Center for Digital Agriculture

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The Digital Transformation of Agriculture: Advancing Productivity Towards a Circular Bioeconomy

Dr. John F. Reid
Executive Director

ILLINOIS
Center for Digital Agriculture

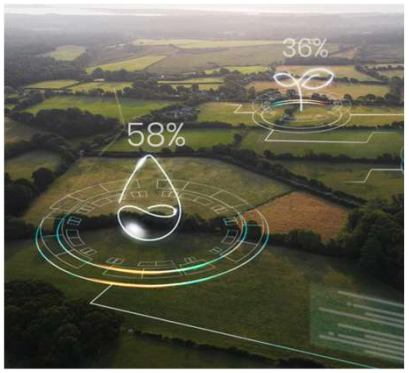
Global Bioeconomy Challenges

- Need to increase food supply (70-90% more food production needed by 2050)
- Limited & declining natural resources (water, land, fossil fuels, nutrients)
- Bioeconomy systems are vulnerable to climate change and climate variability and contribute significant GHG emissions
- Agriculture uses half of arable land and over half of available freshwater
- Between 30 and 40% of produced food is wasted; much is discarded in landfills
- Degradation of water, soil, atmosphere , and ecosystems
- Natural resource use not based on their true financial costs; US spends $1.1 trillion per year on food, true costs are about $2.3 trillion (Rockefeller Foundation, 2021)

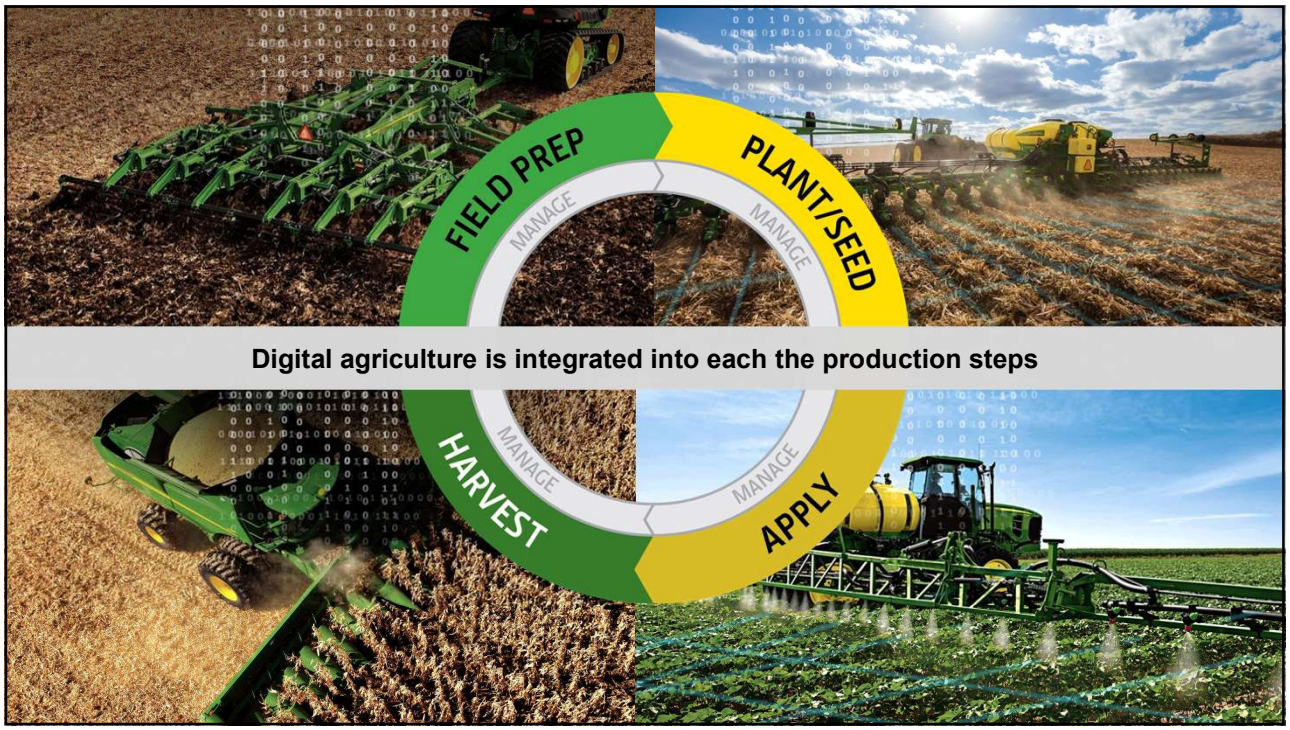
Digital Technologies provide platforms for innovations in the food and agriculture system…

