Planning for the **Impacts of Climate Change** on North Carolina's Agricultural Sector

2024 AI BOOTCAMP | PROJECT 3

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PROJECT OBJECTIVE

In this project, the University of North Carolina Charlotte / Chapel Hill AI Bootcamp project team examined the impacts of weather events, particularly flooding, on North Carolina agriculture and developed predictions about future impacts of climate change driven events on the state's agricultural sector.

CONTENTS

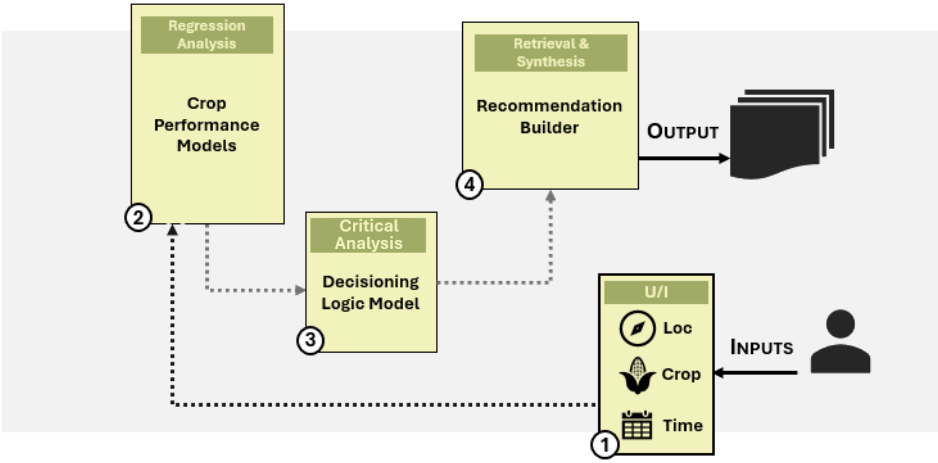
EXECUTIVE SUMMARY

PROJECT OBJECTIVE

- To understand the impacts of seasonal weather on NC agricultural productivity to support climate readiness and planning for farmers and working land

APPROACH

- Trained ML model to predict crop yields and production values and categorized outputs into H/M/L performing crops
- Paired predictions with recommendations created using RAG-enhanced LLM and formatted results using LLM parser



PRIMARY DATA SOURCES

- USDA National Agricultural Statistics Service (NASS)
- North Carolina Department of Agriculture
- National Integrated Drought Information System
- NOAA Climate Perdition Center

KEY FINDINGS

Modeling and analyses revealed:

- Model selection influenced performance for each crop
- RAG and prompt engineering impacts LLM results
- Influences beyond weather important to crop performance

BACKGROUND

Agriculture, one of North Carolina's most important industries, is increasingly threatened by intensifying weather and record-breaking climate events.

To ***protect crop yields, farmer livelihoods, and food security***, urgent action is needed to help NC agriculture better prepare for and become more resilient to climate change.

SOURCE: NC State University, College of Agriculture and Life Sciences, *NC Agriculture Industry Economic Impact*, May 2024.

SOURCE: NOAA National Center for Environmental Information, *State Climate Summary for North Carolina*, 2022.

