Modeling North Dakota Farmers' Historical Acreage Allocation Decisions for Five Major Crops: A Spatially-weighted Seemingly Unrelated Tobit Regression

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Abstract

A large portion of North Dakota cropland—once dominated by small grains such as hard red spring wheat and barley—has rapidly converted to corn and soybean production. This trend in cropland use is most evident in the southeastern portion of the state and the Red River Valley. Included among factors contributing to this land use change are energy, agricultural, and trade policies via their effects on commodity crop prices, increasing yields of some crops (especially corn) related to introduction of new, higher-yielding varieties, as well as varied climate trends and weather volatility over space and time throughout the state. We found statistically discernible effects of commodity crop prices, agricultural input prices, climate variables, and soil type variables on aggregate acreage of each of the crop classifications modeled. Crop coverage data are based on the Cropland Data Layer files from NASS from 1998 through 2013. We divided whole ND into 1355 quadrangle unit to see change of each crop acreage for last 16 years. We are using Seemingly Unrelated Left Censored Tobit Regression estimation method for our analysis. We find that the expected price of a crop is typically (some exceptions) positively related to its own acreage, as predicted by the Law of Supply, whereas effects of *other* crops' prices on a crop's acreage are of mixed sign. Expected yields for each crop also have positive impacts on their planted acreages. Also, the price of ammonium nitrate negatively relate to corn acreage planted, likely because corn is a relatively fertilizer-intensive crop relative to soybean. Thus, as nitrogen fertilizer price increases, farmers appear to substitute to soybean for corn to reduce production cost. Precipitation during May increases it leads to increases crop yields as well as crop acreages. Temperature minimum and maximum positively relate crop acreages during growing season, probably due to their influence on crop yield.

Introduction

National Agricultural Statistics Service data (e.g. Quick Stats 2.0; Cropland Data Layer files, etc.) indicate significant changes in agricultural land use have occurred in North Dakota over the last 20 years—specifically drastic conversion of croplands from wheat and small grains production to corn and soybean cropping systems. However, these changes have not been uniformly distributed, likely for a variety of reasons. Economic theory suggests farmers lean toward producing crops that will generate comparatively higher profits. Profitability for each crop depends on prices of inputs (seed, chemicals, farm diesel, etc.) and input use-efficiency, as well as commodity prices. Producers' land allocation to corn, soybean, rice, and wheat clearly depend on expected commodity prices expectations about price volatility (Haile, Kalkuhl, and Von Braun, 2015). Geophysical factors, however, confer spatially non-uniform comparative advantage in production of certain crops but may cause injury to other crops. For example, climate and weather-related production risk vary substantially over space, as do soil texture and fertility. As a result, changing market conditions are likely to affect farmers' crop selection patterns differently based on their in situ natural resource endowments. For example, precision agriculture and transgenic seed technologies, along with changing federal energy policy over the last 20 year seem to correspond with rapid increases of corn and soybean acreage in North Dakota—and decreases in wheat and small grains—in ways that comport with economic theory, especially in the southeastern quarter of the state and the northern portion of the Red River Valley along the state's eastern border. Per Boerboom et al. (2017) these drivers of North Dakota's modern agricultural evolution have been influential since 1986.

Objectives

The objectives of the study are:

1) to jointly estimate spatially heterogeneous crop acreage response/supply functions for barley, corn, oilseeds, soybean, and wheat based on historical market prices and site-specific attributes,
2) to determine how projected climate change might influence farmers as they autonomously (deliberately or otherwise) adapt their operations to new and changing climate conditions.

