# PRODUCER RETURN ON INVESTMENTS IN SORGHUM RESEARCH, PROMOTION, AND INFORMATION: AN UPDATED ANALYSIS

*Research Report to the*
*United Sorghum Checkoff Program (USCP) Board*

*November 3, 2017*

***Agribusiness, Food, and Consumer Economics Research Center***


Dr. Oral Capps, Jr.
Executive Professor, Regents Professor, and Co-Director of AFCERC

Dr. Gary W. Williams
Professor and Co-Director of AFCERC

Dr. Mark Welch
Professor and Extension Economist

Texas A&M University
Department of Agricultural Economics
2124 TAMU
College Station, TX 77843-2124
Phone: (979) 845-5911
Webpage: http://afcerc.tamu.edu


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***Report to the United Sorghum Checkoff Board by the Agribusiness, Food, and Consumer Economics Research Center (AFCERC), Department of Agricultural Economics, Texas A&M University, College Station, Texas***

**Authors:**

Dr. Oral Capps, Jr.,
Executive Professor, Regents Professor, and Co-Director of AFCERC

Dr. Gary W. Williams,
Professor and Co-Director of AFCERC

Dr. Mark Welch
Professor and Extension Economist

## ABSTRACT

This report is the second evaluation of the effectiveness of the sorghum checkoff program as required by the Sorghum Promotion, Research, and Information Order. The first study was completedin August 2013. The report addresses the most relevant questions to sorghum growers: (1) what have been the effects of sorghum checkoff investments on sorghum production, use, and prices paid to growers and (2) what have been the benefits or returns to producers from their investments in the checkoff program? While not finding that all activities funded have been effective, the report finds that for every checkoff dollar invested in crop improvement andin the promotion of high-value market and renewable uses the returns were $8.57 and $11.59, respectively. The report concludes with recommendations for management of the sorghum checkoff program.

## ACKNOWLEDGEMENTS

The research reported here was conducted under contract with the United Sorghum Checkoff Program Board (USCP). The sorghum advertising and promotion data used in this study were collected with the assistance of USCP. Thanks are due to Keehyun Lee for research assistance and to Loren Burns, AFCERC Program Manager, and Charlotte Hammer, AFCERC Student Worker, for their help in preparing this report. The conclusions reached and any views expressed in this report are those of the authors and may not represent those of USCP or Texas A&M University.

*The Agribusiness, Food, and Consumer Economics Research Center (AFCERC) provides analyses, strategic planning, and forecasts of the market conditions impacting domestic and global agricultural, agribusiness, and food industries. Our high-quality, objective, and timely research supports strategic decision-making at all levels of the supply chain from producers to processors, wholesalers, retailers, and consumers. An enhanced emphasis on consumer economics adds depth to our research on the behavioral and social aspects of health, nutrition, and food safety. Through research efforts, outreach programs, and industry collaboration, AFCERC has become a leading source of knowledge on how food reaches consumers efficiently and contributes to safe and healthy lives. AFCERC is a research and outreach service of Texas A&M AgriLife Research and Texas A&M AgriLife Extension and resides within the Department of Agricultural Economics at Texas A&M University.*

## INTROSPECTIVE SUMMARY

This report is the second evaluation of the effectiveness of the sorghum checkoff program as required by the Sorghum Promotion, Research, and Information Order. The first study was completed in August 2013. This evaluation is intended to provide actionable information for sorghum checkoff program stakeholders as to the effectiveness of the checkoff program and its various promotional activities.

The evaluation entitled "Producer Return on Investments in Sorghum Research, Promotion, and Information: An Updated Analysis" was conducted by Dr. Oral Capps, Jr., Executive Professor, Regents Professor and Co-Director of AFCERC, Dr. Gary W. Williams, Professor and Co-Director of AFCERC, and Dr. Mark Welch, Professor and Extension Economist at Texas A&M University.

The full report is available on www.sorghumcheckoff.com. Excerpts include:

- USCP was established in 2008 with the objective of investing producer dollars to increase profitabilityin the sorghum industry.
- Sorghum checkoff investments in crop improvement activities have boosted sorghum planted acreage in each year bymore than one percenton average since the beginning of the program and annual harvested acreage byabout 0.9% over that same period.
- Sorghum checkoff crop improvement activities did not have a statistically significant impact on sorghum yields, however. This result is not surprising given the short amount of time that the checkoff program has been in operation and the long period of time that is often required for research to register impacts on yields.The increase in yields experienced in recent years was found to be due mainly to weather and other technological innovations, such as adoption of minimum and no-tillage practices.
- The sorghum production consequence of the acreage impact of the checkoff program was an average annual increase of 0.25% (0.97 million bushels) between 2008/09 and 2015/16 for a total increase in sorghum production of 7.8 million bushels over that period.
- Funds committed to crop improvement activities led to a higher sorghum farm price each year by an annual average on the order of 2 to 3 cents per bushel.
- Given the estimated production and price impacts of the sorghum checkoff investments in crop improvement activities, the farm value of U.S. sorghum production was higher by $12.6 million on average in each year (0.79%) for a total of $100.76 million in additional farm revenue($90.2 million after netting out checkoff funds expended on crop improvement) over the period of 2008/09 to 2015/16.
- For every sorghum checkoff dollar invested in crop improvement, the net return to stakeholders was about 8.6 to 1. Thatis for every checkoff dollar invested in crop improvement, the return to producers (net of the checkoff expenditures) was $8.57. Because of the typicallylong lag between research activities, particularly basic research, and the commercialization of new technologies available for adoption by sorghum producers, this return may underestimate the full benefits of checkoff-funded research to sorghum producers.
- No impact or return to stakeholders was found from sorghum checkoff investments in promoting sorghum feed use.

- In contrast, sorghum checkoff investments were found to have increased food and industrial use of sorghum by an average of about 6.0 million bushels each year for a total of 47.8 million bushels of additional sales of sorghum over the period of 2008/09 to 2015/16.
- For every sorghum checkoff dollar invested to promote high-value market and renewable uses,the net return to stakeholders was estimated to be 11.6 to 1. That is, the investment of $9.3 million in sorghum checkoff funds to promote sorghum use in high-value markets and renewables enhanced the farm value of sorghum sales by about $107.4 million (net of checkoff expenditures), a benefit-cost ratio or return-on-investment of 11.6 to 1.
- The USCP provides funds to promote sorghum exports directly to the U.S. Grains Council (USGC). Those funds in turn are used in conjunction with Foreign Agriculture Service (FAS) dollars in the Foreign Market Development (FMD) program and the Market Access Program (MAP). In other words, the USGC leverages USCP dollars with FAS dollars.
- Nevertheless, sorghum export promotion expenditures (USCP and FAS) were found to have a positive but as yet not statistically significant effect of export promotion on sorghum exports.
- Given that checkoff expenditures often require time for those investments in various markets to register statistically significant effects and that the USCP only has been in existence since 2008, this report notes *"movement in the right direction"* in achieving the goal of enhancing profitability in the sorghum industry.
- The study results suggest a number of recommendations for the management of the sorghum checkoff program:

  (1) *Increased funding for crop improvement activities which have successfully boosted acreage under sorghum production as well as the farm value of production.*

  Although yields have yet to show a statistically significant response to research investments, the response time of yields to research is often slow. Maintaining domestic and international competitiveness through research aimed at increasing sorghum yields is likely to be a critically important and strategic choice for the investment of sorghum checkoff funds.

  (2) *A reallocation of promotion funds from feed demand to the demand for sorghum in food and industrial uses (essentially high-value markets and renewables).*

  Promoting the use of sorghum in the production of ethanol, gluten-free products, pet foods, aquaculture, and renewable chemicals rather than for feed used is likely to provide maximum opportunities for enhancing producer profitability. If funds are invested in feed demand promotion, priority investments may include research to enhance the quality of sorghum as a feed grain so as to better compete with corn. Additionally, investments may include the promotion of non-genetically modified (non-GMO) sorghum for livestock feeding.

  (3) *Reconsider the funding of export promotion*

  This study found a small but not statistically significant effect of export promotion on sorghum exports. Thus, reallocating funds to promote more profitable food and industrial uses might be a consideration. However, given the size of export markets and the need to maintain or enhance the competitiveness of U.S. sorghum in international markets, some level of investment and/or re-engineering of export promotion programs is likely critical to the future viability and profitability of the U.S. sorghum industry. Any funds allocated to export promotion would likely be most successful in enhancing producer profitability if focused on two priorities: (1) maintaining market share and export volume in China; and (2) recapturing market share and volume in Japan and in Mexico.

(4) *Maintain quality records on funds committed to various activities over time to support effective evaluation of the sorghum checkoff program.*

A substantial amount of time in this project was devoted to obtaining accurate data on expenditures committed to various activities, namely crop improvement, high-value markets, renewables, and exports. An efficient and accurate record management system and database of checkoff expenditures made over time and across production research and promotional activities would greatly facilitate efforts to effectively evaluate the performance of the sorghum checkoff program.

(5) *Devise a system for collecting and warehousing data in state level checkoff expenditures.*

This program evaluation did not include sorghum checkoff expenditures made by state programs because those data were not available. Efforts to retrieve those data were largely unsuccessful. As a consequence, the results of this study may not reflect the impact of the total amount of producer checkoff funds spent to promote the profitability of the sorghum industry.

## EXECUTIVE SUMMARY

This study is the second evaluation of the impacts and returns to checkoff investments made by the United Sorghum Checkoff Program (USCP) as required by the Sorghum Promotion, Research, and Information Order under authority of the 1996 Farm Bill (FAIR Act).

Specific missions of USCP are to increase yields through investment in research programs and to increase the demand for sorghum through a set of marketing, promotion, and education programs, thereby providing U.S. producers with expanding markets for their commodity. An increase in demand may occur through an expansion of the use of sorghum in the domestic market in the ethanol industry, as a livestock feed or as a feedstock for advanced biofuels, through the development of new uses for sorghum, and/or by expanding sorghum exports. The overriding goal of all USCP activities is to maximize return on grower investment.

USCP was established in 2008 with the objective of investing producer dollars to increase profitability for the sorghum industry. The overall objective of this evaluation of USCP programs is to provide the sorghum industry with meaningful and reliable measurements of the impacts of sorghum checkoff activities on the sorghum industry over time. Thus, this report intends to assist USCP in the management of its programs while meeting legislative requirements and maintaining established academic standards for such evaluations. To accomplish this overall objective, we undertake the following activities:

(1) Provide a qualitative analysis of the U.S. sorghum industry, including a SWOT analysis of the sorghum industry, as background to the subsequent quantitative analysis of the effectiveness of sorghum checkoff programs.

(2) Determine the impacts of USCP sorghum-oriented programs implemented since 2008, as related to promotion, research, and information, on the industry;

(3) Evaluate the effectiveness of the "Crop Improvement Program" in relation to changes in yields, planted and harvested acreage, and hence production as well as in relation to changes in profitability through improved management practices;

(4) Evaluate the effectiveness of the "High-Value Program" in relation to the demand for sorghum in export markets and to the demand for sorghum in domestic markets associated with uses in the food industry, in the livestock industry, and in other industries;

(5) Evaluate the effectiveness of the "Renewables Program" in relation to potential benefits associated with the demand for sorghum in industrial use; and

(6) Assess the availability and adequacy of data currently in place to support the required evaluation of the impacts of USCP activities over time with the intent of establishing key tracking mechanisms that can be analyzed, documented, reviewed and communicated concerning the effectiveness of the checkoff program.

The initial evaluation completed in August 2013 and this updated evaluation use statistical procedures to measurethe effects of the programmatic activities of USCP for domestic and export markets for sorghum as well as for the sorghum production. This analysis provides the basis for determining if the programmatic activities of the USCPBoard have led to increases in sorghum industry profits as well as for calculating the benefit-cost ratio (BCR) metrics to stakeholders related to sorghum checkoff investments. These return-on-investment metrics can be useful in helping to improve the efficiency and effectiveness of the investments in marketing activities and to provide needed feedback to stakeholders.

In essence, this report answers the most relevant questions to sorghum growers: (1) what have been the effects of sorghum checkoff investments on sorghum production, use, and prices paid to growers and (2) what have been the benefits or returns to producers from their investments in the checkoff program?The key findings of this study follow and are organized into four groups: (1) expenditures of the United Sorghum Checkoff Program, (2) qualitative background analysis of the sorghum industry,(3) quantitative analysis of the sorghum checkoff program, and (4) recommendations.

*USCP Expenditures*

- Total revenues associated with the USCP ranged from $6.6 million to $11.8 million, while total expenses ranged from $6.2 million to $13.0 million.
- Compared to the farm value of sorghum, on the order of $1.23 billion to $1.47 billion from 2008 to 2016, the amount of funds collected from the checkoff is extremely small. The ratio of revenue from assessments to farm value of production, often referred to as the investment-intensity ratio, averaged only 0.54% over 2008/09 to 2015/16 period.
- The research share of total checkoff expenditures was in the interval of 20% to 60% between 2008/09 and 2015/16. The information, communication, and education share of total expenditures was on the order of 6% to 30% over that same period. The market development share of total expenditures varied widely from 10% to 67% over that period.
- The administration share of total expenses varied from 5.55% to 9.72%. On average the administration share of total expense was slightly more than 7%. The share of total expenses for USDA oversight varied from 0.2% to 3.6%. On average the USDA oversight share of total expenses was roughly 1.6%.

*Background Analysis of the U.S. Sorghum Industry*

- From 1960/61 to 2016/17, a notable decline in acres planted of sorghum, acres harvested of sorghum, and sorghum production was evident. Over the same period, sorghum yields rose modestly. Average yields prior to the checkoff program were 57.6 bushels per acre but average yields during the checkoff program were 65.2 bushels per acre.
- From 1975/76 to 2016/17, feed use of sorghum was on the decline while food and industrial applications of sorghum were on the rise.
- U.S. sorghum exports represented 40% of total disappearance on average over the period 1975/76 to 2016/17. But for the past four years (2013/14 to 2016/17), the proportion ranged from 48% to 78%, averaging 60%. Total sorghum exports have been on the rise in recent years. Mexico, Japan, and more recently China represent the top destinations for U.S. sorghum exports.
- The principal U.S. sorghum export competitors are Argentina and Australia. The United States, Argentina, and Australia historically have accounted for 90% to 98% of world sorghum exports. Argentina is the main competitive threat to U.S. sorghum exports.

- An extensive Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the U.S. sorghum industry reveals three major areas of strategic importance, including:
  (1) ProductivityIssues
    - Yield increases are necessary to keep up with increasing demand given land area constraints in order to make grain sorghum returns more competitive with alternative crops.
    - Varieties with characteristics such as drought tolerance as well as disease and pest resistance are increasingly important in the face of climate change. Biotech or genetically-modified grain sorghum strains may play a role in this effort. However, product introduction must match consumer acceptance.
    - Management tools, decision aids, economic thresholds for management decisions are important to support growers in their ability to increase profitability from grain sorghum production.

  (2) Product Development Needs
    - Investment is needed in new uses or processes for grain sorghum in all major uses categories: feed, food, fuel, and industrial. These are all growing markets and grain sorghum has the characteristics to make a notable contribution.
    - Advances in grain sorghum product development have the potential to close the price differential between grain sorghum and corn, adding to crop profitability.

  (3) Trade
    - Exports are the number one use of U.S. grain sorghum currently.
    - Product development and trait enhancement have the opportunity to increase the global demand for grain sorghum.
    - Trade agreements and trade policies that support market access and the elimination of trade barriers are particularly important for grain sorghum.

*Quantitative Evaluation of the Sorghum Checkoff Program*

- Sorghum checkoff investments in crop improvement activities have boosted planted acreage by slightly more than one percent (570,700 acres) since the beginning of the program and harvested acreage by slightly more than 0.9% (441,936 acres) over that same period. The incremental increase in planted and harvested acreage likely is linked in part to research and education efforts associated with sugarcane aphid (SCA).

- Sorghum checkoff crop improvement activities have had no statistically significant impact on sorghum yields, however. This result is not surprising given the short amount of time that the checkoff program has been in operation and the long period of time that is often required for research to register impacts on yields.The increase in yields experienced in recent years was found to be due mainly to weather and other technological innovations.

- The sorghum production consequence of the acreage impact of the checkoff program was an average annual increase of 0.25% (0.97 million bushels) between 2008/09 and 2015/16 for a total increase in sorghum production of 7.8 million bushels over that period.

- Funds committed to crop improvement activities led to a higher sorghum farm price each year by an annual average on the order of 2 to 3 cents per bushel.

- Given the estimated production and price impacts of the sorghum checkoff investments in crop improvement activities, the farm value of U.S. sorghum production was higher by $12.6 million on average in each year (0.79%) for a total of $100.76 million in additional farm revenue ($90.2 million (net of checkoff funds expended for crop improvement) over the period of 2008/09 to 2015/16.

- For every sorghum checkoff dollar invested in crop improvement, the net return to stakeholders was about 8.6 to 1. Thatis for every checkoff dollar invested in crop improvement, the return to producers (net of the checkoff expenditures) was $8.57. Because of the typically long lag between research activities, particularly basic research, and the commercialization of new technologies available for adoption by sorghum producers, this return may underestimate the full benefits of checkoff-funded research to sorghum producers.
- No impact or return to stakeholders was found from sorghum checkoff investments in promoting sorghum feed use.
- In contrast, sorghum checkoff investments were found to have increased food and industrial use of sorghum by an average of about 6.0 million bushels each year for a total of 47.8 million bushels of additional sales of sorghum over the period of 2008/09 to 2015/16.
- For every sorghum checkoff dollar invested to promote high-value market and renewable uses,the net return to stakeholders was estimated to be 11.6 to 1. That is, the investment of $9.3 million in sorghum checkoff funds to promote sorghum use in high-value markets and renewables enhanced the farm value of sorghum sales by about $107.4 million (net of checkoff expenditures), a benefit-cost ratio or return-on-investment of 11.6 to 1.
- The USCP provides funds to promote sorghum exports directly to the U.S. Grains Council (USGC). Those funds in turn are used in conjunction with Foreign Agriculture Service (FAS) dollars in the Foreign Market Development (FMD) program and the Market Access Program (MAP). In other words, the USGC leverages USCP dollars with FAS dollars.
- Nevertheless, sorghum export promotion expenditures (USCP and FAS) were found to have a positive but as yet not statistically significant effect of export promotion on sorghum exports.
- Given that checkoff expenditures often require time for those investments in various markets to register significant effects and that the USCP only has been in existence since 2008, this report notes *"movement in the right direction"* in achieving the goal of enhancing profitability in the sorghum industry.

*Recommendations*

The study results suggest a number of recommendations for the management of the sorghum checkoff program, including:

(1) *Increased funding for crop improvement activities which have successfully boosted acreage under sorghum production as well as the farm value of production.*Although yields have yet to show a statistically significant response to research investments, the response time of yields to research and education is often slow. Maintaining domestic and international competitiveness through research aimed at increasing sorghum yields is likely to be a critically important and strategic choice for the investment of sorghum checkoff funds.

(2) *A reallocation of promotion funds from feed demand to the demand for sorghum in food and industrial uses (essentially high-value markets and renewables).* Promoting the use of sorghum in the production of ethanol, gluten-free products, pet foods, aquaculture, and renewable chemicals rather than for feed used is likely to provide maximum opportunities for

enhancing producer profitability. If funds are invested in feed demand promotion, priority investments may include research to enhance the quality of sorghum as a feed grain so as to better compete with corn. Additionally, investments may include the promotion of non-genetically modified (non-GMO) sorghum for livestock feeding.

*(3)* *Reconsider the funding of export promotion.* This study found a small but not statistically significant effect of export promotion on sorghum exports. Thus, reallocating funds to promote more profitable food and industrial uses might be a consideration. However, given the size of export markets and the need to maintain or enhance the competitiveness of U.S. sorghum in international markets, some level of investment and/or re-engineering of export promotion programs is likely critical to the future viability and profitability of the U.S. sorghum industry. Any funds allocated to export promotion would likely be most successful in enhancing producer profitability if focused on two priorities: (1) maintaining market share and export volume in China; and (2) recapturing market share and volume in Japan and in Mexico.

*(4)* *Maintain quality records on funds committed to various activities over time to support effective evaluation of the sorghum checkoff program.* A substantial amount of time in this project was devoted to obtaining accurate data on expenditures committed to various activities, namely crop improvement, high-value markets, renewables, and exports. An efficient and accurate record management system and database of checkoff expenditures made over time and across production research and promotional activities would greatly facilitate efforts to effectively evaluate the performance of the sorghum checkoff program.

*(5)* *Devise a system for collecting and warehousing data in state level checkoff expenditures.* This program evaluation did not include sorghum checkoff expenditures made by state programs because those data were not available. Efforts to retrieve those data were largely unsuccessful. As a consequence, the results of this study may not reflect the impact of the total amount of producer checkoff funds spent to promote the profitability of the sorghum industry.

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# PRODUCER RETURN ON INVESTMENTS IN SORGHUM RESEARCH, PROMOTION, AND INFORMATION: AN UPDATED ANALYSIS

## INTRODUCTION

The Sorghum Promotion, Research, and Information Order, commonly known as the United Sorghum Checkoff Program (USCP),was established in 2008 under the Commodity Promotion, Research, and Information Act of 1996. The goal of the USCPis to maintain and expand sorghum markets thereby enhancing the profitability of U.S. sorghum producers. USCP programs are designed to advance sorghum into the ethanol market, develop foreign markets for sorghum, and, in general, enhance the sorghum industry.As required under the Federal Agricultural Improvement and Reform (FAIR) Act of 1996 (7 U.S.C. 7401), the 2008 Order establishing the USCP calls for the Board to "authorize and fund an independent evaluation of the effectiveness of the Order and other programs conducted by the Board pursuant to the Act."An evaluation is to be done "not less often than every five years." Theinitial required study completed in 2012 was published in 2013 (Capps, Williams, and Málaga, 2013). This report is the second required five-year evaluation of the effectiveness of the sorghum checkoff program.

USCP conducts market research and development projects, promotion, and related activities under the supervision of the Agricultural Marketing Service (AMS). Specific missions of USCP are to increase yields through investment in research programs and to increase the demand for sorghum through a set of marketing and promotion programs, thereby providing U.S. producers with expanding markets for their commodity. The rightward shift in demand may occur through expansion of sorghum in the ethanol industry, the use of sorghum as a feedstock for advanced biofuels, the development of new uses for sorghum, and expansion of sorghum in international markets. The overriding goal of all USCP activities is to maximize return on grower investment.

The overall objective of this evaluation of USCP programs is to provide the sorghum industry with meaningful and reliable measurements of the impacts of sorghum checkoff activities on the sorghum industry over time. This reportprovides updated measures of program impact and return-on-investment (ROI) measures for the sorghum checkoff program. Specifically, the report undertakes seven (7) specific tasks: (1) an analysis of the strengths, weaknesses, opportunities, and threats (SWOT) facing the sorghum industry; (2) measurements of the impacts of USCP sorghum-oriented programs implemented since the inception of USCP in 2008 related to promotion, research, and education; (3) an evaluation of the effectiveness of the "Crop Improvement Program" in boosting yields and production; (4) an evaluation of the effectiveness of the "High-Value Program" in enhancing the demand for sorghum in export markets and in domestic markets associated with uses in the food industry, livestock, other industries; (5) an evaluation of the effectiveness of the "Renewables Program" in enhancing the demand for sorghum;(6) an evaluation of the benefits of the "Information, Communications, and Education Program" for sorghum producers and end-users;and (7) an assessment of the availability and adequacy of data currently in place to support the required evaluation of the impacts of USCP activities over time with regard to establishing key tracking mechanisms that can be analyzed, documented, reviewed and communicated concerning the effectiveness of the checkoff program.

The accomplishment of these tasks require themeasurement, via the use of statistical procedures, of the effects of the programmatic activities of USCPrelating to domestic and export markets for U.S. sorghum as well as to sorghum production. These analyses will provide the basis for determining if the programmatic activities of the USCP Board have increased the domestic and export demand for sorghum and for calculating benefit-cost ratio (BCR) metrics related to stakeholder investments in sorghum market development and promotion, information, and research programs.

In essence, the “metrics” part of program evaluation is an after-the-fact assessment of whether the checkoff program has been “doing things right,” that is, whether the program has effectively met its goals after the funds have been committed and expended. This evaluation will provide checkoff program managers the critically needed information to: (1) improve the efficiency and effectiveness of the program; (2) design and adjust the program’s long-run strategic plan; (3) serve the information needs of contributors, industry, and other stakeholders; and (4) provide the information and program impact analysis required by the legislation establishing the program. The report will also suggest needed adjustments in plans and processes that could facilitate the collection of the data needed for more efficient analyses of the impacts of USCP funded activities over time.

## SCOPE AND ORGANIZATION

The scope of the project covers data from several periods. Data concerning acres planted, acres harvested, yields and production of sorghum range from 1960 to 2016. Data concerning end uses of sorghum range from 1975 to 2016. Funds committed by USCP cover the period 2008 to 2016. The frequency of data is annual, that is, on a year-by-year basis.

The organization this report is as follows. Initially, we discuss data indigenous to the evaluation of checkoff programsNext, we provide details associated with the programmatic activities of USCP as well as details on the funds committed (expenditures) made by USCP. Then, we center attention on trends associated with acres planted, acres harvested, yield and production of sorghum. Further, we focus on trends dealing with end uses of sorghum, namely seed use; food and industry use; feed use; and exports. In addition, we develop the specifications of econometric models for planted acres and yields to determine the impact of the checkoff program on sorghum production. In similar fashion, we also develop econometric models for food and industry use of sorghum, feed use of sorghum, and sorghum exports to assess the effectiveness of the checkoff program on key end uses of the commodity. Subsequently, we provide a SWOT analysis of the activities associated with the USCP. Finally, to end the report, we provide concluding remarks and recommendations to the sorghum board based on this updated analysis.

## DATA INDIGENOUS TO EVALUATION OF CHECKOFF PROGRAMS

Evaluations of programmatic activities associated with any checkoff program face a number of challenges, the most important of which is the extensive set of data covering an extended period of time that is required for such analyses. Because the impacts of checkoff programs in a given year can be spread over a long period of time, several years of program experience and data gathering after a new checkoff program is established may be required before a quantitative evaluation of the impact of the overall program can be attempted. Other types of evaluation of program impacts, including the effects of research expenditures in increasing sorghum yields, the effects of market development and promotion expenditures in expansion of export markets, domestic use of sorghum for feed in various livestock industries, domestic use of sorghum as additives in selected food industries and domestic use of sorghum in ethanol production are data intensive.

In general, three sets of data must be collected on a continuing basis from the outset of a checkoff program: (1) benchmark data, (2) market factor data, and (3) checkoff program expenditure data.

***Benchmark Data***: Data for production, sales, inventories, trade, prices and related information over time are needed to provide benchmarks against which the checkoff program performance can be measured. The impact of the program on exports or domestic uses, for example, would be impossible to measure without detailed data over a sufficiently long period of time.

***Market Factor Data***: A second but related set of data that must be consistently collected over time relates to the various factors that have an influence on the markets of the checkoff commodity, such as weather, competing commodity prices, supply, and demand, government domestic and trade policies, etc. In measuring the impact of the checkoff program, the specific effects of the program must be isolated from those of all other important factors that can influence the market. Without data on these other factors, controlling for their impacts on the market and then isolating the specific effects of the checkoff program is an impossible task.

***Checkoff Program Expenditure Data***: The third set of data that must be systematically and consistently collected over time includes the types, levels, and other details of checkoff program expenditures. These data are the record of the type and level of expenditures approved and made by the checkoff organization over time. Without these data, no assessment of program performance is possible. There are various forms and formats for archiving these important data. However the data are maintained, it is critical that the projects, activities, and related expenditures be related directly to the strategic plan. Because the strategic plan usually identifies more than one program objective, expenditures made to achieve the separate objectives of the program over time must be able to be identified and separated. In this way, the effectiveness of the program in achieving multiple objectives can be assessed using only the relevant program expenditure data. The expenditure data should include funds expended both by USCP and any state sorghum organizations or third party groups as well, particularly if the national checkoff funds are shared in any way with such groups. In addition, collection of historical data is necessary for voluntary programs that were in place prior to the establishment of the mandatory checkoff program in 2008.

