Nutrient Efficiency

Food & Ag Deep Dive Series

Wednesday, November 4th, 2020

Tom Bunn| Venture Associate
tbunn@iselectfund.com

Contents

Executive Summary

- Like humans, plants need nutrients to thrive and reproduce
  - Primary: Carbon, Hydrogen, Oxygen, Nitrogen, Phosphorus, Potassium
  - Secondary nutrients needed in smaller quantities: Calcium, Magnesium, Sulphur
  - Micronutrients: Chlorine, Iron, Zinc, Manganese, Copper, Zinc, Boron, Molybdenum, Copper
- For most of human history, farmers struggled to cycle nutrients for their crops
- In the early 20th century, advances in technology made the requisite nutrients cheap and abundant which resulted in the Green Revolution – a period with unprecedented growth in world food production
- While the Green Revolution contributed to human wellbeing, the excess use of some nutrients causes environmental problems, many of which directly affect human health and welfare
- As we continue to move towards a 10-billion-person planet by 2050, properly addressing nutrient efficiency with novel technologies including biological solutions, nutrient fixing and nutrient solubilizing, and precision agriculture (right nutrient, at the right rate, at the right place, at the right time) can alleviate environmental damage and increase food production and farmer profitability

A Thank You to Our Guests





Yuval Aviel
CEO
Autonomous Pivot

Bill Brady
CEO
Kula Bio

John Kruse
SVP Agronomy
Plant Response

Dave Stanko
Head of AgTech Engagement at Nutrien

Dave Stark
President
Holganix

Nutrient Efficiency

Definitions & Trends

Background on Nutrients

- Nutrients are substances used by an organism to survive, reproduce, and grow
- Farmers deliver key plant nutrients to their crops with synthetic fertilizers, organic amendments, and by building soil health to maintain nutrients in the soil for plants to use
- The three main additive nutrients are nitrogen (N), phosphorus (P) and potassium (K). Together they make up the trio known as NPK
- While some excess nutrients stay in the soil, some will instead be emitted as gases, leach into groundwater, or run off into surface waters
- Farmers and researchers are seeking to boost nutrient use efficiency—the amount of crop yield you get out of the amount of fertilizer you put in—while minimizing nutrient loss

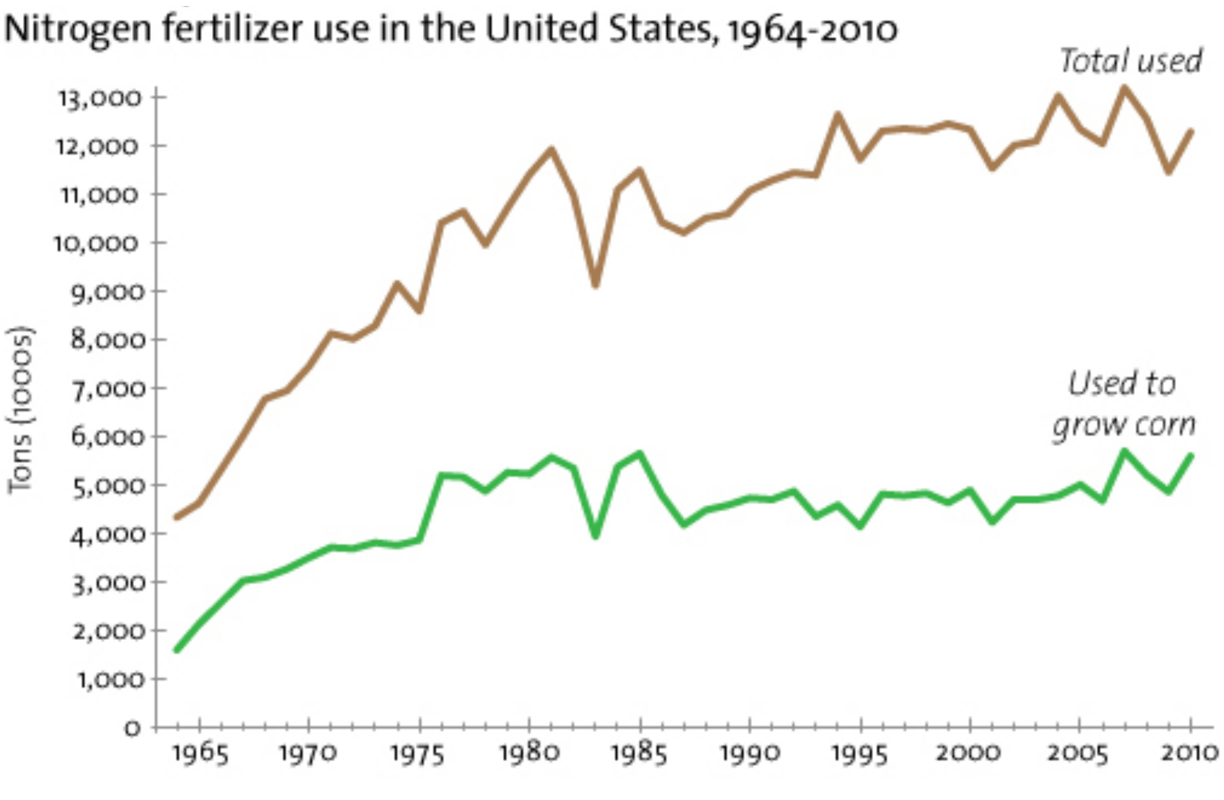
TABLE 1: Form, source, mode of uptake and major functions of the 16 plant essential nutrients.

