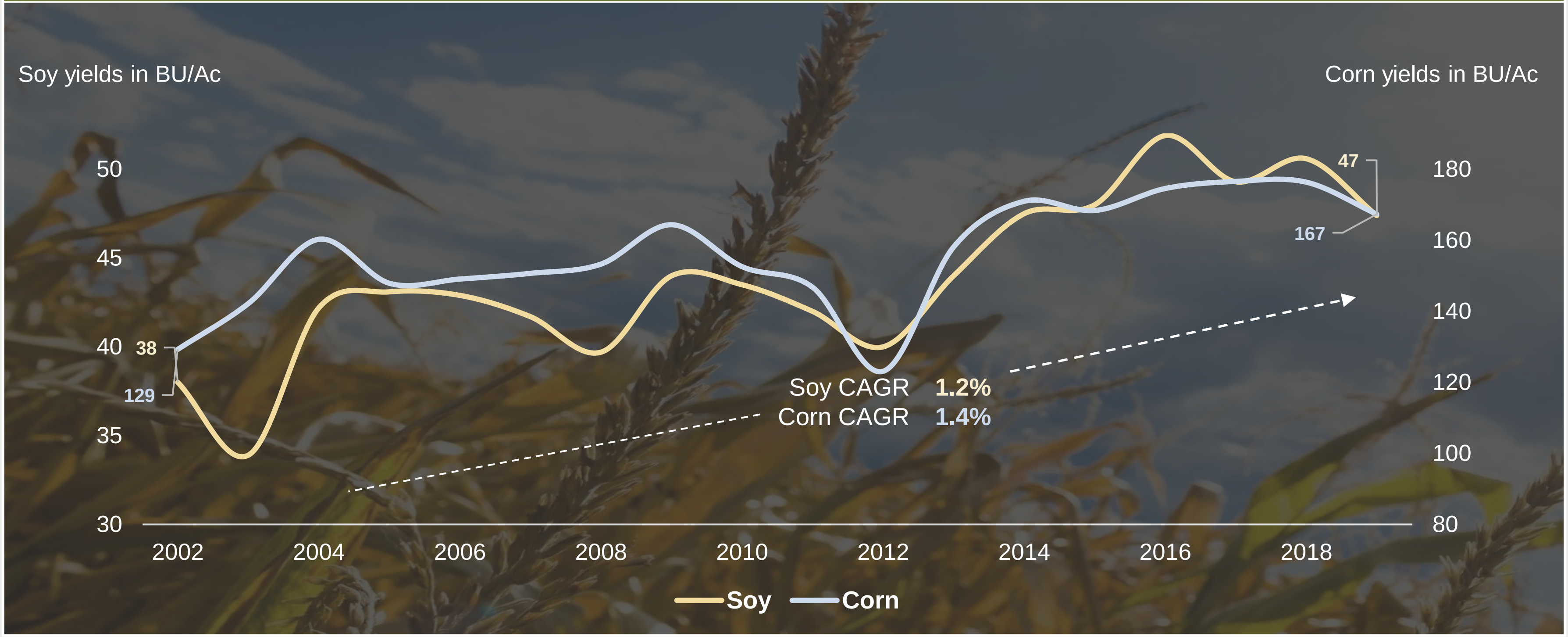
- The Ohio State University
- USDA NRCS
- Purdue University
- Statistics Canada
- University of Kentucky
- North Dakota State University
- Iowa State University
- U of Illinois
- UC Davis
- Agricultural University of Athens, Institute for Agriculture-Belgium, Wageningen Environmental Research, European Commission-Joint Research Centre

Industry Interviews

- Fertilizer Institute representative
- Irrigation Association representative
- USDA representative
- Former Syngenta executive

Over the last 18 years, the growth in corn and soybean yields has coincided with the widespread adoption of precision agriculture technologies