## Revenues and Expenses Associated with the Sorghum Checkoff Program

The Sorghum Promotion, Research, and Information Program, commonly known as the Sorghum Checkoff Program, was established in 2008 under the Commodity Promotion, Research, and Information Act of 1996. The Act authorizes generic promotion, research, and information activities aimed at advancing the demand for agricultural commodities to benefit U.S. producers. Under the auspices of the Agricultural Marketing Service (AMS), the Sorghum Promotion, Research, and Information Order became effective on May 7, 2008. The collection of assessments began on July 1, 2008. USCP is funded by an assessment of 0.6 percent of the net market value of grain sorghum and 0.35 percent of the net market value of sorghum forage, silage, hay, and billets.

All producers must pay the assessment. Imports of sorghum products also are assessed, but imports are very limited presently. The Secretary of Agriculture is authorized, under the Act, to collect assessments. The Order provides that between 15 and 25 percent of the total assessments collected annually be returned to qualified state programs for promotion and research activities. Currently, nine state-level checkoff programs exist for sorghum. The source of this information is the USCP website, http://www.sorghumcheckoff.com. Prior to the establishment of the mandatory USCP, voluntary tax collections occurred in several states from 1977 to 2008. For example, the Kansas commission collected a half cent a bushel tax on sorghum sold.

The set of sorghum checkoff program revenues and expenditures over the period 2008/2009 to 2015/2016 is exhibited in Table 1. The revenue from assessments and total revenues ranged from roughly $6.6 million in 2009/2010 to $11.8 million in 2015/2016. Total expenses ranged from $6.2 million in 2009/2010 to $13.0 million in 2015/2016. On average, total expenses accounted for roughly 95 percent of total revenues over the period 2008/2009 to 2015/2016.

Funds allocated to research activities varied from $1.4 million to $3.9 million; the share of research expenses to total expenses was in the interval 20 percent and 60 percent. Funds allocated to market development activities ranged from $0.7 million to $4.4 million. The share of market development expenses to total expenses varied from 10 percent to 67 percent. Funds allocated to information, communication, and education ranged from 0.4 million to 2.0 million. The share of information, communication, and education expenses to total expenses was on the order of 6 percent to 30 percent. Expenses for administration purposes and for USDA oversight and fees ranged from 5.6 percent to 9.7 percent and 0.2 percent to 3.6 percent respectively.On average, the administration share of total expenses was slightly more than 7 percent. On average, the USDA oversight share of total expenses was roughly 1.6 percent. USCP sends funds back to states that have submitted paperwork to be qualified organizations. These states use funds for research, market development, and education in conjunction with USCP to benefit U.S. producers. Funds allocated to this passback reserve varied from $1.3 million to $2.5 million. Passback reserve accounted for 19 percent to 37 percent of total expenses.

Certified producer organizations and qualified state organizations include:

- Arkansas Corn and Grain Sorghum Board (http://www.corn-sorghum.com/)
- National Sorghum Producers (http://www.sorghumgrowers.com/)
- South Dakota Corn Growers Association (http://sdcorn.org/)
- Colorado Sorghum Producers
- Nebraska Grain Sorghum Association (http://sorghum.state.ne.us/)
- South Dakota Farmers Union (http://sdfu.org/)
- Kansas Grain Sorghum Commission (http://www.ksgrainsorghum.org/)
- Nebraska Farm Bureau (http://nefb.org/)
- Texas Farm Bureau (http://texasfarmbureau.org/)
- Kansas Grain Sorghum Producers Association (http://ksgrains.com/)
- New Mexico Sorghum Producers Association
- Texas Grain Sorghum Association (http://texassorghum.org/)
- Kentucky Small Grain Growers Association (http://kysmallgrains.org/)
- Oklahoma Sorghum Commission (http://oksorghum.com/)
- Texas Grain Sorghum Board
- Louisiana Soybean and Grain Research and Promotion Board
- Oklahoma Sorghum Producers Association
- U.S. Grains Council (http://www.grains.org/)

**Table 1. Sorghum Checkoff Program Revenues and Expenses, 2008/2009 to 2015/2016**

| | 2008/2009 | 2009/2010 | 2010/2011 | 2011/2012 |
|---|---|---|---|---|
| **Revenues** | | | | |
| Revenues from Assessments | $7,470,074 | $6,582,472 | $8,801,109 | $6,995,053 |
| Revenues from Investments | $14,404 | $27,261 | $24,029 | $36,372 |
| Total Revenues[1] | $7,448,213 | $6,604,438 | $8,764,830 | $7,167,847 |
| **Expenses** | | | | |
| Research | $1,726,321 | $1,358,274 | $1,409,065 | $1,588,428 |
| Market Development | $680,718 | $955,147 | $1,137,621 | $1,117,897 |
| Information, Communication, and Education | $1,102,641 | $927,631 | $599,234 | $936,888 |
| Passback Reserve[2] | $1,281,613 | $1,490,010 | $2,325,327 | $2,014,346 |
| Administration | $643,224 | $469,556 | $522,308 | $477,532 |
| USDA Oversight and Fees | $237,295 | $150,000 | $222,833 | $133,650 |
| Total Expenses[3] | $6,618,819 | $6,158,866 | $6,666,388 | $6,268,541 |

| | 2012/2013 | 2013/2014 | 2014/2015 | 2015/2016 |
|---|---|---|---|---|
| **Revenues** | | | | |
| Revenues from Assessments | $7,872,929 | $9,202,775 | $9,243,543 | $11,386,443 |
| Revenues from Investments | $41,767 | $60,783 | $93,027 | $122,913 |
| Total Revenues[1] | $8,096,736 | $9,274,290 | $9,369,315 | $11,778,796 |
| **Expenses** | | | | |
| Research | $3,938,790 | $3,520,415 | $2,661,125[4] | $3,281,186[4] |
| Market Development | $1,275,243 | $1,728,912 | $4,250,621[5] | $4,398,627[5] |
| Information, Communication, and Education | $634,201 | $411,332 | $525,000[6] | $2,000,000[7] |
| Passback Reserve[2] | $1,627,393 | $2,039,099 | $2,043,434 | $2,457,241 |
| Administration | $520,147 | $566,606 | $685,762 | $720,957 |
| USDA Oversight and Fees | $16,896 | $126,778 | $92,657 | $120,818 |
| Total Expenses[3] | $8,012,670 | $8,393,142 | $10,418,095 | $12,978,829 |

[1]Accounts for refunds on double assessments.
[2]USCP sends funds back to states that have submitted paperwork to be qualified organizations. These states use funds for research, market development, and education in conjunction with USCP to benefit producers.
[3]Exclusive of mandatory reserve, referendum reserve, and refund reserve categories
[4]Research is defined to be crop improvement
[5]Market development is defined to be high value markets and renewables
[6]Information, communication, and education is defined to be regional development
[7]7Information, communication, and education is defined to be collaborative sorghum investment program

Source: http://sorghumcheckoff.com, various Annual Reports of the United Sorghum Checkoff Program

Bottom line, this checkoff program is modest in terms of size of expenditures (on the order of $6 million to $12 million) in comparison to other commodity groups. To illustrate, expenditures associated with the milk checkoff program are on the order of $400 million (Capps *et al*, 2013), with the cotton checkoff program, expenditures are on the order of $80 million (Williams *et al*, 2011), and expenditures associated with the soybean checkoff program are on the order of $100 million (Williams, Capps, and Bessler, 2009).

Compared to the farm value of sorghum, on the order of $1.23 billion to $1.97 billion from 2008/2009 to 2015/2016, the amount of funds collected from the checkoff is extremely small. The ratio of revenue from assessments to farm vale of production (often referred to as the investment-intensity ratio), is, on average, 0.54 percent, ranging from a low of 0.48 percent to a high of 0.60 percent over the period 2008/2009 to 2015/2016. In other words, the amount of funds collected by USCP has been on the order of one-half of one percent to three-fifths of one percent.

USCP funds research projects to improve yield, production, profitability, genetic improvement and herbicide tolerance. In the livestock industry, USCP has developed educational material for dairies, cattle, feedlots, other livestock operations, and feed manufacturers to make them aware of the financial benefits of using sorghum. USCP marketing activities focus on the benefits of using sorghum as a feedstock. These benefits include improvements in efficiency due to less water requirements and other inputs compared to corn as well as the ability of sorghum to be produced on marginal land. Further, USCP supports educational efforts focusing on food and industrial uses. Food uses include gluten-free products and food additives that include high-antioxidant specialty sorghums. On the industrial side, checkoff dollars support research and education to make distillers dry grains (DDGs) more valuable by developing unique, renewable industrial products.

At present, a notable segment of the U.S. sorghum crop is used for biofuels production. Grain sorghum is an excellent crop for sustainable ethanol production because it produces the same amount of ethanol per bushel as comparable feed grains while using up to one-third less water in the plant growth process. From the standpoint of ethanol production, grain sorghum is equal to corn as an input. One bushel of grain sorghum or corn produces an equal amount of ethanol. With that in mind, ethanol producers can make grain sorghum part of successful feedstock procurement strategy, especially in areas where there is a ready supply of grain sorghum. Sweet sorghum, also drought-tolerant, grows very tall and the stalks contain a high volume of fermentable sugars. India and Asia are already using this crop to produce ethanol. Research is ongoing in the United States into infrastructure development needs to make sweet sorghum ethanol a mainstream reality. Forage and high tonnage biomass sorghums are under evaluation for their compositional makeup and production potential for use as a renewable feedstock for both the cellulosic and thermochemical process for conversion into biofuels. These annual feedstocks could become an important option for farmers looking to diversify their farming systems and to maintain rotation strategies on their farms.

USCP works in conjunction with the U.S. Grains Council (USGC) (http://www.grains.org/) to explore and develop overseas markets for sorghum. Checkoff dollars support general activities of the Council as well as a full-time USGC employee whose primary responsibility is to expand sorghum markets. In general, the sorghum checkoff helps to facilitate marketing relationships globally that ultimately benefit domestic sorghum producers.

Animal feeding is a key end use for U.S. sorghum production. Sorghum is utilized in the nutrition of dairy and beef cattle as well as swine and poultry. Importantly, besides the livestock industry, the pet food industry is utilizing sorghum in their products. This market is small in comparison to the livestock market at present.

The United Sorghum Checkoff Program is working to enhance the usability of sorghum in industries that reach beyond conventional markets. Traditionally, nearly one-third of the U.S. sorghum crop is used for renewable fuel production, Sorghum produces the same amount of ethanol per bushel as comparable feedstocks while using up to one-third less water. Domestically, checkoff-funded research opportunities are looking at sorghum's potential to fight cancer, high cholesterol and obesity. Sorghum is high in antioxidants, and sorghum is gluten free. As such, sorghum is a versatile product for individuals diagnosed with Celiac disease which concerns intolerance to gluten found in products like wheat.

The pet food industry already uses sorghum because of its low glycemic index which helps it to control diabetes in companion animals. Sorghum is used in florals, birdseed, and deer feeders. Around the world, sorghum is already used for building materials like fencing, a plywood-like product and as a binder is wallboard. Within the aquaculture industry, interest in the use of sorghum has accelerated, particularly as a cost effective protein source. The sorghum checkoff continues to fund projects which encourage new markets for this crop.

Finally, while there are currently no commercialized green chemical products made from sorghum on the market, research has demonstrated that sorghum has potential in meeting demand for environmentally-friendly products. By funding research and market development projects, the sorghum checkoff hopes to increase sorghum's use in green chemicals and consequently demand for U.S. sorghum.

As exhibited in Table 2, we provide the commitment of funds made by USCP in crop improvement, high-value markets, renewables, and exports. We assume that funds committed toward ICE are shared equally among the three key priority areas of crop improvement, high-value markets, and renewables. We make no assumptions as to the distribution of funds committed to passback in relation to crop improvement, high-value markets, and renewables. We have no prior information concerning this particular distribution of funds.

Consequently, exclusive of passbacks, funds committed to crop improvement over the period 2008/2009 to 2015/2016 ranged from $0.69 million to $2.71 million; for high-value markets, the range was $0.50 million to $1.12 million; for renewables, the range was $0.14 million to $1.00 million, and for exports $0.23 million to $0.66 million.. The total commitment of checkoff dollars for crop improvement, high-value markets, exports and renewables ranged from $1.94million to $3.81 million over the period 2008/2009 to 2015/2016.

**Table 2. USPC Programmatic Activities and Funds Actually Spent, 2008-09 to 2015-16**

| Marketing Year | Crop Improvement | High-Value Markets Exclusive of Exports | Exports--USGC | Renewables | Total Funds Actually Spent |
|---|---|---|---|---|---|
| 2008-09 | $1,373,806.49 | $659,004.10 | $306,000.00 | $333,329.10 | $2,672,139.69 |
| 2009-10 | $810,534.00 | $574,028.00 | $228,000.00 | $328,437.75 | $1,940,999.75 |
| 2010-11 | $887,740.33 | $578,250.59 | $400,000.00 | $147,768.33 | $2,013,759.26 |
| 2011-12 | $1,130,698.46 | $287,610.86 | $381,000.00 | $520,137.18 | $2,319,446.50 |
| 2012-13 | $2,749,081.53 | $497,826.03 | $356,000.00 | $142,398.03 | $3,745,305.60 |
| 2013-14 | $1,415,520.58 | $724,122.26 | $390,000.00 | $1,005,365.33 | $3,535,008.18 |
| 2014-15 | $1,463,134.80 | $1,122,674.68 | $390,000.00 | $842,810.50 | $3,818,619.98 |
| 2015-16 | $689,427.16 | $936,186.50 | $656,500.00 | $571,128.66 | $2,853,242.33 |

Source: United Sorghum Checkoff Program

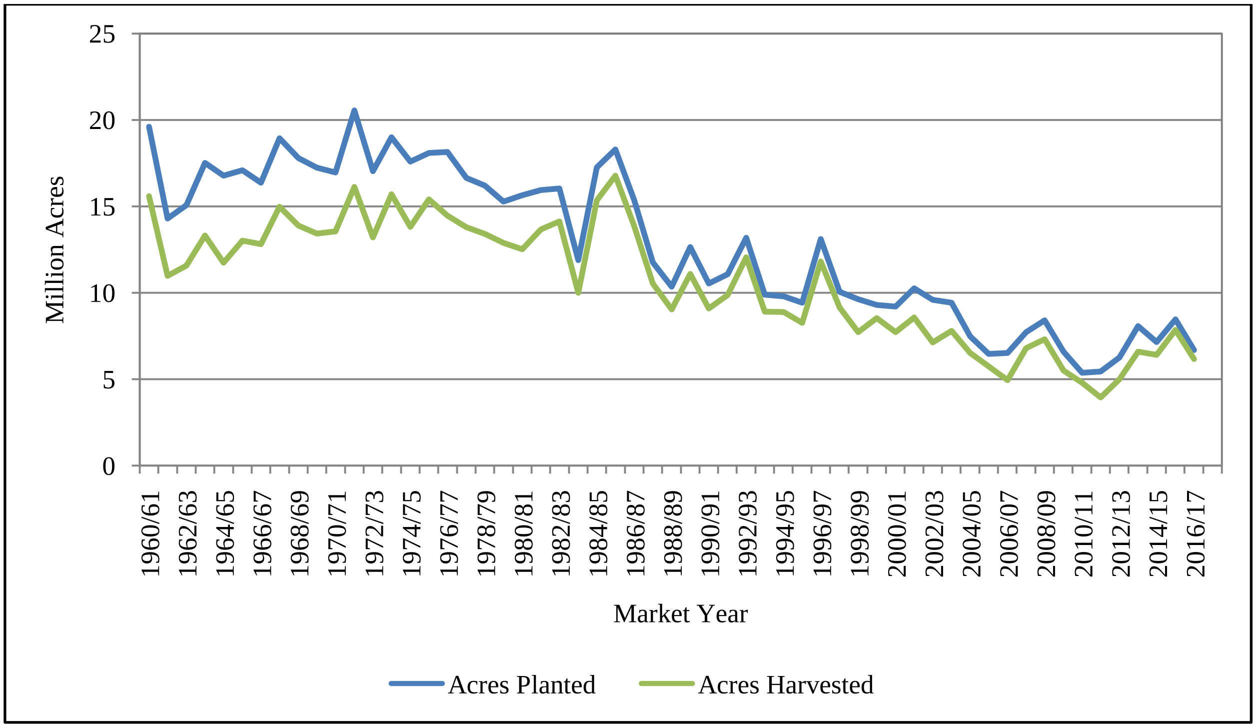
## BACKGROUND ON SORGHUMPRODUCTION AND END USES

Sorghum, also known as milo, is a grain, forage, or sugar crop, among the most efficient crops in conversion of solar energy and use of water. A high-energy, drought tolerant crop, sorghum is produced largely in nine states - Kansas, Texas, Nebraska, Oklahoma, Colorado, South Dakota,Arkansas, and Louisiana. Sorghum is used as a livestock feed in the poultry, beef, and pork industries and as a feedstock in the production of ethanol. A notable amount of U.S. sorghum also is exported to international markets, principally Mexico, Japan, and more recently China. Because it is gluten-free, sorghum is an excellent substitute for wheatin U.S. food products. Finally, sorghum also is used for building materials, fencing, floral arrangements, pet food, and brooms. Clearly, sorghum has a variety of uses including food for human consumption, feed grain for livestock, and industrial applications, particularly ethanol production and use of renewable chemicals (Stroade and Boland, 2003).

### Sorghum Production

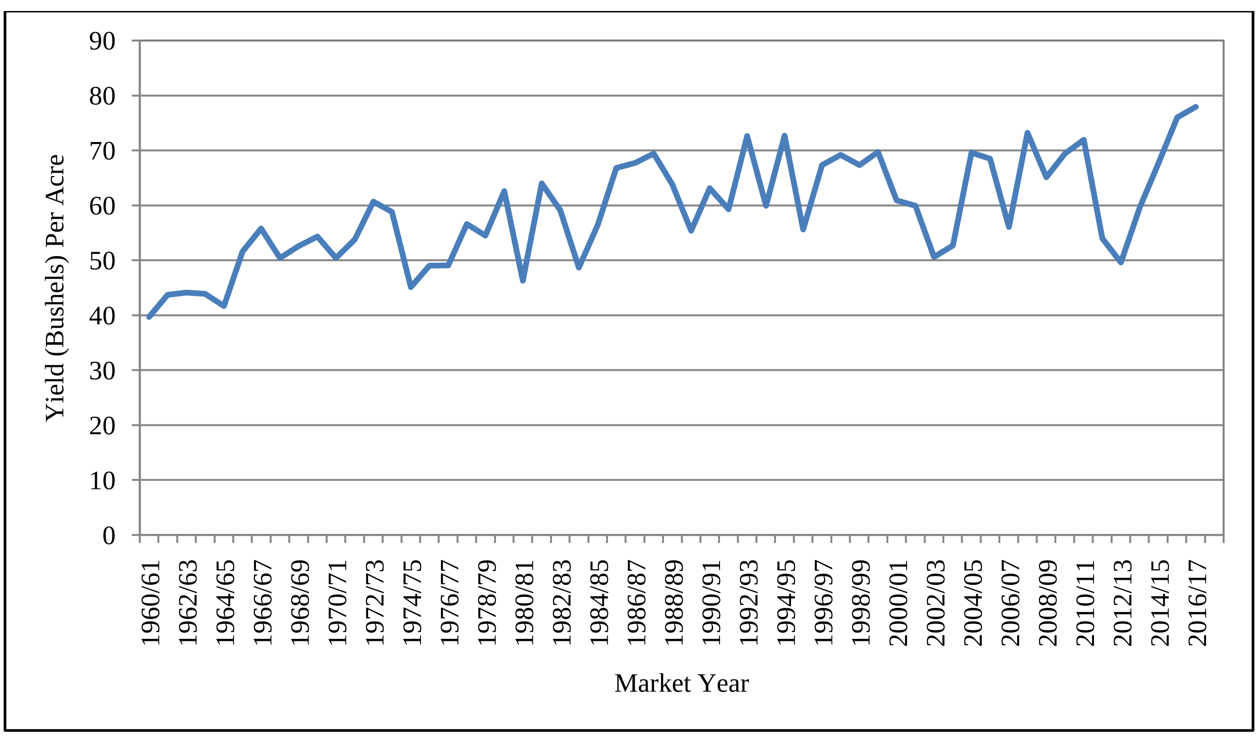
In 2016/17, U.S. grain sorghum production totaled roughly 480 million bushels valuedat $1.97 billion. Over the period 1960/61 to 2016/17, a downward trend in sorghum acres planted and harvested is evident (Figure 1). In particular, the sharp decline in acres in recent years was due to sugarcane aphid (SCA). On the other hand, sorghum yields have experienced a general upward trend, ranging from 40 bushels per acre to 78 bushels per acre (Figure 2). As a consequence,

**Figure 1.Sorghum Planted and Harvested Acres in the United States, 1960/61 to 2016/17**




Source: USDA (2017a).

**Figure 2. Sorghum Yield in the United States, 1960/61 to 2016/17**




Source: USDA (2017a).

sorghum production has ranged from a low of 214 million bushels in 2011/12 to a high of 1,120 million bushels in 1985/86 (Figure 3).

U.S. sorghum acreage, yields, and production have differed substantially from time period to time period over the years. Figures 4 through 6 compare averages of acres planted, acres harvested, yields, and production during three critical time periods: (1) 1960/61 to 1997/98; (2) 1998/99 to 2002/03; (3) 2003/04 to 2007/08; and (4) 2008/09 to 2016/17. The first three periods occurred before the implementation of the sorghum checkoff and the fourth time period includes the years during which the checkoff was in force.

In the period prior to the implementation of the sorghum checkoff, U.S. sorghum planted and harvested area dropped steadily from an average of 15.2 million acres and 12.6 million acres, respectively, between 1960/61 and 1997/98 to averages of 7.5 million acres and 6.4 million acres, respectively, between 2003/04 and 2007/08. Over the most recent period of 2008/09-2016/17 when the checkoff was in force, U.S. planted and harvested acreage continued to decline to averages of 6.9 million acres and 6.0 million acres, respectively.

On the other hand, sorghum yield rose steadily from an average of 56.2 bu/acre during the period of 1960/61-1997/98 to an average of 64.0 bu/acre during 2003/04-2007/08. During the checkoff years (2008/09-2016/17), yields continued to grow, averaging 65.7bu/acre over that period. Without the drought years in 2011/12 and 2012/13, the average sorghum yield for the United States over the period 2008/09 to 2016/17 was 69.6 bu/acre.

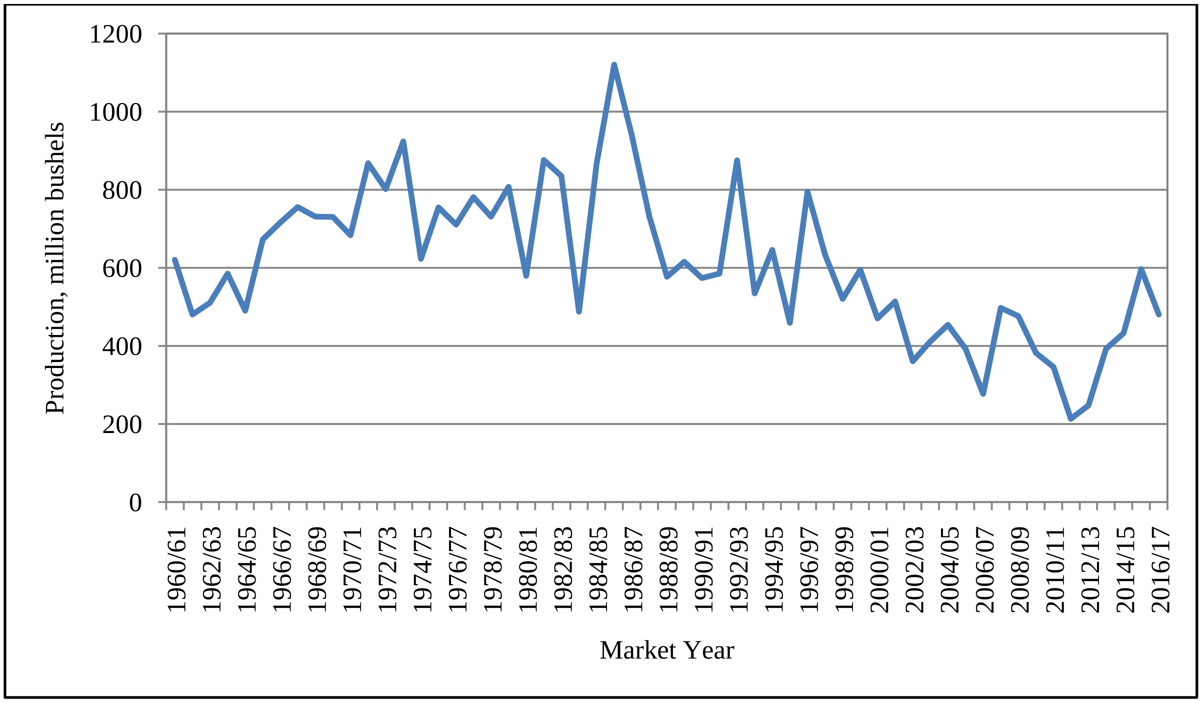
Despite the growth in yields, the sharper decline in acreage resulted in a steady decline in production from an average of 703 million bushels between 1960/61 and 1997/98 to 406 million bushels between 2003/04 and 2007/08. Production continued to decline in the checkoff years (2008/09-2016/17) to an average of 396 million bushels.

Regional sorghum planted and harvested acreage, yields, and production are presented in Figures 7 through 10. Since 1960/61, 19 states have accounted for 99% of sorghum production, planted acreage, and harvested acreage. Historically, Kansas and Texas have been the top two sorghum-producing states. Sorghum producing states are generally grouped into four regions: (1) South-Western (Texas, Arkansas, Louisiana, and Oklahoma); (2) South-Eastern (Alabama, Georgia, Kentucky, Mississippi, South Carolina, and Virginia); (3) Midwest (Illinois, Kansas, Missouri, Nebraska, and South Dakota); and (4) Western (Arizona, California, Colorado, and New Mexico).

The following summarizes the salient information on production in each region over the period of 1960/61 to 2016/17:

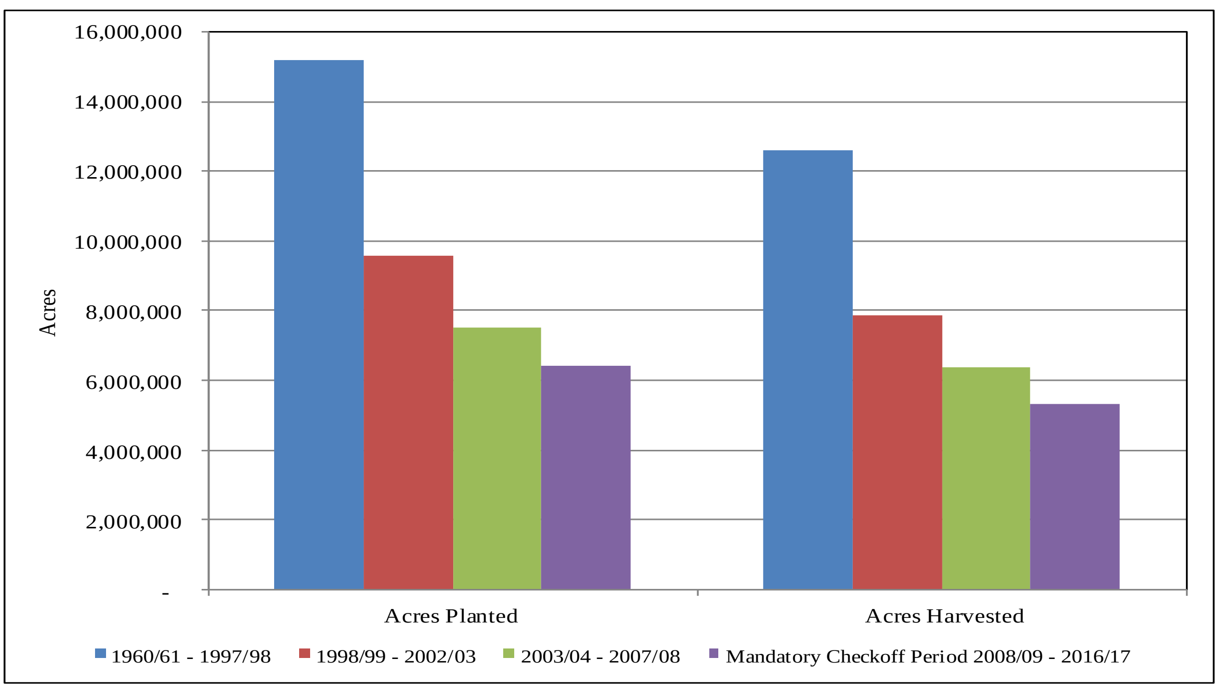
- *The South-Western Region*:
  - The number of acres planted and harvested in Texas generally was on the decline from 1960/61 through 2016/17. The high for planted area was 8.1 million over that period and the low was roughly 1.5 million acres. The high for harvested area was 7.2 million acres and the low was roughly 1.2 million acres.
  - Similarly, acres planted and harvested in Oklahoma have been on the decline.
  - Arkansas and Louisiana both consistently have planted and harvestedless than 500,000 acres each year since 1960/61, with exceptions in the mid-1980s.
  - Increases in yields for all states in this region generally are evident.