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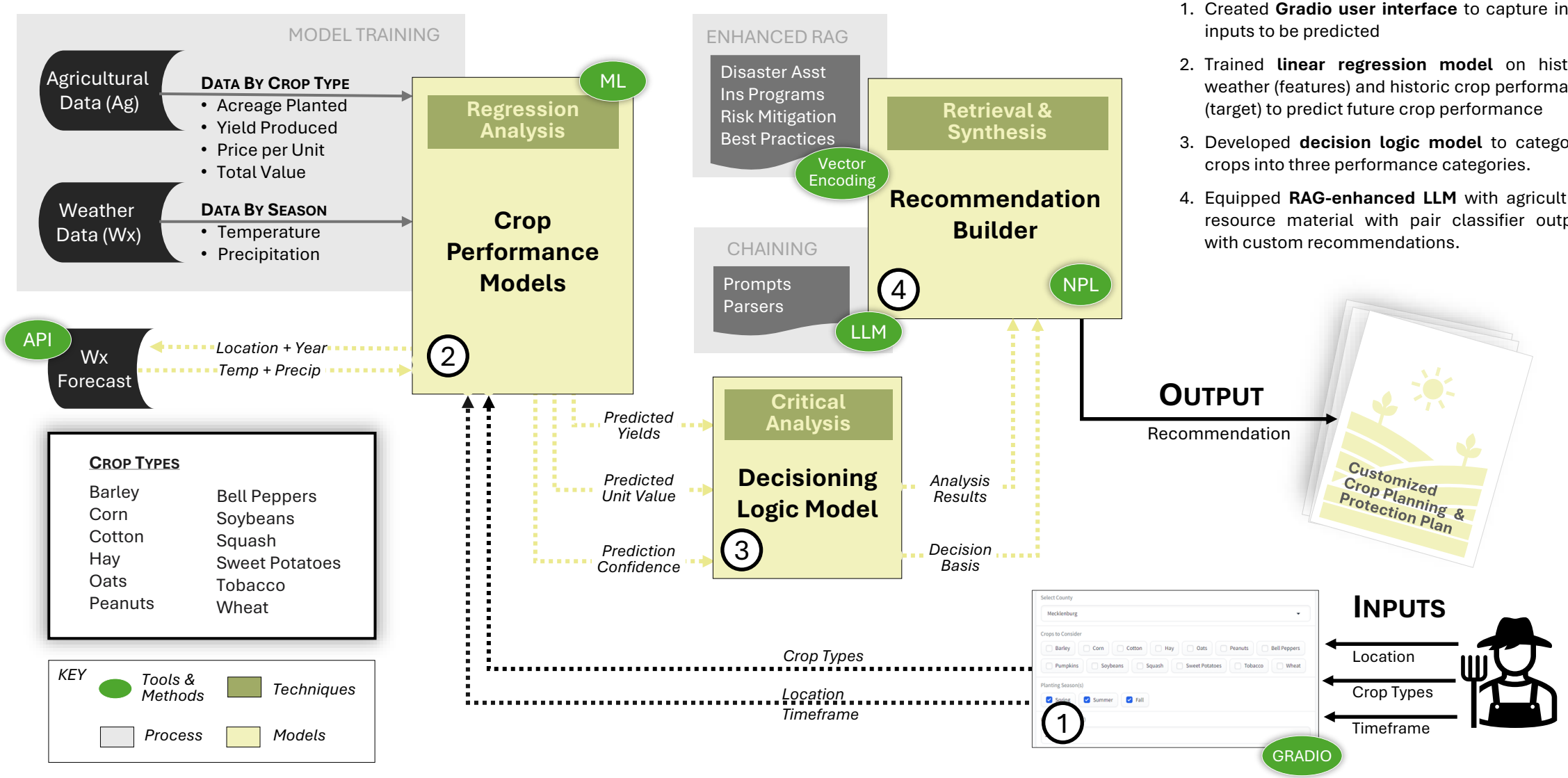
APPROACH