Corn & Soy yields from 2002-19

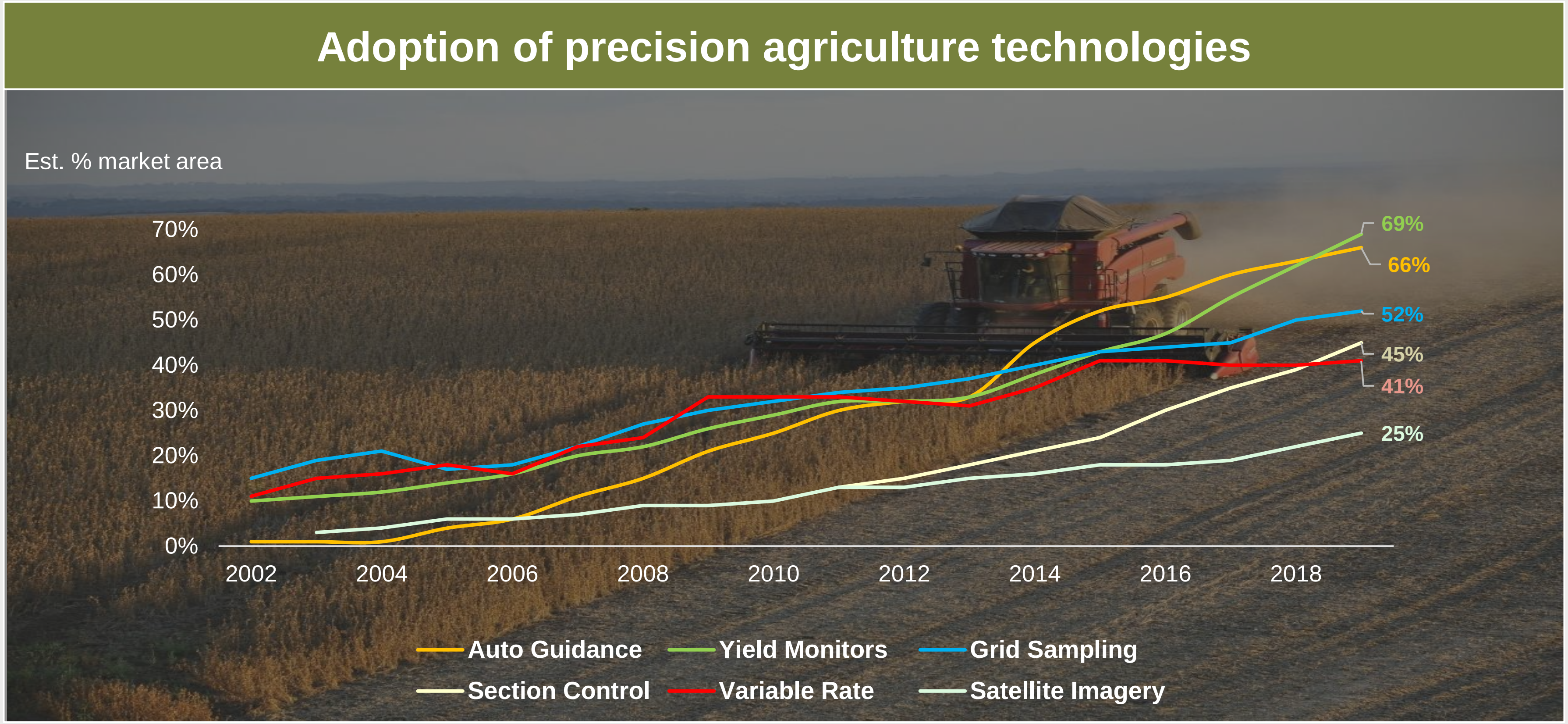


Reasons for rising yields include

1. More effective and resilient hybrids
2. Better inputs & management practices
3. Improved on-farm technology

Source: USDA NASS, Purdue Precision Ag Dealership Survey, Context Analysis and Expert Input

Over the last 18 years, the growth in corn and soybean yields has coincided with the widespread adoption of precision agriculture technologies



Precision agriculture technologies have contributed significantly to the increases in yields for the major crops grown in North America

Source: USDA NASS, Purdue Precision Ag Dealership Survey, Context Analysis and Expert Input

Sustainability has been a part of ag for generations

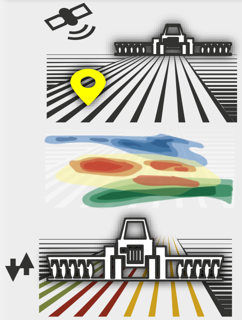
We need to highlight the sustainability gains in terms the public can appreciate.

Productivity has increased an estimated **4%** as a result of current P.A. adoption and has the potential to further increase **6%** with broader P.A. adoption

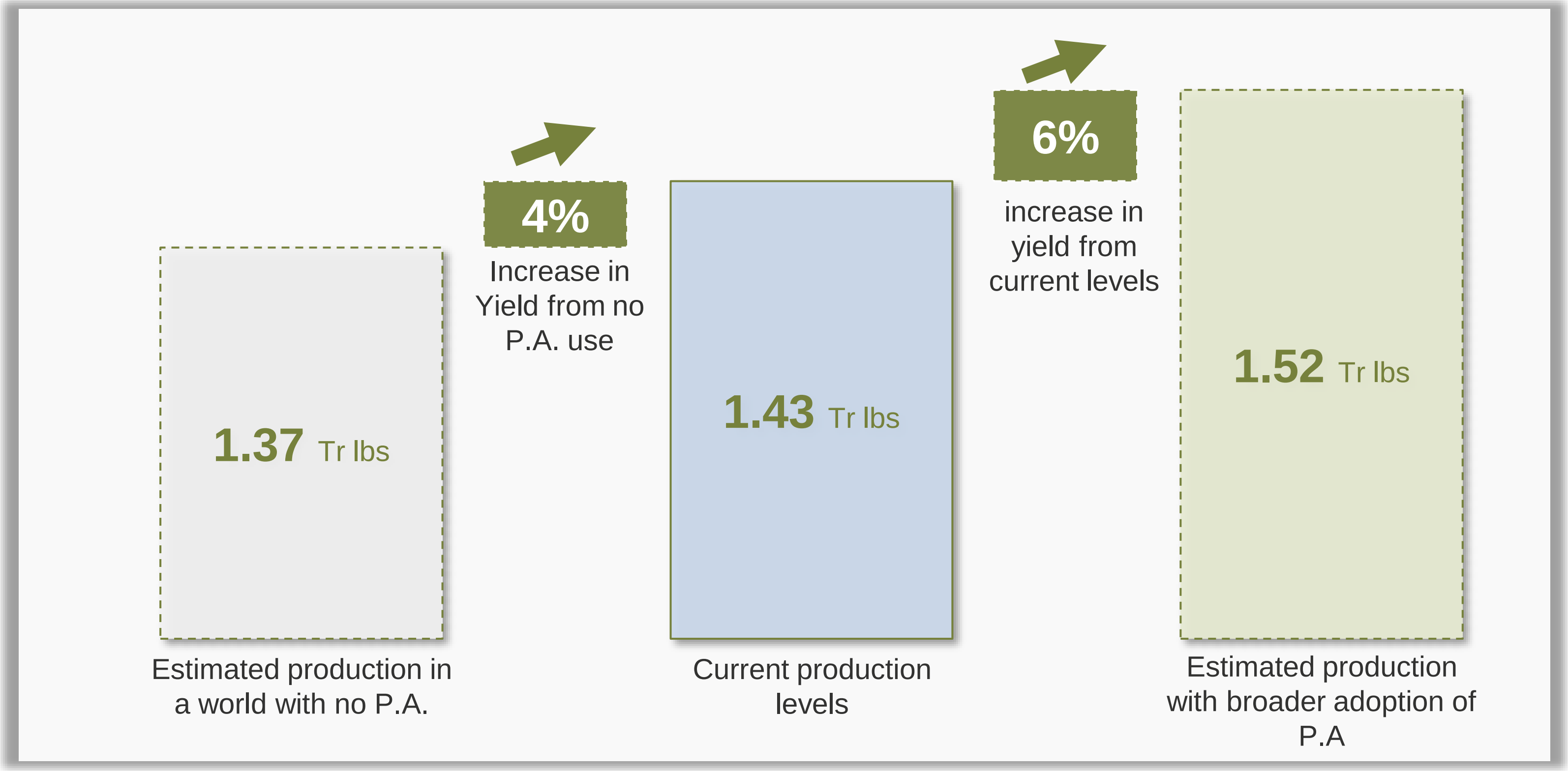
Cultivating an estimated 10.2 million acres of cropland was avoided due to more efficient use of existing land. This is an area equivalent to