**Figure 3. Sorghum Production in the United States, 1960/61 to 2016/17**



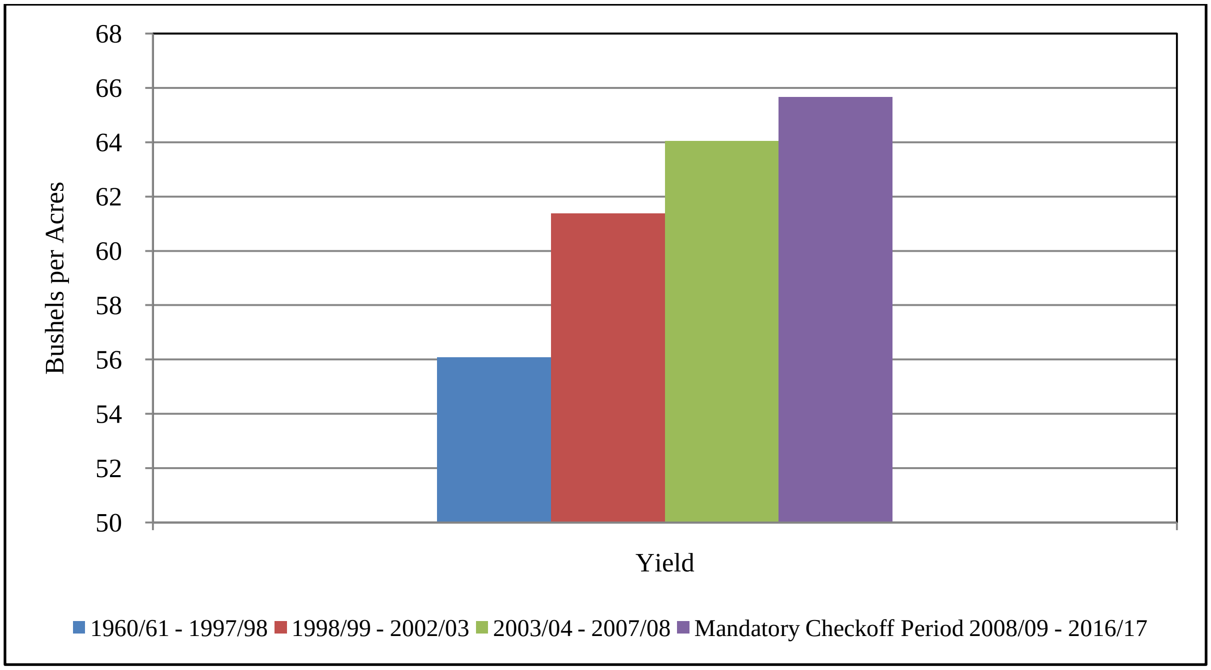

Source: USDA (2017a).

**Figure 4. Average Acres Planted and Acres Harvested of Sorghum by Selected Periods of Time**



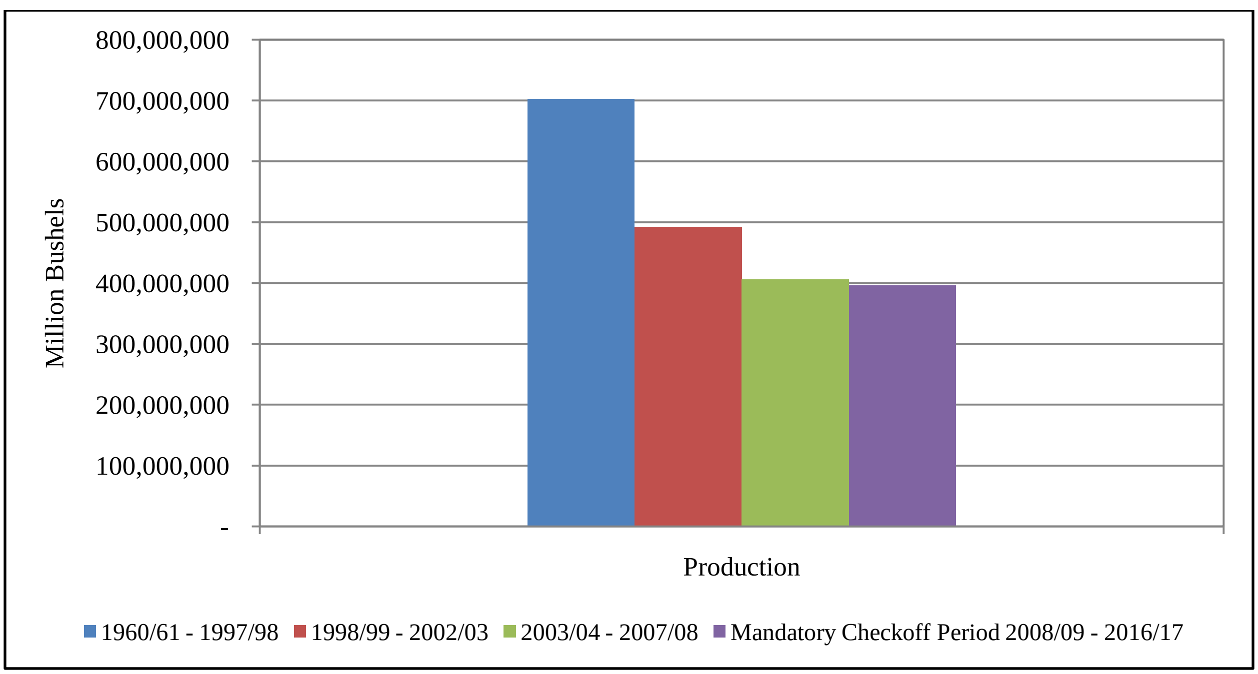

Source: USDA (2017a).

**Figure 5. U.S. Sorghum Yield by Selected Periods of Time**



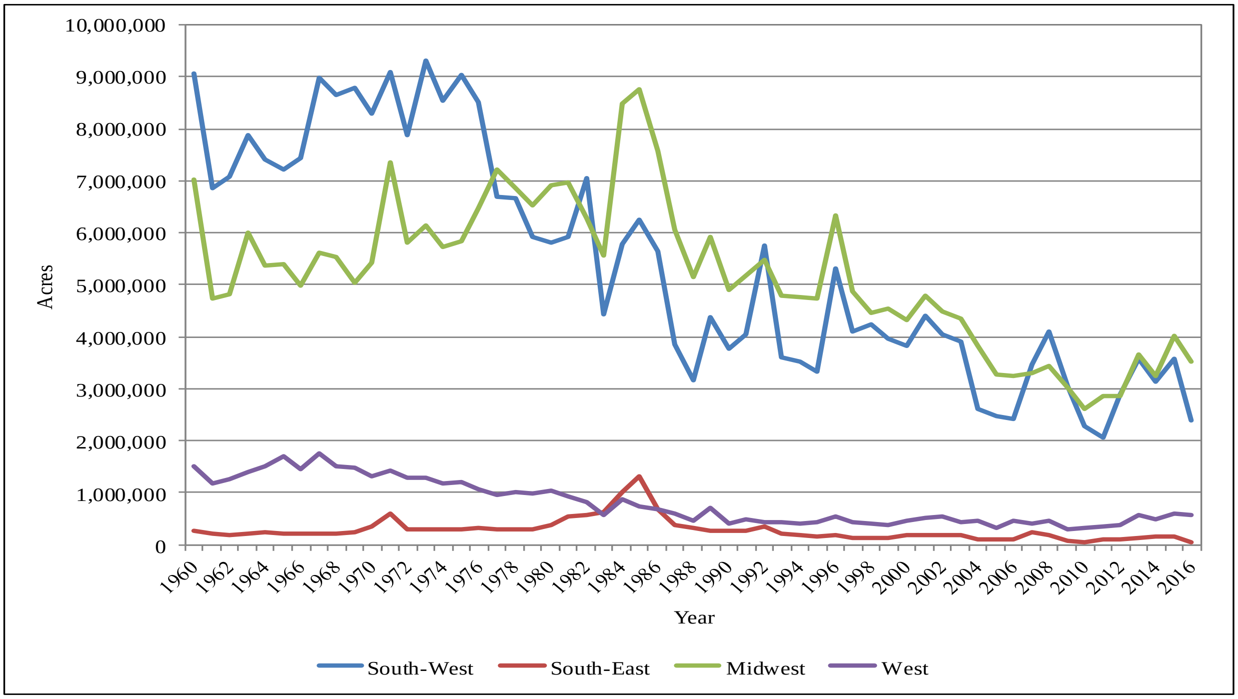

Source: USDA (2017a).

**Figure 6. U.S. Production of Sorghum by Selected Periods of Time**



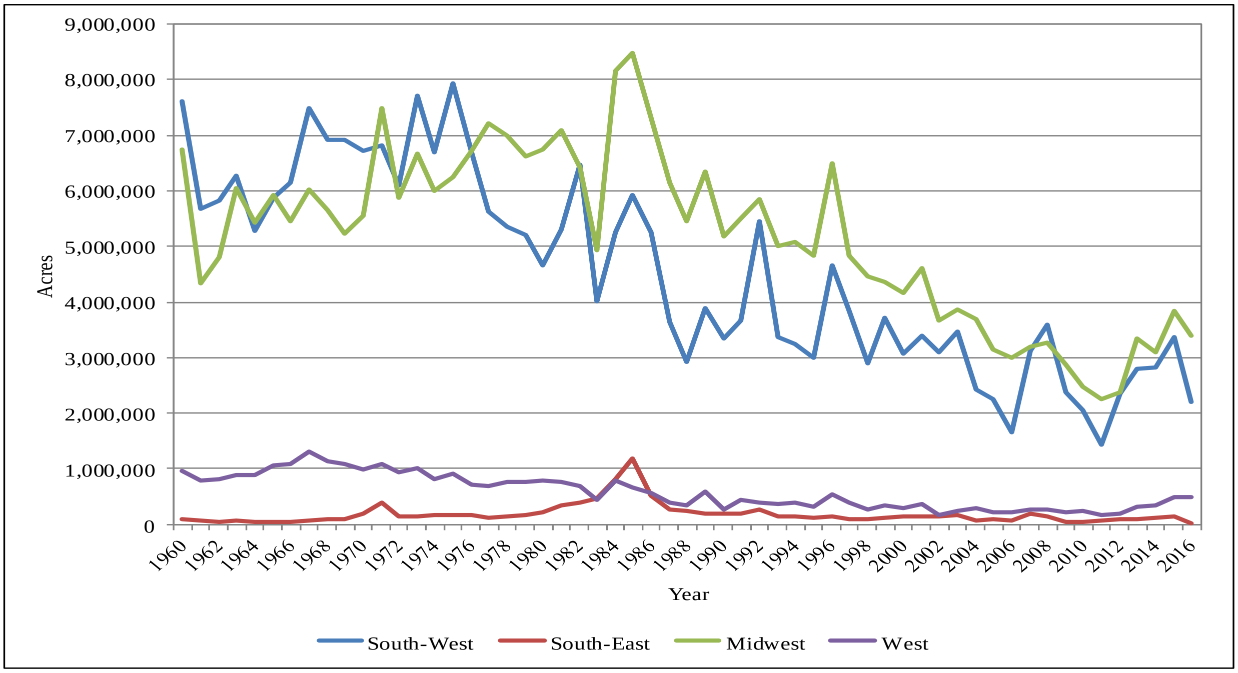

Source: USDA (2017a).

**Figure 7. Number of Acres Planted by Region in the United States, 1960/61 to 2016/17**



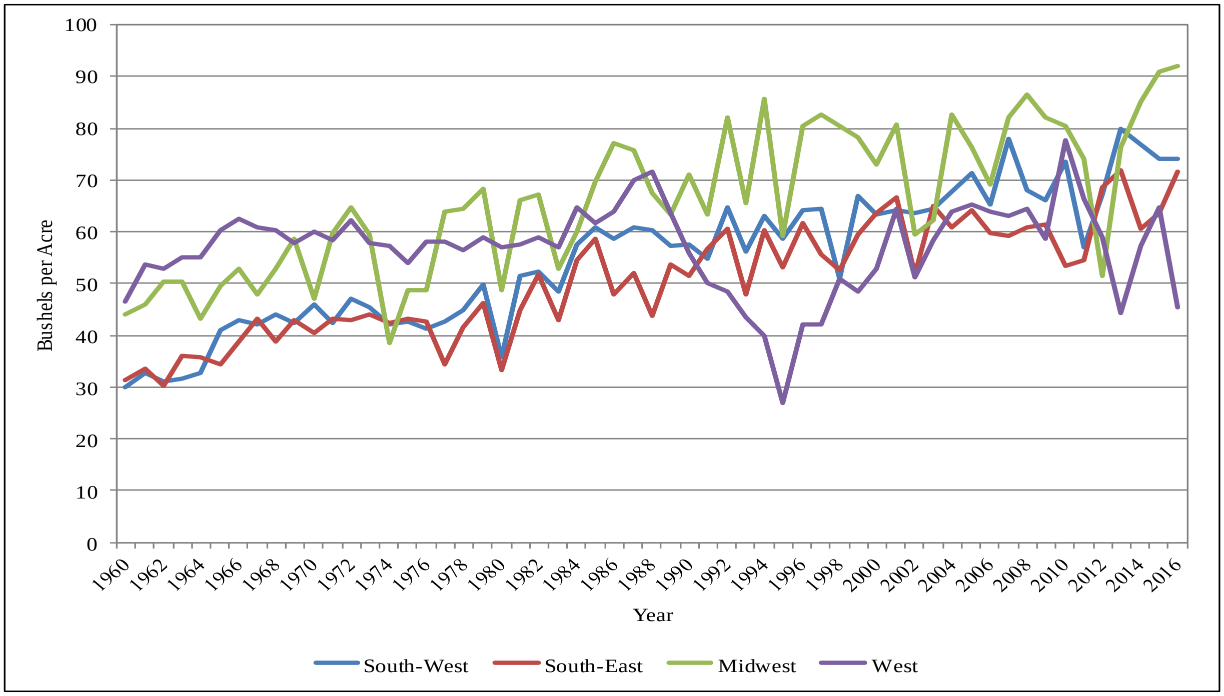

Source: USDA (2017f).

**Figure 8. Number of Acres Harvested by Region in the United States, 1960/61to 2016/17**



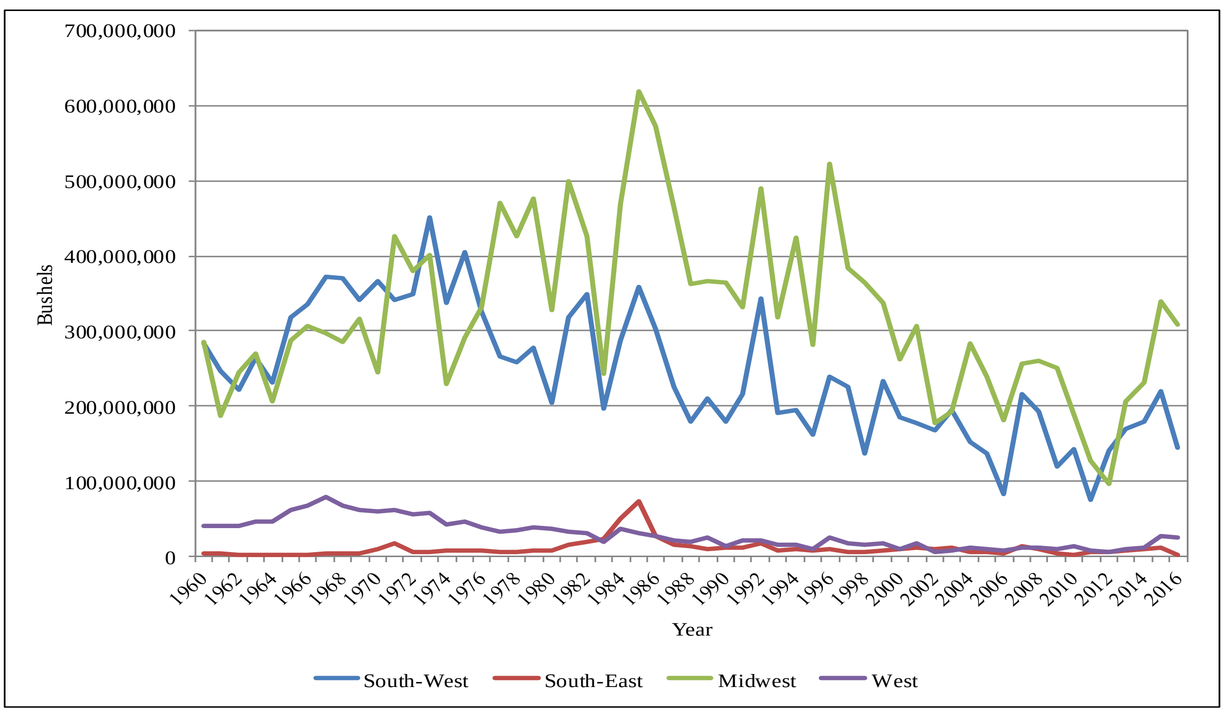

Source: USDA (2017f).

**Figure 9. Average Yield per Acre by Region in the United States, 1960/61 to 2016/17**




Source: USDA (2017f).

**Figure 10. Sorghum Production by Region in the United States, 1960/61 to 2016/17**




Source: USDA (2017f).

- Production in Texas varied greatly over the period, ranging from 55 million bushels to 417 million bushels.
- enerally speaking production levels in Texas generally have diminished over the period.
- Texas continues to be the dominant state in sorghum production in this region.

- *The South-Eastern Region*
    - In Mississippi, the highsfor planted and harvested areas were 650,000 acres and 620,000 acres, respectively, and the lowsabout 12,000 acres and 6,000 acres, respectively.
    - In Georgia, the highs for planted and harvested areas were 225,000 acres and 138,000 acres, respectively, and the lows about 20,000acres and 10,000 acres, respectively.
    - A notable spike was evident in acres planted and harvested for all states in this region except for Virginia in 1984/85 and 1985/86.
    - Yields in Louisiana and Arkansas were higher than yields in Texas and Oklahoma.
    - Yields were highest in Kentucky and Mississippi in the region.
    - Mississippi produced the most sorghum in this region.
    - A spike in production for all states in this region was evident during 1971/72 through 1973/74.
    - A definitive spike in production for all states in this region was evident, especially for Mississippi, in the mid-1980s.

- *The Midwest Region*
    - Kansas had the highest planted and harvested acres in this regionwith an average of around 3.8 million planted acres and 3.3 million harvested acres.
    - All the states in this region exhibited a decrease in the number of acres planted and harvested.
    - Illinois, Kansas, Missouri, Nebraska, and South Dakota followedan upward trend, except for the period of 2010/11 to 2012/13.
    - Yields were highest in Illinois, Nebraska, and Missouri in this region.
    - Kansas, by far, produced the most sorghum in this region followed by Nebraska and Missouri.
    - Production in Kansas ranged from 82 million bushels to 354 million bushels over the period.

- *The Western Region*
    - Colorado accounted for the most planted and harvested acres in this region, followed by New Mexico.
    - On average, the number of planted acres was close to 400,000 for Colorado and close to 240,000 for New Mexico.
    - On average, the number of harvested acres was close to 250,000 for Colorado and close to 180,000 for New Mexico.
    - Arizona, Colorado, and New Mexico followed the same upward trend in yields as in other regions.
    - Yields were highest in California and Arizona in this region in years of production.
    - Sorghum production has been virtually nonexistent in California and Arizona since 1980.
    - Colorado and New Mexico were the primary sorghum-producing states in this region.
    - In recent years, sorghum production in Colorado has been on the rise.

Clearly, sorghum yields have varied greatly by state and by region. However, the states with the highest yields were not the top-producing states. Yields generally have increased in all regions since

1960/61. Clearly sorghum production was highest in Texas and Kansas. The share of sorghum acres harvested accounted for by Texas ranged from 23% to 47% (Figure 11). The share of acres harvested accounted for by Kansas ranged from 22% to 51% (Figure 12). In 2016/17, the Texas share was just under 30% and slightly less than 50% for Kansas. Consequently, those two states accounted for roughly 75% of the acres harvested of sorghum in 2016/17. The share of sorghum production accounted for by Texas ranged from 20% to 50% while Kansas accounted for about 20% to 60% of production over the same period. In 2016/17, the share of sorghum production accounted for by Texas was slightly less than 25% while the share accounted for by Kansas was about 56%. Hence, these two states accounted for about 80% of the U.S. production of sorghum. The South-Eastern region and the Western region were minor players in the production of sorghum.

To provide some perspective, sorghum ranks second to corn in terms of acres planted, acres harvested, and production. Sorghum, barley, and oat yields have been quite similar, ranging from lows of about 30 bushels per acre to highs of near 80 bushels per acre. On average, from 1960/61 to 2016/17, yields of sorghum, barley, and oats were 58.9 bushels per acre, 53.3 bushels per acre, and 55.8 bushels per acre, respectively. In contrast, corn yields varied from a low of about 55 bushels per acre to a high of about 175 with an average of 113.4 bushels per acre of over this same period.

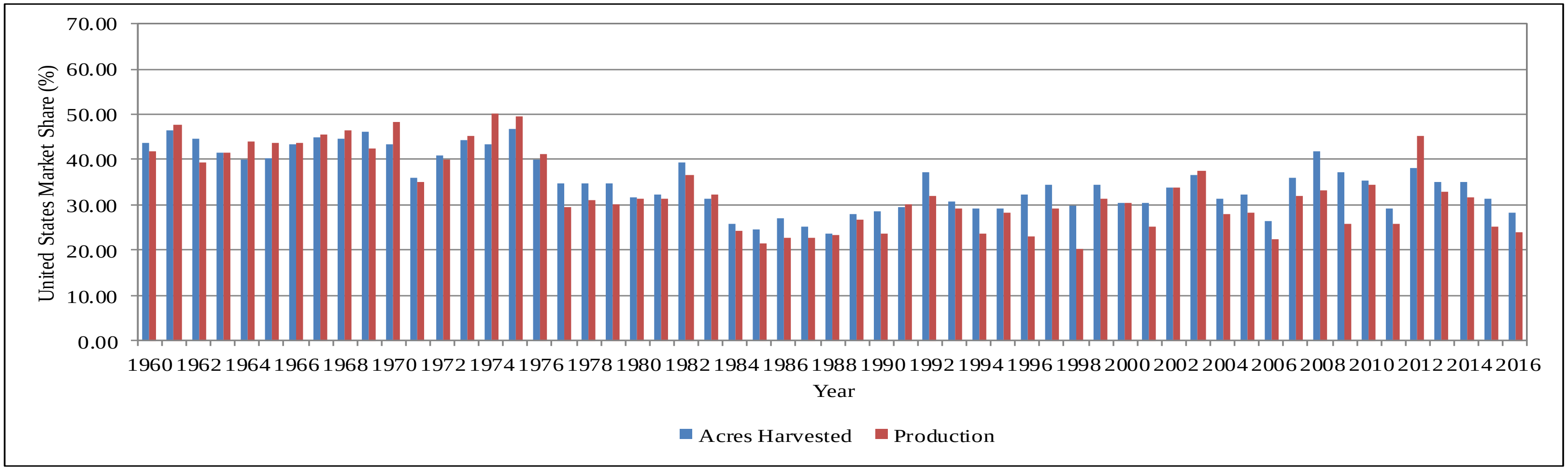
## Sorghum End Uses and Prices

Until 2000/01, the dominant demand or end use component of sorghum historically has been feed use, followed by exports, food and industry use, and seed use in that order (Figure 13). But over the past 15 years, exports have slowly become the major end use component of U.S. produced sorghum. Industry use is defined as any use of sorghum not related to seed use, feed use, food use, or exports.

Historically much of the sorghum crop has been used as a component in livestock feed. Corn is the main substitute for sorghum in livestock feed. .Figure 14 compares the average feed use, seed use, food and industry use, and exports during selected time periods. Sorghum feed use dropped from an average of 457 million bushels between 1975/76 and 1997/98 to an average of 158 million bushels between 2003/04 and 2007/08. During the most recent period during which the checkoff was in force (2008/09-2016/17), feed use dropped further to an average of 119 million bushels. A similar downward trend was evident for exports from an average level of 243 million bushels between 1975/76 and 1997/98, sorghum exports dropped to an average of 201 million bushels between 2003/04 and 2007/08. Exports dropped further to an average 192 million bushels between 2008/09 to 2016/17. Seed use followed the same pattern. However, sorghum food and industry use rose dramatically from an average of only 16.7 million bushels between 1975/76 and 1997/98 to an average of 86.6 million bushels between 2008/09 to 2016/17, an increase of over 420%.

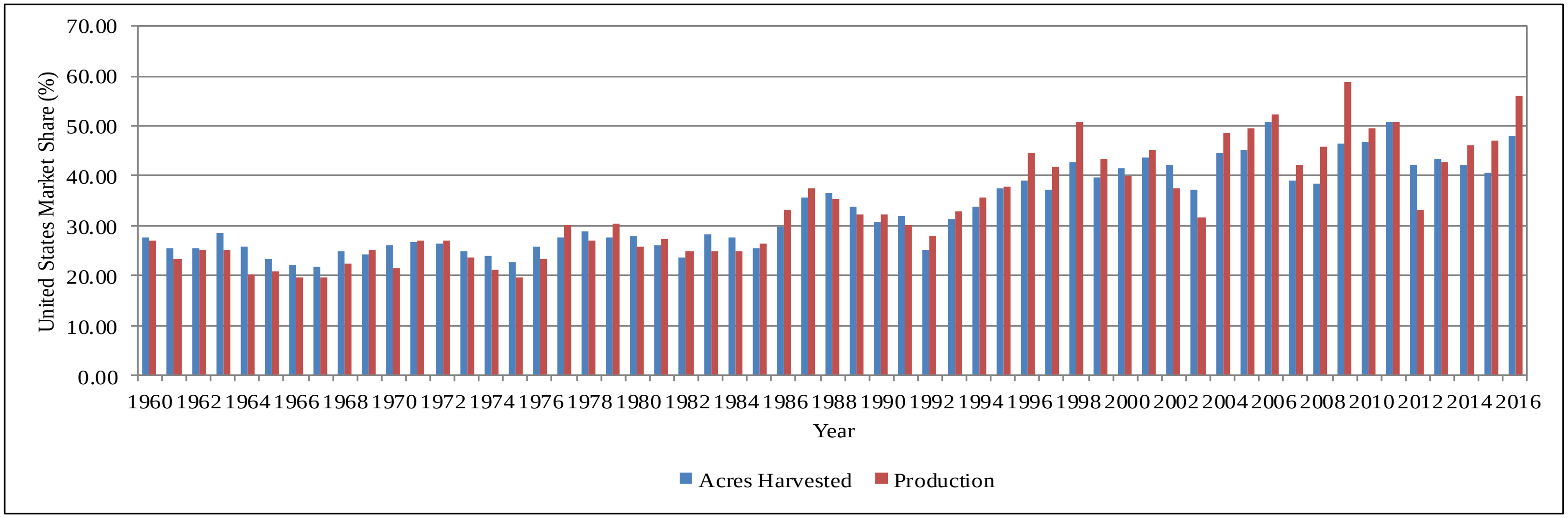
In general, U.S. domestic prices of feedgrains move together (Figure 15). In particular, the correlation of sorghum and corn farm prices was 99% between 1960/61 and 2016/17. The sorghum farm price was roughly 95% of the corn farm prices over the same period. Nominal farm prices of barley, corn, oats, and sorghum averaged $2.50 per bushel, $2.48 per bushel, $1.54 per bushel, and $2.29 per bushel, respectively, over the same period.

