Food Security through Machine Learning, Sustainable Precision Farming, and New Arable Land Creation

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Agenda

Introduction

Sustainable Precision Farming

New Arable Land Creation

Yield Prediction using Machine Learning

Final tips & takeaways

Introduction

- As the global population approaches 10 billion by 2050, ensuring food security has become one of humanity's most pressing challenges.

- This talk explores ways to increase food production and security:

  o Seed-placed banding as a sustainable precision farming technique for enhancing yield and improving nutrient efficiency.

  o As global arable land becomes increasingly scarce, the African savannas have emerged as a new frontier for sustainable agricultural development.

  o Leveraging machine learning and unmanned aerial vehicles (UAVs), the research explores yield prediction, early and pest infestation detection.
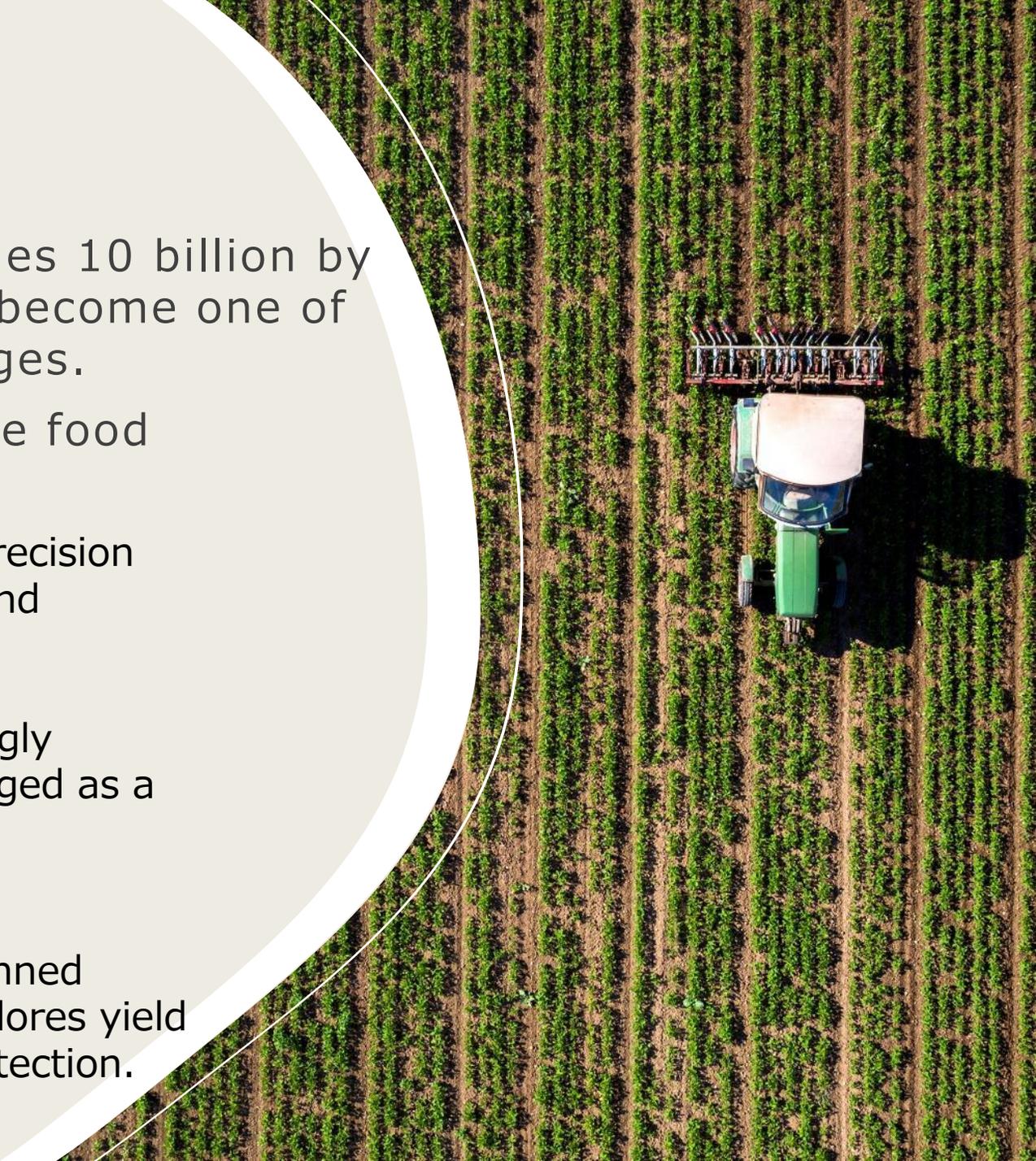
Sustainable Precision Farming

Farming Practices

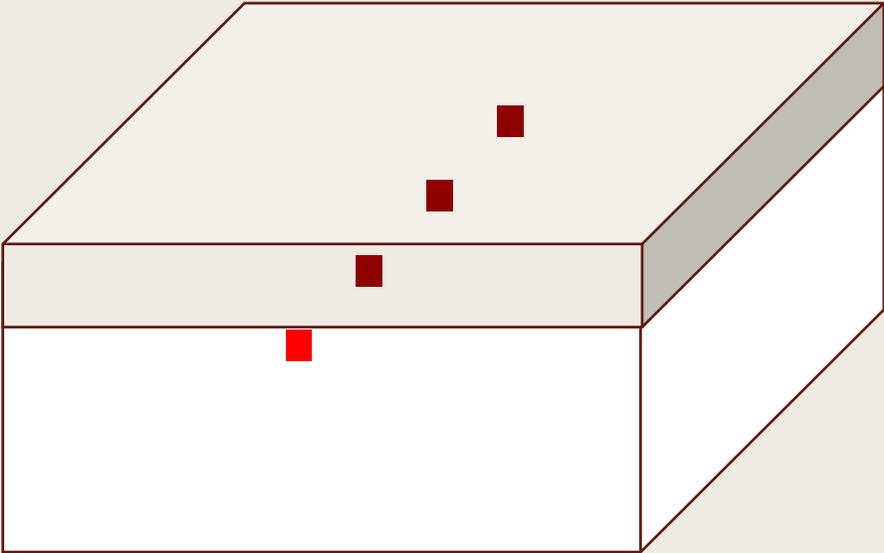Three farming practices are considered:

- Fertilizer Broadcast

- Vertical Fertilizer Banding

- Seed-placed Fertilizer Banding

Plants are planted in rows

Taken from Getting the Most Out of Commercial Fertilizer Applications, www1.agric.gov.ab.ca
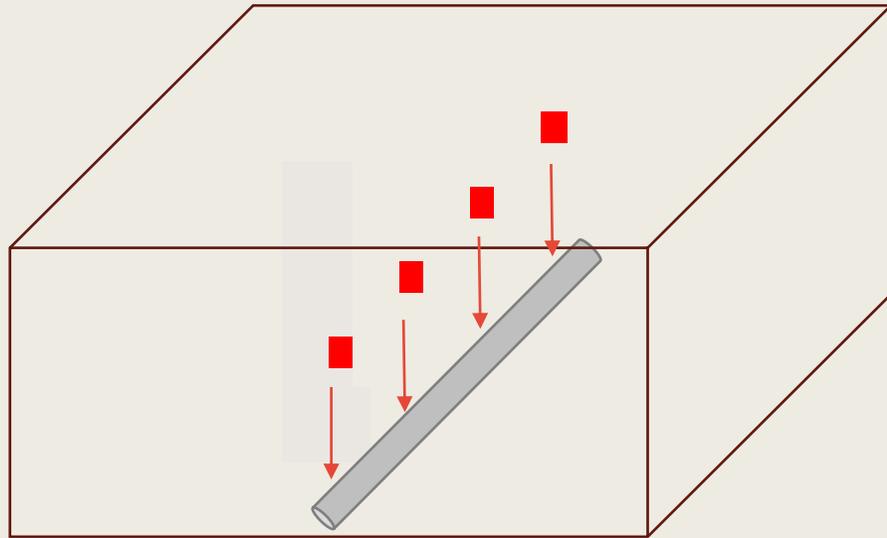
Fertilizer Broadcast

Fertilizer placement
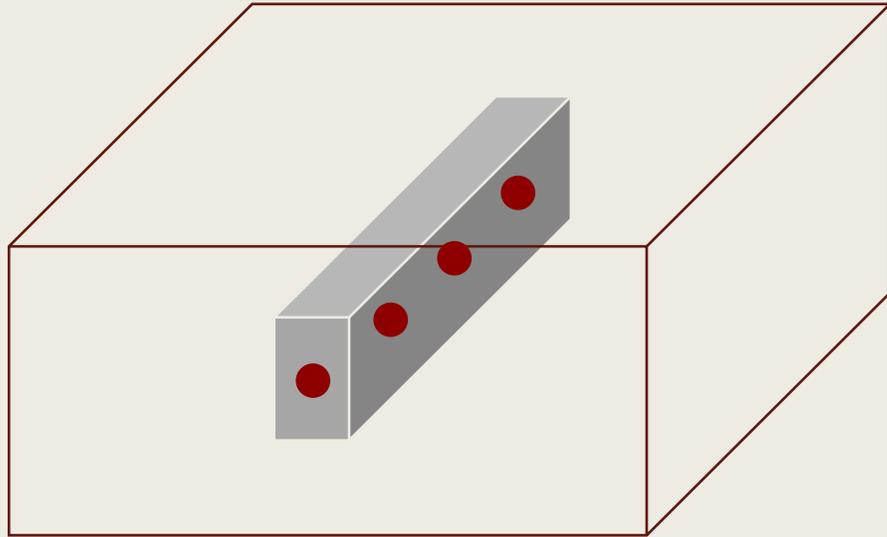
Seed placement

Vertical Fertilizer Banding

Fertilizer placement

Seed placement

Vertical Fertilizer Banding

Fertilizer placement

Seed placement

Seed-placed Fertilizer Banding Benefits

Promoting soil health, particularly through worm activity. Earthworms contribute by:

- **Preferring strip-tilled soil**, which is loose and aerated.

- **Breaking down crop residue** into nutrient-rich worm castings in the root zone.

- **Creating channels** that improve soil aeration and water infiltration.

- **Enhancing drainage** to prevent waterlogging.

- **Aiding deep root growth**, helping corn access moisture during dry periods.