Data and Methodology

The land use data for this research are derived from the Cropland Data Layer files produced each year by geospatial database that classifies land use by crop at a 30-meter resolution from from 1998 through 2013 year. We divided whole of North Dakota into 1,355 quadrangle units (about 50 square miles apiece) to observe changes in each crop's acreage during the study period. Prices of September futures contracts for corn, soybean, and hard red spring wheat from Chicago Mercantile Exchange (CME) on the 15th day of January, February, and March (downloaded from Quandl.com) represent farmer price expectations for these crops from 1998 through 2013. For barley and "oilseeds," on the other hand, one-year lags of statewide average September barley and sunflower spot prices (from USDA-NASS's Quick Stats 2.0 database) served as proxies for farmers' price expectations for the said crops. Nitrogen fertilizer accounts for an outsize proportion of farm operating expenditures, so we use April ammonium nitrate United States farm prices from 1998 through 2013 (Agricultural Prices, National Agricultural Statistics Service, USDA) and the U.S. Energy Information Administration's February third week Midwest retail diesel price data—as diesel is another sizable component of total production cost—as proxies for production costs generally. All prices were adjusted for inflation using the Implicit GDP Price Deflator provided by the Federal Reserve's Economic Research service with 2012 as the base year. Twenty-year averages (1970 to 1990) of climate variables were collected for each month, March through August, including monthly precipitation and monthly averages of daily maximum and minimum temperatures for each of North Dakota's 53 counties. Palmer Drought Severity Index (PDSI) for the months of March and April and growing degree days (GDD) accumulated annually from May through October was also acquired, as were the county-level 30-year averages from North Dakota State University's Climate Change throughout the Dakota's database (https://www.ndsu.edu/climate). We then estimated the parameters of a six-equation system of seemingly unrelated Tobit regressions by simulated maximum likelihood estimation using the mvtobit routine (Barslund, 2007) in STAT 14.1. Subsequently, own and cross-price acreage supply elasticities and marginal effects were calculated from the parameter estimates. We then used Monte Carlo simulation to approximate standard errors for the estimated elasticities and marginal effects.