## Figure 11. Texas: Share of U.S. Acres Harvested and Production, 1960/61 to 2016/17



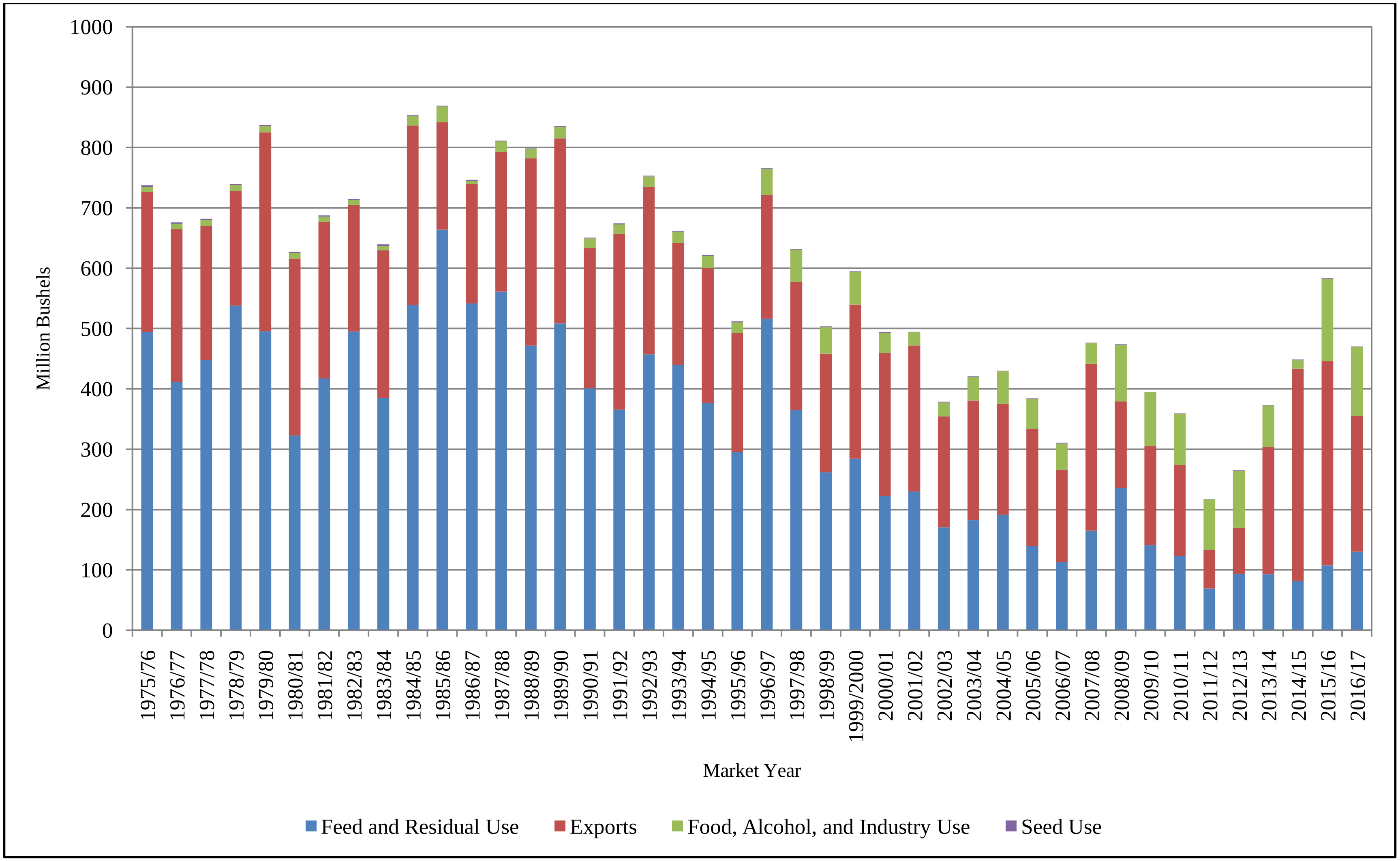

Source: USDA (2017a) and calculations by the authors.

## Figure 12. Kansas: Share of U.S. Acres Harvested and Total Production, 1960/61 to 2016/17



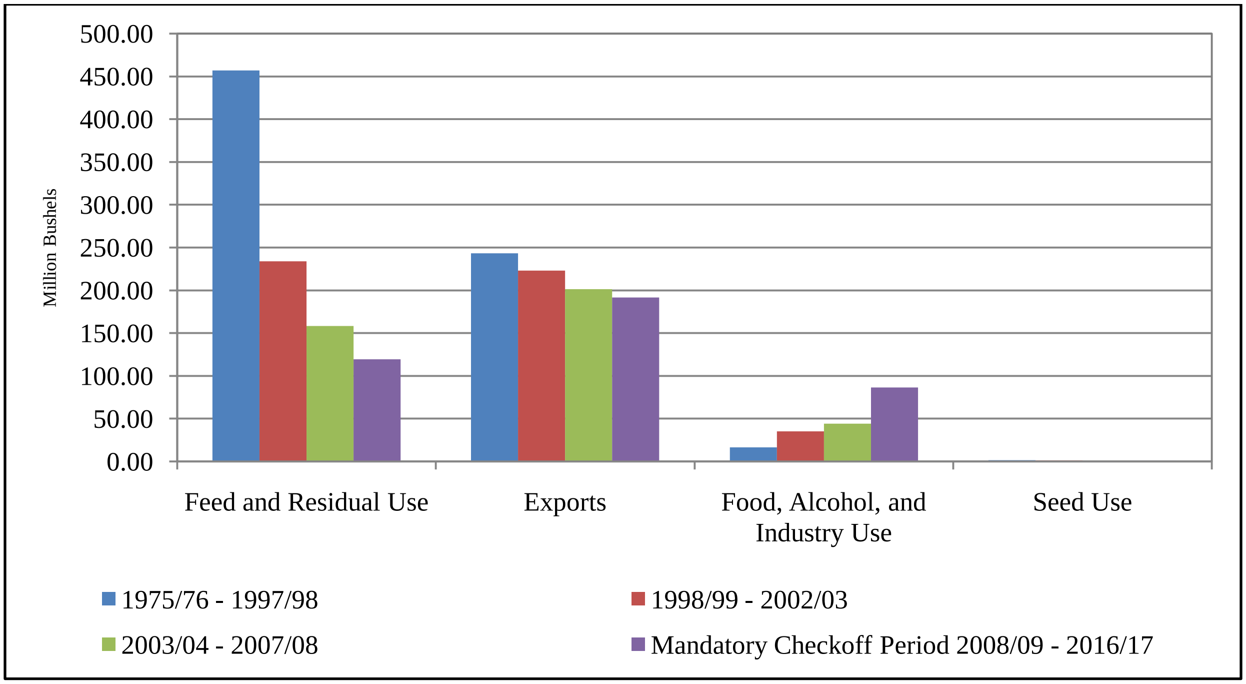

Source: USDA (2017a) and calculations by the authors.

**Figure 13. Sorghum End Uses by Type of Use (Feed, Food, Exports), 1975/76 to 2016/17**



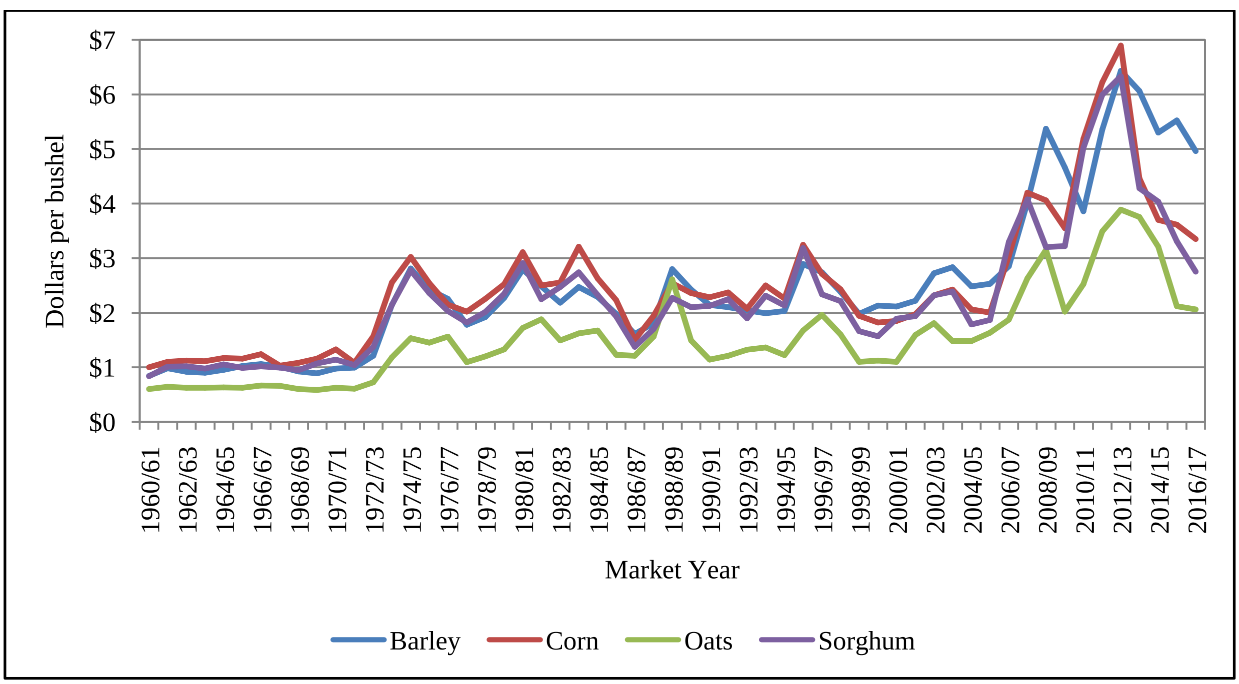

Source: USDA (2017a) and calculations by the authors.

**Figure 14. Sorghum Ends Uses, Average over Selected Time Periods**




Source: USDA (2017a) and calculations by the authors.

**Figure 15. Farm Prices Received by Producers for Feed Grains in the United States, 1960/61to 2016/17**




Source: USDA (2017a) and calculations by the authors.

Until a few years ago, U.S. sorghum exports had been on a slow decline from a high of 329.7 billion bushels in 1979/80 to a low of 63.4 billion bushels in 2011/12 (Figure 16). Then China jumped heavily into global sorghum markets driving U.S. exports quickly to a record high of 351.7 billion bushels in 2014/15. Chinese restrictions on genetically modified (GM) corn imports, a slow corn import approval process, and high corn support prices to Chinese farmers sent the Chinese livestock industry to sorghum, allowing feeders to get around the Chinese GM restrictions and "a variety of trade barriers" on corn (Tran et al., 2015). Within a couple years, China quickly went from not importing any sorghum at all to being the world's largest sorghum importer.

Historically, Mexico and Japan were the top destinations for U.S. sorghum exports but have now been surpassed by China (Figure 17). On average, over the period of 1975 to 2016, Mexico, Japan, and China accounted for roughly 75% of U.S. exports (Mexico 42%, Japan 27% and China 6%). Given the NAFTA connection and its proximity to the United States, Mexico is almost a captive market for U.S. sorghum exports. As well, Mexico historically has been a major market for U.S. sorghum in part because its feeding industry is accustomed to sorghum and its corn imports have been limited by policies of the Mexican government (Hoffman et al, 2007).Japan had been the top market for U.S. sorghum exports until 1981. The entrance of rival exporters to the Japanese market, primarily Australia and Argentina, may make the re-establishment of Japan as a major U.S. export market difficult (Bryant Christie, Inc., 2013).The rest of the world (ROW) markets for U.S. sorghum include the European Union, Morocco, Saudi Arabia, and Sub-Saharan Africa. The European Union (EU) has been an erratic market for U.S. sorghum. For example, the EU took 25% of U.S. sorghum exports in 2006/07 and 60% in the next year while importing almost nothing in other years (Kustudija, 2012). U.S. sorghum exports to Morocco also have been erratic with notable shipments occurring only in 2009/10 and 2010/11. Notable shipments to Saudi Arabia occurred only in 2008/09 (Bryant Christie, Inc., 2013). These countries may have future potential but currently are facing infrastructural issues and policy issues which lead to difficulties for the expansion of imports of U.S. sorghum (Bryant Christie, Inc., 2013).

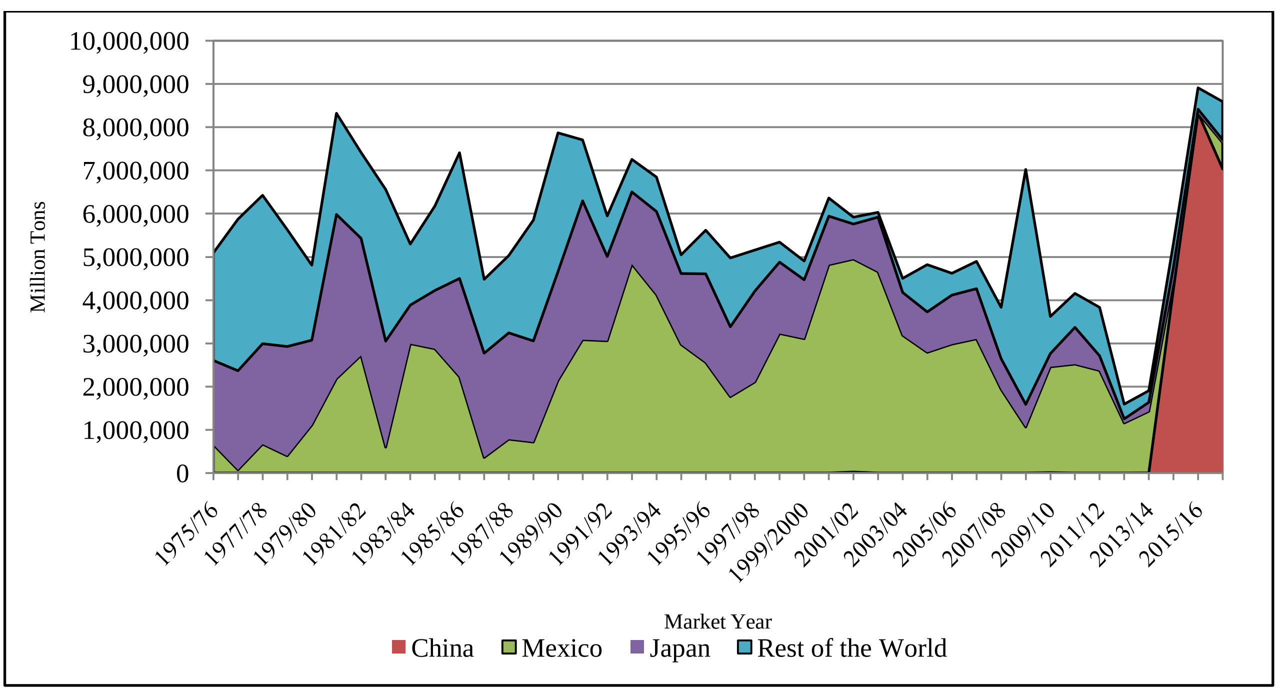
The principal rivals to the United States in terms of sorghum exports are Argentina and Australia (Figure 18). Those three countries have historically accounted for over 90% and as much as 98% of world market exports of sorghum. The United States has been the primary sorghum supplier globally, accounting for 82% of world exports in 2015/16. On average, over the period 1975/765 to 2016/17, the level of U.S. exports of sorghum was 5.6 million metric tons, while the level of sorghum exports from Argentina and Australia was 0.6 million metric tons and 1.7 million metric tons respectively. Argentina presents the largest competitive threat to U.S. sorghum exports with relatively low production costs. Argentina dominates the South American sorghum markets and competes with the U.S. in Asian markets (notably Japan) and in the European Union (EU) (Bryant Christie, Inc., 2013).

On average, over the period 1975 to 2016, export prices (export unit values) of sorghum from the United States, Argentina, and Australia, were $138.60, $112.40, and $161.03 per metric ton, respectively (Figure 19). Export prices of sorghum from Australia historically have been highest followed by those of the United States. Correlations among the sorghum export prices from the United States, Argentina, and Australia ranged from 0.86 (Australia and Argentina), 0.90 (United States and Australia) to 0.96 (United States and Argentina). As such, prices from the major exporting countries of sorghum are highly correlated.

**Figure 16. U.S. Exports of Sorghum to All Countries, 1975/76 to 2016/17**

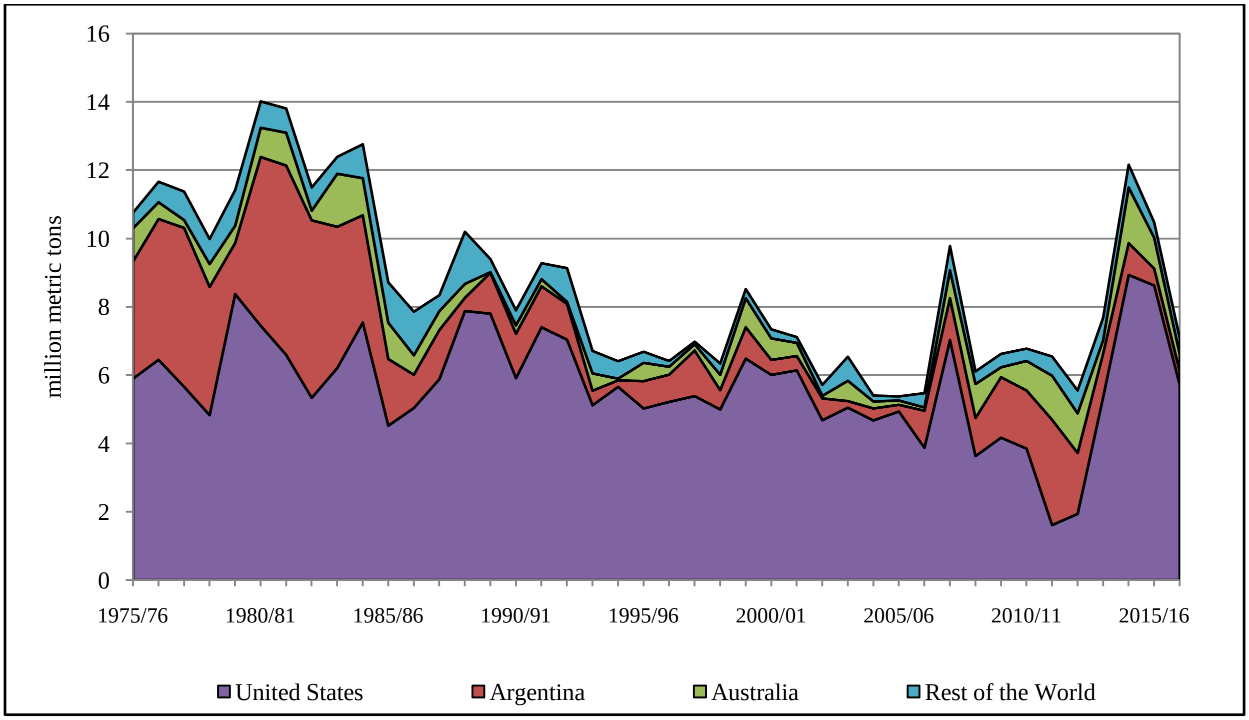

Source: USDA (2017a) and calculations by the authors.

**Figure 17:U.S. Sorghum Exports by Country, 1975/76 to 2016/17**



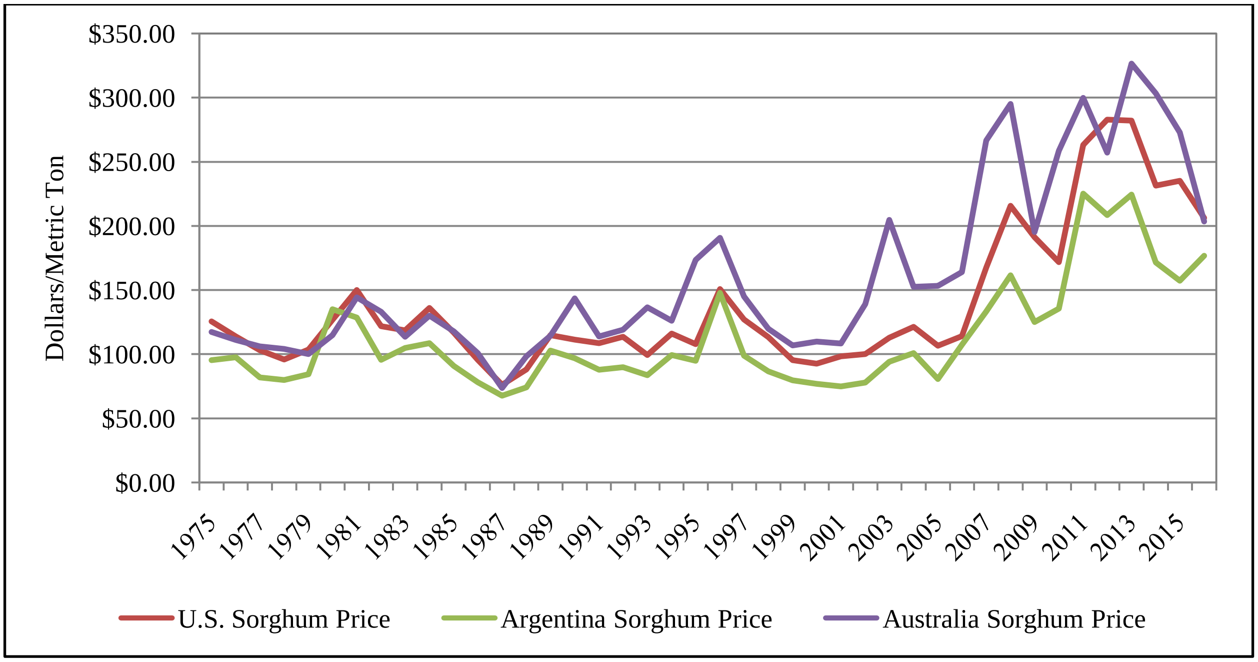

Source: USDA(2017d).

**Figure 18. World Sorghum Exports by Major Exporter, 1975/76 to 2016/17**



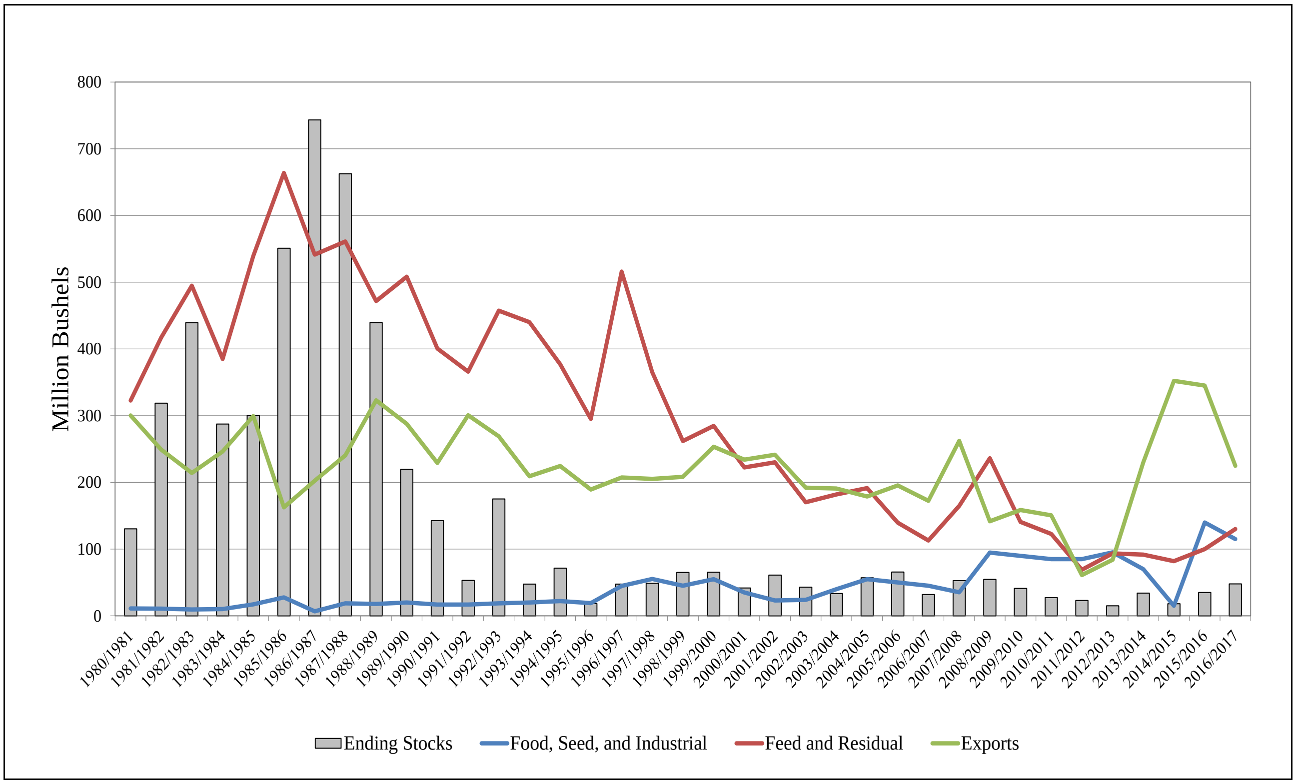

Source:USDA(2017e).

**Figure 19. Sorghum Export Prices for the United States, Argentina, and Australia, 1975 to 2016**




Source: Created from data provided by Shultz (2017).

**Figure 20. U.S. Sorghum Disappearance, 1980/81 to 2016/17**




Source: USDA (2017a).

## Strengths, Weaknesses, Opportunities, and Threats (SWOT) Facing the U.S. Sorghum Industry

Considering all the background information on the U.S. sorghum industry allow for a Strengths, Weaknesses, Threats, and Opportunities (SWOT) analysis of the industry. This analysis provides not only actionable intelligence on the industry but also critical information and context for analyzing the effects of the sorghum checkoff program.The strengths, weaknesses, opportunities, and threats identified as potentially important for the U.S. sorghum industry are enumerated in Table 3.

Overall, world per capita coarse grain consumption continues to increase. Since the 2002/2003 marketing year, per capita consumption of barley, corn, oats, and sorghum has increased from 136 kg per person per year (about 300 pounds) to 175 kg (386 pounds), a 29% increase in 15 years (Table 4). Though U.S. feed use for grain sorghum is on the decline, food, and industrial uses and exports are on the rise as mentioned previously. As a percent of total use, feed was 61% in the early 1980s, falling to 21% the last five years. Over that same period of time, food, seed, and industrial use is up from 1% to 19% and exports have grown from 37% of total use to 59% (Table 5). The ability of grain sorghum to withstand heat and drought offers production advantages in the face of

**Table 3. Potential Strengths, Weaknesses, Opportunities, and Threats Facing the U.S. Grain Sorghum Industry**

| Strengths | Weaknesses |
|---|---|
| • Demand for grain globally is increasing<br>• GMO free/Gluten free<br>• Value as a feed grain and feed stock for biofuel near that of corn<br>• Relatively low cost of production<br>• Drought and heat resistance and other Agronomic benefits<br>• Farm policy safety net | • Grain sorghum's share of coarse grain use is in decline<br>• Yield increases have fallen behind other crops<br>• Price discount relative to corn in most markets<br>• Sugarcane Aphid (SCA)<br>• Feed processing consistency |
| **Opportunities** | **Threats** |
| • Enhance value as feed grain to gain market share<br>• Increase value as a food grain in response to global food needs and consumer preferences<br>• Increase use as a feed stock for biofuel in a growing ethanol market<br>• Trade arrangements and trade policies<br>• Lower production costs<br>• Better crop adaptability to harsh environmental conditions, climate change | • Decline in planted acreage<br>• Less investment in research and product development<br>• Trade barriers and trade policies<br>• Management practices<br>• Climate change |

**Table 4. World Coarse Grain Consumption, Total and Per Capita, 2002/03 and 2017/18**

| Total and Per Capita Consumption | 2002/03 | 2017/18 | % Change |
|---|---|---|---|
| Consumption, mmt | 844 | 1,283 | +52% |
| Population, millions | 6,198 | 7,327 | +18% |
| Per Capita Consumption, kg | 136 | 175 | +29% |

Source: USDA(2017e).