4.5 Yellowstone National Parks.

Precision Technologies Analyzed



- ***Auto Guidance***
- ***Variable Rate***
- ***Section Control***



Production of each of the crops in scope were converted from bushels to pounds in order to normalize for the purposes of aggregation and comparison

Precision agriculture has improved **fertilizer placement efficiency** by an estimated 7% and has the potential to further improve an additional 14% with broader adoption of P.A. technologies

Precision agriculture affects all pillars of nutrient stewardship, but most specifically, application in the right rate and place through variable rate application, auto guidance and section control

CASE STUDY

By transitioning from basic to advanced 4R practices and including strip till and cover crops, a family farm located in Central Illinois was able to **decrease costs per acre by $67**, while reducing CO2 equivalent **GHG emissions by >15%**.

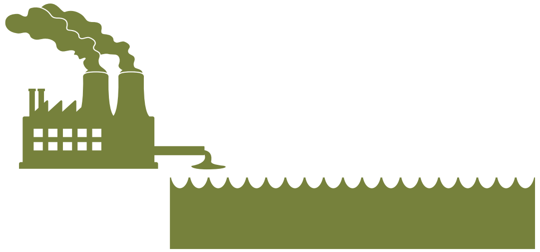
Practices adopted on the farm

- **Fall strip till of nitrogen with stabilizer**
- **Fall application of P+K – broadcast using Variable Rate**
- **Cover crops – termination in spring**
- **Grid soil sampling**

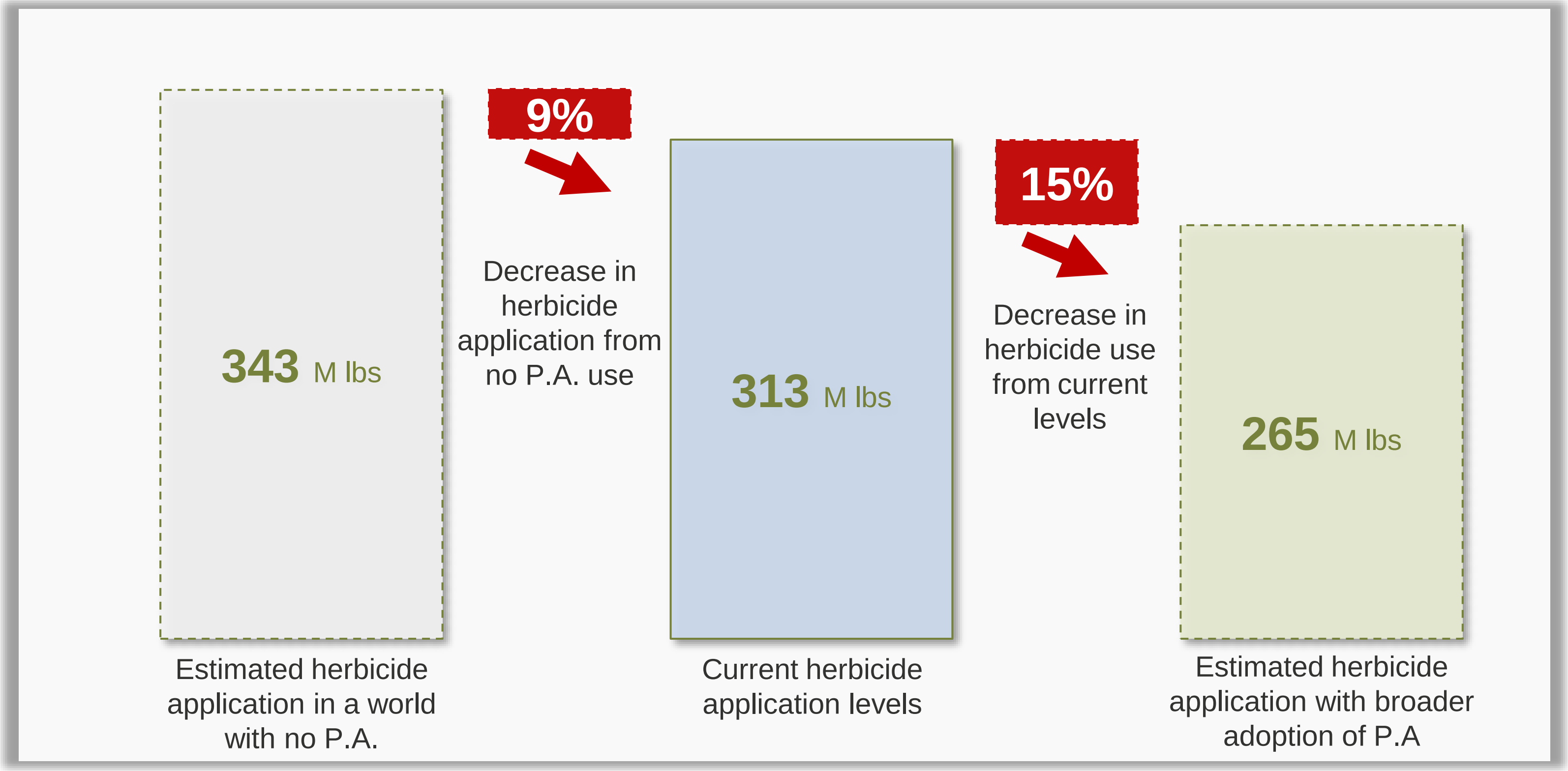
THE FERTILIZER INSTITUTE

Source: 4RFarming.org

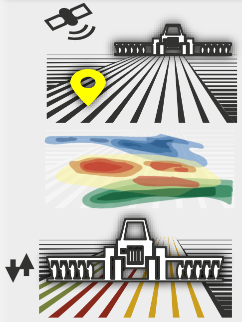
Herbicide Use has been reduced by an estimated 9% as a result of current improved P.A. application practices and has the potential to further decrease 15% at full P.A. adoption



The application of an estimated 30 Million Pounds of herbicide was avoided due to adoption of P.A. technologies, with an estimated 48 M pounds of additional herbicide that could be avoided with broader adoption.