Farming Practices and Root Mass

~ 20 cm

Fertilizer Broadcast

~ 30 cm

Seed-placed
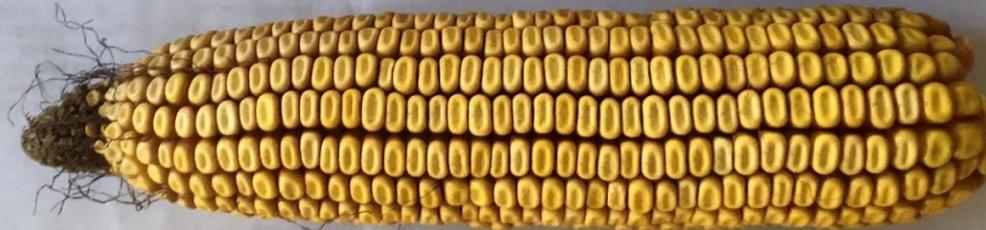
Corn From Different Farming Practices

Fertilizer Applied

150 kg/ha

Seed-placed
Mass per cob: 345g
Yield: 9194 kg/ha

225 kg/ha

Vertical Banding
Mass per cob: 235g
Yield: 7315 kg/ha

225 kg/ha

Fertilizer Broadcast
Mass cob: 190g
Yield: 6923 kg/ha

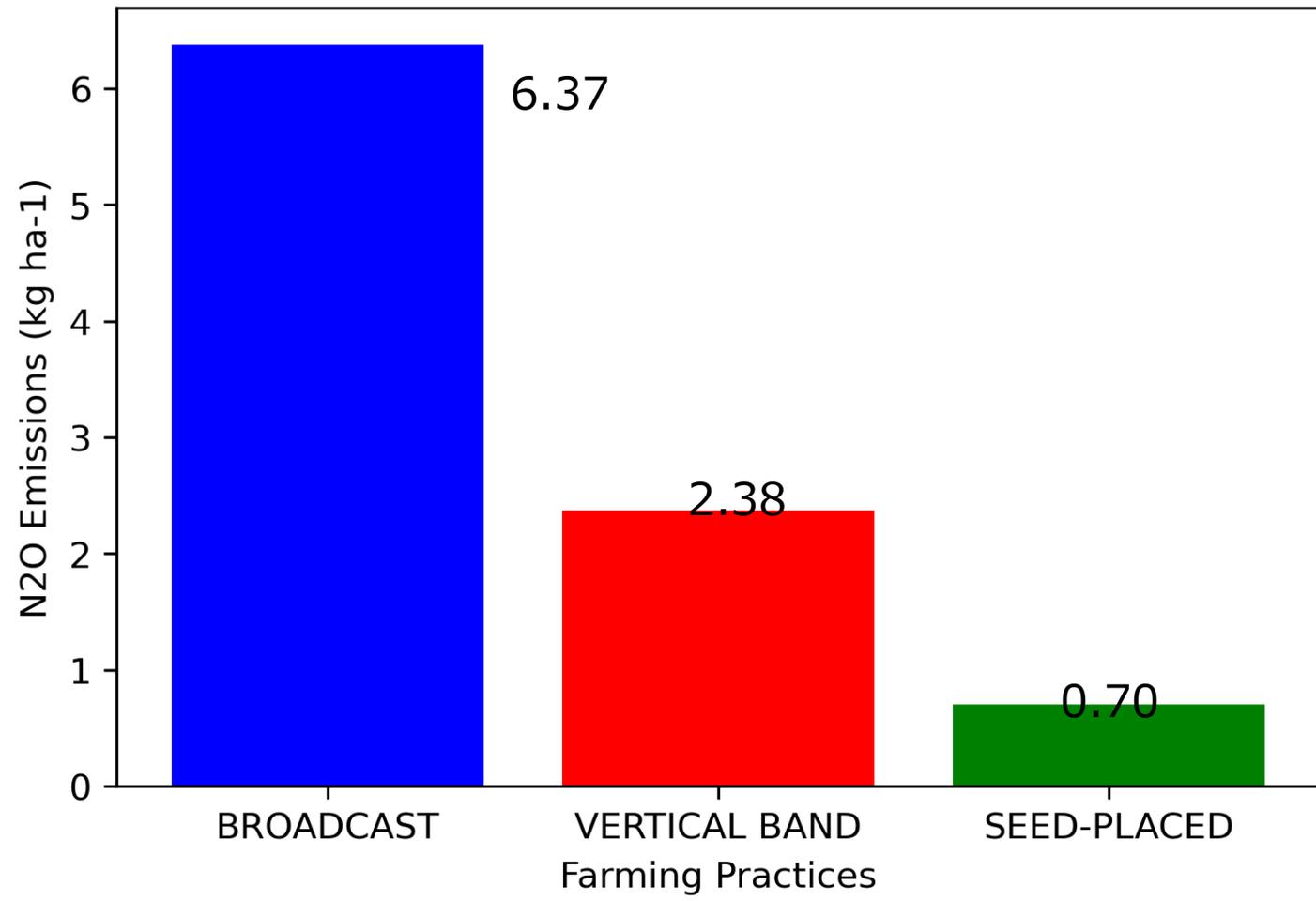# LICOR Equipment to Measure Nitrous Oxide Emissions