**Table 5. Comparison of U.S. Grain Sorghum Use between Selected Periods**

| Uses | Average 1980/1981 to 1985/1986 | | Average 2013/2014 to 2017/2018 | |
|---|---|---|---|---|
| | Million bushels | % of total use | Million bushels | % of total use |
| Feed | 432 | 61% | 93 | 21% |
| Food, Seed, and Industrial | 10 | 1% | 87 | 19% |
| Exports | 261 | 37% | 265 | 59% |

Source: USDA (2017h).

harshgrowing environments or limited irrigation possibilities. U.S. farm policy provides an important safety net forgrain sorghum producers. Grain sorghum has a lower input cost per acre than many other cropping alternatives. As a non-GMO, gluten-free grain, sorghum is favored in markets sensitive to these issues, both domestically and abroad. As indicated previously, U.S. grain sorghum exports, particularly to China, have experienced a huge and sustained surge in recent years (Figure 20).

Grain sorghum's share of the coarse grain market is on the decline. Since 2002/2003, world and U.S. total coarse grain consumption (barley, corn, oats, and sorghum) is up 52% while world grain sorghum consumption is up 11% and U.S. grain sorghum consumption is down 20% (Table 6). The yield growth for sorghum has lagged that of other crops. At the same time, sorghum is losing acres to corn and soybeans as varieties of these crops are being adapted to drier environments. Grain sorghum trades at a price discount to corn in most markets and its lower yields and lower prices do not offer the returns to investment compared to other crops, whether for research or farm level management.

### *Strengths of the U.S. Sorghum Industry*

Sorghum benefits from a number of world trends and competitive advantages that will benefit the U.S. sorghum industry in the future, including (1) growing world food demand, (2) non-GMO and non-gluten characteristics, (3) growing livestock feed and biofuel feedstock demand, (4) relatively low cost of production, (5) drought and heat resistance, (6) agronomic benefits, and (7) farm policy safety net benefits.

*Growing World Food Demand*

Growth in world population is putting increased pressure on world agricultural productivity in the face of limited arable land and water resources. The world population in 2017 stands at 7.3 billion and is increasing by over 70 million annually, an increase of 1.1% per year (USDA ERS, 2017b). UNICEF estimates that by the end of this century, the population of Africa will grow from about 1.2 billion today to 4 billion (You, Hug, and Anthon, 2014). The population of Nigeria, one of the largest users of sorghum in the world, is expected to increase from 191.8 million in 2017 to 1 billion. To feed a global population expected to reach 9 billion by 2050, crop production will likely have to double from present levels according to recent estimates (Foley, 2014).

The world is consuming more grain per person. Since 2002/03, world per capita coarse grain use has increased from 136 kg (300 lb) per person per year to 175 kg (385.8 lb) per person per year, an increase of 29% over that 15 year period (USDA FAS, 2017b) (Figure 21). The surge in world per capita grain consumption coincides with global economic growth patterns since 2003 (Figure 22). Since that time, increasing economic growth has been driven by developing nations such as China, India, Brazil, Russia, Mexico, and Indonesia (in that order) (Figure 23). Growth in these countries, whose people strive for better living conditions and better diets, and which account for over 40% of the world population, is double the annual growth rate in the advanced economies such as Australia, France, Germany, Japan, the United Kingdom, and the United States.

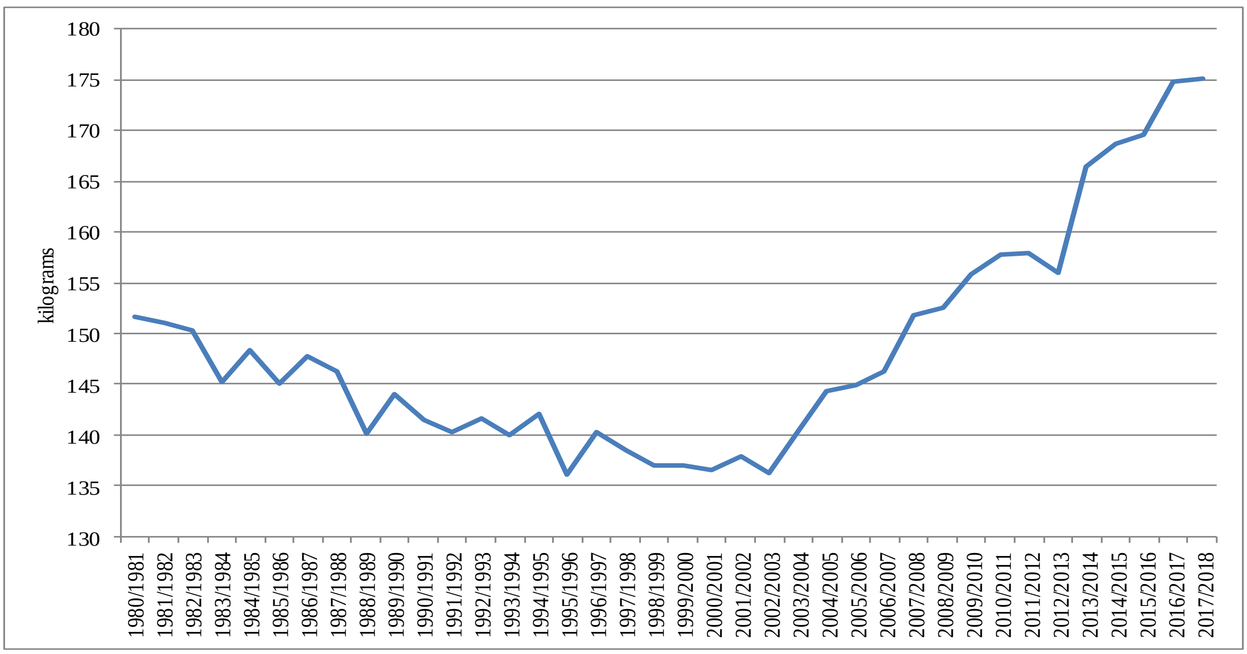
Status as a non-GMO crop also is an advantage in several major export markets. In 2007, adverse weather conditions severely affected feed grain production in Europe. Most corn varieties in the United States and Argentina were non-EU approved due to genetic modification, so feed users in

### Table 6. Coarse Grain[1] Compared to Grain Sorghum Production and Use, 2002/03 vs 2017/18

| Production and Use | Coarse Grains | | | Grain Sorghum | | |
|---|---|---|---|---|---|---|
| | 2002/2003 | 2017/2018 | % increase | 2002/2003 | 2017/2018 | % increase |
| World Production | 818 | 1,253 | +53% | 54 | 59 | +10% |
| World Use | 844 | 1,283 | +52% | 60 | 63 | +11% |
| U.S. Production | 244 | 370 | +52% | 9 | 8 | -8% |
| U.S. Use | 214 | 326 | +52% | 5 | 4 | -20% |

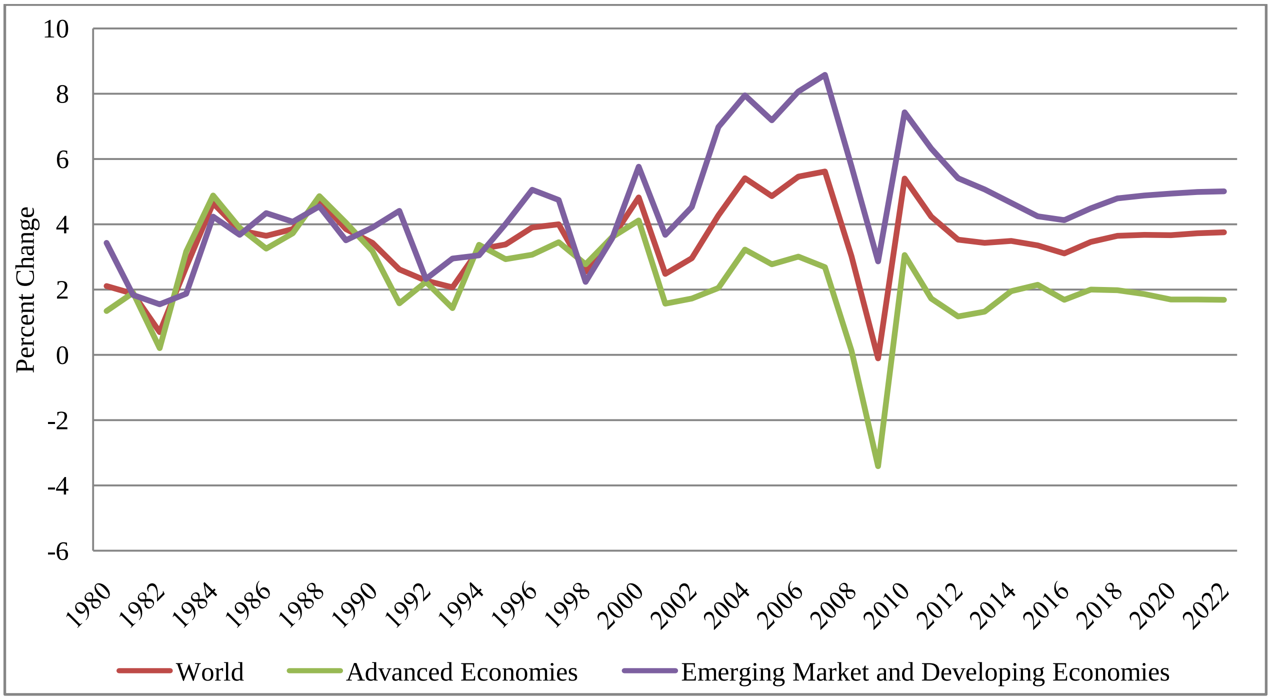
[1] Barley, Corn, Oats, and Sorghum
Source: USDA (2017e).

### Figure 21. World Per Capita Coarse Grain[1] Consumption, 1980/81 to 2016/17



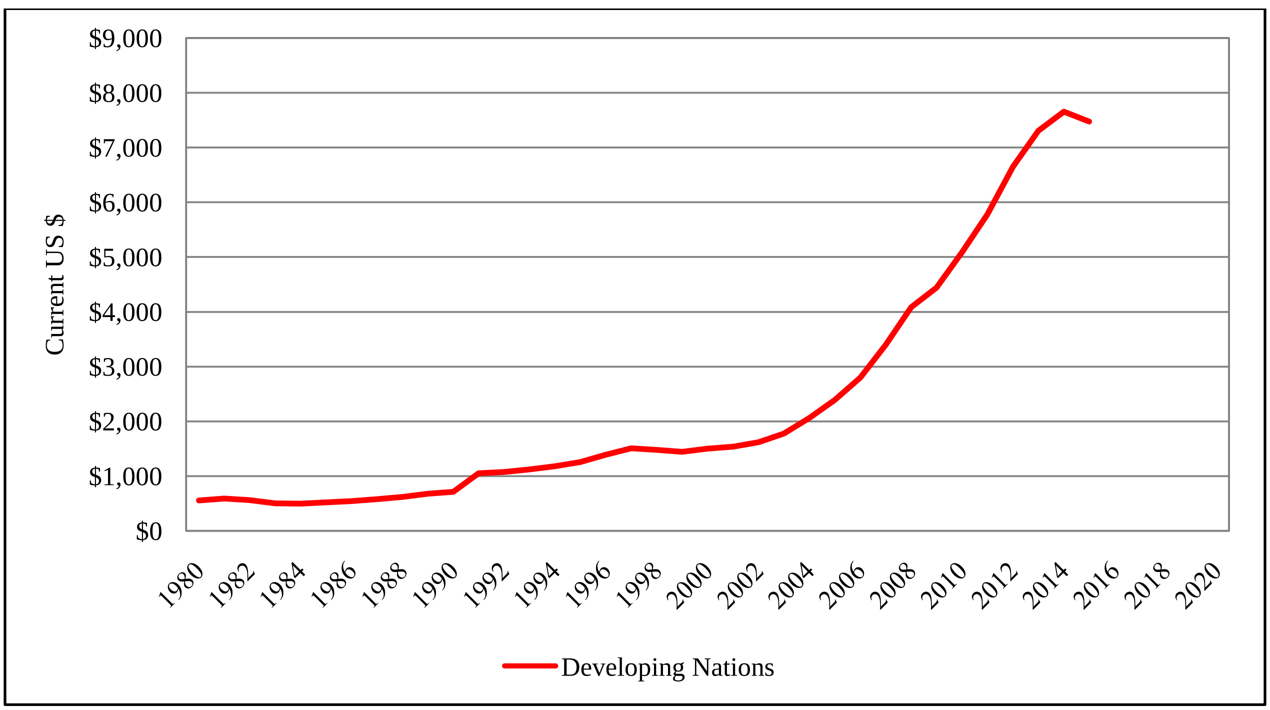

[1] Barley, Corn, Oats, Sorghum
Source: USDA 2017(e).

**Figure 22. Global Economic Growth (Real GDP), Advanced vs Emerging Economies, 1980 to 2022**




Source: IMF (2017).

**Figure 23.Weighted Average Income of Developing Countries: China, India, Brazil, Russia, Mexico, Indonesia, 1980 to 2020**




Source: World Bank(2016).

Europe turned to imports of certified biotech-free corn from Brazil and non-GMO grain sorghum from theUnited States. Their sorghum imports increased from 653,000 tons in marketing year 2006/07 to 4.5 mmt in 2007/08 (USDA, GAIN Report, 2008). In 2013, China rejected U.S. corn imports due to the presence of non-approved biotech traits. Again, grain users turned to grain sorghum as a cost effective alternative. Marketing year imports of grain sorghum increased from 500,000 tons in 2013/14 to 3.5 mmt in 2014/15 (USDA, GAIN Report, 2014).

*Non-GMO, Gluten-Free Characteristics*

Non-genetically modified and gluten-free, sorghum has particular appeal to consumers and markets with sensitivity to these issues. The market for food that excludes genetically modified or genetically engineered seeds is expanding, both in organic and conventionally grown cropping systems (Greene, Wechsler, Adalja, and Hanson, 2016). Almost a third of adults in the United States (29%) say they want to cut down on the gluten they eat or consume a gluten-free diet (Hellmich, 2013). A study of advertisements of new food and beverage products in the United States found that in 2009, 1,121 newproducts claimed to be gluten-free and 297 claimed to be GMO-free.By 2016, that number had grown to 6,123 new gluten-free products and 3,732 new GMO-free products (USDA-ERS, 2017c).

*Feed Grain and Biofuel Feed Stock Demand*

Processed grain sorghum as a livestock feed is at a slight disadvantage to corn but the difference is very small, depending on the form of processing. Studies of dried distillers' grain (DDG) resulted in no significant differences between corn and grain sorghum (Brouk, 2012). The yield of ethanol and DDGS from a bushel of grain sorghum are on par with that of corn (Kansas Grain Sorghum, 2017). Sweet sorghum grown for biofuel production can produce high biomass yields with relatively low rates of nitrogen fertilizer (Stevens, 2014).

*Relatively Low Cost of Production*

The cost per acre to grow grain sorghum is less than that of corn due primarily to lower seed and fertilizer costs. To illustrate, for average yields in North Central Kansas in 2017, direct (variable) costs per acre for corn are $316 per acre compared to $248 per acre for grain sorghum. Projected returns above direct expenses were $50.12 per acre for corn and $72.24 per acre for grain sorghum (Ibendahl, O'Brien, and Duncan, 2016). In the Coastal Bend region of Texas, variable costs for corn in 2017 are projected at $323 per acre compared to $260 per acre for grain sorghum. Projected returns are $54.35 per acre for corn and $77.09 for grain sorghum (Texas AgriLife Extension, 2017).

*Drought and Heat Resistance and Other Agronomic Benefits*

Grain sorghum is often grown in areas prone to water and heat stress. A study of corn and grain sorghum trials across Kansas and Nebraska found that in areas where corn yields are 100 bushels per acre or less, drought and temperature tolerance of grain sorghum provides a production advantage over corn (Staggenborg, Dhuyvetter, and Gordon, 2008).

In terms of water efficiency, from 2005 to 2011 in the Texas Panhandle, grain sorghum yielded 17.4 bushels per acre inch of water (irrigation plus rainfall) compared to 13.8 bushels for corn; profit per inch of water was $37.80 for grain sorghum, $31.80 for corn (TAWC, 2013).

In addition, the benefits of grain sorghum in rotation with other crops maintains soil productivity, improves soil moisture, and reduces the incidence of pests and disease, and helps with weed control and resistance management, especially for cotton (Lemon, 2009 and Godfrey et al., 2015).

*Farm Policy Safety Net*

The Agricultural Act of 2014 established two commodity programs that serve as an important safety net for crops: (1) Price Loss Coverage (PLC) and (2) Agricultural Risk Coverage (ARC). PLC pays on base acres if the national marketing year average price falls below the reference price. The reference price for grain sorghum in the 2014 farm bill is $3.95 per bushel. The reference price is lower for corn at $3.70 per bushel.

ARC is more similar to the old ACRE program. It pays on base acres if actual revenue falls below a guaranteed level of revenue. This benchmark is based on a five-year Olympic average (high and low values excluded) of county yields and national marketing year average prices. During the debate on the farm bill, ARC was referred to as a program protecting against shallow losses and PLC as a program to protect against deep losses (Outlaw, 2014).

PLC participants are able to add the Supplemental Coverage Option (SCO) to their crop insurance coverage. SCO is a crop insurance product that provides county level coverage for insured losses (yield or revenue depending on the underlying insurance product purchased) from 86% down to the coverage level of the underlying policy. The SCO program can be of significant benefit to crop producers in high-risk production areas, a condition facing many U.S. grain sorghum producers. SCO will make affordable levels of insurance coverage for high-risk sorghum growers similar to that enjoyed by relatively low risk corn and soybean producers. Grain sorghum PLC enrollment as a percent of base acres is 66% nationwide, 54% in Kansas and 94% in Texas.

## ***Weaknesses of the U.S. Sorghum Industry***

Despite its various strengths, the U.S. sorghum industry also has a number of weakness that affect the markets and competitiveness of the U.S. sorghum industry, including: (1) a declining share of coarse grain consumption, (2) lower yield gains, (3) price discounts relative to corn, (4) effects of sugarcane aphids, and (5) feed processing consistency issues.

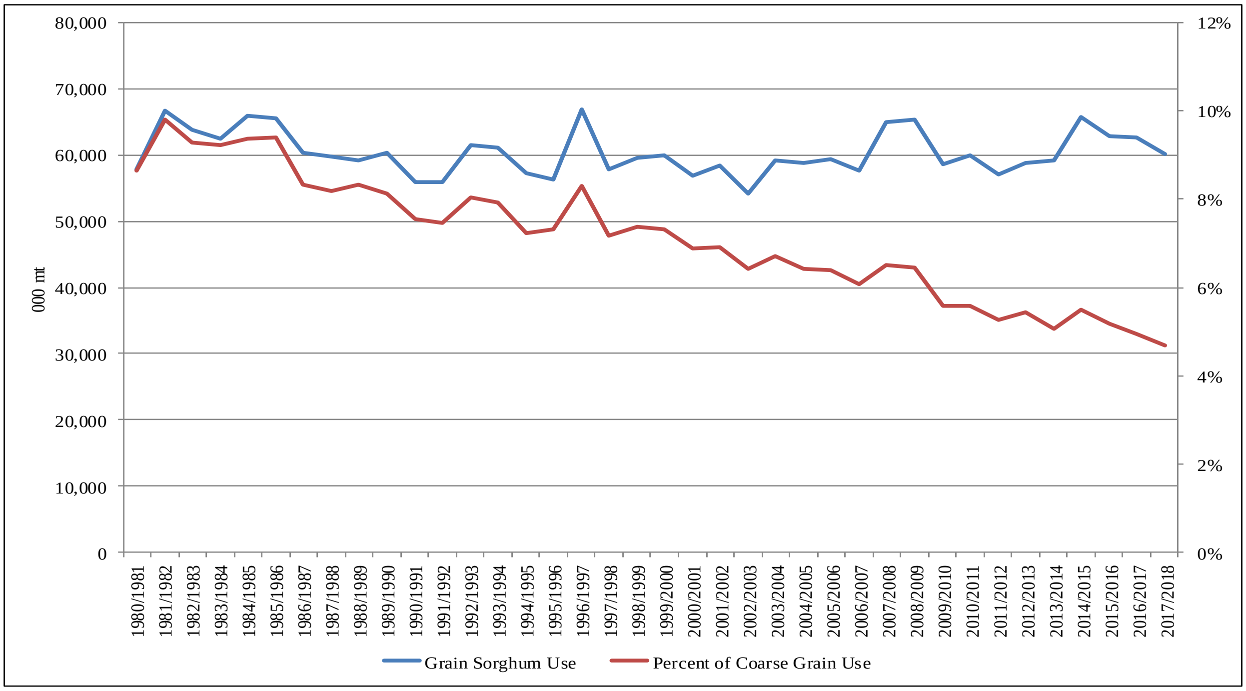
*Declining Share of Coarse Grain Consumption*

Global consumption of grain sorghum is basically unchanged since 1980 at about 60 million metric tons (2.362 billion bushels). As a result, the sorghum share of world coarse grain consumption has fallen from 10% to 5% since 1980 (Figure 24).

*Yield Gains for Grain Sorghum Less than Competing Crops*

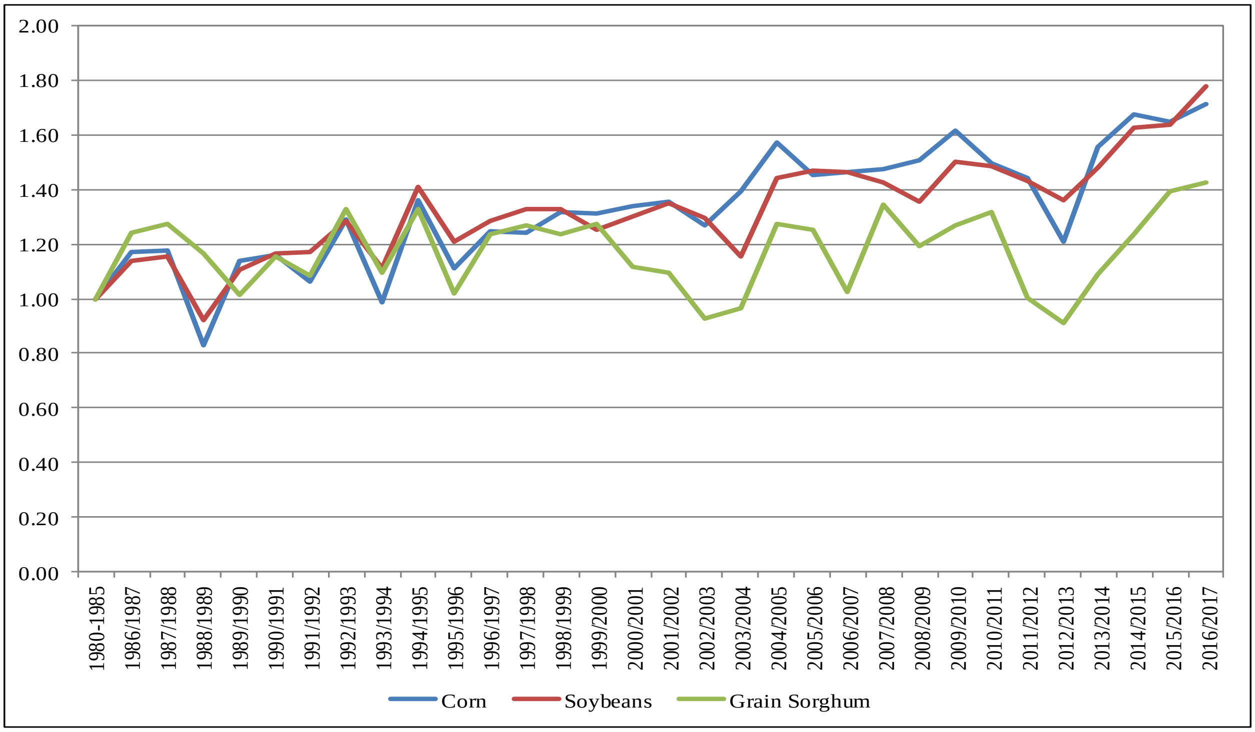
The gains in productivity for grain sorghum have lagged those of competing crops. Since the early 1980s, U.S. corn and soybean yields have increased over 70%, while grain sorghum yields are up about 40% (Figure 25).

## Figure 24.World Grain Sorghum Consumption, 1980/81 to 2016/17




Source: USDA (2017e).

## Figure 25.Corn, Soybean, and Sorghum Yield Index (1980/81-1985/86 base), 1986/87 to 2016/17




Source: Calculated by authors from data in USDA (2017a).

### *Opportunities for the U.S. Sorghum Industry*

Several opportunities provide the basis for optimism about the future of the U.S. sorghum industry, including: (1) growing feed demand, (2) growing food demand, (3) growing fuel demand, (4) export market potential, (5) lower production costs, and (6) suitability for harsh production environments.

*Increased Feed Demand*

The market for energy feed is increasing. Grain Consuming Animal Units (GCAU) are at an all-time record high and energy feed per GCAU is up 11% since 2012, the year of all-time record high grain prices (Figure 26). Research confirming and enhancing the value of grain sorghum as a feed grain could increase market share for sorghum.

*Increased Food Demand*

The growing demand for food globally and the increasing consumer preference for non-GMO, gluten-free products offer opportunities for sorghum to become a larger contributor to world food consumption.

*Increased Fuel Demand*

The U.S. ethanol industry continues to grow with production increasing 5% this year (Figure 27). This provides an opportunity for grain sorghum to capture a larger share of this market, both as a grain and a forage-based biofuel feedstock.

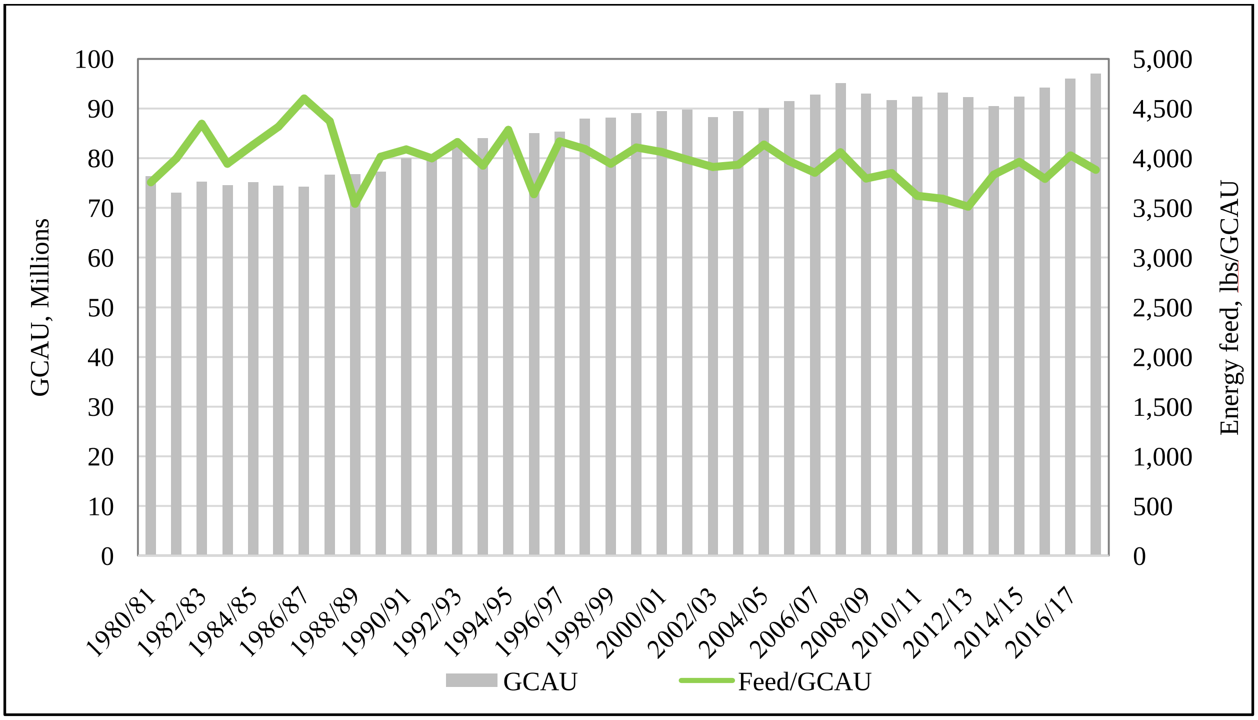
*Export Potential*

Historically, Mexico and Japan have been the major importing countries of U.S. grain sorghum. Between 1980/81 and 2013/14, exports to these two destinations accounted for an average of 76% of the total value of U.S. grain sorghum exports. Grain sorghum has emerged as a favored feed and food grain in foreign markets where GMO is a concern or trade barriers exist for other commodities. Exports to Europe in 2007/08 and 2008/09 captured most of the export value in response to a short feed grain crop in those years and a preference for non-GMO feed grain. More recently, China has become the major buyer of U.S. sorghum due to sales cancellations of U.S. corn when unapproved genetic traits were discovered. In addition, even though China now holds abundant stocks of surplus corn, the absence of a tariff rate quota system for grain sorghum means that grain sorghum can be bought on the world market more cheaply than corn sourced domestically. China is now the numberone buyer of U.S. grain sorghum. Over the last three years China has accounted for 87% of exports for an average value of $1.469 billion (Figure 28).