Digital technologies in production agriculture

- The modern ag operating system has enabled quantification of job outcomes enabled by *smart-connected machinery*
- Transitioned from productive machines to *precision job outcomes* and *worksite optimization*
- Key elements are in place for *sustainable productivity* and reframing production systems to *catalyze circular bioeconomy*.



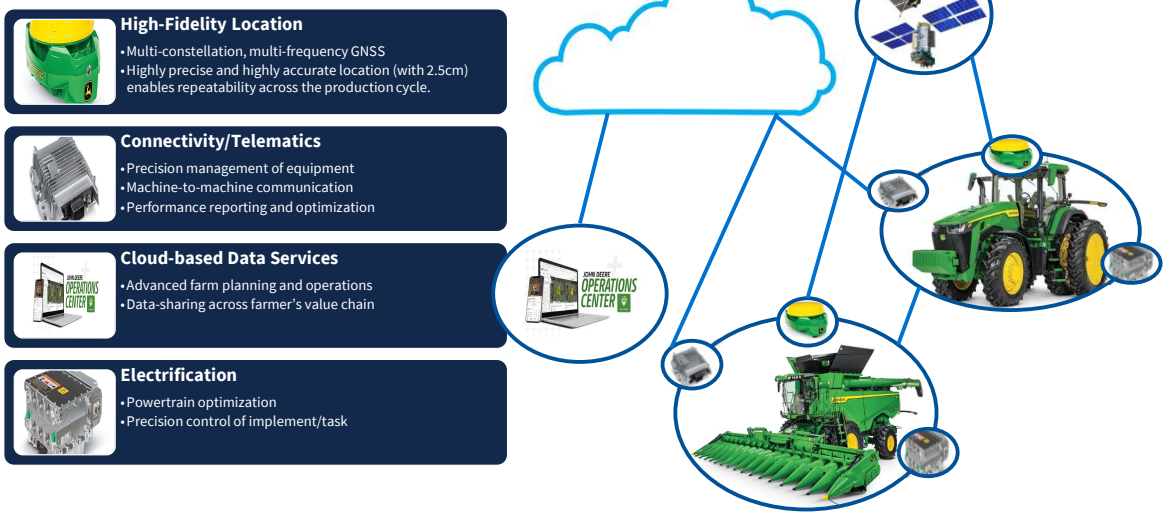
National Academies of Sciences, Engineering, and Medicine 2020. Information Technology Innovation: Resurgence, Confluence, and Continuing Impact. Washington, DC: The National Academies Press. https://doi.org/10.17226/25961.



Digital agriculture is integrated into each the production steps

Digital Transformation of Agriculture

The Modern Ag Operating System



The New Era of Digital Precision Agriculture. April 11, 2023. https://www.nationalacademies.org/event/04-11-2023/the-new-era-of-digital-precision-agriculture#sectionEventMaterials