Daily N2O Emissions
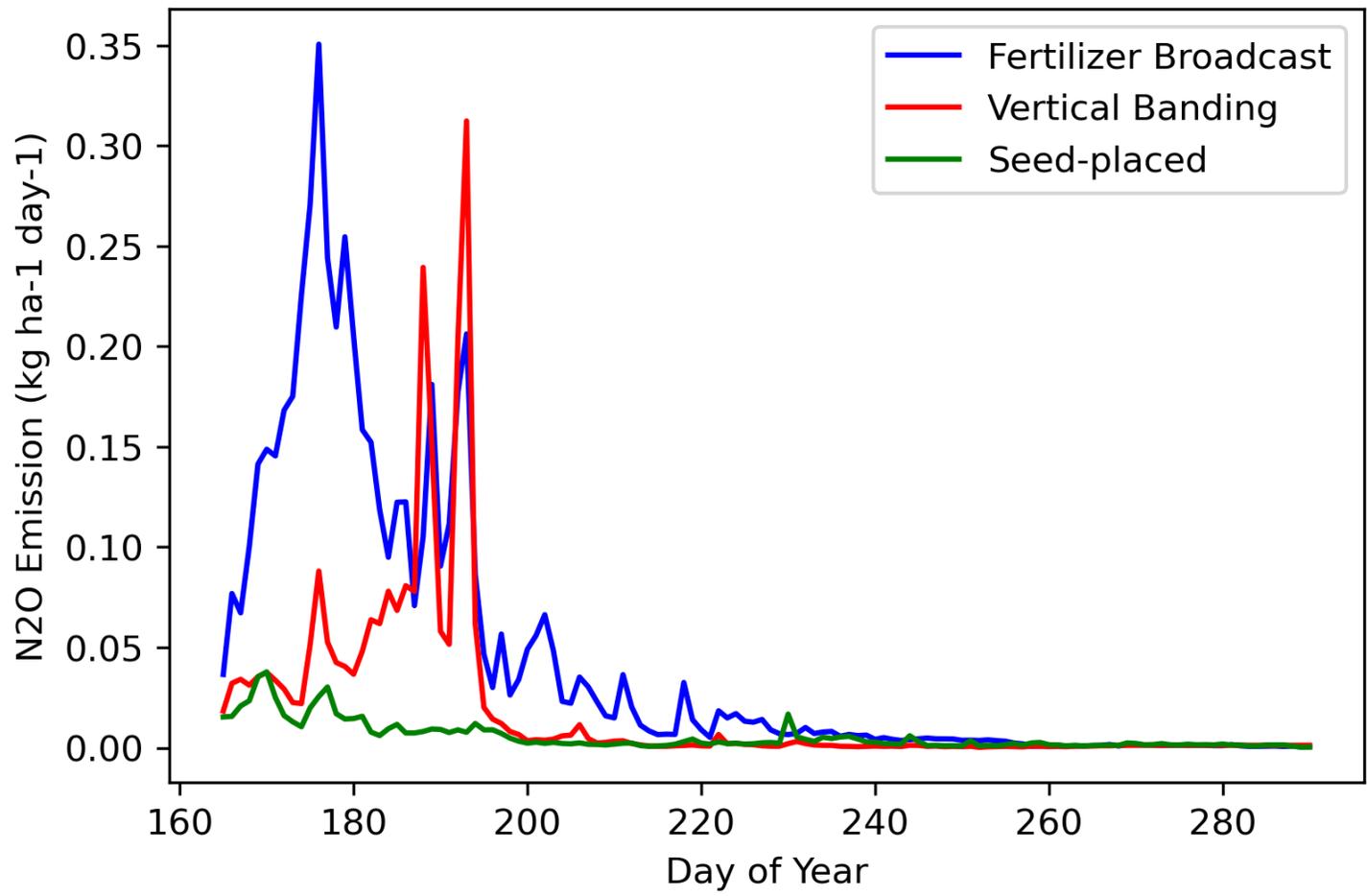
Seasonal N2O Emissions

Corn Harvest (2021-2023)

Switching from Fertilizer Broadcast to Seed-placed Fertilizer Banding

Year	Fertilizer Decrease (%)	Yield Increase (%)	Nitrous Oxide Emissions Decrease (%)
2021	33	33	>85
2022	33	17	>85
2023	33	33	>85

What was learned?

- Seed-placed fertilizer banding is highly recommended to achieve sustainable agriculture.

- More research is needed on planter equipment to reduce the risk of failure and achieve the accuracy needed

- Ideally, we may need to design a planter that supports a one-pass, low-tillage farming practice that is sustainable and cost-effective for many farmers in developing countries to adopt.

New Arable Land Creation

Increase Crop Production

- Fertile arable land becomes scarce.

- Increasing efficiency is not sufficient.

- Global food security becomes an increasing concern.

- We need more arable land!

Opportunities?

- Sandy savannas are abundant in (sub)tropical regions of the world (e.g., Africa). Attention is turning toward their potential for sustainable agricultural expansion to support hundreds of millions to go beyond subsistence farming.

- Can we transform these savannas into arable land?

Proposal

- Develop reduced tillage farming: leapfrogs full tillage farming of the US Midwest and Canadian prairies

- Cost-effective and appropriate technologies:

  o **Planter** adapted to grassy and sandy savanna terrains

  o **Roller/crimper** to support weed suppression, reduced tillage, and henceforth enhance regenerative practices in sandy savannas

AgriSmart Technologies

(www.agrismarttech.ca)

Mission

- Democratizing climate-smart farming technologies to improve global food security through cost-effective precision solutions

- Making advanced, sustainable, and data-informed farming practices accessible, cost-effective, and scalable

Two Patent-pending Technologies

- **Precision planter**
  - enables seed-placed banding with practical deployment — without dual-antenna GPS systems or specialized soil levelers. Built on three years of field validation.

- **Advanced roller/crimper**
  - a novel land-preparation system designed to suppress weeds, reduce tillage intensity, and support regenerative practices — developed in collaboration with the National Soil Dynamics Laboratory (USDA), Auburn, Alabama.

Pilot Operations

- 100 acres at Area X.O, Ottawa

- 5 acres in collaboration with the National Soil Dynamics Laboratory of the USDA, Auburn, Alabama

- 10,000 – 100,000 ha of savannas near Kinshasa (DR Congo), with unique sandy terrain, presents an ideal environment to test our planter and roller/crimper technologies (in collaboration with the U. of Kinshasa)

Bateke Plateau: Location, Climate, and Soil

- A savanna plateau located within a radius of 150 km east and north of Kinshasa.

- The **climate** is hot tropical with a dry season of 4 months (from June to September). Average annual temperatures vary around 25°C.