Nutrient family	Nutrient	Percentage of plant	Form taken up by plants (ion)	Mode of uptake	Major functions in plants
Primary	Carbon	45	Carbon dioxide (CO_2), bicarbonate (HCO_3^-)	Open somates	Plant structures
	Oxygen	45	Water (H_2O)	Mass flow	Respiration, energy production, plant structures
	Hydrogen	6.0	Water (H_2O)	Mass flow	pH regulation, water retention, synthesis of carbohydrates
	Nitrogen	1.75	Nitrate (NO_3^-), ammonium (NH_4^+)	Mass flow	Protein/amino acids, chlorophyll, cell formation
	Phosphorus	0.25	Dihydrogen phosphate ($H_2PO_4^-$, HPO_4^{2-}), phosphate (PO_4^{3-})	Root interception	Cell formation, protein syntheses, fat and carbohydrate metabolism
	Potassium	1.5	Potassium ion (K+)	Mass flow	Water regulation, enzyme activity
Secondary	Calcium	0.50	Calcium ion (Ca^{2+})	Mass flow	Root permeability, enzyme acitivity
	Magnesium	0.20	Magnesium ion (Mg^{2+})	Mass flow	Chlorophyll, fat formation and metabolism
	Sulfur	0.03	Sulfate (SO_4^{2-})	Mass flow	Protein, amino acid, vitamin and oil formation
Micro	Chlorine	0.01	Chloride (Cl^-)	Root interception	Chlorophyll formation, enzyme activity, cellular development
	Iron	0.01	Iron ion (Fe^{2+}, Fe^{3+})	Root interception	Enzyme development and activity
	Zinc	0.002	Zinc ion (Zn^{2+})	Root interception	Enzyme activity
	Manganese	0.005	Manganese ion (Mn^{2+})	Root interception	Enzyme activity and pigmentation
	Boron	0.0001	Boric acid (H_3BO_3), borate (BO_3^{3-}), tetraborate (B_4O_7)	Root interception	Enzyme activity
	Copper	0.0001	Copper ion (Cu^{2+})	Mass flow	Enzyme activity
	Molybdenum	0.00001	Molybdenum ions ($HMoO^{4-}$, MoO_4^{2-})	Mass flow	Enzyme activity and nitrogen fixation in legumes

Texas A&M

Nitrogen (N)