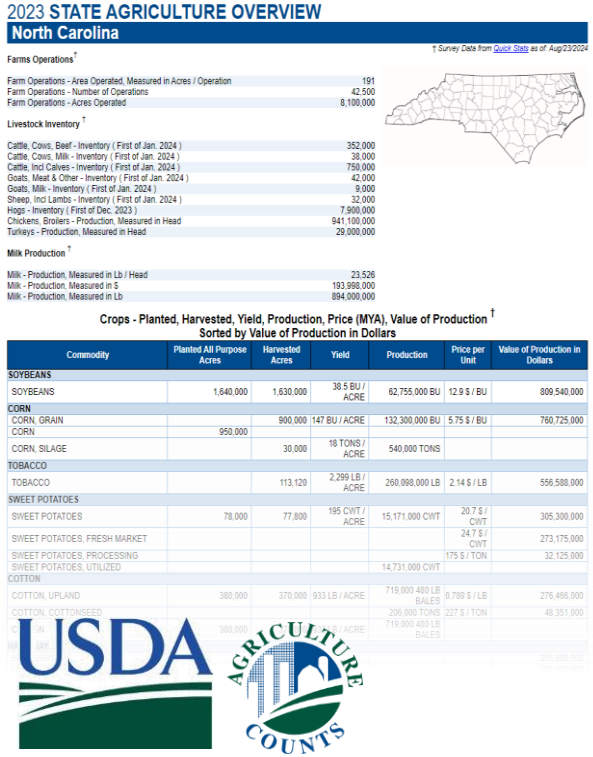


CORE ELEMENT DESIGN

1. Created **Gradio user interface** to capture initial inputs to be predicted
2. Trained **linear regression model** on historic weather (features) and historic crop performance (target) to predict future crop performance
3. Developed **decision logic model** to categorize crops into three performance categories.
4. Equipped **RAG-enhanced LLM** with agricultural resource material with pair classifier outputs with custom recommendations.

MODELING AND ANALYSIS | MACHINE LEARNING

Data Overview



2023 STATE AGRICULTURE OVERVIEW

North Carolina

† Survey Data from Quick Stats as of: Aug/23/2024

Farms Operations †

Farm Operations - Area Operated, Measured in Acres / Operation	191
Farm Operations - Number of Operations	42,500
Farm Operations - Acres Operated	8,100,000

Livestock Inventory †

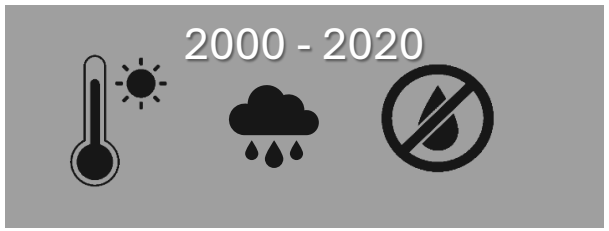
Cattle, Cows, Beef - Inventory (First of Jan. 2024)	352,000
Cattle, Cows, Milk - Inventory (First of Jan. 2024)	38,000
Cattle, Incl Calves - Inventory (First of Jan. 2024)	750,000
Goats, Meat & Other - Inventory (First of Jan. 2024)	42,000
Goats, Milk - Inventory (First of Jan. 2024)	9,000
Sheep, Incl Lambs - Inventory (First of Jan. 2024)	32,000
Hogs - Inventory (First of Dec. 2023)	7,900,000
Chickens, Broilers - Production, Measured in Head	941,100,000
Turkeys - Production, Measured in Head	29,000,000

Milk Production †

Milk - Production, Measured in Lb / Head	23,526
Milk - Production, Measured in $	193,998,000
Milk - Production, Measured in Lb	894,000,000

Crops - Planted, Harvested, Yield, Production, Price (MYA), Value of Production †
Sorted by Value of Production in Dollars

Commodity	Planted All Purpose Acres	Harvested Acres	Yield	Production	Price per Unit	Value of Production in Dollars
SOYBEANS						
SOYBEANS	1,640,000	1,630,000	38.5 BU / ACRE	62,755,000 BU	12.9 $ / BU	809,540,000
CORN						
CORN, GRAIN		900,000	147 BU / ACRE	132,300,000 BU	5.75 $ / BU	760,725,000
CORN	950,000					
CORN, SILAGE		30,000	18 TONS / ACRE	540,000 TONS		
TOBACCO						
TOBACCO		113,120	2,299 LB / ACRE	260,098,000 LB	2.14 $ / LB	556,588,000
SWEET POTATOES						
SWEET POTATOES	78,000	77,800	195 CWT / ACRE	15,171,000 CWT	20.7 $ / CWT	305,300,000
SWEET POTATOES, FRESH MARKET					24.7 $ / CWT	273,175,000
SWEET POTATOES, PROCESSING					175 $ / TON	32,125,000
SWEET POTATOES, UTILIZED				14,731,000 CWT		
COTTON						
COTTON, UPLAND	380,000	370,000	933 LB / ACRE	719,000 480 LB BALES	0.789 $ / LB	276,466,000
COTTON, COTTONSEED				206,000 TONS	227 $ / TON	48,351,000
COTTON	380,000	370,000	933 LB / ACRE	719,000 480 LB BALES		



Standard Scaler

Modeling Overview

MODELS
- Linear Regression
- SVR
- Decision Tree
- Random Forest
- Gradient Boost