Precision Technologies Analyzed

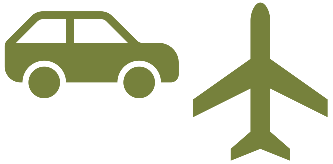


Auto Guidance

Variable Rate

Section Control

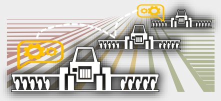
Fossil Fuel Use has decreased an estimated 6% as a result of current P.A. adoption and has the potential to further decrease 16% at full P.A. adoption



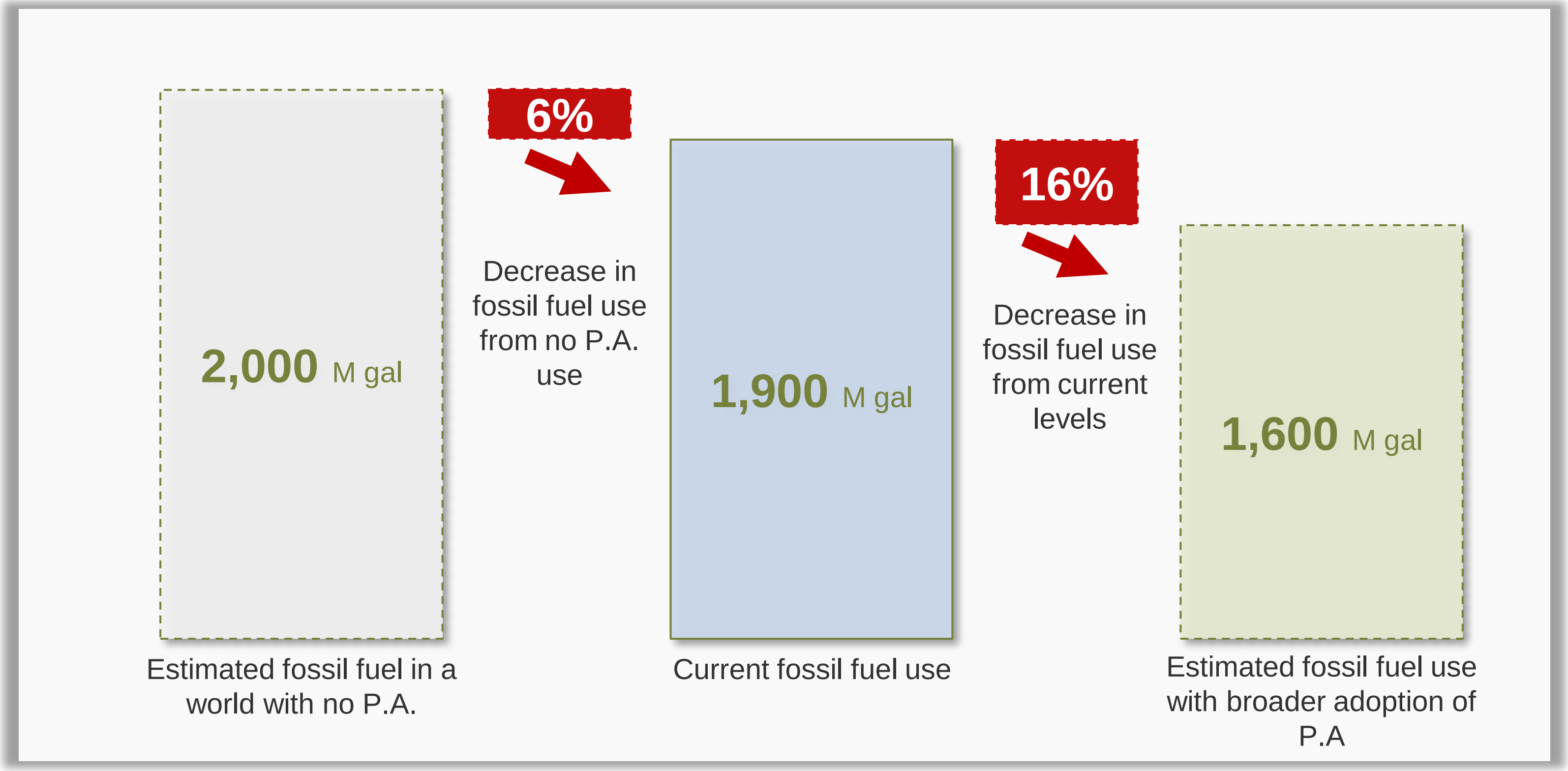
The use of an estimated 100 M gallons of fossil fuels was avoided due to adoption of P.A. technologies, equivalent to an estimated 193,000 cars off the road annually or 18,000 average flights.

Precision Technologies Analyzed

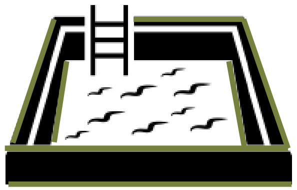
Auto Guidance



Fleet Telematics

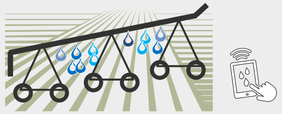


Water Use has decreased an estimated 4% as a result of current P.A. adoption and has the potential to further decrease 21% at full P.A. adoption



The application of an estimated 750,000 Olympic swimming pools worth of water was avoided due to adoption of P.A. technologies.

Precision Technologies Analyzed



Variable Rate Precision Irrigation

Soil Moisture Sensors

11,800,000
M gal

Estimated water application in a world with no P.A.