- The **soils** are mainly sandy, acidic, chemically poor, and have a very low water retention capacity. Kaolinite is the most important material in the clay fraction. The Ph is generally less than 5.5 and varies with the organic matter content.
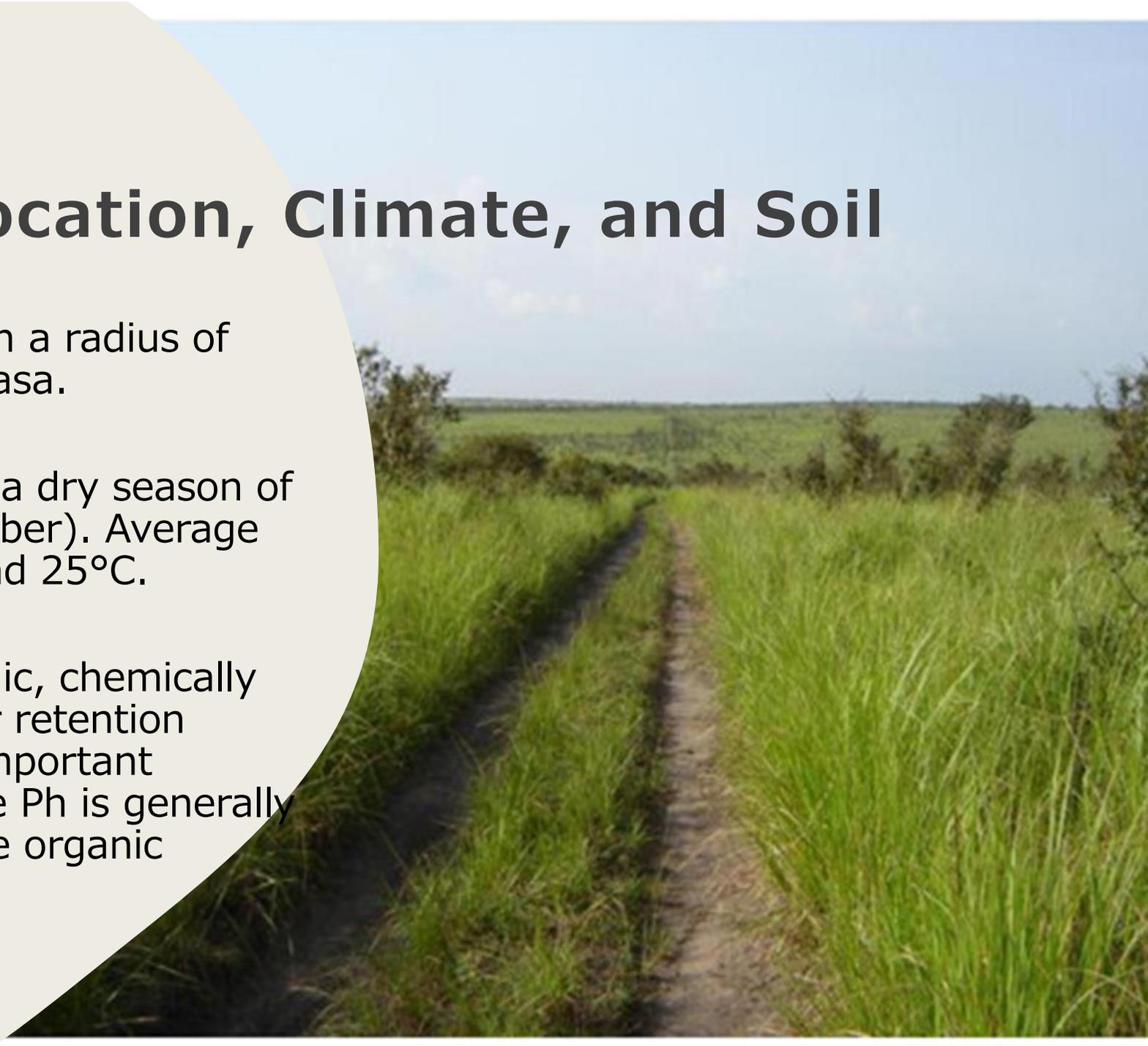
Comprehensive Africa Agriculture Development Programme - CAADP

- CAADP is about boosting investment to stimulate growth in the agricultural sector in Africa.

- Under the Kampala Declaration and the CAADP Strategy (2026–2035), African Union Member States have committed to accelerating agricultural growth through sustainable intensification, agro-industrialization, and expanded trade.

- One objective is to increase crop yields and overall agrifood output while maintaining environmental sustainability and strengthening food security

Observations from Dr. John Ulimwengu

- Senior Research Fellow of the International Food Policy Research Institute (www.ifpri.org)

- AgriSmart Technologies Inc. is an agri-technology company developing tools intended to improve precision in input use and support regenerative land management practices.