Digital Technologies help…

Improve Machine Performance

- Vision-based Guidance, Path Planning, Mission Execution

Augment Human Performance

- Stereovision sensing for fill-control management, Synchronized machines

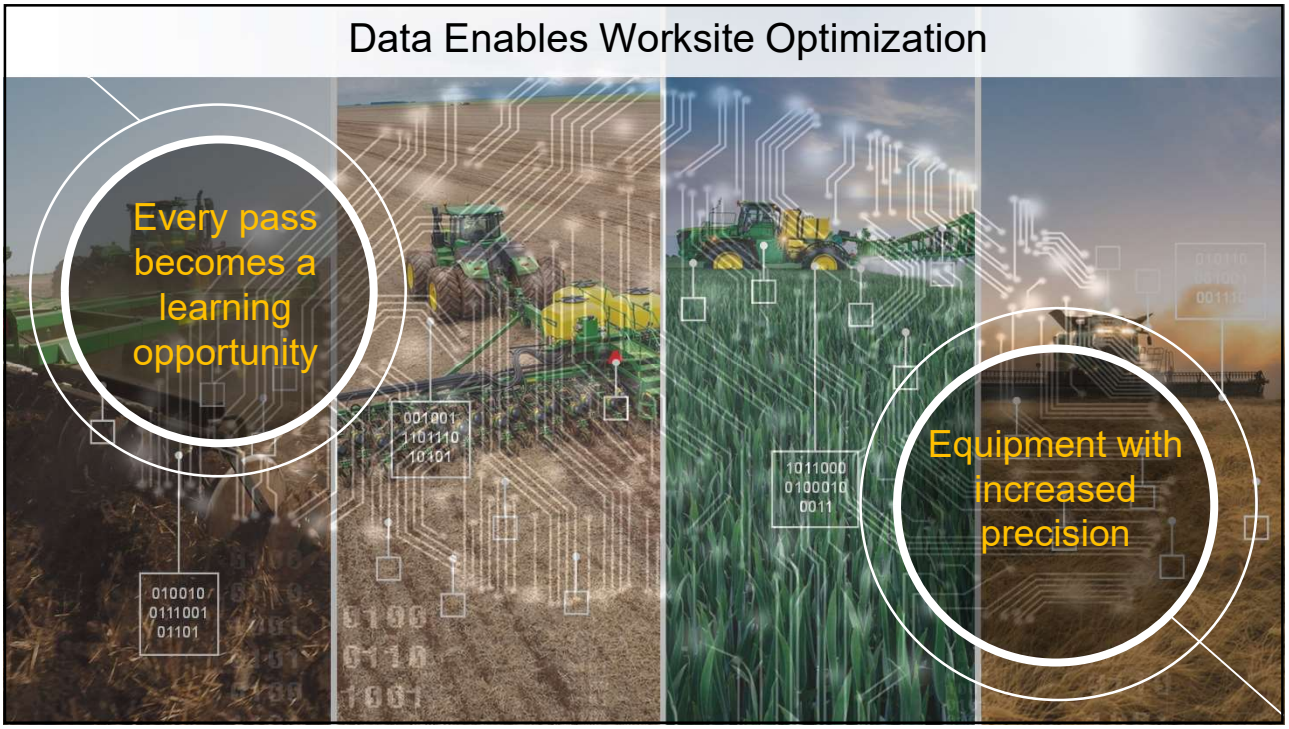
Multiply Human Performance

- Autonomous operations to address labor challenges

Exceed Human Performance

- High Precision selective spraying

Data Enables Worksite Optimization



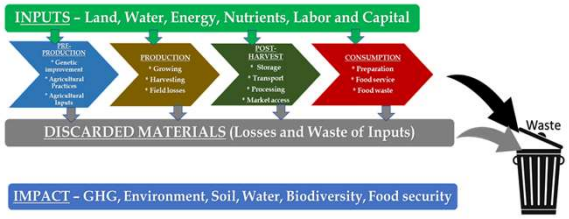
Despite these advancements, it just feels like something is not right.

Some of the challenges…

- Digital Transformation is *revealing*, because it is coupled with a highly-mechanized linear bioeconomy system
- Productivity gains are linked to a *dependency* on fossil fuels:
  - Mechanization
  - Synthetic Fertilizers
  - Pesticides and Herbicides, Irrigation
  - Transportation and Distribution of Global Supply Chains
- Production Agriculture is a highly-developed *linear bioeconomy* that has evolved for the last 100 years.
  - Decreases in diversity in favor of productivity
  - Optimization for the transport of seed and grain for food production
  - Excess biomass is returned to the land
- The technology benefits for large scale production systems have not scaled to small to medium enterprises.
  - Recall that this revolution started with automatic guidance for the large farmer
  - High costs, lack of infrastructure, training and education, and access to data

