Carbon Footprint Study

Study Background

April 2020
In 2012, The United Sorghum Checkoff Program developed a model to analyze the carbon footprint of sorghum used for ethanol production based on information obtained from sorghum growers. This information was collected in an extensive study over time and included the following:

- Sorghum acres – including both irrigated and non-irrigated acres in past five years; seeding rate; crop acres preceding 2012 sorghum.
- Sorghum inputs (brands and acres treated) - including fertilizer, herbicide, insecticides, fungicides, seed treatments.
- Sorghum outputs - including yields, sorghum stubble for grazing and bale.
- Field operations (type of operation and sorghum acres covered) – including specific tillage practices; fertilizer, herbicide, insecticide and fungicide application methods; planting methods, cultivation methods, and harvest methods.
- Energy use (type and quantity) – including energy for drying; energy for irrigation; residual energy; energy for delivery.

The Sorghum Checkoff Program is now interested in redocumenting and confirming the model estimates using some of the primary predictors from the 2012 Sorghum Carbon Footprint Study. Thus, the current study will gather information from growers, with the purpose of confirming estimates and verifying near future estimates or sorghum’s carbon footprint.

Specifically, this study will gather the following information about sorghum production for both non-irrigated and irrigated acres for the years 2017, 2018 and 2019:

- Sorghum production acres (seeding rates and crop acres)
- Yields
- Tillage practices (no till, minimum/strip till and conventional till acres)
- Crop inputs (nitrogen fertilizers, phosphorus, potassium, sulfur and lime application rates and acres treated)
- Organic matter percentage
- Soil type
To gather information used in this study, phone interviews were conducted with 101 sorghum growers in Kansas in April 2020. Kansas was selected due to its high concentration of sorghum growers and high sorghum output. Kansas produces nearly half (48%) of all sorghum acres grown in the U.S. To participate in this study, growers had to meet the following criteria:
- Have input into decisions about sorghum for their farming operation.
- Not employed by or affiliated with advertising, sales promotion, market research or public relations organizations/companies.
- Not employed by or affiliated with energy manufacturing company, distributor, or dealership.
- Planted at minimum of 50 sorghum acres in 2019.

To get a representative sample of sorghum growers across Kansas, counties were divided into three regions: Central, East and West (see appendix for a list of counties in each region). Soft quotas were imposed on each region. Below is the number of interviews completed in each region versus the quota.

<table>
<thead>
<tr>
<th>Sampled Growers</th>
<th>Acres Represented</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Desired</td>
</tr>
<tr>
<td>Central</td>
<td>62</td>
</tr>
<tr>
<td>East</td>
<td>5</td>
</tr>
<tr>
<td>West</td>
<td>33</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>
Carbon Footprint Study

Sorghum Production

April 2020
• About 5% of sorghum acres are irrigated. Growers in this study planted on average 471 sorghum acres in 2019. Sorghum acres increased from 2017 and 2018 by about 8%.

**Average Irrigated and Non-irrigated Sorghum Acres***

<table>
<thead>
<tr>
<th>Year</th>
<th>Non-Irrigated</th>
<th>Irrigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>467</td>
<td>26</td>
</tr>
<tr>
<td>2018</td>
<td>452</td>
<td>24</td>
</tr>
<tr>
<td>2019</td>
<td>448</td>
<td>23</td>
</tr>
</tbody>
</table>

**Average Sorghum Acres**

<table>
<thead>
<tr>
<th>Year</th>
<th>Average Sorghum Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>439</td>
</tr>
<tr>
<td>2018</td>
<td>438</td>
</tr>
<tr>
<td>2019</td>
<td>471</td>
</tr>
</tbody>
</table>

**% of All Sorghum Acres that are Irrigated**

<table>
<thead>
<tr>
<th>Year</th>
<th>5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>101</td>
</tr>
</tbody>
</table>