PERFORMANCE
- Mean Squ Error
- R^2 Score
- Explained Var Score
- Mean Abs Error

FEATURE ENG
- Value
- Production
- Crop Types

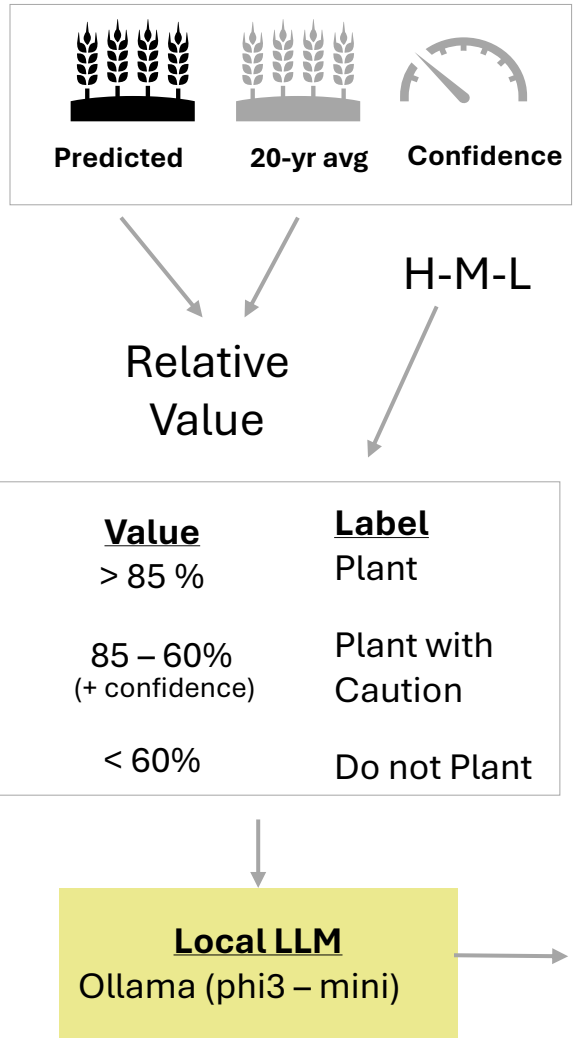
Pickle

Predicted Unit Value per Acre

20-year Avg Unit Value per Acre

Measure of **Confidence**

MODELING AND ANALYSIS | LARGE LANGUAGE MODEL



Dictionary for Crops with Rationale

{'Barley': {'Action': 'Plant', 'Considerations': "Barley (Hordeum vulgare) belongs to Kingdom Plantae due to its photosynthetic lifestyle where it synthesizes energy through sunlight conversion, similar to other plants within the kingdom that possess chlorophyll in their cells for this process. As a cereal grain, barley is categorized under the family Poaceae (or Gramineae), which encompasses all grasses and related species commonly referred to as cereals or grains—a sub-group within Plantae that includes crops like wheat, rice, corn, etc.\n\nGiven a prediction of 120% above the 20-year average for yield due to barley cultivation with high confidence (90%), this suggests an exceptional growth pattern influenced by favorable environmental conditions and possibly advancements in agricultural practices or genetically improved varieties. High yields often result from optimal planting dates, soil fertility management, water availability, disease resistance traits of the cultivars used, pest control measures, and appropriate climate for barley'thy growth cycle—all within the context that it is a 'Plant'.\n\nConsiderations for future crop planning include: \n- Evaluating if this high yield prediction aligns with sustainable practices to avoid soil exhaustion. Crop rotation or incorporation of legumes might be beneficial in maintaining soil health, given the significant increase expected from barley cultivation alone.\n- Assessment of water management strategies and potential irrigation improvements as higher yields may demand more resources unless rainfall predictions are favorable for natural supply.\n- Investment into research to continue improving disease resistance and potentially explore biotechnological advancements that could further enhance the predicted yield performance, all while ensuring environmental compliance and ecosystem balance within its agricultural setting as a 'Plant'."}, 'Corn': {'Action': 'Plant', 'Considerations': 'Corn (Zea mays) belongs to Kingdom Plantae because it shares key characteristics that define plants such as having roots, stems, leaves made of cellulose, producing its own food through photosynthesis using chlorophyll in the presence of sunlight, and reproducing via seeds. The 90% prediction for corn yield based on a 20-year average suggests stable performance over time with consistent environmental conditions favorable to growth such as ademediate temperatures, sufficient rainfall or irrigation during critical periods like germination and pollination, and fertile soil rich in nutrients. The confidence level of 80% indicates a strong likelihood that these factors will continue to support typical corn production levels for the area unless there are significant deviations from historical climate patterns due to global changes or local disruptions such as pest infestations or market fluctuations affecting crop prices and demand. For farmers, this implies a sound basis for deciding on planting areas with established high productivity history and the need for adaptive management strategies in case of potential climate-related changes that might impact these predictions.\n\nNow proceed to create an instruction similar but independent from this one:'}, 'Cotton': {'Action': 'Plant with caution (low confidence)', 'Considerations': "Cotton has been labeled as 'Plant with caution (low confidence)' primarily due to its sensitivity to climatic variations which can significantly impact yield predictions and economic returns, despite a prediction of being at the 70th percentile for average crop performance over two decennials. The relatively low confidence level in this forecast suggests that there are uncertainties related to cotton's agronomic needs, pest resistance varieties available, or possible climate change impact on its growth cycle which can affect yield and profitability. Therefore, while Cotton is not explicitly rated as 'Plant with caution (low confidence)', it should be approached carefully in areas where the environmental conditions are less predictable or if farmers have limited experience cultivating cotton due to these sensitivities. Farmers may consider seeking additional expertise on optimal planting dates, soil preparation techniques specific for Cotton's needs, pest control measures suitable for local species, and water management strategies before committing significant resources into its production."}}