Deeper Understanding of the Bioeconomy

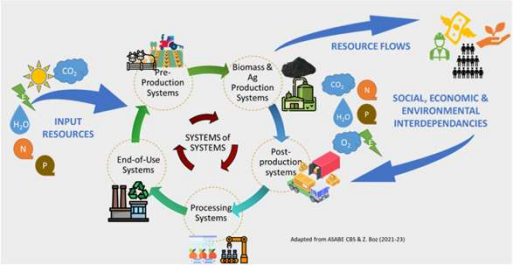
Linear Systems Value Chains



Extremely productive, but at a cost:

- The value of bioproducts, materials, and resources are currently maintained in the economy for a short period of time
- Significant resource losses and wastes
- Some systems are optimized

Circular Systems Value Chains



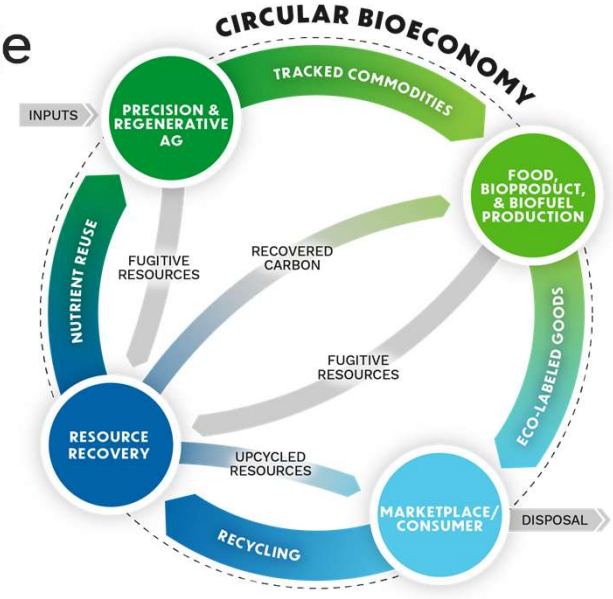
Re-thinking Productivity:

- The values of bioproducts, materials and resources are maintained in the economy for as long as possible.
- Cascading use of biomass from biological resources
- Producing minimal wastes using a systems approach for economic development

The CBS Challenge

To transition the food and agriculture system to a thriving circular bioeconomy that:

- *Reduces, recycles, and reuses* waste productively
- *Optimizes* production systems
- *Displaces fossil fuels* with renewables



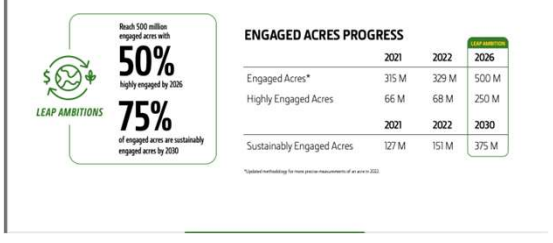
Digital Tech enables a platform for sustainability and a bioeconomy transformation…

Growing interest in sustainable productivity is connecting manufacturers, input providers, and farmers…

Scope 3*: Indirect emissions in the value chain of the reporting org:

- Transportation and distribution of products (upstream and downstream)
- Raw material extraction and production (upstream)
- Use of products (downstream)
- Waste generated and its disposal

Enabling Digital Tech



Example from John Deere Sustainability Report (2022)