- Two of its technologies—a precision seed-banding planter and a reduced-tillage land preparation system—illustrate how farm-level innovations may contribute to CAADP-aligned productivity and sustainability outcomes.
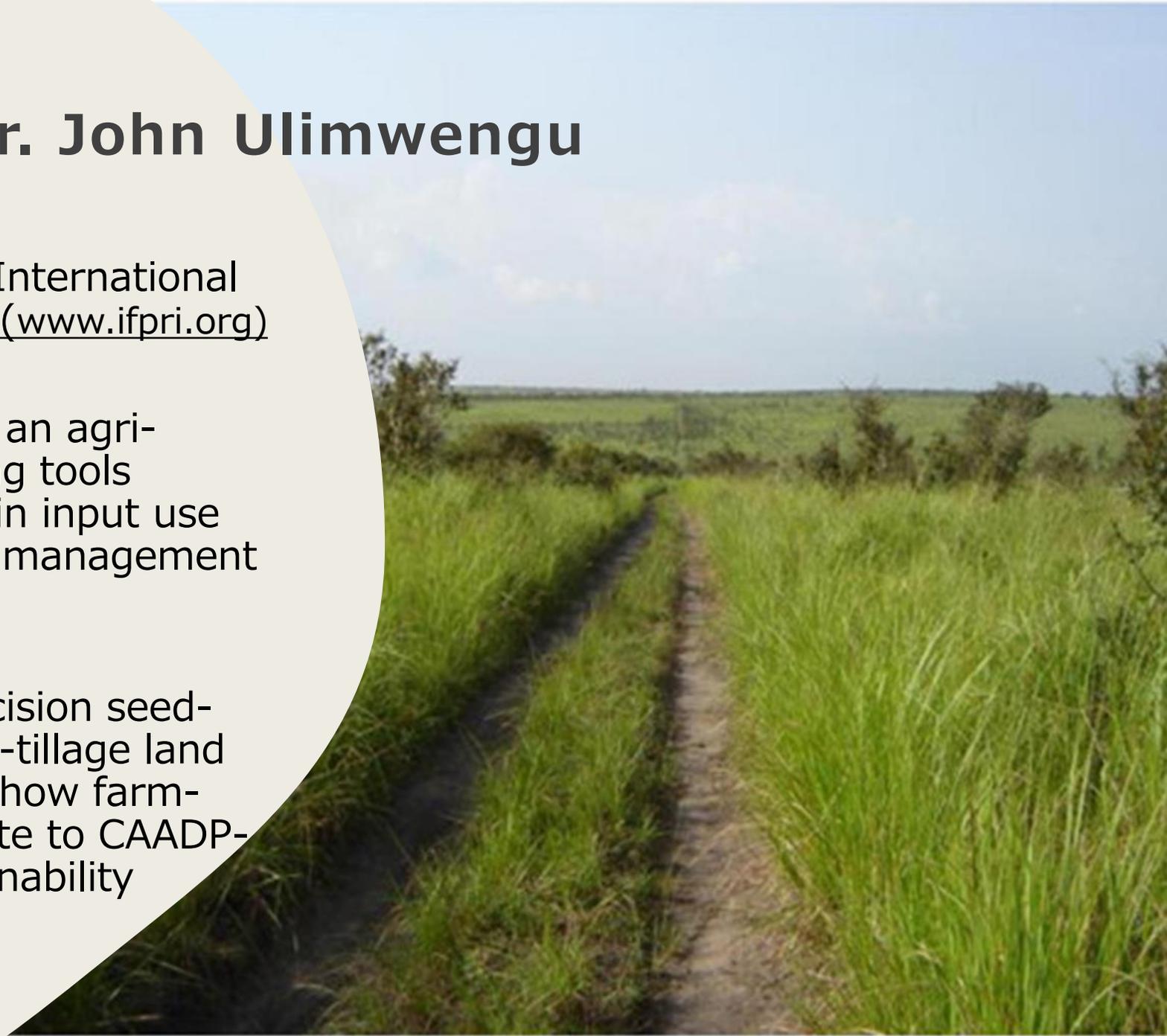
Gambia – Country Overview

- A small African country with a population of 2.42 million

- The majority are small holder farm

- Emerging commercial farming in horticulture and poultry

- Land is generally flat, ideal for the cultivation of maize, groundnut(peanut), rice, millet, horticulture
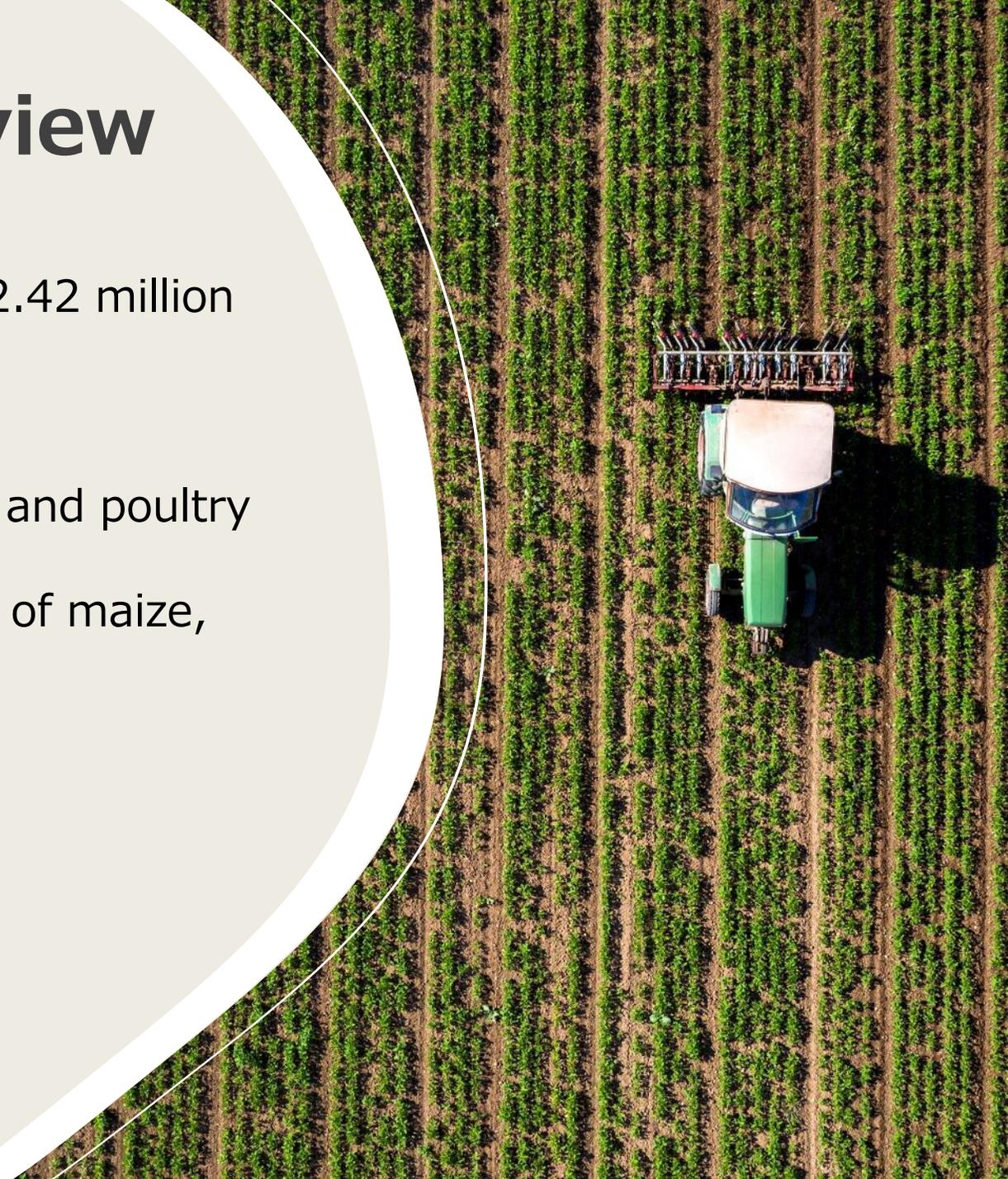
Gambia – Pilot Prospect