4 %

Decrease in water use from no P.A. use

11,300,000
M gal

Current water application levels

21 %

Decrease in water use from current levels

8,900,000
M gal

Estimated water application with broader adoption of P.A

The model only measures the benefits of sensor driven precision pivots that have seen sizable adoption across the crops within scope. Drip and other methods of irrigation do provide water savings but are not widely adopted in the crops within scope of the analysis.

Significant headway remains for continued increases in yields and further input savings as precision agriculture technologies become widely adopted

Annual crop production could increase a further 6% with broader adoption of Precision Agriculture Technologies

Broader adoption of precision ag technology has the potential to provide significant further improvements

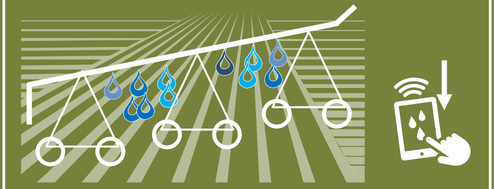
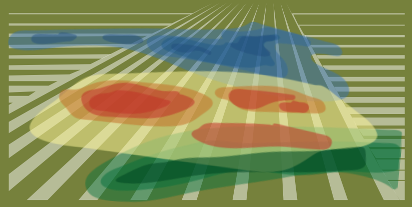
14% Improvement in fertilizer placement efficiency

15% Improvement in herbicide application efficiency

16% fewer fossil fuels

21% less water

Technology Adoption Rates Today

 AUTO GUIDANCE/STEER	 MACHINE & FLEET ANALYTICS	 PRECISION CENTER PIVOT IRRIGATION	 MACHINE SECTION CONTROL	 VARIABLE RATE
25% to 80%	12%	0% to 22%	Fertilizer 10% to 45% Herbicide 5% to 22%	Fertilizer 15% to 54% Herbicide 2% to 13%

How do we get to full adoption?

- Policies that reward innovation
- Improve enabling infrastructure
  - Wireless over croplands
- Grow Farm Income
  - Capital to invest in operations
- Improve consumer communication
  - Build trust in science