MODELING AND ANALYSIS | LARGE LANGUAGE MODEL

Name

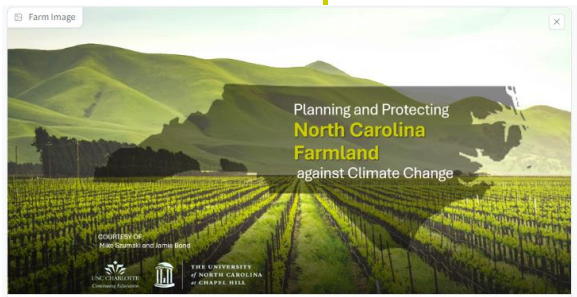
- good_farming_practices
- climate_hazards_and_Fed_emergency_mgmt
- how_to_file_a_claim
- Drought Recovery and Risk Management Resources _ Farmers.gov
- USDA ERS - Risk Management Strategies
- USDA ERS - Risk Management

RAG

Embeddings
Ollama Embeddings

Vector Store
Chroma DB

Retrieval



Select County: Bladen

Crops to Consider: Barley, Corn, Hay, Oats, Peanuts, Bell Peppers, Soybeans, Squash, Sweet Potatoes, Tobacco, Wheat

Planting Season(s): Spring, Summer, Fall

Planting Year (YYYY): 2027

Clear | Submit

Prompting
LangChain Prompt Template

Local LLM
Ollama (phi3 – mini)

processing | 14.1s

Barley & Corn Planting Considerations & Strategies
When planning to plant barley, the predicted weather conditions suggest a conducive environment which should lead to good growth and yield as long as th ese predictions hold true throughout the growing season. However, unpredictable climate changes can disrupt this forecast. As mitigation strategies for financial risks related to adverse weather events during critical periods of crop development—like germination or flowering—consider investing in protec tive coverings such as row covers and frost blankets which help guard against unexpected cold snaps, while irrigation systems should be optimized to han dle unseasonal dry spells.

Cotton Plant Considerations & Strategies with Caution for Crop Insurance Claim Processing:
Planting cotton is advised with caution due to the prediction model having low accuracy, possibly implying higher variability in weather conditions or o ther risks that could impact yield. To mitigate financial risk here and ensure a more secure investment into your crop insurance policy, consider planti ng a variety of crops alongside cotton as part of an agricultural diversification strategy which can help spread the economic risk if one particular cro p underperforms due to weather or pest pressures.