- Government's priority is to promote food security

- Groundnut (peanut) is the main cash crop

- Maize is cultivated as a staple and cash crop

- Growing demand for maize in the poultry industry (chicken feed)

- Demand for skills and capacity in agricultural technology and entrepreneurship, especially for women and youth

# Yield Prediction using Machine Learning

Yield Prediction

- Traditional Methods
  - Historical Averages, Expert Knowledge, and Plot Trails
- Vegetation Indices
  - Numerical values drive from remote sensing data
  - NDVI (Normalized Difference Vegetation Index) is the most widely used that quantifies the greenness by comparing the reflectance of near-infrared (NIR) and red light
- Machine Learning
  - Data analysis, pattern recognition, and predictive modeling
  - Random Forest was most popular for this task, followed by SVM
- Deep Learning
  - Automatic Feature extraction and Handling of high volume of data
  - Extract complex and long-term dependencies

3D CNN Deep Learning Network
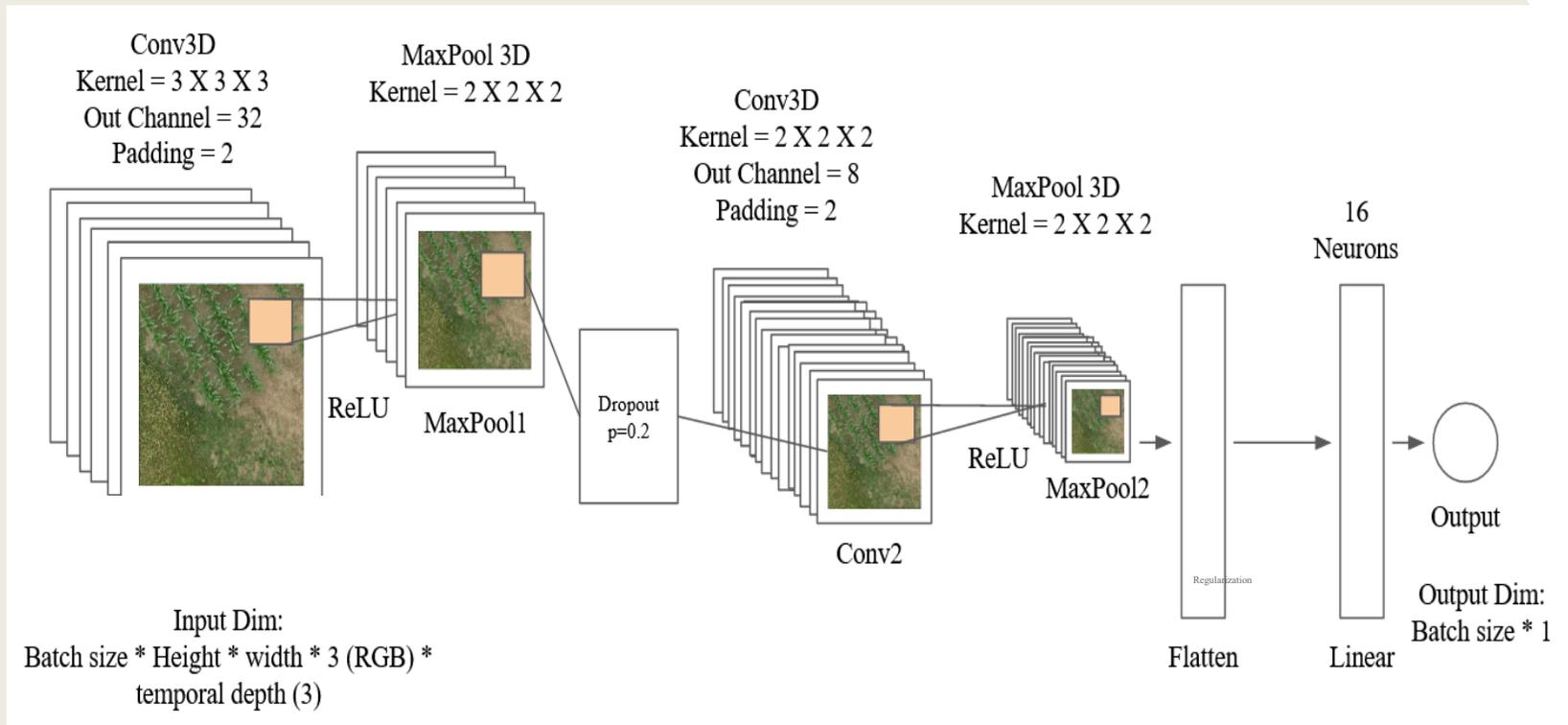
- Convolutional Neural Networks with 3D kernels slide across three dimensions (height, width and depth) of the input image