AEM
Association of Equipment Manufacturers

ASA
American Soybean Association®

CropLife
AMERICA

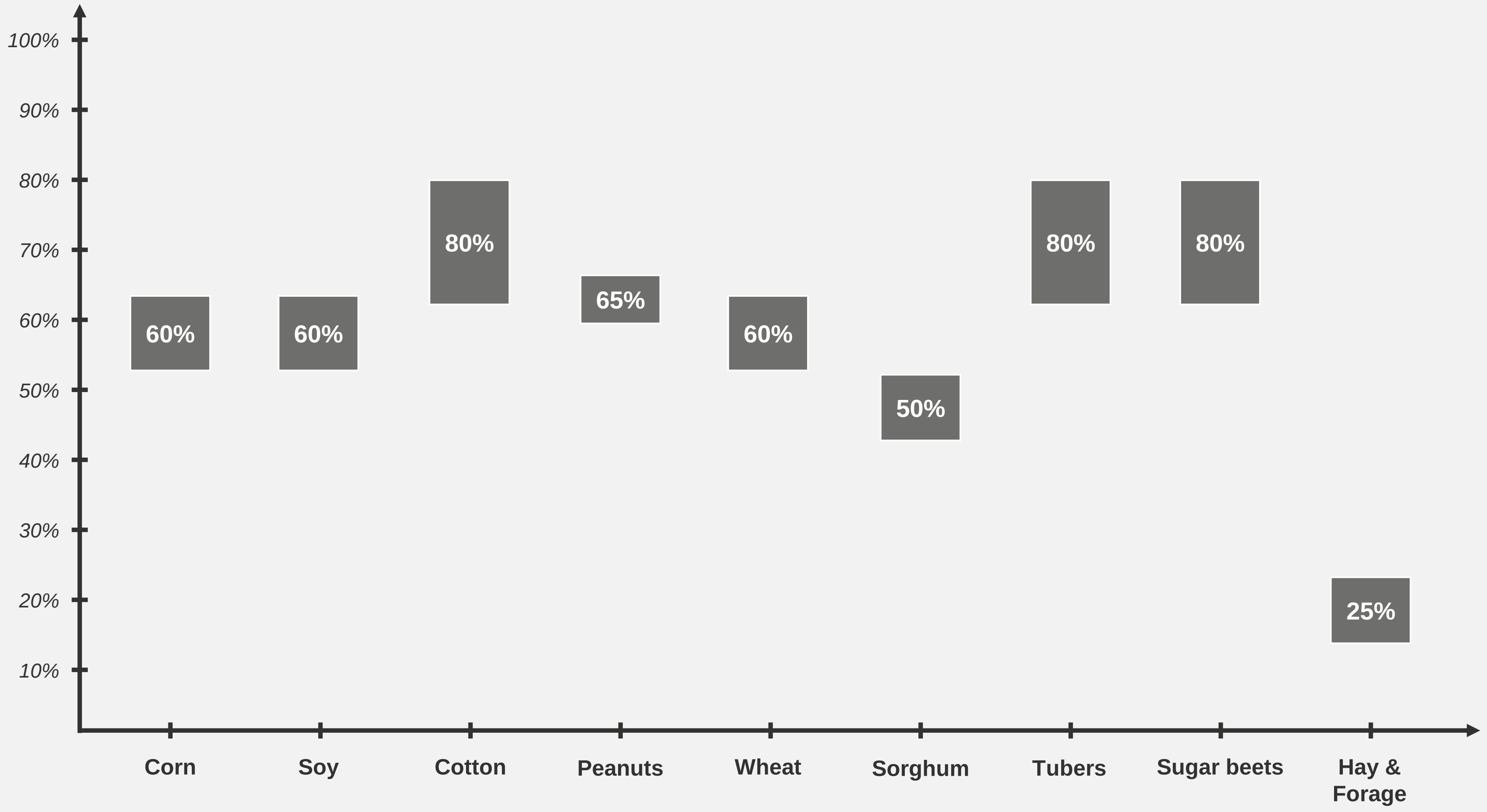
NATIONAL CORN GROWERS ASSOCIATION

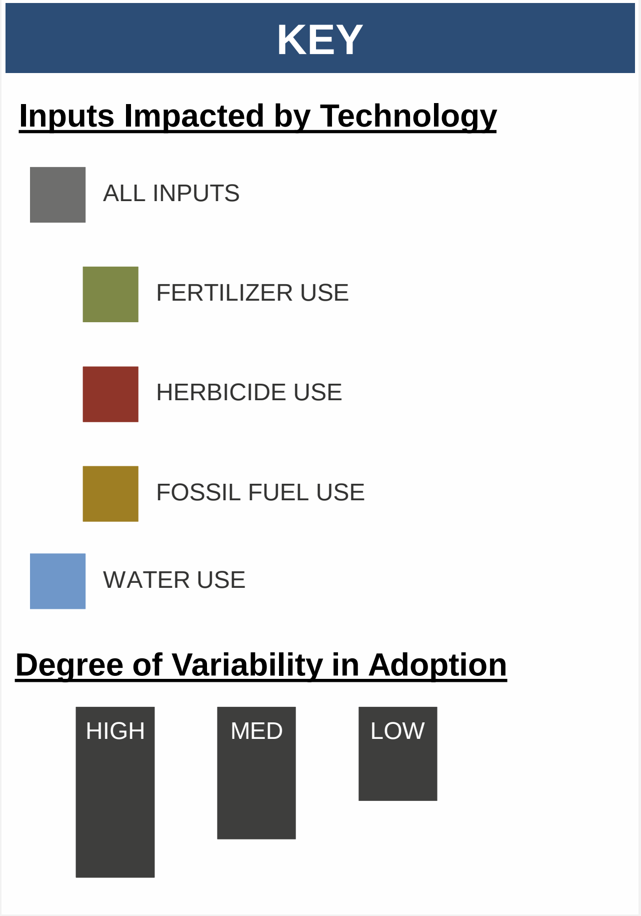



APPENDIX

Rate of adoption of Auto Guidance

Auto guidance achieves an environmental benefit from reduced overlap, avoided skips for field passes with tillage, planters, sprayers, and harvesters.