*Lower Production Costs*

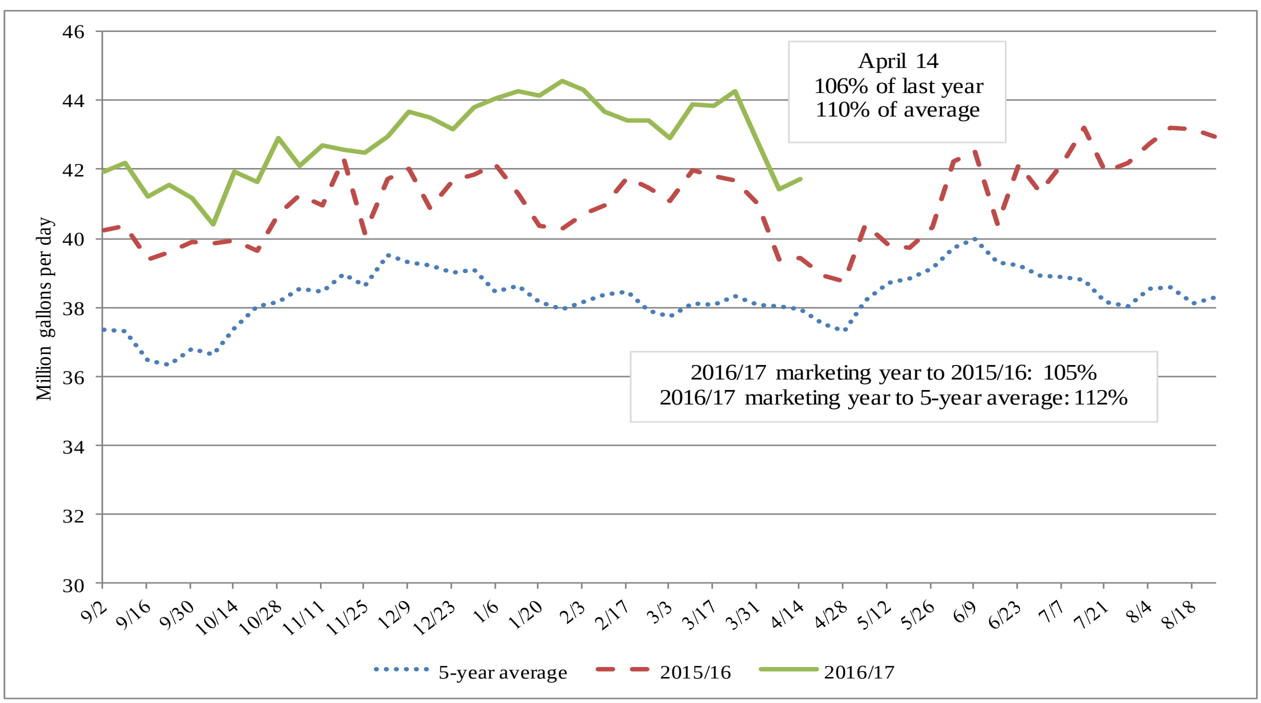
In an economic climate of low commodity prices and tight margins, many producers are struggling to obtain the credit they need to operate their farms and ranches. Grain sorghum has a low input cost per acre so a producer choosing between corn and sorghum could either: (1) plant the same number of acres to sorghum that would have been planted to corn and lower total expenses or (2) plant up to the total line of credit and plant more acres to sorghum than could have been planted to corn. Option one canresult in smaller net profit but considerably less financial risk. Option 2 may produce less income per acre but greater overall farm revenue (Tables7 and 8).

**Figure 26. Grain Consuming Animal Units and Energy Feed Use, 1980/81 to 2016/17**



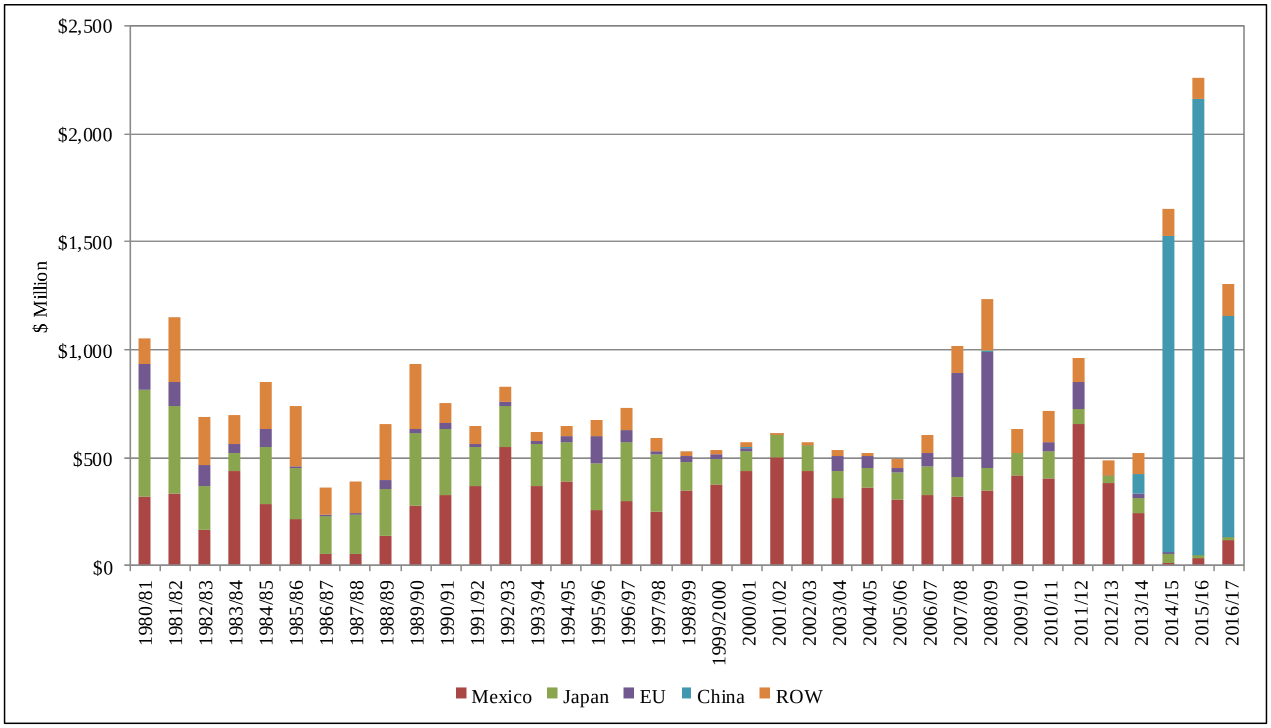

Source: USDA (2017a).

**Figure 27. Weekly U.S. Ethanol Production, 2015/16 to 2016/17**




Source: USDE (2017) and USDA (2017i).

**Figure 28.Total Value of U.S. Grain Sorghum Exports by Destination, 1980/81 to 2016/17**




Source: USDA (2017d).

**Table 7. Net Profit from Corn and Grain Sorghum with $500,000 operating note, Option 1**

| Crop | Expense per acre | Acres | Total Expenses | Yield | Price/bu | Income per acre | Total Income | Net Profit |
|---|---|---|---|---|---|---|---|---|
| Corn | $326 | 1,533 | $499,758 | 100 | $3.80 | $380 | $582,540 | $82,782 |
| Sorghum | $260 | 1,533 | $398,580 | 90 | $3.40 | $306 | $469,098 | $70,518 |
| Sorghum minus Corn | ($66) | 0 | ($101,178) | (10) | ($0.40) | ($74) | ($113,442) | ($12,264) |
| Sorghum as % of Corn | 80% | 100% | 80% | 90% | 89% | 81% | 81% | 85% |

Source: Texas A&M AgriLife Extension (2017).

**Table 8. Net Profit from Corn and Grain Sorghum with $500,000 operating note, Option 2**

| Crop | Expense per acre | Acres | Total Expenses | Yield | Price/bu | Income per acre | Total Income | Net Profit |
|---|---|---|---|---|---|---|---|---|
| Corn | $326 | 1,533 | $499,758 | 100 | $3.80 | $380 | $582,540 | $82,782 |
| Sorghum | $260 | 1,920 | $499,200 | 90 | $3.40 | $306 | $587,520 | $88,320 |
| Sorghum minus Corn | ($66) | 387 | ($558) | (10) | ($0.40) | ($74) | $4,980 | $5,538 |
| Sorghum as % of Corn | 80% | 125% | 100% | 90% | 89% | 81% | 101% | 107% |

Source: Texas A&M AgriLife Extension (2017).

*Better Suited to Harsh Growing Environmental Conditions*

Grain sorghum's adaptability to hotter and drier growing conditions makes it a less risky enterprise choice in areas where these conditions are more likely. The agricultural risk from global climate change comes from a hotter climate, altered precipitation amounts, altered precipitation intensity, and higher sea levels (McCarl, 2008). But this risk varies regionally as overall climate change would likely be beneficial to crop production in some areas but cause declines in others. The regions at greatest risk are closer to the equator, specifically the Southern Regions of the United States (McCarl, 2006).

The impacts of climate change on corn and grain sorghum are similar in that yields decline when precipitation declines and/or temperature increases. The differences being that with rising temperatures, corn yields become more variable and grain sorghum less variable, demonstrating sorghum's adaptability to warmer growing conditions (Chen, McCarl, Schimmelpfennig, 2004).

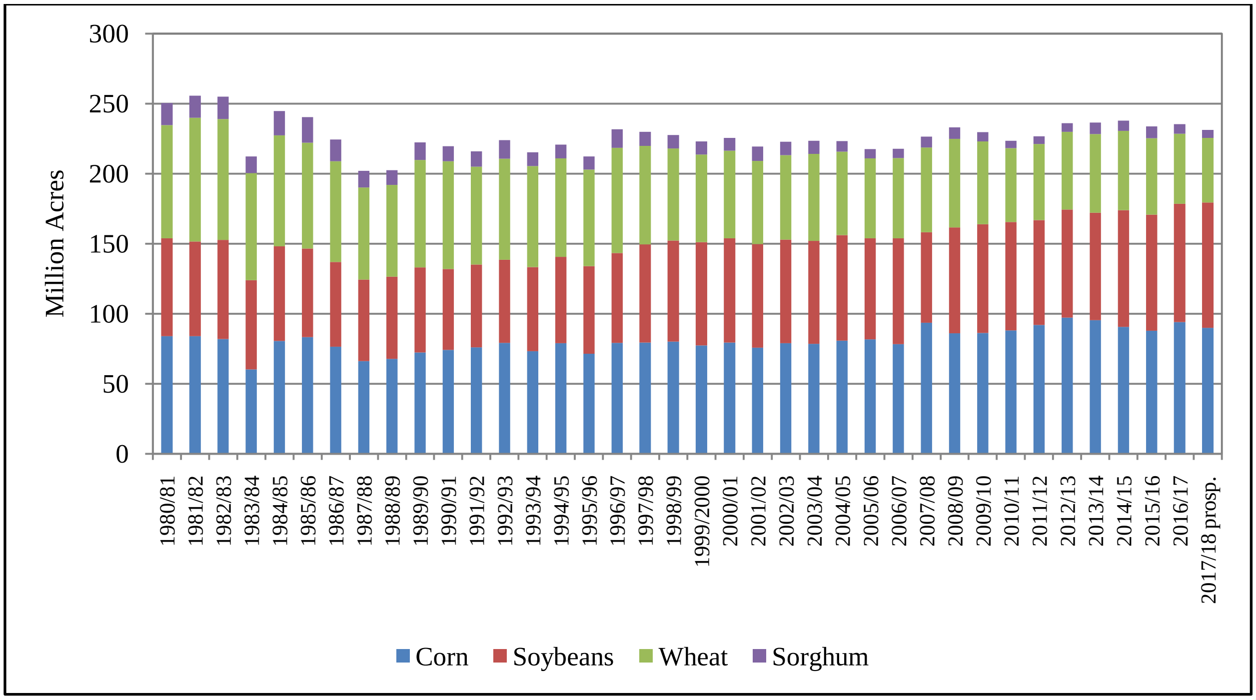
### *Threats Facing the U.S. Sorghum Industry*

Despite the opportunities facing the U.S. sorghum industry, a number of threats exist that will challenge the industry's resilience and growth potential, including: (1) declining crop area;(2) lack of research investment; (3) increasing dependence of exports on fewer buyers; (4) relative difficulty of management practices; (5) climate change; and (6) trade barriers and policy.

*Declining Crop Area*

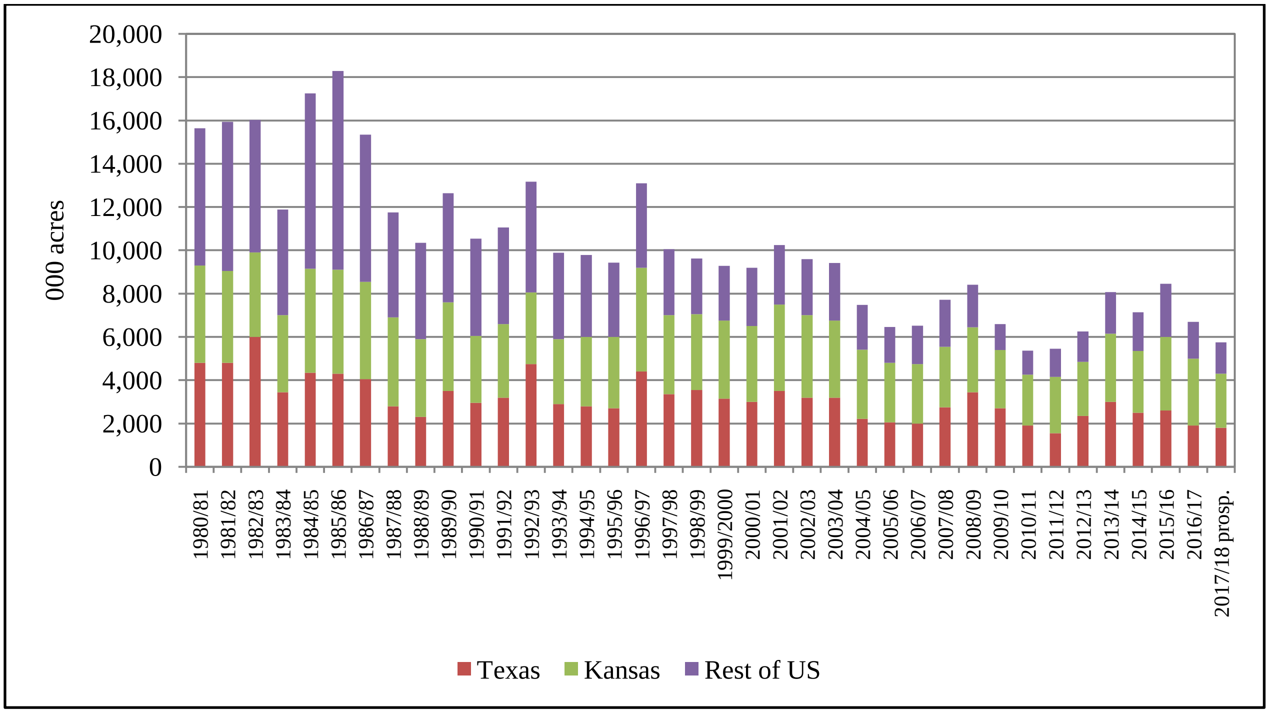
With a slower rate of yield increase compared to corn and soybeans and a price discount relative to corn, grain sorghum planted acres are on the decline (Figure 29). Since 1980, U.S. corn acres are up 6 million (+7%), soybean acres up 20 million (+28%), and grain sorghum acres are down 10 million (-63%). In the top two producing states, Kansas and Texas, plantings are down from 10 million acres to about 4 million (Figure 30).

**Figure 29.U.S. Corn, Soybeans, Wheat, and Grain Sorghum Planted Acres, 1980/81 to 2016/17**




Source: USDA (2017a).

**Figure 30. U.S. Grain Sorghum Acres, 1980/81 to 2016/17**




Source: USDA (2017g).

*Lack of Research Investment*

With relatively low acreage and per acre revenue, grain sorghum does not get as much investment as other crops for variety development, disease and pest resistance, new pesticides, andother traits that increase productivity or consumer demand. Dekalb is one of the top grain sorghum varieties in the United States with yield performance in Kansas in 2016 at the top in 8 out of 10 dryland field trials andthe top of all three irrigated trials (Kansas State University Agricultural Experiment Station, 2017). Dekalb is owned by Monsanto had net sales of $9.988 billion for seed traits in 2016 (Monsanto, 2016). About 80% or $7.987 billion came from the sale of corn and soybean traits with cotton and vegetable seeds accounting for 12% or $1.241 billion. All other crop seeds and traits (e.g. alfalfa, canola, sugar beets, and sorghum) had net sales of $760 million or 8%.

*Increasing Export Dependence on Fewer Buyers*

Exports are the number one use category for U.S. grain sorghum. The top two customers are China and Mexico. Any issues that result in a breakdown of trade relations or the imposition of trade barriers to these two countries would have a significant impact on the U.S. grain sorghum market. The increasing dependence of exports on these two markets makes U.S. sorghum markets increasingly vulnerable to even small shifts in policy in only two countries. The highly variable nature of Chinese production and buying strategies as well as farm policies over the years interjects substantial uncertainty into sorghum export forecasts.

*Relative Difficulty of Sorghum Management Practices*

Grain sorghum has a lower cost of production per acre than many other crop alternatives. Being non-GMO, grain sorghum does not have built-in resistance to many pests. Also, weed control options are either more limited or more costly. Critical points in the growing season can require daily scouting to monitor insect pests.Disease outbreaks can severely reduce yields if left untreated. Unfortunately, herbicide options are limited for post-emergence weed control (Trostle and Fromme, 2010). Diligence above that required for many genetically modified crops is required to make timely, efficient, and economically viable crop management decisions.

*Climate Change*

The impacts of climate change, while perhaps less detrimental to grain sorghum production than other crops,will still be significant, including potentially lower yields, increased water requirements, and increased pressure from weeds, pests, and fungi that thrive in warmer environments (Melillo, Richmond, and Yohe, 2017).

## ***SWOT Summary and Conclusions***

An overview of strengths, weaknesses, opportunities, and threats facing the U.S. grain sorghum industry reveals areas of strategic importance:

*Supply Issues*

<u>Productivity</u>

- Yield increases are necessary to keep up with increasing demand given land area constraints, to make grain sorghum returns more competitive with alternative crops.
- Varieties with characteristics such as drought tolerance and disease and pest resistance are increasingly important in the face of climate change. Biotech or genetically-modified grain

sorghum strains may play a role in this effort. However, product introduction must match consumer acceptance.
- Management tools, decision aids, economic thresholds for management decisions are important to support growers in their ability to increase profitability from grain sorghum production.

*Demand Issues*

Product Development
- Investment is needed in new uses or processes for grain sorghum in all major consumption categories: feed, food, fuel, and industrial use. These are all growing markets, and grain sorghum has the characteristics to make a notable contribution.
- Advances in grain sorghum product development have the potential to close the price differential between grain sorghum and corn, adding to crop profitability.

Trade
- Exports are the number one use of U.S. grain sorghum currently.
- Product development and trait enhancement have the opportunity to increase the global demand for grain sorghum.
- Trade agreements and trade policies that support market access and the elimination of trade barriers are particularly important for grain sorghum.

## ANALYSIS OF THE IMPACTS AND RETURNS FROM USCP ACTIVITIES

In this section, two sets of analyses of the impacts of sorghum checkoff program expenditures (funds committed by USCP) are conducted: (1) analysis of the impact of sorghum checkoff expenditures for crop improvement (research) on sorghum acres planted, yields, and consequently production and (2) analysis of the impact of sorghum checkoff expenditures intended to boost the various uses (demand) for U.S. sorghum. The analyses include calculations of the returns to producers from the respective expenditures using benefit-cost analysis.

The first analysis is designed to determine whether or not USCP program expenditures over the years effectively led to increases in sorghum production. The second set of analyses is designed to determine whether the sorghum checkoff program shifted out the demand for sorghum by enhancing any of the various uses of sorghum. If the answer to those questions is "yes," then the next question is whether or not any increase in sorghum production or increase in demand achieved through the checkoff program actually generated benefits to those who have contributed to the program. Obviously, if the answer to the first questions is "no," then the answer to the second question is "no" as well. However, if the answer to the first questions is "yes," then answer to the second is not necessarily "yes" because any consequent increase in revenues to the contributors may or may not be sufficient to cover the cost to them of USCP programmatic activities.

To measure the returns to USCP program expenditures, the first step is to isolate the effects of those investments in domestic and international markets from those of other events that may have affected those markets over the years. For this purpose, checkoff expenditures over the years must be incorporated into appropriate structural models of domestic and international sorghum markets. These models then are simulated over the historical period under alternative assumptions regarding sorghum checkoff expenditure levels. The results are used subsequently to calculate benefit-cost ratios. We pioneered this cutting edge evaluation procedure and have used this evaluation procedure in our various other checkoff program analyses including those for soybeans, pork, cotton, and dairy, lamb, orange juice, cotton, and many others.

The use of the aforementioned structural or econometric models generates a baseline simulation of the various key endogenous or dependent variables (domestic sorghum production; domestic uses of sorghum; exports of sorghum to various foreign countries; and grower prices of sorghum). Because the programmatic expenditures made by USCP are set to their actual or historical values, the baseline simulation represents the *"With Expenditures" scenario.*Subsequently, these expenditures are set to zero and the simulation is conducted again over the relevant time period to generate the *"Without Expenditures" scenario*results for the respective key variables in the structural models. These results then provide a measure of what the levels of production, prices, domestic uses, and exports would have been in the absence of the marketing activities of the USCP Board.

Differences in the solution values of the key variables in the *"Without Expenditures"scenario* (sometimes referred to as the "counterfactual" scenario) from their baseline solution values (the *"With Expenditures scenario"*) consequently are direct measures of the effects of the programmatic activities of the USCP board over time. Because no other exogenous or predetermined variables in the simulation model are allowed to change, this process effectively isolates the impacts of the checkoff program activities associated with the USCP board on production, domestic uses, exports, and prices of sorghum. Therefore, our study indeed presents econometric evaluations of the impacts of USCP market development and promotion, information, and research activities that ultimately lead to the calculations of the returns to producer investments associated with the programmatic activities of USCP.

All models are estimated using sorghum checkoff program expenditure data made available by the USCP.Those expenditures fall into three program areas: (1) research (crop improvement), (2) market development (high value markets, renewables, and exports), and (3) promotion, and information, communication, and education. Data required for this analysis relating to sorghum markets, such as grower prices, production, yields, and planted and harvested acreage, are publicly available from the U.S. Department of Agriculture, National Agricultural Statistics Service (USDA, NASS). Sorghum export data are published by the Foreign Agricultural Service (FAS) of the U.S. Department of Agriculture and gathered by the U.S. Department of Commerce.Other data required for the analysis such as inflation, gross domestic incomes of foreign countries, and exchange rates are publicly available from various U.S. government agencies.

### Impactsand Returns from USCP Crop Improvement Research Expenditures

Checkoff expenditures for agricultural research (crop improvement) are intended to shift out the supply of U.S. sorghum by increasing production efficiency (yield) and/or by reducing production costs. Typically, agricultural research expenditures that reduce production costs would be expected to lead to an expansion in acreage dedicated to sorghum production. On the other hand, agricultural research expenditures that increase production efficiency would be expected to increase production yields, that is, the output per acre in production. Since production is the product of harvested acreage and yield, successful agricultural research of either type would tend to increase output.

The effects of investments in research on the market supply of a commodity like sorghum however, are often not immediate, measureable, or direct. Research investments may fund either basic, long-term types of research or more applied, short-term types of research. Because the lag between research activities, particularly basic research, and the commercialization of new technologies available for adoption by sorghum producers may be quite lengthy, the full market impacts and any benefits of checkoff-funded research to sorghum producers may not be felt for a long time following the research investment.

Also, research investments may not always result in measurable market impacts. For example, basic or applied research that provides knowledge about what does *not* work in increasing yields or reducing costs has value but is not measurable in terms of market impacts. At the same time, applied research often is related to or depends on previous investments in basic research. Consequently, investments in basic research may have only indirect market effects to the extent that the results of that research lead to more applied research to develop new technologies. An added complication is the difficulty of obtaining the necessary data over a sufficiently long enough period of time to be able to statistically identify the relations between research and production. Thus, it may not be possible to quantify accurately the total effectiveness of sorghum checkoff research expenditures on the sorghum industry given that the program has been in existence only 9 years. We address these issues in our analysis of checkoff expenditures on agricultural research.

### *Specification of the Supply Model*

Major contributions to both the theory and measurement of the returns to producers from investments in agricultural research have been made by a variety of researchers (see, for example, Schultz, 1953; Griliches, 1958; Evenson, 1967; Peterson, 1967; Fox, 1985; Pardey and Craig, 1989; Chavas and Cox, 1992; and Williams, Shumway, and Love, 2002). A number of commodities have been analyzed, including corn, cotton, poultry, rice, rapeseed, wheat, wool, and soybeans. The reality is that little research is available on the returns and supply effects of either public or private investments in sorghum research.

The economic relationships between sorghum checkoff-funded agricultural research expenditures and sorghum planted or harvested acreage and yield are measured using econometric analysis. Crop year data on planted acreage, harvested acreage and yield are available back to marketing years 1960/61. But data on USCP crop improvement activities are available only from 2008/09. We assume zero committed funds in crop improvement programs, prior to 2008/09, although we recognize that this assumption may not be tenable. Simply put, data on crop improvement activities prior to the establishment of USCP(state-funded activities) were not available.

Agricultural research expenditures, defined as expenditures on crop improvement, may affect planted acreage and yields and, therefore, production. The economic relationship between sorghum checkoff-funded agricultural crop improvement or research expenditures and sorghum planted and harvested acreage and yield is measured with the use of econometric analysis.We implement, where necessary, a polynomial distributed lag (PDL) formulation to account for the potential carryover effects of agricultural research expenditures on planted acreage and on yields. Otherwise, funds committed by USCP are contemporaneously related to planted acreage and yields. In particular, we specify planted acreage in the current period to be a function of several variables: (1) prices of sorghum and corn received by producers in the previous year; (2) a one-year lag of planted acreage; and (3) a PDL formulation or contemporaneous formulation of the funds committed to crop improvement activities by USCP. In the analysis of checkoff expenditure impacts on sorghum yield, yield in the current period is specified to be a function of: (1) weather effects, with the use of

ElNiño and LaNiña proxy variables; (2) technological developments with the use of trend variables as proxies; and (3) a PDL formulation or contemporaneous formulation of crop improvement expenditures made by USCP. We use a natural logarithmic transformation of the variables in each equation which allows us to account for the diminishing returns to promotion expenditures as is commonly done in checkoff program evaluation studies. Various lag lengths are considered with the optimal lag lengths chosen based on statistical criteria, namely the Schwarz Information Criterion (SIC), the Akaike Information Criterion (AIC), and the Hannan-Quinn Criterion (HQC).