Source: How many [irrigated/non-irrigated] sorghum acres did you plant in the following years? *Includes 0. Base=101.
Irrigation in Sorghum

Average Acres Among Growers with Irrigated Sorghum Acres *

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Growers With Irrigated Sorghum</td>
<td>14%</td>
<td>14%</td>
<td>15%</td>
</tr>
<tr>
<td>Average Acres Irrigated</td>
<td>182</td>
<td>170</td>
<td>165</td>
</tr>
<tr>
<td>Average Acres Non-Irrigated</td>
<td>479</td>
<td>533</td>
<td>747</td>
</tr>
</tbody>
</table>

% of Growers

<table>
<thead>
<tr>
<th></th>
<th>101</th>
<th>101</th>
<th>101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Irrigated</td>
<td>13</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Average non0-irrigated</td>
<td>10</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>

Source: Were any of your sorghum acres irrigated in [insert year]? How many [irrigated/non-irrigated] sorghum acres did you plant in the following years?

*Caution due to small sample sizes.
Other Crops Planted

- Winter wheat is the next most planted crop among sorghum growers.

### Average Acres of Other Crops (Excluding Sorghum) Planted by Year

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>248</td>
<td>267</td>
<td>306</td>
</tr>
<tr>
<td>Cotton</td>
<td>29</td>
<td>42</td>
<td>34</td>
</tr>
<tr>
<td>Soybeans</td>
<td>219</td>
<td>234</td>
<td>239</td>
</tr>
<tr>
<td>Winter Wheat</td>
<td>638</td>
<td>630</td>
<td>639</td>
</tr>
<tr>
<td>Other</td>
<td>14</td>
<td>14</td>
<td>14</td>
</tr>
</tbody>
</table>

Source: How many acres of the following other crops did you plant in the following years? If none, enter 0. 0’s included in average.
Sorghum Yields

- Sorghum yields have remained consistent over the past year at about 82 bushels per acre. Irrigated sorghum acres yield about 20% to 25% more bushels per acre than non-irrigated sorghum.

![Average Sorghum Yields (Bushels per Acre) by Year]

Source: What was your average sorghum yield in bushels per acre or pounds per acre for your [irrigated/non-irrigated] sorghum in the following years? Sorghum yields include 0’s (i.e., growers who reported planting sorghum, cut said they had 0 yields).

* Caution due to small sample size.
Growers over the past three years have produced about 83 bushels per acre of sorghum on non-irrigated land. However, yields vary widely with most growers (80%) reporting yields between 50 and 120 bushels per acre.

Source: What was your average sorghum yield in bushels per acre or pounds per acre for your [non-irrigated] sorghum in the following years?
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Tillage Practices

April 2020
• Roughly half of growers use strip till on their irrigated sorghum acres (50%). This was also true in 2017 and 2018.

Percent of Sorghum Acres On Which Tillage Practice is Used by Year*

<table>
<thead>
<tr>
<th></th>
<th>No till</th>
<th>Minimum/Strip till</th>
<th>Conventional till</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>13</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>2017</td>
<td>27%</td>
<td>51%</td>
<td>22%</td>
</tr>
<tr>
<td>2018</td>
<td>23%</td>
<td>53%</td>
<td>23%</td>
</tr>
<tr>
<td>2019</td>
<td>31%</td>
<td>50%</td>
<td>19%</td>
</tr>
</tbody>
</table>

Source: How many of your sorghum acres were no till, minimum/strip till or conventional tillage in [year]?

* Caution due to small sample.
• Most all growers practice no till on their non-irrigated sorghum acres (76%). This was true in 2017 (79%) and 2018 (78%).
• Directionally, the practice of no till appears to be declining slightly and minimum till increasing.