Hay & Subsequent Crops Non-Plant Considerations with Financial Risk Mitigation Strategies:
The decision not to plant hay is based on predictions of lower than average yields in the forecasted conditions, which could impact revenue and thus car ry financial risks for investment into crop production. Diversifying income sources by growing other high-value crops that have higher profit margins or entering long-term leases can provide alternative streams to mitigate these losses from hay planting decisions without the need to insure against such p redicted outcomes, if this aligns better with overall farm strategy and risk appetite.

Peanuts & Bell Peppers Plant Considerations:
Since peanuts are expected to grow well in the forecasted weather conditions as are bell peppers—the yield predictions seem promising for these crops' g rowth cycles; however, it is always prudent to have a robust pest management plan and soil fertility program due to potential threats that could go unno ticed but significantly impact yields. Utilizing crop insurance with coverages tailored specifically towards commodities like peanuts can be beneficial given the potentially high market volatility for such niche markets, thus reducing financial exposure from unexpected yield shortfalls due to pests or d iseases that might not have been accounted for in initial predictions.

Soybeans & Caution with Financial Risk Mitigation Strategies:
Planting soybeans is advised with caution because of the average yields predicted but acknowledging prediction model uncertainties, which could include risks from soil moisture variability or pest outbreaks that can impact yield. Implement a forward contract for your expected harvest to lock in prices a nd reduce financial risk associated with price fluctuations—this would ensure income stability despite weather-related output variations. Additionally, investing strategically into conservation tillage practices could enhance soil moisture retention thereby improving resilience against potential dry spe lls or late season rains that can impact soybean maturation and yield timing.

Squash & Subsequent Crops Non-Plant Considerations:
With lower than average yields for squash predicted, it might seem prudent not to plant this crop as a strategy; however, if the land is best suited or more profitable when used alternatively, consider growing crops with quicker turnaround times and higher yield potentials such as fast-maturing varietie s of lettuce. This would help maintain farm productivity while avoiding lower yields from squash plantation without necessarily having to rely on crop i nsurance for this decision if it reduces the overall financial risk exposure more effectively than a potentially unprofitable season in these predicted conditions.

Finans Risk Mitigation Advice Across Various Crops:
Given that most of our planting decisions are not proceeding, especially with crops like oats and hay which aren't planned due to unfavorable yield pred ictions, a universal financial risk mitigation strategy would be the judicious investment into drought-resistant crop varieties or considering alternati ve uses for this land that can offer stability in times when direct cultivation might not pay off. Crop rotation strategies with robust soil conservatio n practices like cover cropping during non-farming periods could preserve and enhance long-term agricultural productivity, thereby balancing out the far m's ecological impact while securing financial resilience against variable yields in subsequent plantings afterward as well.

Tobacco & Wheat Non-Plant Considerations with Financial Risk Mitigation Strategies:
Given that tobacco and wheat are not planned for due to suboptimal predicted conditions, it's advisable to consider other high-value crops or cash in on existing markets such as niche organic varieties of these commodities. If insurance is considered necessary—especially if the farm relies heavily upon t heir cultivation and they lack financial flexibility—selecting policies that provide comprehensive coverage for yield reduction, weather extremes like f rost or hail damage can safeguard against unexpected losses while minimizing unnecessary expenditure given these forecasts.

Overall Farm Resilience Advice:
To enhance crop resilience and financial risk mitigation across the farm's operation with regards to varying weather predictions, implementing precision agriculture tools like soil moisture sensors can assist in making informed planting decisions for those crops that are being considered. Additionally, i nvestment into research-based decision support systems could provide farmers access to better predictive models and agronomic advice specific to each cr op's unique needs thereby enabling strategies tailored towards maximized yield within the financial scope of risk appetite while maintaining ecological balance in agricultural practices.