Separate single-equation models are specified for U.S. sorghum planted acreage, U.S. sorghum harvested acreage, and U.S. sorghum yield.The data for this analysis cover the marketing years 1960/61 through 2016/17. Agricultural research expenditures finance projects intended primarily to enhance sorghum yield and quality, improving sorghum's resistance to temperature extremes and to insects and diseases, advances in biotechnology, reduced dependence on pesticides, and profitable conservation tillage practices. Agricultural research expenditures that reduce production costs would be expected to give rise to expanding acreage dedicated to sorghum production.

The logarithm of planted acreage is specified to be a function of several variables: (1) the logarithm of the ratio of sorghum farm prices to corn prices in the previous year; (2) a one-year lag of the logarithm of planted acreage; and (3) the logarithm of USCP funds committed to crop improvement. Additionally, we capture other factors affecting yields through the use of a trend variable and indicator variables representing qualitative events in 1961, 1971, 1983, 1984, 1985, 1987, 1996, 2010, and 2013. Further, we estimate the relationship between acres harvested and acres planted. This relationship is important in establishing the impact of changes in harvested acreage attributed to USCP crop improvement activities.

Harvested acres are specified to be a function of planted acres in a given year. For yield, the logarithm of yield in the current period is specified to be a function of: (1) weather effects, with the use of El-Niño and La-Niña as proxy variables; (2)a PDL ofthe logarithm of USCP funds (lag length of one year) committed to crop improvement; and (3) the use of trend variables and indicator variables representing qualitative events in 1980, 1983, 2002, 2003, 2006, and 2015.

Following the work of Mitchell (2009), weather effects are proxied through the occurrences of the ElNiño/LaNiña phenomena. ElNiño and LaNiña are two extreme phases of the ElNiño/Southern Oscillation (ENSO) climate cycle. ElNiño occurs when there is an irregular warming of subsurface temperatures from Peru to Ecuador to the Pacific. Over the period 1960/61 to 2016/17, major El Niño occurrences were recorded in 1972/73, 1982/83, 1997/98, 2009/10, and 2015/16 (Stormfax, 2017).

The effects of ElNiño give rise to more rain across the southern part of the United States. LaNiña events were recorded in 1964/65, 1970/71, 1973/74, 1975/76, 1988/89, 1995/96, 1998/99, 2010/11, 2011/12, and late 2016 (Stormfax, 2017). LaNiña leads to warmer conditions and less rain across the southern part of the United States. Consequently, for years in which LaNiña occurred, owing to more drought conditions, yields are expected to be lower. For years in which ElNiño occurred, yields are expected to be higher.

We may summarize the econometric specifications of the supply model as follows:

(1) $\log(\text{Planted Acreage of Sorghum}_t) = f_1(\log((\text{sorghum farm price}_{t-1}) /$

(corn farm $price_{t-1}$)), $time^2$, log (USCP_crop_improv)˙, log (Planted Acreage of $Sorghum_{t-1}$), D1961, D1983, D1984, D1985, D1996, D2010, D1971, D1987, D2013) + $v_1$

(2) Harvested Acres of Sorghum = $f_2$(Planted Acreage of Sorghum) + $v_2$

(3) log(Sorghum $Yield_t$) = $f_3$ ($LA\_NINA_t$, $EL\_NINO_t$, $time^2$, PDL log ($USCP\_crop\_improv_t$)˙, D1980, D1983, D2002, D2003, D2015, D2016) + $v_3$

(4) Sorghum Production = Harvested Acres of Sorghum * Sorghum Yield

where D1961, D1971, D1980, D1983, D1984, D1985, D1987, D1996, D2002, D2003,D2010, D2013, D2915, and D2016 are indicator variables, taking on the value of 1 for the year following the D prefix, and 0 otherwise, time is a time trend variable which takes on the values of 0,1,2, etc. The indicator variables reflect structural changes while the time trend variable is a proxy for technological innovations and other trends affecting planted acreage and yield.

To close this system, we add a model specification for the farm price of sorghum:

(5) log (sorghum farm price) = $f_4$ (log (corn farm $price_t$), log (sorghum $production_t$), log (price of no. 2 sorghum at Kansas $City_t$), PDL log (USCP_crop_improv)) + $v_4$

Corn prices are hypothesized to positively affect sorghum prices whereas sorghum production is hypothesized to be inversely related to sorghum prices. The price of no. 2 sorghum at Kansas City is hypothesized to be positively related to the farm price of sorghum. This relationship affects the price transmission process for farm prices to downstream prices in the marketing channel. This system of equations (1) through (5) can be used to captures the impacts of funds committed to USCP crop improvement activities on planted acres, harvested acres, yields, production, and farm prices.

### *Empirical Resultsfor the Supply Model*

For planted acreage (equation (1) above), the $R^2$and adjusted $R^2$ measures of goodness-of-fit are 0.95 and 0.94, respectively, which reflect that roughly 95% of the variation in the number of acres planted is accounted for by the econometric model (Table 9). The drivers of acres planted to sorghum in the United States are the ratio of the farm price of sorghum to the farm price of corn with a one-year lag, the number of acres planted in the previous year, qualitative factors occurring in various years (1961, 1983, 1984, 1985, 1986, 2010, 1971, 1987, and 2013), and a nonlinear (squared) trend. The estimated coefficient of the square of the trend variable is negative and statistically different from zero. The results indicate that if the ratio of the farm price of sorghum to the farm price of corn in the previous year changes by one percent, then the number of acres planted of sorghum changes by 0.84% in the same direction. The significance of the number of acres of sorghum planted in the previous year is indicative of inertia on the part of growers.

Of note, funds committed to crop improvement activities made by USCP are positively and contemporaneously related to acres planted to sorghum. The use of the logarithmic transformation captures diminishing marginal returns in planted acres attributed to USCP expenditures over the

**Table 9. Econometric Analysis of U.S. Sorghum Planted Acres, 1960/61 to 2016/17**

Dependent Variable: LOG(Acres Planted)

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 8.679130 | 1.670416 | 5.195788 | 0.0000 |
| Log(sorghum farm price(t-1)/corn farm price (t-1)) | 0.847371 | 0.232556 | 3.643728 | 0.0007 |
| LOG(USCP crop improv) | 0.010236 | 0.003948 | 2.592557 | 0.0131 |
| $(\text{Time Trend})^2$ | -0.000256 | 4.57E-05 | -5.601082 | 0.0000 |
| LOG(Acres Planted)(t-1) | 0.486024 | 0.099934 | 4.863425 | 0.0000 |
| D1961 | -0.210907 | 0.093728 | -2.250211 | 0.0299 |
| D1983 | -0.289338 | 0.092833 | -3.116749 | 0.0033 |
| D1984 | 0.348926 | 0.093979 | 3.712812 | 0.0006 |
| D1985 | 0.208291 | 0.093421 | 2.229610 | 0.0313 |
| D1996 | 0.249261 | 0.093238 | 2.673401 | 0.0107 |
| D2010 | -0.232663 | 0.097750 | -2.380192 | 0.0220 |
| D1971 | 0.228449 | 0.092296 | 2.475181 | 0.0175 |
| D1987 | -0.178874 | 0.091787 | -1.948792 | 0.0582 |
| D2013 | 0.265004 | 0.097673 | 2.713179 | 0.0097 |

| | | | |
|---|---|---|---|
| R-squared | 0.956486 | Mean dependent var | 16.29454 |
| Adjusted R-squared | 0.942689 | S.D. dependent var | 0.374939 |
| S.E. of regression | 0.089759 | Akaike info criterion | -1.768046 |
| Sum squared resid | 0.330324 | Schwarz criterion | -1.257088 |
| Log likelihood | 62.62126 | Hannan-Quinn criter. | -1.570454 |
| F-statistic | 69.32577 | Durbin-Watson stat | 2.279325 |
| Prob(F-statistic) | 0.000000 | | |

marketing years 2008/09 to 2015/16. The results indicate that a one percent change in funds committed to USCP crop improvement activities translates into a statistically significant 0.0102% change in the number of acres planted to sorghum. As exhibited in Table 10, this sensitivity or elasticity of planted acreage tofundscommitted to crop improvement activities means that as a result of the checkoff program roughly an additional 54,957 to 86,586 acres of sorghum were planted as a direct result of those research investments.

For sorghum harvested acreage (equation (2) above), a one-unit change in number of acres planted leads to a 0.77unit change in the number of acres harvested (Table 11). Consequently, funds committed to crop improvement activities made by USCP generated additional harvested acreage between 42,557 to 67,049 acres on average each year. Put another way, as a result of the checkoff program, planted acreage rose on average over 2008/09 to 2015/16 slightly more than one percent and harvested acreage rose slightly more than 0.9% on average each year as a result of the research activities funded by the sorghum checkoff program (see Table 10).

For sorghum yield (equation (3) above), the goodness-of-fit measure ($R^2$)is 0.77, meaning that roughly 77% of the variation in sorghum yields is explained by the model specification (Table 12). Key determinants of yield as hypothesized, were weather effects, trends (proxies for technological change), and qualitative events occurring in marketing years 1980, 1983, 2002, 2003, 2015, and 2006. The weather effects associated with La Niña reduced yields by close to 8% while the weather effects

## Table 10.Sorghum Checkoff-Funded Crop Improvement Research: Impacts and Benefit-Cost Ratio

### Impact on Planted Acres and Harvested Aces

| Year | Elasticity | Planted Acres | Incremental Planted Acres[1] | % Increase Planted Acres | Harvested Acres | Incremental Harvested Acres[2] | % Increase Harvested Acres |
|---|---|---|---|---|---|---|---|
| 2008/09 | 0.010236 | 8,404,000 | 86,023 | 1.02 | 7,312,000 | 66,613 | 0.91 |
| 2009/10 | 0.010236 | 6,599,000 | 67,547 | 1.02 | 5,502,000 | 52,306 | 0.95 |
| 2010/11 | 0.010236 | 5,369,000 | 54,957 | 1.02 | 4,806,000 | 42,557 | 0.89 |
| 2011/12 | 0.010236 | 5,451,000 | 55,796 | 1.02 | 3,945,000 | 43,207 | 1.10 |
| 2012/13 | 0.010236 | 6,259,000 | 64,067 | 1.02 | 4,995,000 | 49,611 | 0.99 |
| 2013/14 | 0.010236 | 8,076,000 | 82,666 | 1.02 | 6,585,000 | 64,014 | 0.97 |
| 2014/15 | 0.010236 | 7,138,000 | 73,065 | 1.02 | 6,401,000 | 56,579 | 0.88 |
| 2015/16 | 0.010236 | 8,459,000 | 86,586 | 1.02 | 7,851,000 | 67,049 | 0.85 |
| OVERALL | | 55,755,000 | 570,708 | 1.02 | 47,397,000 | 441,936 | 0.93 |

### Impact on Yields

| Year | Elasticity | Yield (Bushels/Acre) | Incremental Yield[3] (Bushels/Acre) |
|---|---|---|---|
| 2008/09 | -0.006790 | 65.1 | -0.4 |
| 2009/10 | -0.006790 | 69.4 | -0.5 |
| 2010/11 | -0.006790 | 71.9 | -0.5 |
| 2011/12 | -0.006790 | 54.0 | -0.4 |
| 2012/13 | -0.006790 | 49.6 | -0.3 |
| 2013/14 | -0.006790 | 59.6 | -0.4 |
| 2014/15 | -0.006790 | 67.6 | -0.5 |
| 2015/16 | -0.006790 | 76.0 | -0.5 |
| OVERALL | AVERAGE | 64.2 | -0.4 |

[1]Incremental planted acres is the product of the estimated elasticity from Table 11 times the number of planted acres.
[2]Incremental harvested acres is the product of incremental planted acres times 0.774364 from Table 9.
[3]Incremental yield is the product of the estimated elasticity from Table 10 times the yield. Note, however, the estimated elasticity is not statistically different from zero.

## Table 10. Sorghum Checkoff-Funded Crop Improvement Research: Impacts and Benefit-Cost Ratio (Continued)

### Impact on Sorghum Farm Prices

| Year | Elasticity | Actual Farm Price ($/Bushel) | Incremental Change in Farm Price[4] ($/Bushel) | Increase Farm Price (%) | Simulated Farm Price Without USCP ($/Bushel) |
|---|---|---|---|---|---|
| 2008/09 | 0.005300 | $3.20 | $0.02 | 0.53 | $3.19 |
| 2009/10 | 0.005300 | $3.22 | $0.02 | 0.53 | $3.20 |
| 2010/11 | 0.005300 | $5.02 | $0.03 | 0.53 | $4.99 |
| 2011/12 | 0.005300 | $5.99 | $0.03 | 0.53 | $5.96 |
| 2012/13 | 0.005300 | $6.33 | $0.03 | 0.53 | $6.29 |
| 2013/14 | 0.005300 | $4.28 | $0.02 | 0.53 | $4.26 |
| 2014/15 | 0.005300 | $4.03 | $0.02 | 0.53 | $4.01 |
| 2015/16 | 0.005300 | $3.31 | $0.02 | 0.53 | $3.29 |
| OVERALL | AVERAGE | $4.42 | $0.02 | 0.53 | $4.40 |

[4]The incremental change in farm price is the product of the estimated elasticity from Table 7 times actual farm price.

### Impact on Sorghum Farm Revenue

| Year | With USCP in Place Farm Revenue ($) | Without USCP in Place Farm Revenue ($) | Incremental Change in Farm Revenue ($) | Increase Farm Revenue (%) | USCP Crop Improvement ($) | Benefit-Cost Ratio |
|---|---|---|---|---|---|---|
| 2008/09 | $1,524,663,874 | $1,512,970,650 | $11,693,224 | 0.77 | $1,373,806 | 7.51 |
| 2009/10 | $1,229,520,936 | $1,219,602,907 | $9,918,029 | 0.81 | $820,534 | 11.09 |
| 2010/11 | $1,733,976,925 | $1,721,121,583 | $12,855,342 | 0.74 | $887,740 | 13.48 |
| 2011/12 | $1,276,475,760 | $1,264,331,123 | $12,144,637 | 0.95 | $1,130,698 | 9.74 |
| 2012/13 | $1,567,774,656 | $1,554,460,149 | $13,314,507 | 0.85 | $2,749,082 | 3.84 |
| 2013/14 | $1,678,969,548 | $1,665,065,608 | $13,903,940 | 0.83 | $1,415,521 | 8.82 |
| 2014/15 | $1,744,677,043 | $1,731,770,167 | $12,906,876 | 0.74 | $1,463,135 | 7.82 |
| 2015/16 | $1,974,997,560 | $1,960,977,777 | $14,019,783 | 0.71 | $689,427 | 19.34 |
| OVERALL | $12,731,056,302 | $12,630,299,964 | $100,756,338 | 0.79 | $10,529,943 | 8.57 |

## Table 10. Sorghum Checkoff-Funded Crop Improvement Research: Impacts and Benefit-Cost Ratio(Continued)

| Year | Production With USCP in Place (Bushels) | Production Without USCP in Place (Bushels) | Incremental Production Due To USCP (Bushels) | Increase Production Due to USCP (%) | Farm Revenue With USCP in Place ($) | Farm Revenue Without USCP in Place ($) | Incremental Farm Revenue Due to USCP ($) | Increase Farm Revenue Due to USCP (%) |
|---|---|---|---|---|---|---|---|---|
| 2008/09 | 476,011,200 | 474,877,340 | 1,133,860 | 0.24 | $1,524,663,874 | $1,512,970,650 | $11,693,224 | 0.77 |
| 2009/10 | 381,838,800 | 380,776,784 | 1,062,016 | 0.28 | $1,229,520,936 | $1,219,602,907 | $9,918,029 | 0.81 |
| 2010/11 | 345,551,400 | 344,817,085 | 734,315 | 0.21 | $1,733,976,925 | $1,721,121,583 | $12,855,342 | 0.74 |
| 2011/12 | 213,030,000 | 212,127,467 | 902,533 | 0.42 | $1,276,475,760 | $1,264,331,123 | $12,144,637 | 0.95 |
| 2012/13 | 247,752,000 | 246,956,809 | 795,191 | 0.32 | $1,567,774,656 | $1,554,460,149 | $13,314,507 | 0.85 |
| 2013/14 | 392,466,000 | 391,289,733 | 1,176,267 | 0.30 | $1,678,969,548 | $1,665,065,608 | $13,903,940 | 0.83 |
| 2014/15 | 432,707,600 | 431,795,003 | 912,597 | 0.21 | $1,744,677,043 | $1,731,770,167 | $12,906,876 | 0.74 |
| 2015/16 | 596,676,000 | 595,597,081 | 1,078,919 | 0.18 | $1,974,997,560 | $1,960,977,777 | $14,019,783 | 0.71 |
| OVERALL | 3,086,033,000 | 3,078,237,301 | 7,795,699 | 0.25 | $12,731,056,302 | $12,630,299,964 | $100,756,338 | 0.79 |

Note:
1. Statistically significant change in planted acreage/harvested acreage and in farm prices due to sorghum checkoff.
2. No statistically significant change in yields due to sorghum checkoff.

## Table 11. Econometric Analysis of U.S. Sorghum Harvested Acres, 1960/61 to 2016/17

Dependent Variable: Sorghum Acres Harvested

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 712687.9 | 289584.7 | 2.461069 | 0.0170 |
| Sorghum Acres Planted | 0.774364 | 0.021482 | 36.04686 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.959391 | Mean dependent var | 10578578 |
| Adjusted R-squared | 0.958653 | S.D. dependent var | 3512501. |
| S.E. of regression | 714234.6 | Akaike info | 29.83027 |
| Sum squared resid | 2.81E+13 | Schwarz criterion | 29.90195 |
| Log likelihood | -848.1626 | Hannan-Quinn crit. | 29.85813 |
| F-statistic | 1299.376 | Durbin-Watson stat | 0.824077 |
| Prob(F-statistic) | 0.000000 | | |

## Table 12. Econometric Analysis of U.S. Sorghum Harvested Yields, 1960/61 to 2016/17

Dependent Variable: LOG(Sorghum Yield)

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 3.808498 | 0.039355 | 96.77373 | 0.0000 |
| La Niña | -0.077524 | 0.025701 | -3.016339 | 0.0043 |
| El Niño | 0.098972 | 0.035533 | 2.785333 | 0.0079 |
| Time Trend | 0.017401 | 0.003922 | 4.436893 | 0.0001 |
| $(\text{Time Trend})^2$ | -0.000183 | 8.20E-05 | -2.230925 | 0.0310 |
| D1983 | -0.325197 | 0.091582 | -3.550902 | 0.0009 |
| D1980 | -0.248170 | 0.087020 | -2.851869 | 0.0067 |
| D2002 | -0.292527 | 0.088351 | -3.310970 | 0.0019 |
| D2003 | -0.253706 | 0.089070 | -2.848388 | 0.0067 |
| D2015 | 0.212690 | 0.092683 | 2.294804 | 0.0267 |
| D2006 | -0.194519 | 0.092196 | -2.109850 | 0.0407 |
| PDL01 | -0.005093 | 0.003822 | -1.332436 | 0.1897 |

| | | | |
|---|---|---|---|
| R-squared | 0.768592 | Mean dependent var | 4.063519 |
| Adjusted R-squared | 0.709395 | S.D. dependent var | 0.155974 |
| S.E. of regression | 0.084082 | Akaike info criterion | -1.923813 |
| Sum squared resid | 0.304002 | Schwarz criterion | -1.485850 |
| Log likelihood | 64.90486 | Hannan-Quinn criter. | -1.754449 |
| F-statistic | 12.98354 | Durbin-Watson stat | 2.087617 |
| Prob(F-statistic) | 0.000000 | | |

| Lag Distribution of LOG(Crop Improv) | i | Coefficient | Std. Error | t-Statistic |
|---|---|---|---|---|
| * .\| | 0 | -0.00340 | 0.00255 | -1.33244 |
| * .\| | 1 | -0.00340 | 0.00255 | -1.33244 |
| Sum of Lags | | -0.00679 | 0.00510 | -1.33244 |

associated with El-Niño led to increases in yield by close to 10%. The results indicate that while research had the effect of enhancing acres planted, they did not significantly enhance sorghum yields. Again, a logarithmic transformation of dollar expenditures associated with crop improvement activities was used to reflect diminishing marginal returns.

Given that sorghum production is the product of harvested acreage and yield, the results suggest that the efforts of USCP led to an increase in production of 0.25% on average over 2008/09 to 2015/16. That translates into an addition of 7.8 million bushels of sorghum production as a result of the sorghum checkoff program (see Table 10).

To provide a measure of the impact of crop improvement activities on farm revenue, we develop a model specification for sorghum farm prices. As given in Table 13, the goodness-of-fit for this relationship is 0.9947. Hence, more than 99% of the variation in sorghum farm price is accounted for by this econometric analysis. Drivers of sorghum farm prices were corn farm prices, sorghum production, sorghum prices at the terminal market in Kansas City, and USCP crop improvement expenditures. The results indicate that a one percent change in corn price generates a 0.15% change in sorghum prices in the same direction while a one percent change in sorghum production generates a 0.02% change in sorghum prices in the opposite direction. Also, a one percent change in downstream prices generates a 0.80% change in sorghum farm prices in the same direction.

The impact of USCP funds committed to crop improvement activities on farm prices was not felt all at once but, instead, the impact was distributed over the current year and the previous year. The results suggest that a one percent change in crop improvement expenditures generates a 0.0053% change in sorghum farm prices in the same direction. As shown in Table 10, crop improvement expenditures led to the increase in sorghum farm prices by 2 to 3 cents per bushel over the period of 2008/09 to 2015/16. Importantly, this change in sorghum farm prices was statisticallydifferent from zero.

### *Returns to Producers from Checkoff Expenditures on Research*

The results from estimating the supply model and the associated impacts of USCP research expenditures on acreage, yields, production, and price derived from those models as summarized in Table 10 indicate that funds committed by USCP to crop improvement activities generated $100.8 million of additional farm revenue or a 0.79% increase in farm revenue over 2008/09 to 2015/16.

Given that the USCP expended $10.53 million on crop improvement research over that same period, the benefit-cost ratio (BCR) for USCP crop improvement research investments over 2008/09 to 2015/16 net of the research expenditures is calculated to be 8.57. That is, for every dollar invested in crop improvement research, producers realized a net return of nearly $8.60. Realize however, that this set of calculations rests on the changes in harvested acres and yields (and hence production) as well as the changes in farm prices attributed to the checkoff.

## Impacts and Returns from USCP Expenditures to Enhance the Demand for U.S. Sorghum

The analysis of the impact of USCP programs on the demand for sorghum (either in domestic markets or in international markets) relies on a structural econometric model approach (essentially single-equation regression analysis). This analysis specifically examines the relationship between USCP

**Table 13. Econometric Analysis of U.S. Sorghum Farm Price, 1960/61 to 2016/17**

Dependent Variable: LOG(Sorghum Farm Price)

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.120891 | 0.371759 | -0.325185 | 0.7471 |
| LOG(Corn Farm Price) | 0.148872 | 0.080787 | 1.842768 | 0.0744 |
| LOG(Sorghum Production) | -0.018968 | 0.017409 | -1.089525 | 0.2838 |
| LOG(Sorghum Price No. 2) | 0.803880 | 0.076497 | 10.50860 | 0.0000 |
| D2006 | 0.110280 | 0.031445 | 3.507044 | 0.0013 |
| D2010 | -0.145066 | 0.034529 | -4.201321 | 0.0002 |
| D1976 | 0.070634 | 0.028922 | 2.442181 | 0.0201 |
| PDL01 | 0.003972 | 0.001029 | 3.859504 | 0.0005 |

| | | | |
|---|---|---|---|
| R-squared | 0.994728 | Mean dependent var | 0.912242 |
| Adjusted R-squared | 0.993610 | S.D. dependent var | 0.352449 |
| S.E. of regression | 0.028174 | Akaike info criterion | -4.127680 |
| Sum squared resid | 0.026194 | Schwarz criterion | -3.793325 |
| Log likelihood | 92.61745 | Hannan-Quinn criter. | -4.005927 |
| F-statistic | 889.5576 | Durbin-Watson stat | 1.972380 |
| Prob(F-statistic) | 0.000000 | | |

| Lag Distribution of LOG(Crop improv) | i | Coefficient | Std. Error | t-Statistic |
|---|---|---|---|---|
| . *\| | 0 | 0.00265 | 0.00069 | 3.85950 |
| . *\| | 1 | 0.00265 | 0.00069 | 3.85950 |
| Sum of Lags | | 0.00530 | 0.00137 | 3.85950 |

expenditures and high value sorghum uses and renewables (feed demand and food and industrial demand) and export demand[1].

Empirical findings from previous studies support the hypothesis that market development and promotion expenditures have carryover or lagged effects (Nerlove and Waugh, 1961; Lee and Brown, 1992; Ward and Dixon, 1989; Williams, Capps, and Palma, 2008; and Williams, Capps, and Dang, 2010; Williams, Capps, and Lee, 2014)). That is, expenditures in one period have impacts not only demand in the current period but also demand in future periods. However, theory provides relatively little guidance as to the structure and length of these dynamic processes. Whatever the specification used, however, accounting for the time lag between the market development and promotion expenditures and any changes in sorghum use that may occur is critical.

The use of polynomial distributed lags (PDLs) is consistent with the quantitative evaluation of checkoff programs in general to account for the time lag in the impact of checkoff expenditures (Lee and Brown, 1992; Forker and Ward, 1993; Williams, Capps, and Palma, 2008; Williams, Capps, and Dang, 2010; and Capps Williams, and Hudson, 2016). Given lags between market development expenditures and market impact, and demand impacts, short-run as well as long-run effects of the checkoff expenditures can be captured as well as average length of time before changes in expenditures made by USCP affect the level of domestic uses or exports of sorghum.

[1] Seed demand is not analyzed owing to the relatively small size of seed use in the industry.

Regardless of the approach taken, the analysis must measure the shift in the demand attributed to the market development and promotion efforts of USCP. To carry out this task and to avoid confounding of effects, the analysis must account and control for all possible drivers of the demand for sorghum. In this way, the effects of the market development and promotion activities separate from those of any other factor that affects the demand for sorghum can be isolated and measured.

### *Impacts of Promotion on High-Value Markets and Renewables*

To analyze the impacts of USCP funds committed to high-value markets and renewables, separate single-equation econometric specifications for feed use and food and industrial use of sorghum are developed and estimated. The results are then used to calculate the returns to producers from expenditures to promote each category of demand.

*Feed Use of Sorghum*

Animal agriculture is a key market for sorghum production in the United States. Sorghum is utilized in the beef, swine, dairy, and poultry industries. Sorghum grain, stalks, and leaves can be utilized in various feed ingredients. In the livestock industry, checkoff funds have been expended to develop education materials, conducting research, and visiting livestock operations as well as feed manufacturers to heighten awareness of the benefits of the use of sorghum.

The econometric model specification, in essence, is a derived demand function for feed use of sorghum, given by equation (6):

(6) log (feeduse$_t$) = g (log (sorghum price no2at Kansas City$_t$ / corn price no2 at Chicago$_t$), log (number of grain consuming units$_t$), log (feed use$_{t-1}$), PDL log (USCP renewables and high value market expenditures$_t$)), D1996, D2011, D1976, D1980, D1983, D1992 ) + $v_t$

This specification is similar to the econometric model for feed use developed by Roy and Ireland (1975). The data associated with this analysis cover market years 1975/76 to 2015/16. Dummy variables pertaining to qualitative events that occurred in 1996/97, 2011/12, 1976/77, 1980/81, 1983/84, and 1992/93 are included in this specification as well to account for structural shifts in feed use.

As given in Table 14, the goodness-of-fit associated with the specification in equation (6) is 0.9721 meaning that slightly more than 97% of the variability in feed use is accounted for by the model specification. Determinants of feed use werethe ratio of sorghum prices (no. 2) at the Kansas City terminal market to corn prices (no. 2) at the Chicago terminal market, the number of grain-consuming animal units, and feed use in the previous year. The results in Table 14 suggest that aone percent rise in the ratio of downstream sorghum prices to corn prices led to a decrease in sorghum feed use by 2.27%. At the same time, a one percent rise in grain consuming animal units is associated with a decrease in feed use of sorghum by 2.71%. This finding reflects in part increases in efficiency over time, that is, more grain per pound of feed. Inertia was evident in feed use owing to the significance of the estimated coefficient of feed use in the previous year. Also, the results in Table 12 indicate that a one percent changes in funds committed to high-value markets and renewablesmade by USCP resulted in a statistically significant decline in feed use of 0.0273% between 2008/2009 and 2015/2016.