- They capture spatiotemporal features and patterns in addition to the spatial features captured by 2D CNNs

What have we learned?

- An end-to-end architecture for developing a deep learning-based yield prediction model

- Integrating the temporal dimension and harnessing 3D CNNs to model intricate spatial and temporal relationships with MAPE of 15.18% and RMSE of 17.63 bu/ac

- The CNN models are able to generalize by making predictions and assessing performance on data from different fields
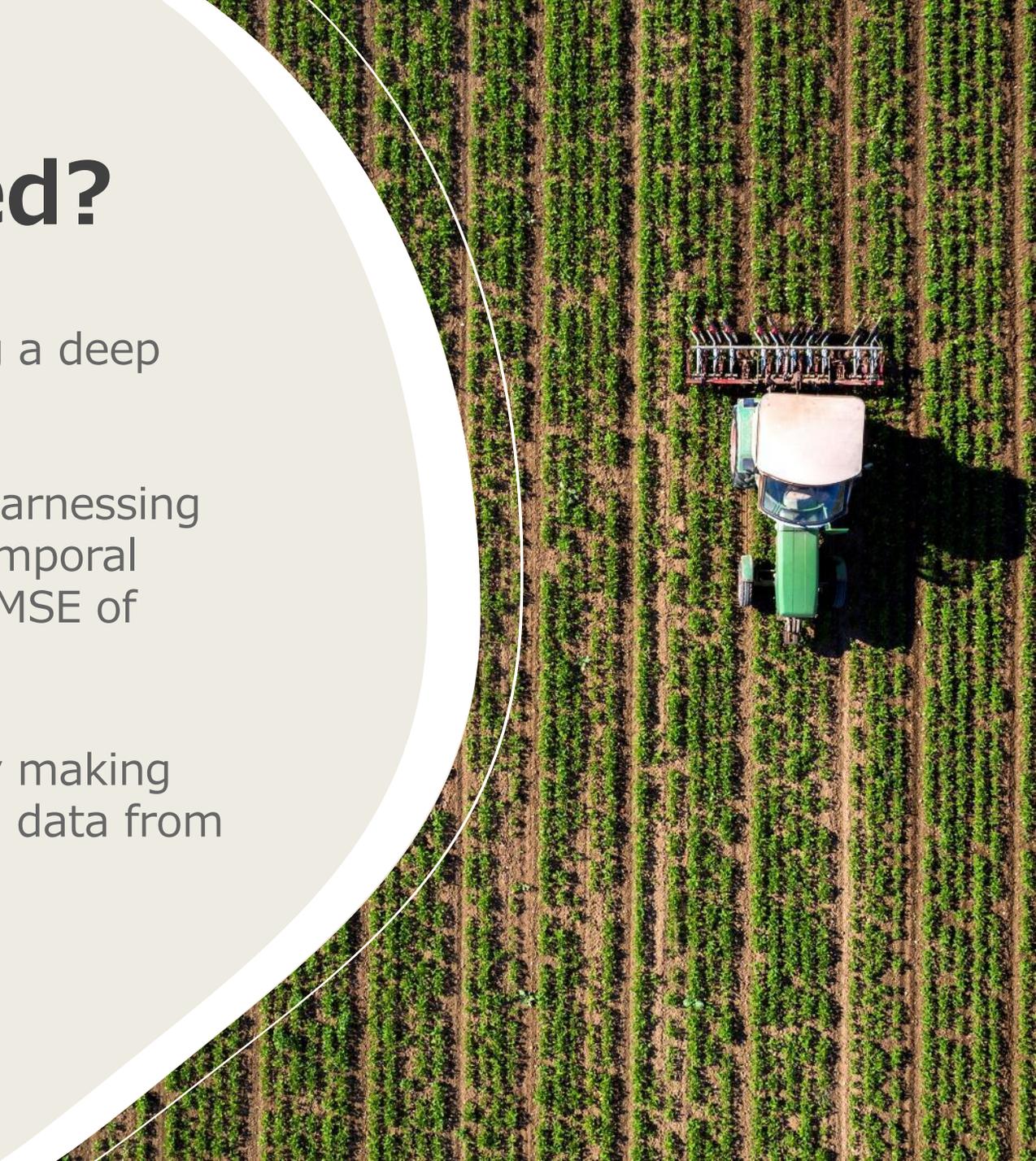
Conclusions

- Seed-placed fertilizer banding is highly recommended to achieve sustainable agriculture.

- R/D is needed on planter equipment to support a one-pass, low-till farming practice that is sustainable and cost-effective to adopt by many farmers in developing countries.

- R/D is needed on roller/crimper technology to convert current savannas to new arable land to ensure food security in the future.

- R/D is needed on crop yield prediction using UAV

- As a novice in farming, I find that this type of conference is very helpful. Therefore, as we gather here, we should work together to solve the world food security problem.

Thank You

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