*Science-Based Targets: https://sciencebasedtargets.org

Addressing Bioeconomy Systems Challenges

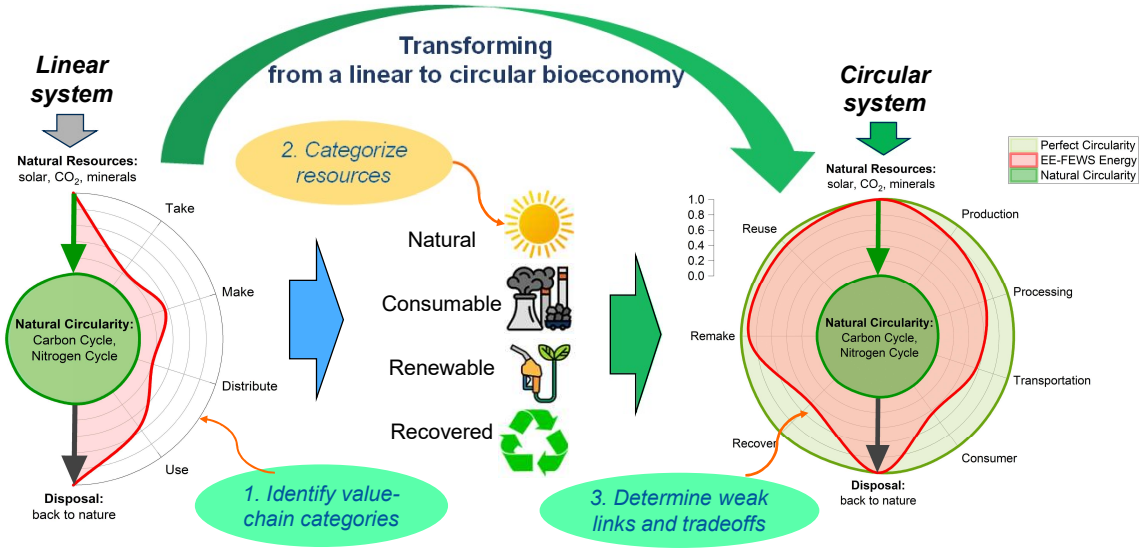
Multiple target goals need to be pursued:

- *Decarbonizing* economic activities, reduce GHG
- *Regenerating* soil health, sequester carbon in soils, natural systems
- *Eliminating* or greatly reduce wastes and losses
- *Reducing* environmental degradation
- *Displacing* fossil carbon sources with biomass carbon sources or alternative fuels
- *Increasing* food security and resiliency
- *Transforming* economic potential

Creating a more circular bioeconomy will contribute to each of these target goals. Required knowledge, techniques, and skills will emerge from the integration of disciplinary perspectives and technologies to create innovative solutions for constituent systems and overall systems of systems.

Image by Chat GPT 4.0 and Dall-E

Transforming from a linear to circular bioeconomy



The Ellen MacArthur Foundation, Granta Design, Material Circularity Indicator (MCI) (2015).
Zhang, Y, S. Summers, JJ Jones and JR Reid. An Index for Quantifying Circularity of Bioeconomy.

The challenges in changing the objective function…

Agriculture and Food Security

- **Challenges:**
  - Climate Change and carbon footprint reduction
  - Long global supply chains impacted by geopolitical forces
  - Unevenly distributed technology across populations of farmers
- **Opportunities**
  - Technological Innovation in precision ag and biotechnology
  - Creating sustainable practices and circular bioeconomy
  - Advancing new approaches including local and urban agriculture
  - Policies to expand global collaboration

Agriculture and National Security

- **Economic Stability:**
  - Job creation and income support
  - Contribution to GDP
  - Export revenues
  - Raw materials for industry
- **Food Independence:**
  - Self-sufficiency
  - Resilient supply chains
  - Provides strategic food reserves
  - International cooperation and trade

Image by DALL-E

Strategies for a Secure and Sustainable Future

- **Policy and Governance:**
  - Integrated policy frameworks
  - Support for sustainable practices
  - Innovation/research funding
  - Infrastructure development
- **Collaboration and Innovation**
  - Multi-stakeholder partnerships
  - Expanded research networks
  - Cross-sector integration
  - Capacity building and education

EPILOGUE: FUTURE REFLECTION FROM THE PAST

I believe that the great Creator has put ores and oil on this Earth to give us a breathing spell... as we exhaust them, we must be prepared to fall back on our farms, which are God's true storehouse.

We can learn to synthesize materials for every human need from things that grow.

~George Washington Carver, Circa 1930's

John F. Reid
J-reid1@illinois.edu

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