Graphs and Maps

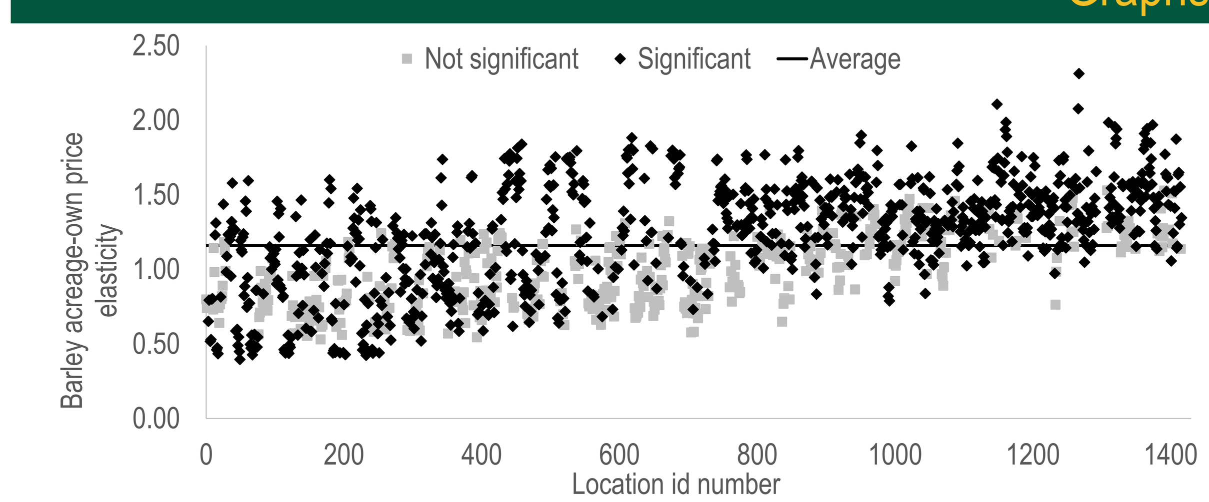

Fig. 1. Own-price elasticity and significance level of barley acreage

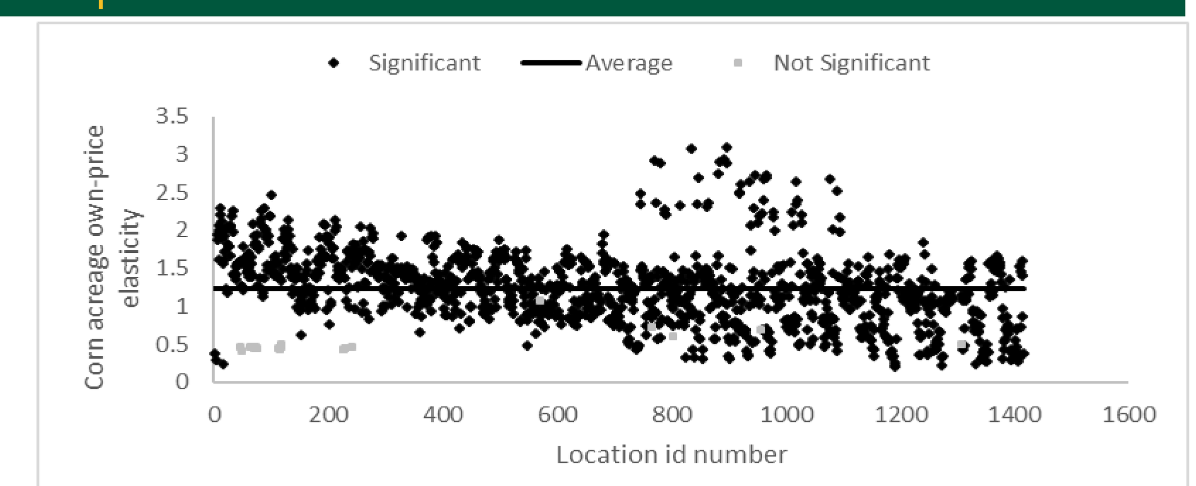

Fig. 2. Own-price elasticity and significance level of corn acreage

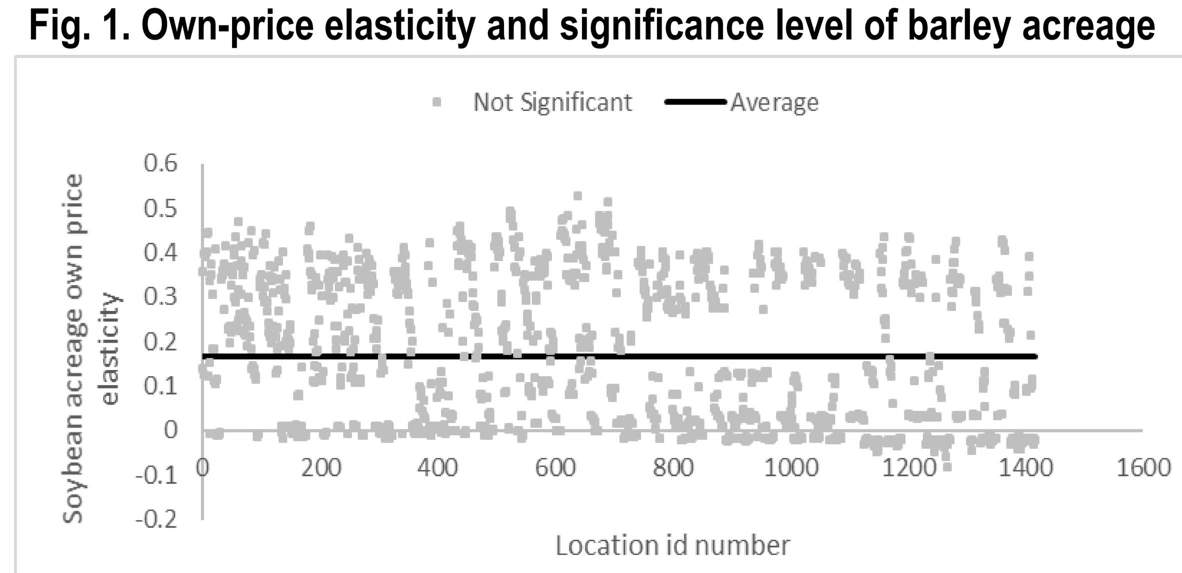

Fig. 3. Own-price elasticity and significance level of soybeans acreage

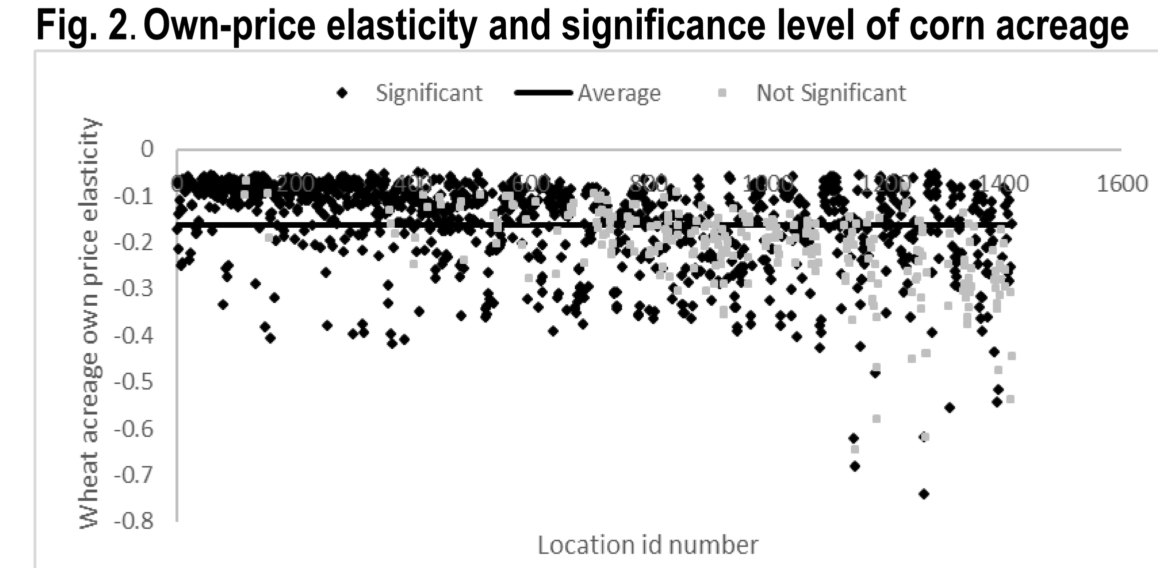

Fig. 4. Own-price elasticity and significance level of wheat acreage

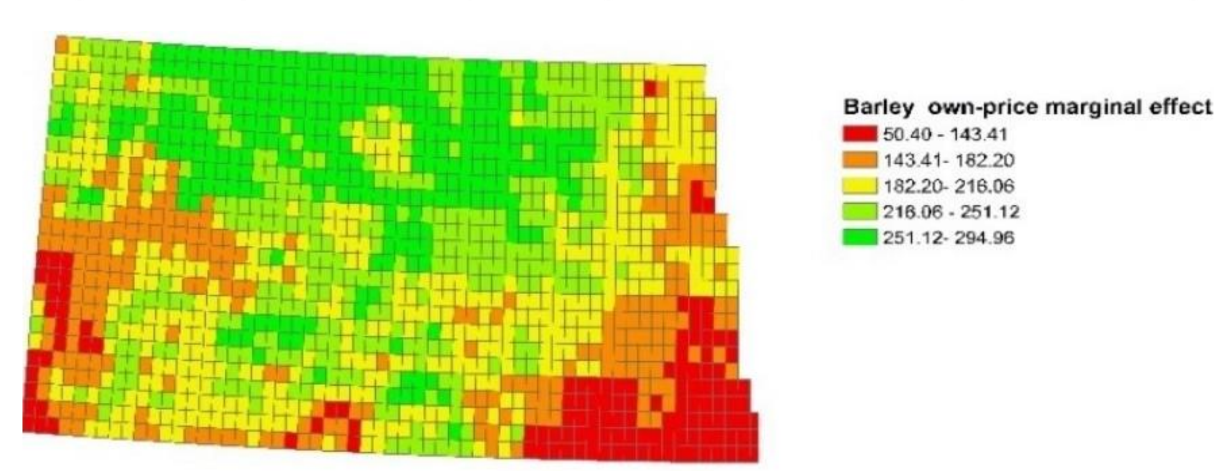

Fig. 5. Estimated marginal effects of barley price on barley acreage

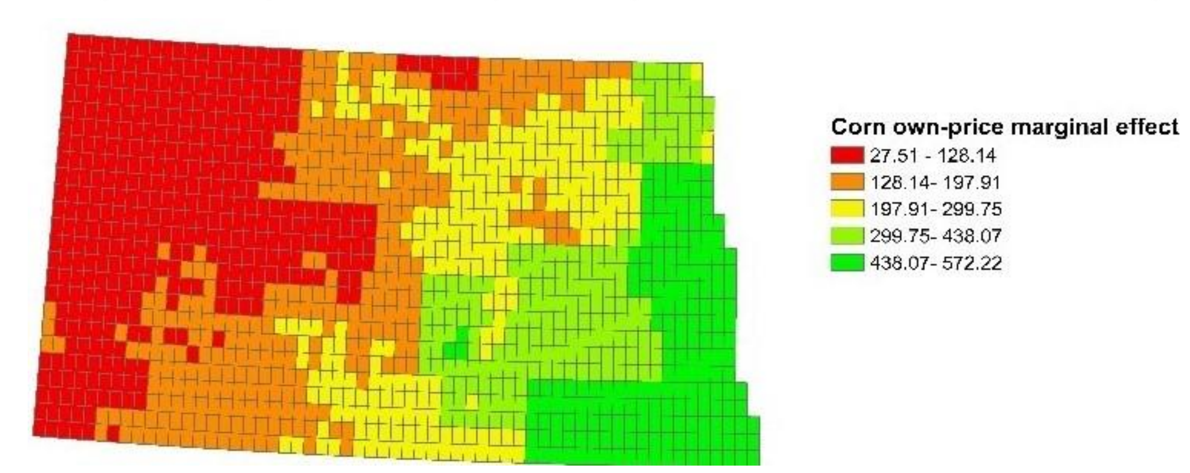

Fig. 6. Estimated marginal effects of corn price on corn acreage

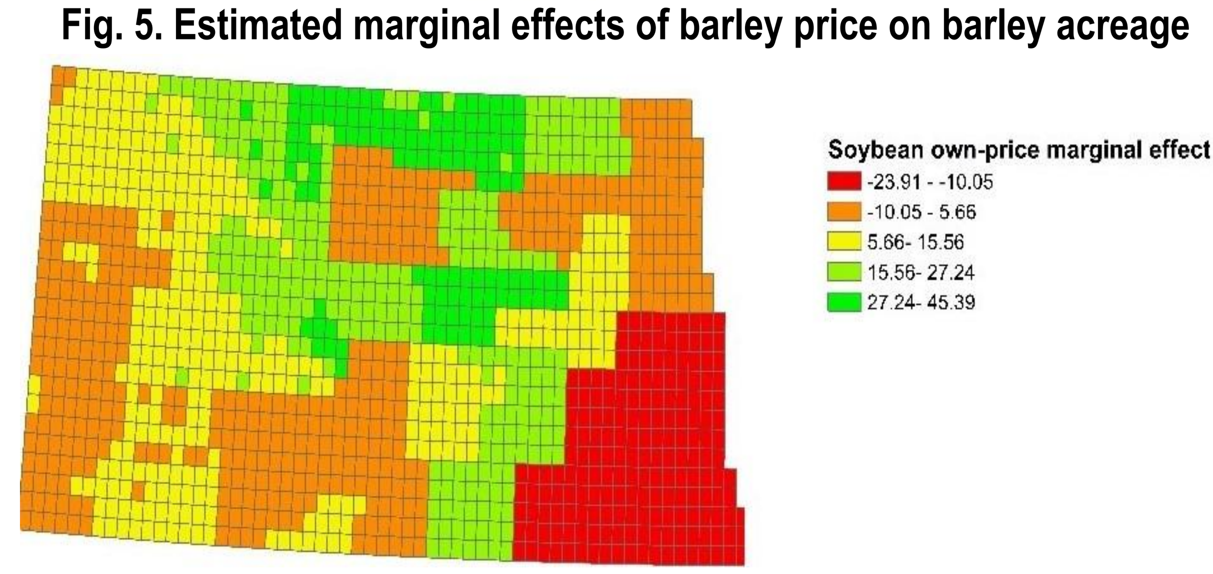

Fig. 7. Estimated marginal effects of soybeans price on soybeans acreage

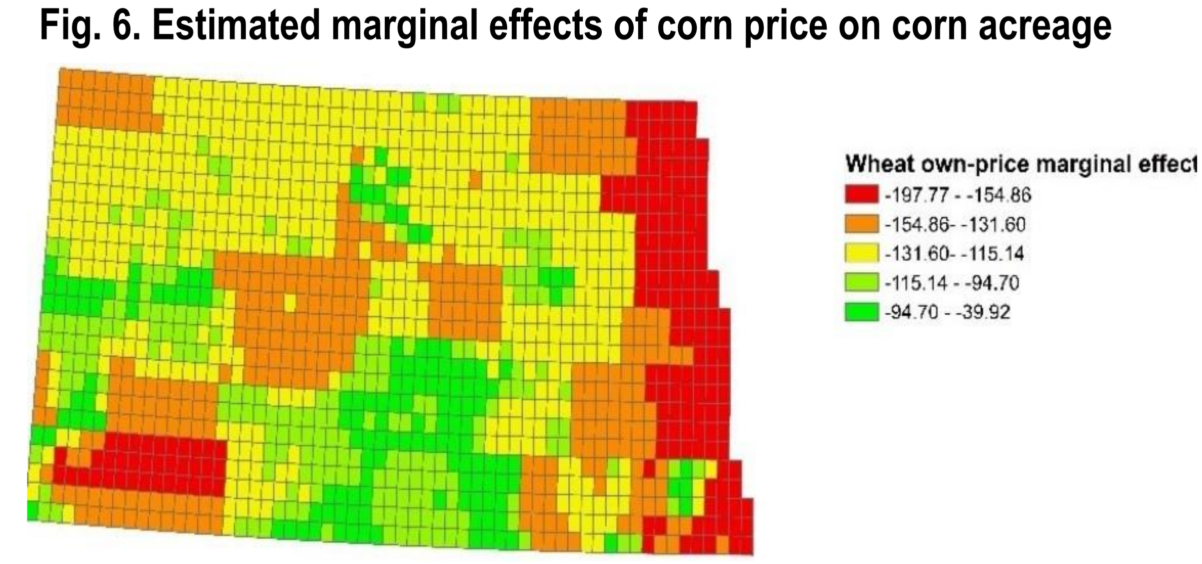

Fig. 8. Estimated marginal effects of wheat price on wheat acreage

Results and Discussion