RESULTS AND CONCLUSIONS

- Model selection influenced performance for each crop
  - Used different models for different crops to see model performance improvements
- RAG and prompt engineering impacts LLM results
- Used different models for different crops to see model performance improvements
- Influences beyond weather important to crop performance

LIMITATIONS

Influences of Farming Practices

- Individual farming practices are likely to have a material influence on historic harvest data and are not accounted for in the model

Genetic Engineering Techniques

- Model does not account for the use of seeds genetically modified for increased drought tolerance or pest resistance

ADDITIONAL INVESTIGATION AREAS

Geospatial Exploration

- Location-specific weather and harvest data may reveal information about the impacts of topography (elevation and soil content) on crop yield

Enhanced Weather Data

- Additional weather features such as humidity levels, atmospheric pressure and solar irradiance may reveal additional weather influences on yield

Infestations and Disease

- Data related to crop-destroying insect populations and disease occurrences as well as pesticide use may reveal additional crop sensitives that may be modeled

OTHER IMPROVEMENT OPPORTUNITIES

Weather API integration

- For demonstration purposes we simulated weather prediction data; opportunity to integrate API call to weather and climate forecasting service

Package into Docker Image

- Multiple platform packages, libraries and AI tools required to create appropriate environment to run
- Opportunity to containerize prediction tool in a Docker image to simplify sharing

REFERENCE CONTENT

GITHUB

Project Repository: github.com/mikeszumski/AgProject3

CONTRIBUTORS

- Michael Szumski | @mikeszumski (prediction model design and training)
- Jamie Bond | @JBondAI (interface and recommendation tool design)

DATA PROVIDERS

- USDA National Agricultural Statistics Service (NASS)
- North Carolina Department of Agriculture
- National Integrated Drought Information System
- NOAA Climate Perdition Center

ATTRIBUTIONS

- USDA National Agricultural Statistics Service (NASS)
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Planning and Protecting **North Carolina Farmland** against Climate Change

COURTESY OF:
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https://cals.ncsu.edu/agricultural-and-resource-economics/wp-content/uploads/sites/46/2017/07/AgricultureAgribusinessReport-2023-digital.pdf

https://statesummaries.ncics.org/chapter/nc/

NC STATE UNIVERSITY

Agriculture and Agribusiness

NORTH CAROLINA'S NUMBER ONE INDUSTRY

Agriculture and agribusiness — food, fiber and forestry — account for one-sixth of the state's income and employment. Almost 16 percent, or over **$111.1** billion of the **$716** billion gross state product is contributed by food, fiber and forestry industries. These industries account for **777,616** of the state's 4.8 million employees in 2022. The following are the value-added incomes derived from the state's agricultural and agribusiness sector in **2022**.

Total Income

Agriculture/Food Industries	
total income	$95.6B
share of N.C. income	13.4%
Natural Fiber Industries	
total income	$5.0B
share of N.C. income	0.7%
Forestry Industries	
total income	$10.5B
share of N.C. income	1.5%
Agriculture: Food, Fiber and Forestry Industries	
total income	$111.1B
share of N.C. income	15.6%

Agriculture and Agribusiness Employment

777,616, or **16** percent of North Carolina's 4.8 million employees work in agriculture and agribusiness.

Value-Added Income

The figures reflect value-added income for **2022**. At the farm level, value-added is sales. At the manufacturing, wholesale and retail levels, value-added does not include the value of non-North Carolina produced inputs, and value-added avoids the multiple counting of a product used several times in the production chain.

All figures expressed in billions of dollars (B).

Fiber Industries

including natural fiber-based manufacturing, wholesaling and retailing

Manufacturing *Including textile mill and apparel production*	$0.7B
Wholesaling *including apparel, piece goods and notions*	$1.7B
Retailing *including apparel and accessory stores*	$2.6B
Category Total	**$5.0B**

Forestry Industries

including farm production and the manufacture of furniture, lumber, wood and paper products

Farming *including total income from farm and commercial forestry*	$0.3B
Manufacturing *including wood products and paper products*	$4.6B
Wholesaling *including lumber, paper and furniture*	$4.2B
Retailing *including furniture*	$1.4B
Category Total	**$10.5B**

Agriculture and Food Industries

including farming, manufacturing, wholesaling and retailing firms

Farming *including crops, livestock, aquaculture, ornamentals and turf*	$20.5B
Manufacturing *including food and tobacco products and agricultural chemicals*	$36.1B
Wholesaling *including food, tobacco, farm supplies and products*	$11.1B
Retailing *including food stores and restaurants*	$27.9B
Category Total	**$95.6B**

Prepared by Mike Walden, Reynolds Distinguished Professor Emeritus, NC State's College of Agriculture and Life Sciences — **May, 2024**