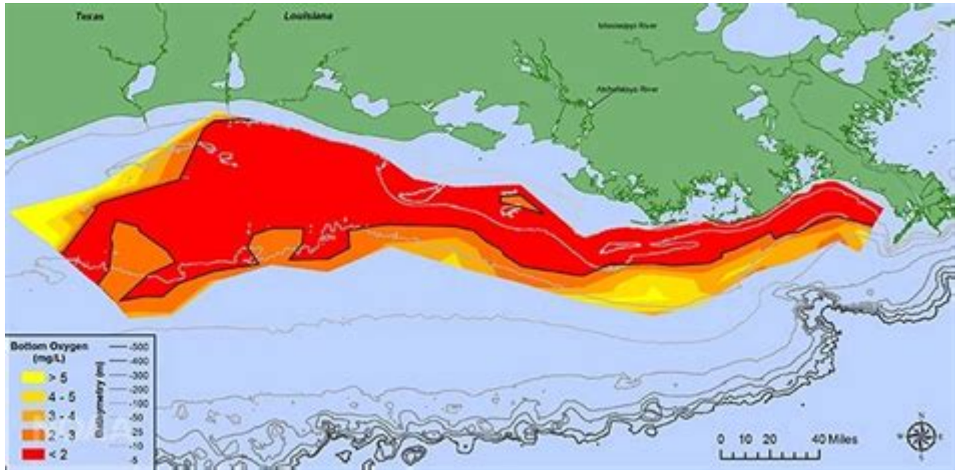
- Nitrogen is a major component of chlorophyll, the compound by which plants conduct photosynthesis. It is also a major component of amino acids, the building blocks of proteins
- Plant-available nitrogen, known as nitrate, is scarce, and for most of agriculture's 10,000-year-old history, the main challenge was figuring out how to cycle usable nitrogen back into the soil
- It makes up 78% of the air we breathe
- Atmospheric nitrogen (N^2) is joined in tight bond that makes it unusable by plants
- In 1909, two German chemists, Fritz Haber and Carl Bosch, developed a high-temperature, energy-intensive process to synthesize plant-available nitrate from air
- $54.6B market in 2019



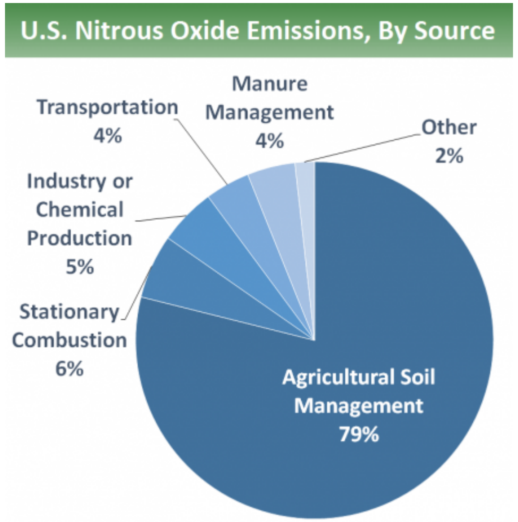
Source: USDA

Problems Associated with nitrogen fertilizer

- Problems associated with excess nitrogen fertilizer:
  - Eutrophication and dead zones
  - When soils are exposed to excess nitrogen, microbial reactions take place that release nitrous oxide, a greenhouse gas 300 times more potent than carbon dioxide
  - Haber-Bosch Process responsible for ~1% of CO2 emissions
- In total, chemical N fertilizer is responsible for an estimated 5% of global GHG



Source: Washington Post



Source: EPA

Ammonia by the numbers

157.3 million:
Metric tons of NH_3 produced worldwide in 2010

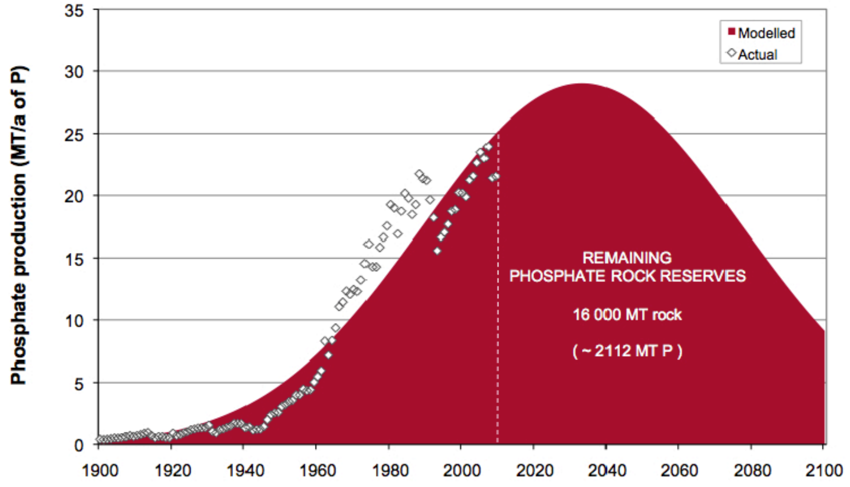
451 million:
Metric tons of CO_2 emitted by NH_3 synthesis worldwide in 2010.