The objective of this study was to estimate a system of crop acreage response functions to quantify the influences of crop and input prices, along with farmers' site-specific resource endowments, on their decisions to supply (or allocate) land to various crops available to them. We find statistical evidence that farmers' land allocation decisions are influenced by crop price expectations and input price expectations, as well as temperatures, rainfall, soil moisture, and soil type. We have developed a system of equations that performs well in predicting corn, soybean, and wheat acreage based on these factors. However, the model performs quite poorly in predicting of acreages of barley and oilseeds. Two possible reasons for the poor predictive ability of the barley and oilseeds acreage supply functions are (1) the use of one-year price lags (as opposed to commodity futures market contract prices) as proxies for farmer price expectations for these two crops, (2) the fact that much of the barley grown in North Dakota is planted under contract, and (3) the fact that acreage of oilseeds is actually an aggregation of several different crops' acreages, including sunflower, canola, and a few other minor crops.

Our analysis indicates that marginal effects of crop prices on crop acreages mostly comport with economic theory—especially the own-price marginal effects and elasticities being positive for all crops apart from wheat, as predicted by the law of supply. The cross-price marginal effects and elasticities indicate substitutability (if negative) or complementarity (if positive) of each pair of crops. That is, they tell whether farmers replace one crop with the other in their rotations or whether farmers grow the two crops in succession over time.

Conclusions

Our models predict how the acreages of the five crops studied may change in the future in response to climate change and in response to structural changes in markets for agricultural commodities. For example, these estimates might be useful in predicting how farmers may adjust acreages of corn, soybean, and wheat in response to the drastic soybean price decline related to recent trade developments with China, a major destination for the US soybean crop. Trade policy analysts might, therefore, find the results and methods used herein to be valuable. Additionally, the possibility of forecasting how acreages of these crops may expand, decline, or shift to new locations could be of great benefit to farmers in planning on-farm infrastructure projects, such as new grain storage capacity. Large agribusinesses could also benefit from such forecasts in determining where rail cars will be needed and where new grain elevators will be needed to accommodate shifting grain production areas. Further effort should also be made to enhance predictive success of the barley and oilseeds acreage supply functions.

References

Boerboom, C., Khwaja, H., Greg, L., Holly, M., and Mark, W. (2017). Agriculture, Envision 2030. Retrieved from http://envision2030.ndus.edu/wp-content/uploads/2017/06/DRAFT-Envision-Ag.pdf

Haile, M.G., Kalkuhl, M., and von Braun, J. (2015). Worldwide Acreage and Yield Response to International Price Change and Volatility: A dynamic Panel Data Analysis for Wheat, Rice, Corn, And Soybeans. American Journal of Agricultural Economics, 97(3):1–19

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