**Percent of Sorghum Acres On Which Tillage Practice is Used by Year**

<table>
<thead>
<tr>
<th>Tillage Practice</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>No till</td>
<td>79%</td>
<td>78%</td>
<td>76%</td>
</tr>
<tr>
<td>Minimum/Strip till</td>
<td>8%</td>
<td>9%</td>
<td>13%</td>
</tr>
<tr>
<td>Conventional till</td>
<td>12%</td>
<td>12%</td>
<td>9%</td>
</tr>
<tr>
<td>Other</td>
<td>0%</td>
<td>0%</td>
<td>2%</td>
</tr>
</tbody>
</table>

*Source: How many of your sorghum acres were no till, minimum/strip till or conventional tillage in [READ YEAR]?*
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Carbon Inputs

April 2020
Nutrient Use

- Roughly 85% of growers apply nitrogen to their irrigated sorghum acres and 90% of growers apply nitrogen to the non-irrigated sorghum acres.
- Most all growers (irrigated and non-irrigated sorghum) apply phosphate to their acres. A higher portion of growers with irrigated acres apply this nutrient than growers with non-irrigated sorghum acres.
- The portion of growers with irrigated sorghum acres who applied potash increased year over year from 2017 to 2019. Few growers with non-irrigated sorghum apply potash (10%)*.

**Nutrient Use Among Growers who Plant Sorghum in Indicated Years**

**Irrigated Sorghum Acres***

<table>
<thead>
<tr>
<th>Year</th>
<th>Nitrogen</th>
<th>Phosphate</th>
<th>Potash</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>85%</td>
<td>85%</td>
<td>15%</td>
</tr>
<tr>
<td>2018</td>
<td>85%</td>
<td>77%</td>
<td>23%</td>
</tr>
<tr>
<td>2019</td>
<td>87%</td>
<td>80%</td>
<td>33%</td>
</tr>
</tbody>
</table>

**Non-Irrigated Sorghum Acres**

<table>
<thead>
<tr>
<th>Year</th>
<th>Nitrogen</th>
<th>Phosphate</th>
<th>Potash</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>90%</td>
<td>70%</td>
<td>10%</td>
</tr>
<tr>
<td>2018</td>
<td>90%</td>
<td>70%</td>
<td>10%</td>
</tr>
<tr>
<td>2019</td>
<td>91%</td>
<td>68%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Source: What was your nitrogen fertilizer target [lbs/acre] in [year] for your [irrigated/non-irrigated] sorghum acres? Please tell me the application rate for [phosphate/potash] to your [irrigated/non-irrigated] sorghum acres in [year]?

*Caution due to small sample.
Nitrogen Use

• Growers with irrigated sorghum acres generally apply nitrogen at a rate of 108 lbs. per acre, compared to a target rate of 77 lbs. per acre for growers with non-irrigated sorghum acres. Over the past three years, growers with non-irrigated sorghum apply 30 lbs. to 35 lbs. less per acre to their sorghum than growers with irrigated acres. Growers' target rate for nitrogen has not changed significantly over the past three years.

• Most growers (with or without irrigated acres) treat the majority of their sorghum acres with nitrogen.

<table>
<thead>
<tr>
<th>Nitrogen Target Application Rates and Acres Treated at Target Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated*</td>
</tr>
<tr>
<td>-----------------------</td>
</tr>
<tr>
<td>Average Target Rate (lbs./acre)</td>
</tr>
<tr>
<td>% of Sorghum Acres Treated</td>
</tr>
<tr>
<td>Average Sorghum Acres Treated (among users only)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Non-Irrigated</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Target Rate (lbs./acre)</td>
<td>77.9</td>
<td>78.0</td>
<td>77.4</td>
</tr>
<tr>
<td>% of Sorghum Acres Treated</td>
<td>92%</td>
<td>92%</td>
<td>93%</td>
</tr>
<tr>
<td>Average Sorghum Acres Treated (among users only)</td>
<td>417.7</td>
<td>402.1</td>
<td>396.4</td>
</tr>
</tbody>
</table>

Source: What was your nitrogen fertilizer target rate in lbs. per acre in [year] for your [irrigated/non-irrigated] sorghum acres? For context, a recent study found a target rate of 0.91 pounds per bushel. How many acres were treated at that rate in [year]?