~1%:
Percentage of global CO_2 emissions that come from NH_3 synthesis.

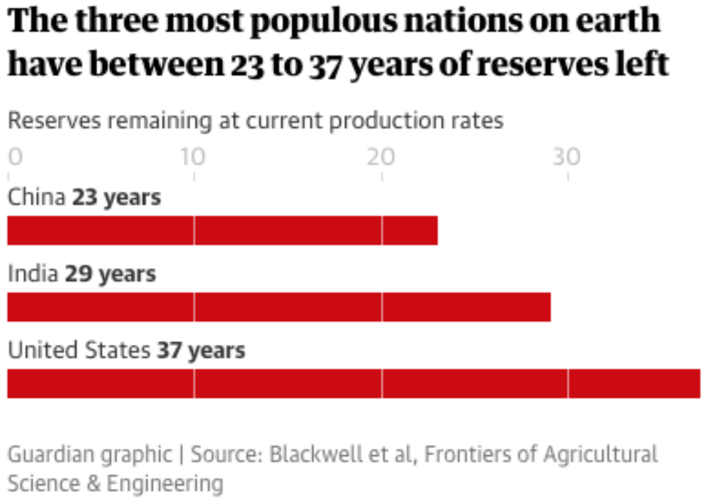
Sources: Institute for Industrial Productivity.

Phosphorous (P)

- P is involved in respiration, energy transfer, and photosynthesis. It is critical to DNA and the P in ATP - the molecule the carries energy around cells
- Without an adequate supply of P, maturity is delayed, and plant growth and yield are reduced
- 2nd largest nutrient applied as fertilizer, $58B market
- Phosphorous is a finite, diminishing, and irreplaceable resource that is concentrated in only a few countries
- Combined economic losses in the USA associated with high phosphorus levels in freshwaters is estimated at $2.2 billion annually



Peak Phosphorous curve indicating a peak in production by 2033, derived from US Geological Survey and industry data. Source: Cordell et al. 2009