**Table 14. Econometric Analysis of the Feed Demand for Sorghum, 1975/76 to 2016/17**

Dependent Variable: LOG(Sorghum Feed Demand)

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 15.39142 | 2.140699 | 7.189901 | 0.0000 |
| LOG(Sorghum Price (no. 2)/ Corn price (no.2) | -2.270404 | 0.515436 | -4.404820 | 0.0002 |
| LOG(Grain Cons. Animal Units) | -2.705380 | 0.416829 | -6.490380 | 0.0000 |
| LOG(Feed Demand)$_{t-1}$ | 0.377024 | 0.072262 | 5.217432 | 0.0000 |
| D1996 | 0.496212 | 0.126661 | 3.917644 | 0.0006 |
| D2011 | -0.470081 | 0.132119 | -3.558016 | 0.0014 |
| D1976 | -0.473756 | 0.135826 | -3.487957 | 0.0017 |
| D1980 | -0.485418 | 0.127554 | -3.805589 | 0.0007 |
| D1983 | -0.492440 | 0.134366 | -3.664908 | 0.0011 |
| D1992 | 0.321530 | 0.125829 | 2.555294 | 0.0166 |
| PDL01 | -0.020443 | 0.004580 | -4.463603 | 0.0001 |

| | | | |
|---|---|---|---|
| R-squared | 0.972092 | Mean dependent var | 5.648100 |
| Adjusted R-squared | 0.961756 | S.D. dependent var | 0.627367 |
| S.E. of regression | 0.122688 | Akaike info criterion | -1.121148 |
| Sum squared resid | 0.406412 | Schwarz criterion | -0.647110 |
| Log likelihood | 32.30182 | Hannan-Quinn crit. | -0.952489 |
| F-statistic | 94.04798 | Durbin-Watson stat | 2.398071 |
| Prob(F-statistic) | 0.000000 | | |

| Lag Distribution of LOG(USCP Renewable and High Value Market Expenditures) | i | Coefficient | Std. Error | t-Statistic |
|---|---|---|---|---|
| * . \| | 0 | -0.01363 | 0.00305 | -4.46360 |
| * . \| | 1 | -0.01363 | 0.00305 | -4.46360 |
| Sum of Lags | | -0.02726 | 0.00611 | -4.46360 |

The market share of feed use of sorghum has diminished over time while the market shares of food and industrial use of sorghum and sorghum exports have increased over time. This substitution in end uses of sorghum reflects in part higher-value market opportunities. A logarithmic transformation is used to account for diminishing marginal returns of USCP expenditures on feed use of sorghum.

The use of sorghum for feed use was on the decline prior to the existence of the sorghum checkoff program. The statistically significant coefficient for the USCP expenditures in Table 14 indicates that over itsrelatively short existence, the efforts made by USCPhave not stemmed the decline in feed use.

*Food and Industrial Use of Sorghum*

The econometric model specification, in essence, is a derived demand function for food and industrial use of sorghum given by the equation (7):

(7) $\log$ (food and industrial use$_t$) = h (log(sorghum price in terminal market in Kansas City$_t$), log(corn price in terminal market in Chicago$_t$), log( industrial production index$_t$),PDL log (USCP renewables and high value markets expenditures$_t$), D2014, D1985, D1986, D1996, D1997, D2001, D2002) + $e_t$

Ethanol can be made from grain sorghum within some technical limitations. In the ethanol industry, checkoff funds have been expended to develop awareness of the benefits of the use of sorghum as a fuel and feedstock. Renewables include renewable fuels and renewable chemicals. Additionally, celiac and gluten intolerance is on the rise. The Center for Celiac Research estimates that approximately 7.5% of the U.S. population suffers from gluten sensitivity. In 2010, 12% of new products are claimed to be "gluten free," up from one percent in 2001 (Martinez, 2013). U.S. sales of gluten-free foods have risen from $4.8 billion in 2009 to $15.6 billion at the end of2016(Douillard, 2017). The largest increase in health and nutrition-related claims over the period 2001 to 2010 was for "no gluten" (Martinez, 2013).

Sorghum is also a viable replacement for corn in pet food. According to the 2017/18 National Pet Owners Survey conducted by the American Pet Products Association, Inc. (APPA), 68% of U.S. households own a pet (APPA, 2017a). Given the steady historical growth trends in pet food and other product sales, from $17 billion in 1994 to an estimated $69billion in 2017, strong growth in pet food and products sales are likely to continue (APPA, 2017b). Brands of pet foods currently using sorghum include IAMS, Eukanuba, Pet Wants, Mr. Bucks Pet Food, Hills Pet Nutrition, Newman's Own Organics, Blackwood, Adirondack, Verus, Victor Super Premium Dog Food, GNC, and Muenster Natural (United Sorghum Checkoff Program, 2017).

Finally, many chemicals can be produced from corn, sorghum, and other sugar sources. The global renewable chemicals industry has experienced notable growth over the last five years. This market was forecasted to reach $76 billion in 2015, up from $37 billion in 2009 (Informa Economics, 2013).At present, the global renewable chemicals market is expected to reach $102.76 billion in 2022, growing at a compound annual growth rate of 11.29% between 2017 and 2022 (Zion Market Research, 2017).

Dummy variables pertaining to qualitative events that occurred in 2014, 1985, 1986, 1997, 2001,and 2002 are included in this specification as well to account for structural shifts in feed use.As exhibited in Table 15, this econometric relationship accounted for 98% of the variation in sorghum use for food and industrial purposes. The econometric results indicate that prices in downstream markets for sorghum and for corn were influential factors for food and industrial uses of sorghum. A one percent increase in sorghum prices (no. 2) at the Kansas City terminal market gave rise to a 2.32% decline in food and industrial use of sorghum. Similarly a one percent increase in corn prices (no. 2) Chicago terminal market leads to a 1.93% increase in food and industrial use of sorghum. Corn, as expected, is a notable substitute for sorghum in food and industrial uses. This result is mainly due to the use of sorghum and corn for ethanol production. The end use of sorghum for food and industrial purposes is very sensitive to changes in corn and sorghum prices at principal terminal markets.

As well, the demand for sorghum in food and industrial uses is quite sensitive to changes in industrial production. The base year for the industrial production index is 2007 (Federal Reserve

**Table 15. Econometric Analysis of the Food and Industrial Demand for Sorghum, 1975/76 to 2016/17**

Dependent Variable: LOG(Sorghum Food and Industrial Use Demand)

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -5.980411 | 0.517863 | -11.54825 | 0.0000 |
| LOG(Sorghum Price (no. 2)) | -2.324525 | 0.640355 | -3.630058 | 0.0012 |
| LOG(Corn Price (no. 2)) | 1.933676 | 0.671401 | 2.880060 | 0.0079 |
| LOG(Industrial Production Index) | 2.472367 | 0.120106 | 20.58487 | 0.0000 |
| D2014 | -1.988088 | 0.176075 | -11.29114 | 0.0000 |
| D1985 | 0.662555 | 0.146188 | 4.532226 | 0.0001 |
| D1986 | -0.971084 | 0.157108 | -6.181010 | 0.0000 |
| D1996 | 0.501552 | 0.146753 | 3.417666 | 0.0021 |
| D1997 | 0.502010 | 0.147650 | 3.399992 | 0.0022 |
| D2001 | -0.587324 | 0.153326 | -3.830552 | 0.0007 |
| D2002 | -0.427107 | 0.155236 | -2.751336 | 0.0107 |
| PDL01 | 0.053837 | 0.006096 | 8.831768 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.981099 | Mean dependent var | 3.200874 |
| Adjusted R-squared | 0.973102 | S.D. dependent var | 0.862114 |
| S.E. of regression | 0.141393 | Akaike info criterion | -0.822465 |
| Sum squared resid | 0.519788 | Schwarz criterion | -0.305332 |
| Log likelihood | 27.62683 | Hannan-Quinn criter. | -0.638473 |
| F-statistic | 122.6869 | Durbin-Watson stat | 2.615015 |
| Prob(F-statistic) | 0.000000 | | |

| Lag Distribution of LOG(USCP Renewable and High Value Market Expenditures) | i | Coefficient | Std. Error | t-Statistic |
|---|---|---|---|---|
| . *\| | 0 | 0.03589 | 0.00406 | 8.83177 |
| . *\| | 1 | 0.03589 | 0.00406 | 8.83177 |
| Sum of Lags | | 0.07178 | 0.00813 | 8.83177 |

Bank of St. Louis, 2017). A one percent rise in the industrial production index leads to a 2.47% rise in sorghum for food and industrial use, all other factors invariant.

The results in Table 15 also indicate that USCP funds committed to renewables and high-value markets were positively linked to sorghum food and industrial use demand. This impact was not felt in one year. Rather, the impact was distributed over the current year and the previous year. The results suggest that the cumulative impact of a one percent increase in USCP funds to renewables and to high-value markets generated a 0.0718% increase in the demand for sorghum for food and industrial purposes over the period 2008/09 to 2015/16. This effect unequivocally was not only positive but also statistically significant.

Table 16 shows the impacts to the USCP expenditure of checkoff funds to promote foodand industrial uses of sorghum. The estimated food and industrial use promotion elasticity of 0.0718% implies that the sorghum checkoff funds spent for that purpose generated an average annual increase in sorghum use of nearly 6.0 million bushels over the 2008/09 to 2015/16 period for a total of nearly 48 million bushels in additional sales of sorghum over that period. Given prices of

## Table 16. Impact and Returns to USCPExpenditures Associated with Food and Industrial Use of Sorghum

| Year | Elasticity | Food and Industrial Use (Million Bushels) | Incremental Food and Industrial Use (Million Bushels) | Sorghum Price no2 KC ($/Bushel) | Incremental Food and Industrial Use (Dollars) | USCP Renewables and High Value (Dollars) | Sorghum Farm Price ($/Bushel) | Ratio of Farm Price to Terminal Market Price | From Margin Sorghum Farm Price ($/Bushel) | Ratio of Farm Price from Margin to Terminal Market Price |
|---|---|---|---|---|---|---|---|---|---|---|
| 2008/09 | 0.071780 | 94.146 | 6.758 | $3.24 | $21,920,636 | $992,333 | $3.20 | 0.99 | $1.73 | 0.5326 |
| 2009/10 | 0.071780 | 89.257 | 6.407 | $3.22 | $20,647,903 | $902,466 | $3.22 | 1.00 | $1.72 | 0.5328 |
| 2010/11 | 0.071780 | 84.350 | 6.055 | $6.18 | $37,415,526 | $726,019 | $5.02 | 0.81 | $3.22 | 0.5208 |
| 2011/12 | 0.071780 | 84.226 | 6.046 | $6.33 | $38,267,332 | $807,748 | $5.99 | 0.95 | $3.29 | 0.5205 |
| 2012/13 | 0.071780 | 94.347 | 6.772 | $6.71 | $45,427,200 | $640,224 | $6.33 | 0.94 | $3.49 | 0.5198 |
| 2013/14 | 0.071780 | 69.010 | 4.954 | $4.36 | $21,597,755 | $1,729,488 | $4.28 | 0.98 | $2.29 | 0.5263 |
| 2014/15 | 0.071780 | 13.971 | 1.003 | $3.88 | $3,894,857 | $1,965,485 | $4.03 | 1.04 | $2.05 | 0.5285 |
| 2015/16 | 0.071780 | 136.139 | 9.772 | $3.32 | $32,434,631 | $1,507,315 | $3.31 | 1.00 | $1.77 | 0.5321 |
| Average | 0.071780 | 83.181 | 5.971 | $4.66 | $27,700,730 | $1,158,885 | $4.42 | 0.96 | $2.44 | 0.5267 |
| | | | | At Terminal Market | $221,605,840 | | | | | |
| | | | | At Farm Level[a] | $116,713,918 | | | | | |
| | | | | BCR | 11.59 | $9,271,078 | | | | |

| Year | Elasticity of Price Transmission |
|---|---|
| 2008/09 | 0.514190 |
| 2009/10 | 0.508200 |
| 2010/11 | 0.625356 |
| 2011/12 | 0.536373 |
| 2012/13 | 0.538243 |
| 2013/14 | 0.517454 |
| 2014/15 | 0.489103 |
| 2015/16 | 0.509223 |
| Average | 0.529768 |

[a] Multiply the incremental value at the terminal market times the ratio of the farm price of sorghum to sorghum no2 prices at Kansas City.

sorghum at the Kansas City terminal, the value of that additional sales in dollars over this period amounted to $221.6 million. The cumulative amount of expenditures to promote food and industrial uses made by USCP over that period was $9.3 million.

To determine the returns to producers from this checkoff investment, the farm level value of the additional sales of sorghum generated by the checkoff must first be calculated. To that end, we relate the price spread (or marketing margin) relationship between sorghum prices at the terminal market of Kansas City and the farm price of sorghum as specified in equation (8):

(8) $\quad$ (Price of Sorghum at Kansas City (no.2))$_t$ – Sorghum Farm Price$_t$ = f(Price of Sorghum at Kansas City (no.2))$_t$ + $u_t$

As exhibited in Table 17, the estimation of this relationship accounted for about 97% of the variation in the price spread. From this specification, we may derive the farm price transmission elasticity which represents the percentage change in sorghum farm prices due to a one percent change in sorghum downstream prices (the prices of sorghum (no2) at the terminal market of Kansas City). This elasticity of price transmission was calculated to be 0.53 which implies that if the price of no2 sorghum at Kansas City increases by one percent then the farm price of sorghum increases by 0.53%.

To translate the benefits associated with investment in renewables and high-value markets to the farm level, we can use the ratio of the farm price of sorghum to sorghum no. 2 price at Kansas City. On average, this ratio was equal to 0.5267over the period of analysis (1975/76 to 2015/16). Thus, the $221.6 million in additional dollars at the terminal market associated with the USCP investment in renewables and high-value markets is equivalent to a farm value of $116.7 million. Given the investment of slightly more than $9.2 million in funds committed by USCP, the benefit-cost ratio or BCR(net of the investment of the expenditures of checkoff funds in this promotion activity) is calculated to be 11.59 to 1.

### *Impacts of Promotion on Sorghum Exports*

Promotional activities to expand the demand for U.S. sorghum exports have been conducted over the years by the U.S. Grains Council (USGC) using USCP funds allocated for export promotion and matching funds through the Foreign Market Development (FMD) program and the Market Access Program (MAP) administered by the Foreign Agriculture Service (FAS) of the U.S. Department of Agriculture. USGC is the FAS cooperator in the FMD and MAP export market development programs. USCP essentially leverages its export funds through the USGC. Thus, this analysis of the impacts of USCP sorghum export promotion efforts considers the effects of the total of USCP and FAS (FMD and MAP) funds expended to promote sorghum exports. Both USCP and FAS expenditures for sorghum exports were provided by USGC for the period 2008/09 through 2015/16 (Shultz, 2017). Prior to 2008, no funds were provided to FAS from the USCP for export promotion.

As discussed previously, U.S. sorghum exports basically declined from the late 1970s through about 2012/13. Then a sudden surge in sorghum demand by China boosted exports to record levels in 2013/14 and 2014/15. An overwhelming majority of exported sorghum is used in the animal feed sector. Exports represented 40% of total disappearance over the period 1975/76 to 2016/17. Over the past four years (2013/14 to 2016/17), however, this proportion ranged from 48% to 78%, averaging 60% over the full period.

**Table 17. Econometric Estimation of the Price Spread between Sorghum Prices at the Terminal Market in Kansas City and the Farm Price of Sorghum, 1975/76 to 2015/16**

Dependent Variable: Sorghum Price (no. 2 KC) - Sorghum Farm Price

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | -0.080664 | 0.069461 | -1.161279 | 0.2524 |
| Sorghum Price (no. 2 KC) | 0.492238 | 0.012584 | 39.11517 | 0.0000 |

| | | | |
|---|---|---|---|
| R-squared | 0.974522 | Mean dependent var | 2.424482 |
| Adjusted R-squared | 0.973885 | S.D. dependent var | 1.078378 |
| S.E. of regression | 0.174266 | Akaike info criterion | -0.610015 |
| Sum squared resid | 1.214751 | Schwarz criterion | -0.527269 |
| Log likelihood | 14.81033 | Hannan-Quinn criter. | -0.579686 |
| F-statistic | 1529.996 | Durbin-Watson stat | 2.121921 |
| Prob (F-statistic) | 0.000000 | | |

The econometric specification for total U.S. exports includes as drivers the U.S. export price (unit value) of sorghum, the export price of sorghum from Argentina, non-U.S. world sorghum production, trade weighted real per capita GDP (in 2010 U.S. dollars for China, Japan, and Mexico), U.S. exports in the previous year, and total sorghum export promotion expenditures (including funds from both USCP as well as FMD and MAP funds from FAS for sorghum export promotion).

The level of total sorghum export promotion expenditures since the existence of the USCP ranged from $2.5 million to $3.5 million over 2008/09 and 2015/16. Dummy variables corresponding to years 1980/81, 1986/87, 2008/09, 2009/10, 2012/13, 2014/15, and 2015/16 are proxies for structural changes that occurred in total U.S. sorghum exports.

The level of total sorghum export promotion expenditures since the existence of the USCP ranged from $2.5 million to $3.5 million over 2008/09 and 2015/16. Dummy variables corresponding to years 1980/81, 1986/87, 2008/09, 2009/10, 2012/13, 2014/15, and 2015/16 are proxies for structural changes that occurred in total U.S. sorghum exports.

The econometric model accounts for nearly 88% of the variation in total U.S. exports of sorghum (Table 18). The econometric estimates of the parameters of this equation indicate that a one percent change in the U.S. sorghum export price gave rise to a modest 0.39% change in the level of exports in the opposite direction over the period of analysis. Hence, price sensitivity is not a major issue in the aggregate of U.S. sorghum exports. Also, the results indicate that a one percent change in non-U.S. world sorghum production led to a 0.23% change in aggregate U.S. exports of sorghum in the opposite direction over the same period. At the same time, changes in the trade-weighted per capita GDP of major trading partners of sorghum were found to have had no statistically significant impact on total U.S. sorghum exports. A one percent change in the price of sorghum exports from Argentina gave rise to a 0.11% change in total U.S. sorghum exports which implies that sorghum exports from the United States and Argentina are weak substitutes. Inertia also was present in total U.S. exports of sorghum as evident by the significance of the coefficient associated with level of U.S. exports of sorghum in the previous year. Importantly, however, the results indicate that total

**Table 18**. **Econometric Analysis of Total U.S. Exports of Sorghum, 1975 to 2016**

Dependent Variable: LOG(US_EXPORTS_TOTAL_FAS)

| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C | 10.08211 | 3.320915 | 3.035944 | 0.0053 |
| LOG(US_SORG_EXPORT_PRICE_FAS) | -0.389789 | 0.466287 | -0.835941 | 0.4105 |
| LOG(US_EXPORTS_TOTAL_FAS(-1)) | 0.680796 | 0.102930 | 6.614139 | 0.0000 |
| LOG(TRADE_WEIGHTED_RGDNEW) | -0.142824 | 0.112747 | -1.266763 | 0.2161 |
| D2008 | 0.462932 | 0.194504 | 2.380067 | 0.0246 |
| LOG(NON_US_WORLD_SORG_PROD) | -0.228396 | 0.190493 | -1.198970 | 0.2410 |
| D2012 | -0.857122 | 0.173365 | -4.944041 | 0.0000 |
| D2015 | 0.517935 | 0.192932 | 2.684548 | 0.0123 |
| D2014 | 0.754919 | 0.186573 | 4.046236 | 0.0004 |
| D1986 | -0.490336 | 0.160773 | -3.049858 | 0.0051 |
| D1980 | 0.558530 | 0.185811 | 3.005908 | 0.0057 |
| D2009 | -0.535614 | 0.205210 | -2.610075 | 0.0146 |
| LOG(ARG_SORG_EXPORT_PRICE) | 0.114603 | 0.426032 | 0.269001 | 0.7900 |
| PDL01 | 0.005441 | 0.006975 | 0.780117 | 0.4421 |

| | | | |
|---|---|---|---|
| R-squared | 0.878448 | Mean dependent var | 15.49881 |
| Adjusted R-squared | 0.819923 | S.D. dependent var | 0.342422 |
| S.E. of regression | 0.145308 | Akaike info criterion | -0.754724 |
| Sum squared resid | 0.570093 | Schwarz criterion | -0.169602 |
| Log likelihood | 29.47185 | Hannan-Quinn criter. | -0.541655 |
| F-statistic | 15.00976 | Durbin-Watson stat | 2.323969 |
| Prob(F-statistic) | 0.000000 | | |

| Lag Distribution of LOG(FAS_EXPORTS_DOL_LOG) | i | Coefficient | Std. Error | t-Statistic |
|---|---|---|---|---|
| . * \| | 0 | 0.00363 | 0.00465 | 0.78012 |
| . * \| | 1 | 0.00363 | 0.00465 | 0.78012 |
| Sum of Lags | | 0.00725 | 0.00930 | 0.78012 |

sorghum export promotion expenditures had no statistically significant impact on U.S. sorghum exports.

Holding other factors constant, a one percent increase in total export promotion expenditures resulted in a positive though statistically insignificant 0.00725% change in U.S. sorghum exports. In other words, the effect of sorghum export promotion expenditures on U.S. sorghum exports was found to be not statistically different from zero. Consequently, a benefit-cost ratio for the sorghum export promotion program cannot be calculated.

## CONCLUDING REMARKS AND RECOMMENDATIONS

This report provides the second independent evaluation of the effectiveness of the United Sorghum Checkoff Program (USCP). USCP was only recently established in 2008 with the objective of investing producer dollars to increase profitability for the sorghum industry. Hence, the overall objective of this report is to provide USCP stakeholders with a meaningful and reliable evaluation of the impacts of USCP activities on the U.S. sorghum industry. The results of the report provide the basis for developing actions/strategies needed to improve producer profitability via demand and productivity opportunities.

## Major Conclusions

The major points associated with this updated evaluation are as follows:

- Since its inception in 2008, the USCP was responsible for generating additional planted and harvested acreage, modest increases in farm prices, and modest increases in farm revenue.Funds committed by USCP to crop improvement activities had no statistically significant impact on sorghum yields.

- As a result of the checkoff program, planted acreage rose 570,708 acres and harvested acreage rose 441,936 acres. Due to the fact that sorghum production is the product of harvested acreage and yield, the efforts of USCP led to increases in production of 0.18% to 0.42%. Consequently, funds committed by USCP to crop improvement activities generated increases in sorghum production of 734,315 bushels to 1,133,860 bushels since the inception of the USCP.

- As a result of the effort made by USCP in crop improvement activities, sorghum farm prices increased from 2 cents per bushel to 3 cents per bushel.

  Funds committed by USCP to crop improvement activities generated a 0.79% increase in farm revenue. This figure hinges on the changes in harvested acres and yields (and hence production) as well as the changes in farm prices attributed to the checkoff. Consequently, funds committed by the USCP to crop improvement activities generated $100.76 million of additional farm revenue. As such, for every dollar invested in crop improvement activities, a return of close to $9 was evident.

- Funds committed to high-value markets and renewable made by USCP were not able to abate the downward trend in domestic feed use of sorghum. From marketing years 1975/76 to 1999/2000, feed use relative to total disappearance of sorghum ranged from 51.46% to 76.35%. However, since then, this proportion varied from 18.24% to 49.80%. Over the last three marketing years, feed use relative to total disappearance of sorghum was 18.24%, 18.44%, and 27.66% respectively.

- Funds committed to renewables and high-value markets were positively linked to sorghum for food and industrial uses. This impact was not felt at one time but instead this impact was distributed over a period of two years. The cumulative impact of a one percent change in USCP funds to renewables and to high-value markets generated a 0.0718% increase in the use of sorghum for food and industrial purposes since the inception of the USCP. This investment of $9.2 million in funds committed by USCP in renewables and high-value markets generated a farm value of $116.7 million, a benefit-cost ratio or return-on-investment of 11.59 to 1.

- Historically, U.S. sorghum exports represented 40% of total disappearance over the period 1975 to 2016. But for the past four years from 2013 to 2016, this proportion ranged from 48% to 78%, averaging 60%. Hence, total sorghum exports have been on the rise in recent years.Mexico, Japan, and more recently China represent the top destinations for U.S. sorghum exports.

- The principal rivals to the United States in terms of sorghum exports are Argentina and Australia.Historically, exports from the United States, Argentina, and Australia have comprised 90% to 98% of world sorghum exports. Argentina presents the main competitive threat to U.S. sorghum exports.

- The USCP provides funds directly to the USGC. Those funds in turn are used in conjunction with Foreign Agriculture Service (FAS) dollars. Consequently, the USGS leverages USCP dollars with FAS dollars. The effect of aggregate (USCP and FAS) export promotion expenditures on U.S. sorghum exports was found to be positive but as yet not statistically significant.

- A checkoff evaluation requires time for the activities put in place to take hold in various markets as well as historical data dealing with expenditures associated with programmatic activities. Given that the USCP only has been in existence since 2008, indications point to *"movement in the right direction"* in achieving the goal of enhancing profitability in the sorghum industry.

## Recommendations

The analysis and conclusions lead to several important recommendations for management of the U.S. sorghum checkoff program.

- The study results suggest increased funding to crop improvement activities which have significantly boosted acreage, sorghum production,and the farm value of production. While yields show no statistically significant effect from sorghum checkoff investments in research activities, the response of yields to research is often slow. In addition, given the need to enhance or at least maintain the competitiveness of the sorghum industry relative to other feedgrains and sorghum produced by U.S. sorghum export competitors, a focus on research activities aimed at increasing sorghum yields is likely to be a critically important and strategic choice for the investment of sorghum checkoff funds. To compete with corn, sorghum needs higher yields, additional nutrient value, and/or lower costs of production. Attention might well need to be centered on sorghum as a naturally drought-tolerant, input-efficient crop.

- With limited resources, maximum returns can be obtained by allocating funds for demand promotion on the basis of the highest and best uses for sorghum. The results of this study suggest that an increase in funds allocated to enhancing the demand for sorghum in food and industrial uses (essentially high-value markets and renewables) rather than for livestock feed would lead to higher producer profits. Opportunities for enhancing producer profitability appear to exist in the use of sorghum for the production of ethanol, gluten-free products, pet foods, aquaculture, and renewable chemicals. These uses appear to be growth areas in the near to intermediate future. Further, efforts could focus on the visibility of sorghum not only as a healthy choice for cooking and baking but also as a gluten-free nutritious grain.

- Priorities for any funds invested in feed demand promotion include research to enhance the quality of sorghum as a feed grain so as to better compete with cornas well as the promotion of non-genetically modified (non-GMO) sorghum for livestock feeding.

- Despite the results of this study indicating a positivebut as yet not statistically significant effect of export promotion on sorghum exports, maintaining or growing the competitiveness of U.S. sorghum in international markets is likely critical to the future viability and profitability of the U.S. sorghum industry. Any funds allocated to export promotion would likely be most successful in enhancing producer profitability if focused on two priorities: (1) maintaining market share and export volume in China; and (2) recapturing market share and volume in Japan and in Mexico. Differentiating U.S. sorghum from other competitive coarse grains and from sorghum supplies from other regions is also likely critical to building long-term demand for U.S. sorghum.

- It is imperative for USCP to maintain quality records on funds committed to various activities over time to support effective evaluation of the sorghum checkoff program. A substantial amount of time in this project was devoted to obtaining accurate data on expenditures committed to various activities, namely crop improvement, high-value markets, renewables, and exports. An efficient and accurate record management system and database of checkoff expenditures made over time and across production research and promotional activities (feed use, food use, pet use, exports by destination, ethanol production, etc) would greatly facilitate efforts to effectively evaluate the performance of the sorghum checkoff program.

- In the same vein, this program evaluation did not include sorghum checkoff expenditures made by state programs or historical relating to stake checkoff program expenditures prior to the 2008 implementation of the United Sorghum Checkoff Program because those data were not available. Efforts to retrieve those data were largely unsuccessful. As a consequence, the results of this study may not reflect the impact of the total amount of producer checkoff funds spent to promote the profitability of the sorghum industry.

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