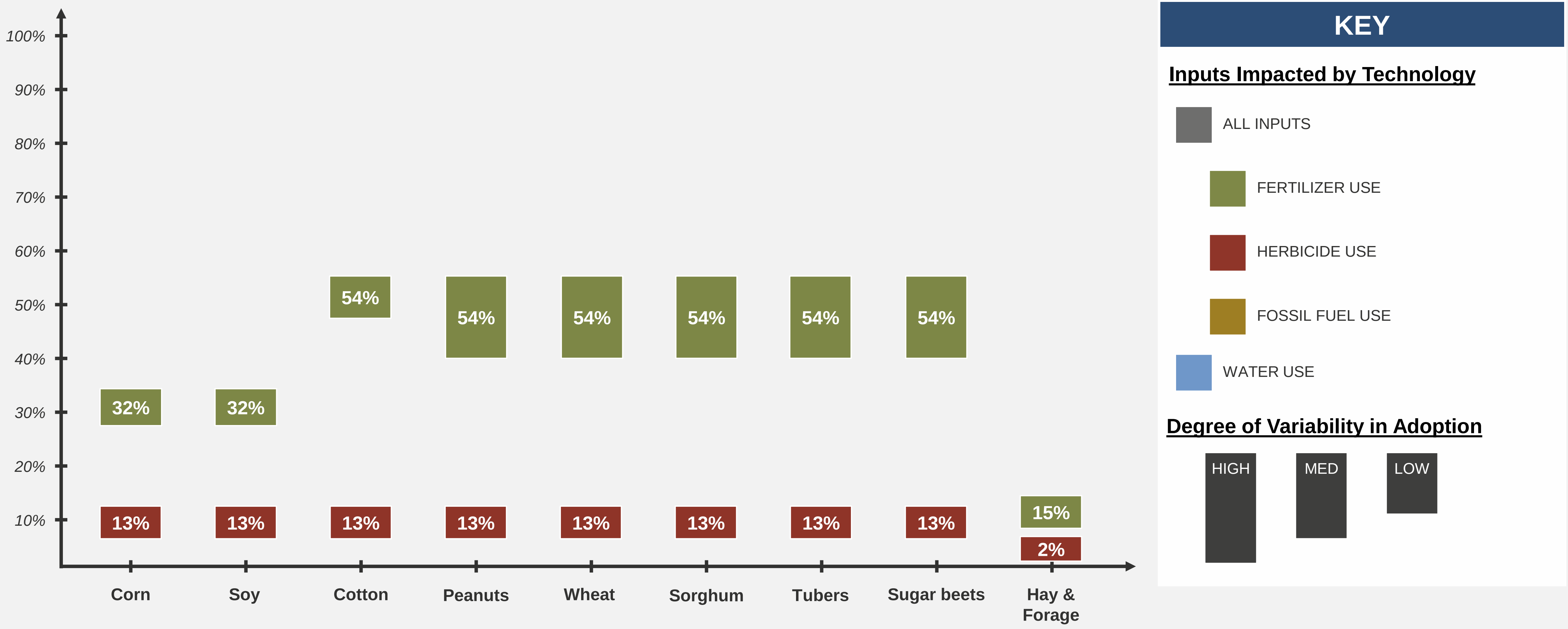




Source: Purdue Precision Agriculture Dealer Survey, Context Expert Estimates

Rate of adoption of Variable Rate Application

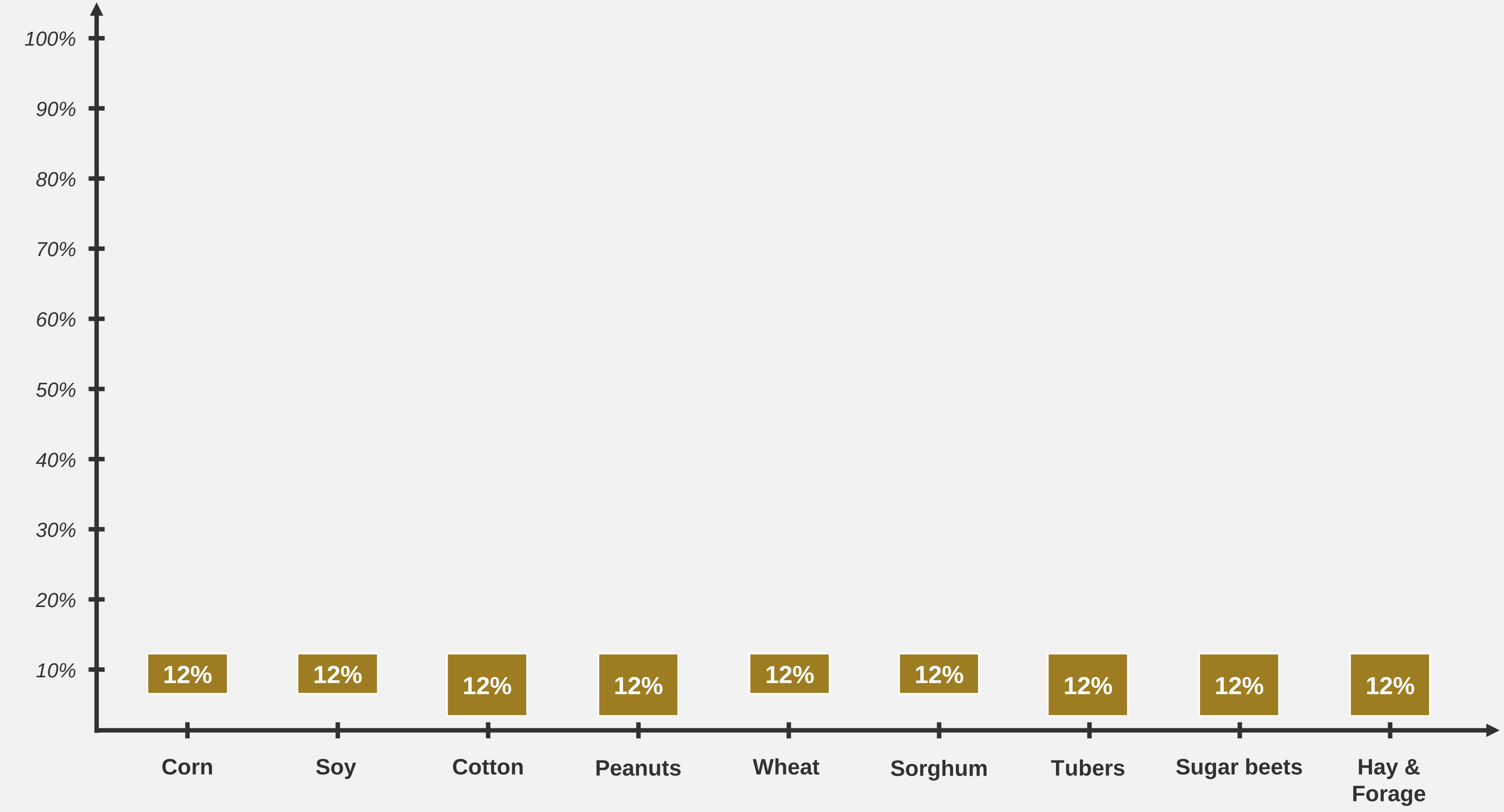
Variable rate technologies achieve and environmental benefit from optimizing the rate of seed / fertilizer / crop protection applications using predetermined prescription maps.

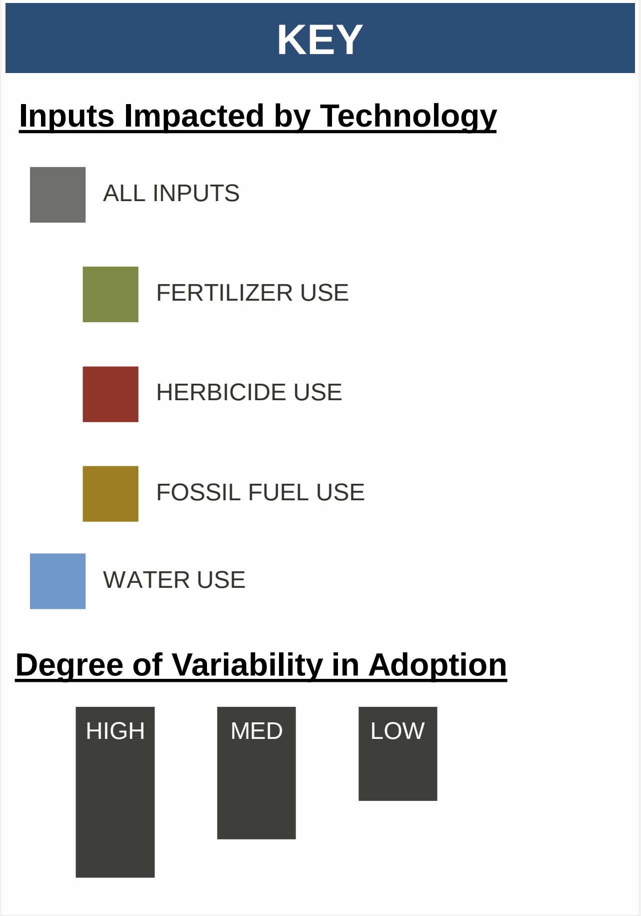


Source: Purdue Precision Agriculture Dealer Survey, Context Expert Estimates

Adoption of Fleet Telematics

Fleet telematics achieves an environmental benefit from allowing the operator of a fleet of machinery to optimize the use of individual machinery and monitor overall fleet utilization, thereby generating savings of fossil fuels in the long run.

