Title: Forecasting Wheat Futures Using CNNs and Satellite Images
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Introduction: What problem are you trying to solve and why?

We are re-implementing "*Forecasting Agriculture Commodity Future Prices with Convolutional Neural Networks with Application to Wheat Futures"* written by Thaker, Chan, and Sonner. The paper predicts whether wheat futures will go up or down 20 days in the future using both satellite images and tabular weather features. We chose this paper because, to us, multi-modal DL models tend to not overfit as much and are relevant in this day and age. Along with that, it allows us to expand our knowledge and learn about a new ML model through time-series forecasting. Additionally, the dataset utilized is readily available. This project matters because commodity prices influence global food supply chains and food security. As big food lovers and huge proponents of solving the world hunger crisis, we felt as if this would be a fitting problem to explore. This problem is a binary classification problem because we are predicting upward or downward price movements.

Related Work: Are you aware of any, or is there any prior work that you drew on to do your project?

The paper we drew on to do our project is called *"Estimating the impact of weather on CBOT corn futures prices using machine learning"* by Singh. The paper is about how weather affects corn futures prices using county-level weather data from major US-based corn producing states. We decided to read this as it applies numerous ML models to predict both changes in future prices and the direction of price movements (what we are planning to do in this project). Singh focuses on a null and alternative hypothesis to test whether weather shocks still affect futures prices once the forecasts are priced in. He accomplished this using a wide range of models including CNNs, LSTMs, and Random Forests. His work shows that ML methods can extract meaningful signals from complex tabular and spatial data to improve forecasting in agricultural commodity markets.

Here are some public implementations that we plan to take inspiration from:

- https://github.com/google/earthengine-api
- https://github.com/openclimatefix/graph_weather
- https://github.com/ccaspar/weather_commodities

Data: What data are you using (if any)?

The data we are using is from the Landsat Collections (https://developers.google.com/earth-engine/datasets/catalog/landsat) from Google Earth Engine.

Specifically, we plan to use Landsat 8 OLI/TIRS satellite imagery for Hard Red Winter wheat regions because it provides high-quality images from 2013 onward. We hope this will reduce our preprocessing complexity. We hope to use these images with cloud-cover metadata and wheat future prices (our tabular data) to create a predictive CNN classifier. The dataset is not that large and high-quality and clean so we don't need to do much preprocessing.

Methodology: What is the architecture of your model?.

For the CNN model, we hope to train region-by-region where each region has one CNN branch. Our branch will be standard consisting of a Conv2D layer with ReLU activation and pooling. We will then create a tabular branch that contains two Dense layers with ReLU activation with the purpose of capturing additional price and weather context the image alone can't show. We will then combine these outputs and pass it through two more Dense layers with ReLU and Sigmoid activations, respectively, to output the probability that the price moves up after 20 days. We think the hardest part of implementing the paper will be dealing with missing data especially on cloudy days along with aligning each image data with the correct futures price level.

Metrics: What constitutes "success?"

For us, success means accurately predicting the direction that futures prices move >70% of the time as well as dealing with imbalanced data. We plan to experiment with varying CNN depth levels, the presence of tabular features, and the number and size of regions. The notion of accuracy does apply to our project since it is binary classification however it will not be the main metric. We plan to use F1 score as this balances precision and recall and there's a chance of our dataset being imbalanced. We also plan to use a confusion matrix to analyze false positives and negatives. The authors of the paper were hoping to find directional accuracy and standard trading simulation metrics such as P/L over time and the Sharpe ratio. Our base goal is better accuracy than random guessing, so >50%. Our target goal is 65-70% accuracy and a F1 score above 0.6. Our stretch goal (hoping!) is an accuracy above 70% and a model that generalizes to Landsat 9 test images.

Ethics: Choose 2 of the following bullet points to discuss; not all questions will be relevant to all projects so try to pick questions where there's interesting engagement with your project. (Remember that there's not necessarily an ethical/unethical binary; rather, we want to encourage you to think critically about your problem setup.)

- What broader societal issues are relevant to your chosen problem space?

Since wheat is a global staple crop, inaccurate predictions can wrongly influence food prices, food security, and basic goods for low-income communities. This project also delves deeper into the inequality in agricultural markets because access to these satellite images are exclusive to trading firms, creating a disadvantage for smaller farmers and market participants.

- Who are the major "stakeholders" in this problem, and what are the consequences of mistakes made by your algorithm?

The major stakeholders in this problem would be farmers and commodities traders. The consequences of a mispredicted price direction include financial losses for traders and may mislead farmers' planting decisions.

Division of labor: Briefly outline who will be responsible for which part(s) of the project.

Navyaa will take charge of satellite image collection and preprocessing the data. Anish will take charge of the spatial data model building. Risheetha will take charge of building the tabular data model. Krish will work on combining the outputs of the two models. We will then all work together to train and validate the model, tune the model, evaluate the results, and write up our final report.