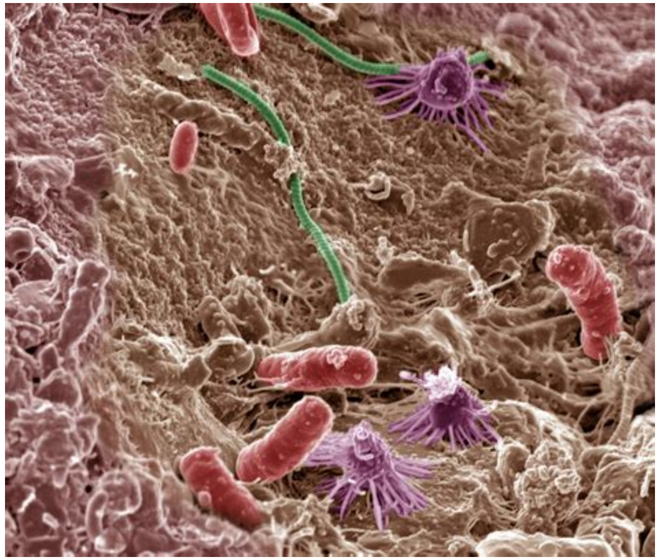


Technology Innovators

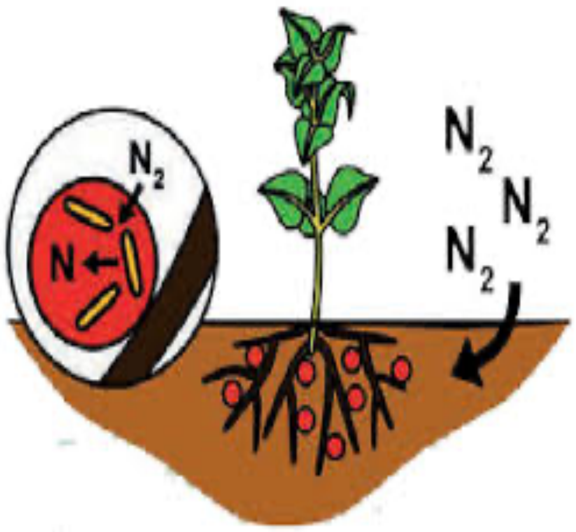
Opportunities & Challenges

Three Highlighted Areas

Microbials and Biologicals



Nutrient Fixing & Solubilizing



Precision Ag

Microbials and Biologicals

Solution Providers

indigo, reazent, concentric (THE PHYTO-MICROBIOME COMPANY), growcentia, NewLeaf Symbiotics, Pattern

Innovator Highlight

Holganix (Soil Nourishing Root Stimulating), PlantResponse (Stronger by Nature)

State of the Industry

- 100s companies vying for acres
- Biologicals are the fastest growing segment of ag inputs
- Farmer skepticism / Inconsistency issues
- Last decade has begun to change perception

The Opportunity

- Opportunity to limit synthetic fertilizer usage while increasing yield
- Ag biologicals projected to grow from $7.4B in 2018 to $20.5B by 2026, 13.6% CAGR

Challenges Remaining

- We understand only a fraction of what microbes do to aid plant growth
- Developing consistent results takes time and data
- Live microbial products require more complex distribution

Nutrient Fixation and Solubility

Startup Solutions

PIVOT BIO

PHOSPHOLUTIONS

ANUVIA PLANET INSPIRED PRODUCTS

JOYN BIO

azotic TECHNOLOGIES

Sound Agriculture

Innovator Highlight

KULA BIO

Overview

- Kula Bio uses unique bioreactor technologies to substantially improve the fitness and longevity of nitrogen fixing microbes

State of the Industry

- Most companies focus on symbiotic nitrogen fixation or nutrient use efficiency whereby the crop supplies the needed carbon

The Opportunity

- 4.2 tons CO_2 emitted per ton of N fertilizer produced
- 50% of N is lost as toxic runoff or greenhouse gases

Challenges Remaining

- Many are live microbes and distribution remains difficult
- Incumbent fertilizer companies

iSELECT FUND®

Precision Agriculture for Nutrient Management

Startup Solutions

sentera
VULTUS
ceres
teralytic
Veris technologies
FarmersEdge™

Innovator Highlight

Overview

- Proximal nitrogen sensor and ground penetrating radar to measure volumetric water content, both mounted on center pivot irrigation systems

State of the Industry

- In 2018, investors pooled $945M across 177 deals in farm management software, sensing, and IoT
- Valued at $4.7B in 2019