*Caution due to small sample.
• Growers generally apply phosphate at a slightly higher rate on their irrigated acres (35 lbs./acre) than non-irrigated acres (29 lbs./acre). Over the past three years, phosphate is applied to 70% to 75% of both irrigated and non-irrigated sorghum acres.

Phosphate Application Rates and Acres Treated at Application Rate

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Rate (lbs./acre)</td>
<td>32.3</td>
<td>31.5</td>
<td>35.0</td>
<td>11,10,12</td>
</tr>
<tr>
<td>% of Irrigated Sorghum Acres Treated</td>
<td>76%</td>
<td>69%</td>
<td>77%</td>
<td>13,13,14</td>
</tr>
<tr>
<td>Average Sorghum Acres Treated (among users only)</td>
<td>162.7</td>
<td>152.0</td>
<td>147.1</td>
<td>11,10,12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Irrigated</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Rate (lbs./acre)</td>
<td>29.0</td>
<td>29.4</td>
<td>29.2</td>
<td>61,63,67</td>
</tr>
<tr>
<td>% of Sorghum Acres Treated</td>
<td>74%</td>
<td>75%</td>
<td>70%</td>
<td>87,90,98</td>
</tr>
<tr>
<td>Average Sorghum Acres Treated (among users only)</td>
<td>508.3</td>
<td>502.7</td>
<td>469.6</td>
<td>61,63,67</td>
</tr>
</tbody>
</table>

Source: Please tell me the application rate for [phosphate] to your [irrigated/non-irrigated] sorghum acres in [year]? How many acres were treated at that rate?

* Caution due to small sample.
• Potash is applied to about 10 percent of sorghum acres (irrigated and non-irrigated) at a rate of about 30 lbs. to 35 lbs. per acre.

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Irrigated</strong>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Rate (lbs./acre)</td>
<td>45.0</td>
<td>30.7</td>
<td>40.0</td>
</tr>
<tr>
<td>% of Sorghum Acres Treated</td>
<td>7%</td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>Average Sorghum Acres Treated (among users only)</td>
<td>85.0</td>
<td>77.7</td>
<td>91.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Non-Irrigated</strong>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Rate (lbs./acre)</td>
<td>30.8</td>
<td>33.6</td>
<td>31.5</td>
</tr>
<tr>
<td>% of Sorghum Acres Treated</td>
<td>11%</td>
<td>9%</td>
<td>10%</td>
</tr>
<tr>
<td>Average Sorghum Acres Treated (among users only)</td>
<td>505.6</td>
<td>418.3</td>
<td>444.0</td>
</tr>
</tbody>
</table>

* Caution due to small sample.
Other Farm Information
Crop Rotation

- Wheat is the crop that typically follows sorghum for the single largest portion of growers (38%).

Source: Common Kansas rotational systems include sorghum-wheat and sorghum-soybeans. What is your typical sorghum rotation?
The diagram below shows crops following sorghum in the first year followed by the two most mentioned second year crops. The highest portion of growers plant wheat (35%) or soybeans (28%) following sorghum in the first year. Half of growers who plant soybeans following sorghum plant wheat in the second year following sorghum.

Source: Common Kansas rotational systems include sorghum-wheat and sorghum-soybeans. What is your typical sorghum rotation?
Growers report an average of 2% organic matter. About 20% of growers did not know the percent of organic matter.

Source: What is your typical organic matter percentage? For context, typical Kansas soils have organic matter between 0% and 3%.

Base = 101.
Among growers with non-irrigated sorghum acres, growers with higher percentages of organic matter report having a higher target rate for nitrogen on average.