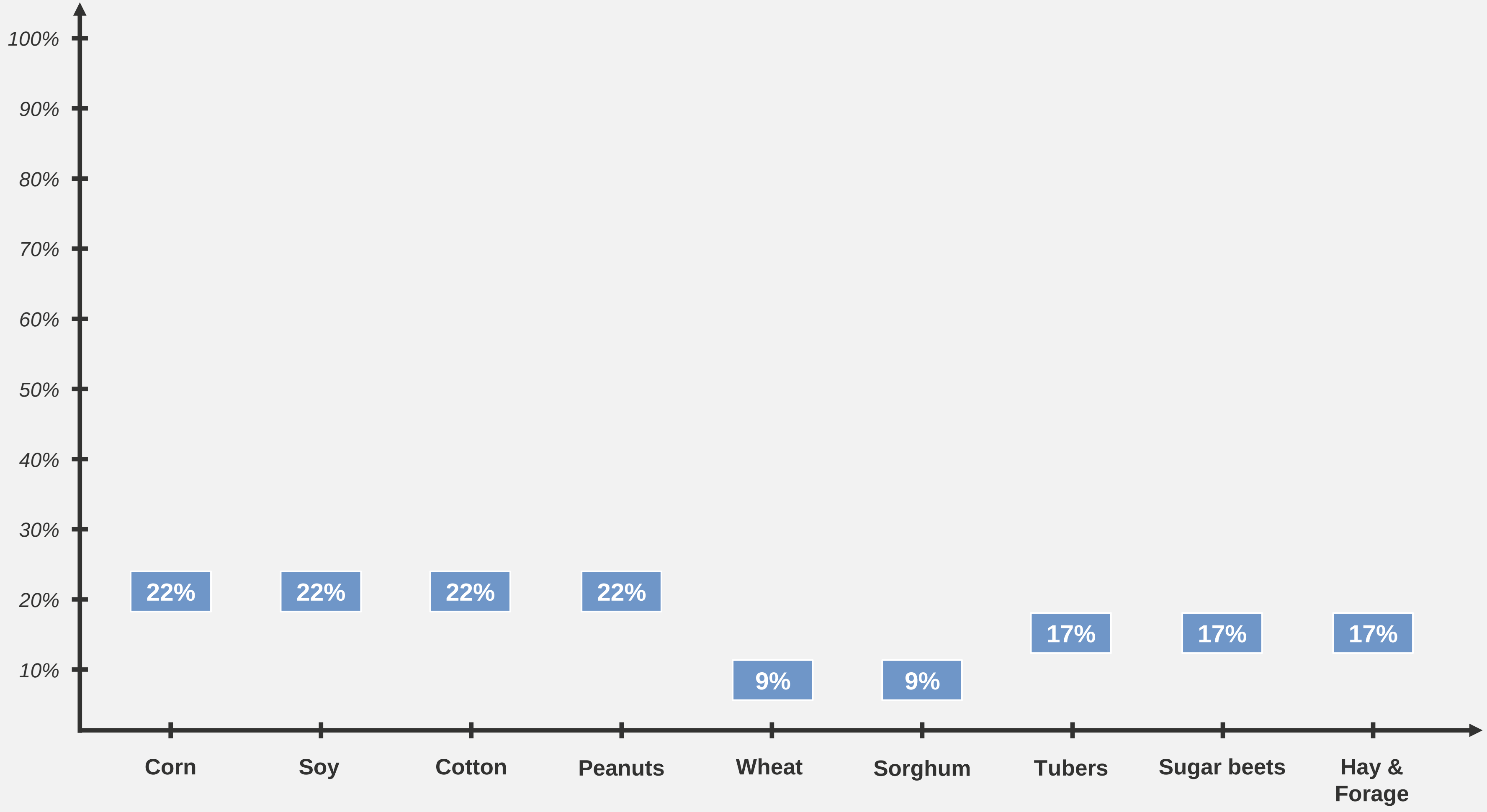


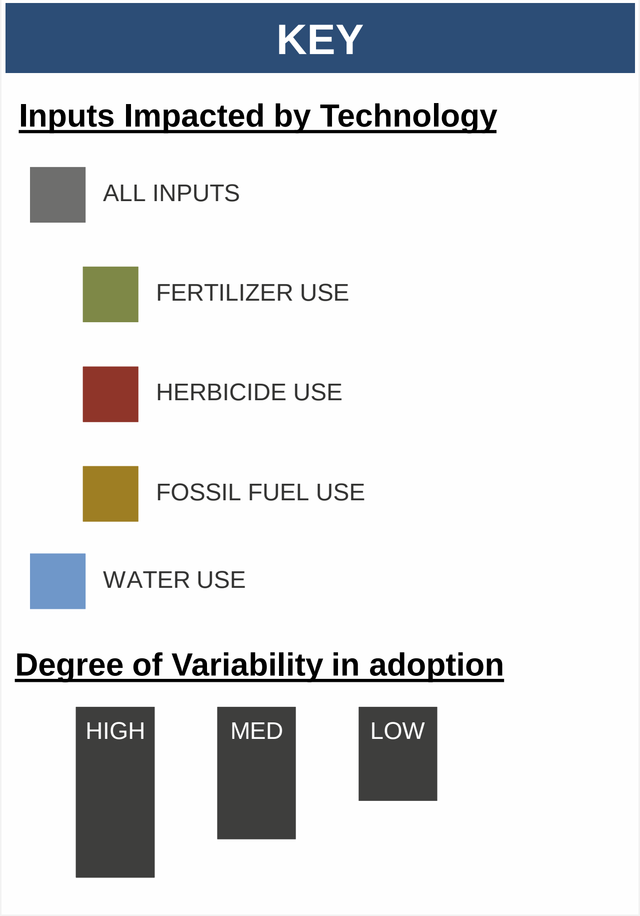


Source: Purdue Precision Agriculture Dealer Survey, Context Expert Estimates

Adoption of Precision Irrigation

Adoption of computer sensor-driven precision pivots has reduced the overall usage of water on acres adopting precision irrigation.





Source: Ohio State University, USDA NRCS, University of Kentucky, NDSU, ISU, University of Illinois, UC Davis, Wageningen University, Context Expert estimates