The Opportunity

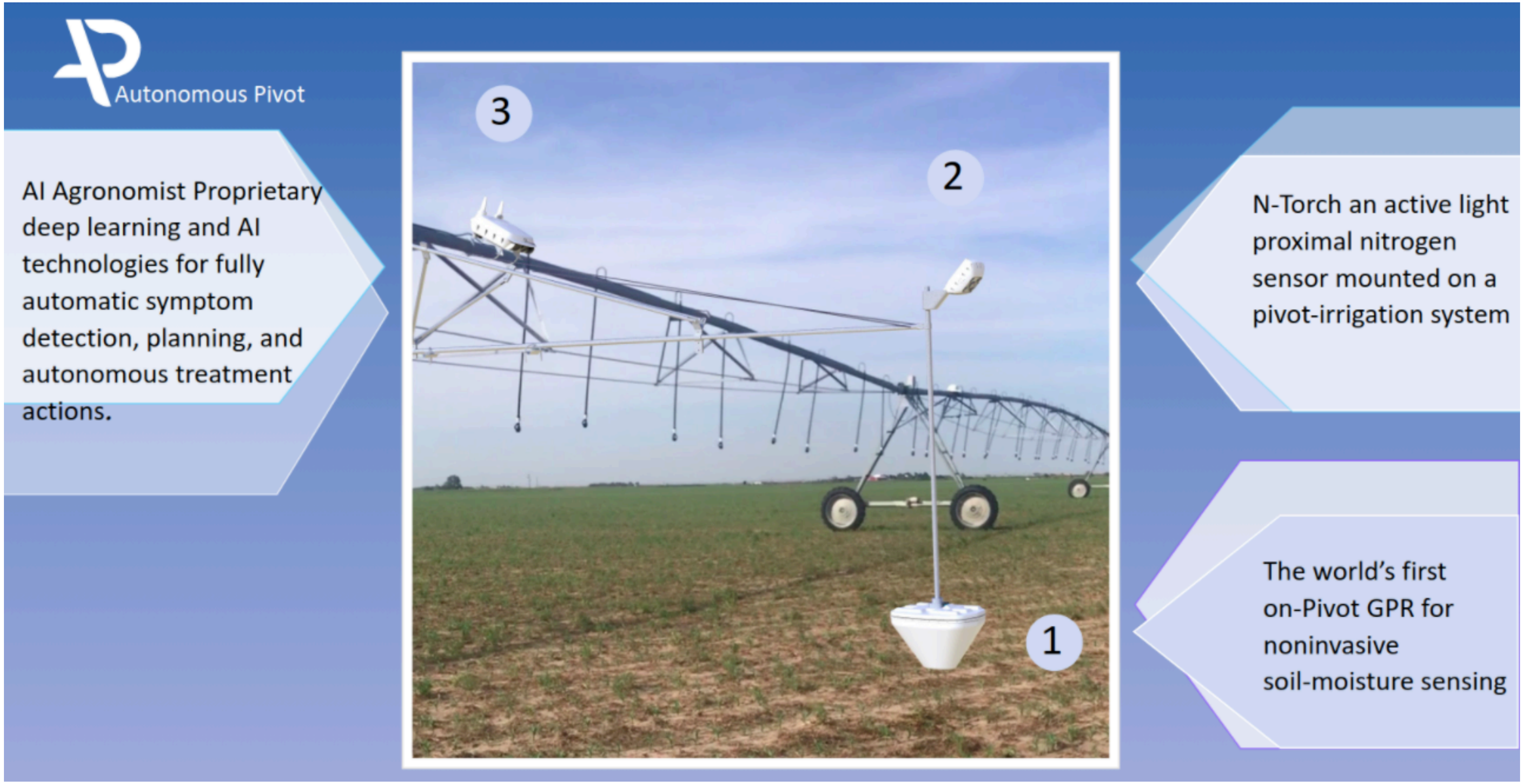
- Right input, right rate, right place, right time translates to higher farmer profitability
- Massive input efficiency gains

Challenges Remaining

- High switching costs and learning curve associated with technology
- ROI needs to be front of mind

iSELECT FUND®

Autonomous Pivot



iSELECT FUND®

Discussion

Thoughts Going Forward

Thoughts & Discussion

Key Risks & Considerations Going Forward

- Consistency**:** Novel technologies must prove to be as consistent in delivering nutrients & yield as synthetics
- ROI: Related to consistency, these technologies need to stand on their own two feet in terms of price and performance for farmers. Positive environmental externalities will follow-suit

Other Areas of Opportunity

- Soil mapping: Understanding the nutrient balance and microbial community in different parts of a farmer's field
- Regenerative Ag: Cover crops, no-till, composting, animal grazing and other regenerative ag practices all reduce the need for synthetic inputs. Consumer awareness and demand for products produced under such conditions is increasing the use of such practices

Discussion Questions

- International: Many technologies are untested on foreign soil. E.g. Biofertilizer has been shown to work better in dry climates than wet ones. Combined with the distribution risk, what needs to be true for widespread international adoption of these technologies?
- 2030: How prevalent will the technologies discussed be by 2030? How much of their markets can they win?