Average Target Nitrogen Rate by Percent Organic Matter

Source: What was your nitrogen fertilizer target [lbs/acre] in [year] for your [irrigated/non-irrigated] sorghum acres? Please tell me the application rate for [phosphate/potash] to your [irrigated/non/irrigated] sorghum acres in [year]? What is your typical organic matter percentage? For context, typical Kansas soils have organic matter between 0% and 3%.

*Caution due to small sample.
Most growers, regardless of region, describe their soil type as medium.

Source: How would you define your typical soil type---course, medium or fine?
*Caution due to small bases.
Carbon Footprint Study

Appendix
## Counties in Regions

<table>
<thead>
<tr>
<th>County</th>
<th>Region</th>
<th>County</th>
<th>Region</th>
<th>County</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barber</td>
<td>Central</td>
<td>Cheyenne</td>
<td>West</td>
<td>Coffey</td>
<td>East</td>
</tr>
<tr>
<td>Barton</td>
<td>Central</td>
<td>Clark</td>
<td>West</td>
<td>Douglas</td>
<td>East</td>
</tr>
<tr>
<td>Butler</td>
<td>Central</td>
<td>Decatur</td>
<td>West</td>
<td>Johnson</td>
<td>East</td>
</tr>
<tr>
<td>Clay</td>
<td>Central</td>
<td>Finney</td>
<td>West</td>
<td>Labette</td>
<td>East</td>
</tr>
<tr>
<td>Cloud</td>
<td>Central</td>
<td>Ford</td>
<td>West</td>
<td>Marshall</td>
<td>East</td>
</tr>
<tr>
<td>Comanche</td>
<td>Central</td>
<td>Gove</td>
<td>West</td>
<td>Morris</td>
<td>East</td>
</tr>
<tr>
<td>Cowley</td>
<td>Central</td>
<td>Graham</td>
<td>West</td>
<td>Nemaha</td>
<td>East</td>
</tr>
<tr>
<td>Dickinson</td>
<td>Central</td>
<td>Grant</td>
<td>West</td>
<td>Riley</td>
<td>East</td>
</tr>
<tr>
<td>Edwards</td>
<td>Central</td>
<td>Gray</td>
<td>West</td>
<td>Shawnee</td>
<td>East</td>
</tr>
<tr>
<td>Ellis</td>
<td>Central</td>
<td>Greeley</td>
<td>West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ellsworth</td>
<td>Central</td>
<td>Hamilton</td>
<td>West</td>
<td>Saline</td>
<td>Central</td>
</tr>
<tr>
<td>Harper</td>
<td>Central</td>
<td>Haskell</td>
<td>West</td>
<td>Sedgwick</td>
<td>Central</td>
</tr>
<tr>
<td>Harvey</td>
<td>Central</td>
<td>Hodgeman</td>
<td>West</td>
<td>Smith</td>
<td>Central</td>
</tr>
<tr>
<td>Jewell</td>
<td>Central</td>
<td>Kearny</td>
<td>West</td>
<td>Stafford</td>
<td>Central</td>
</tr>
<tr>
<td>Kingman</td>
<td>Central</td>
<td>Lane</td>
<td>West</td>
<td>Sumner</td>
<td>Central</td>
</tr>
<tr>
<td>Kiowa</td>
<td>Central</td>
<td>Logan</td>
<td>West</td>
<td>Washington</td>
<td>Central</td>
</tr>
<tr>
<td>Lincoln</td>
<td>Central</td>
<td>Meade</td>
<td>West</td>
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<tr>
<td>Marion</td>
<td>Central</td>
<td>Morton</td>
<td>West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>McPherson</td>
<td>Central</td>
<td>Ness</td>
<td>West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitchell</td>
<td>Central</td>
<td>Norton</td>
<td>West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osborne</td>
<td>Central</td>
<td>Rawlins</td>
<td>West</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ottawa</td>
<td>Central</td>
<td>Scott</td>
<td>West</td>
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