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Brief Communication

Agricultural producer and non-producer perceptions of crop residue burning: a focus on arkansas

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Abstract
Agricultural producers adopt management practices that positively and negatively affect the lives of non-producers in their communities. CRB has important environmental and human health implications, and local non-producers might have different perceptions and attitudes from agricultural producers about crop residue burning. In this paper, we use a multi-stakeholder approach to study the issue of crop residue burning (CRB). Survey data were collected from a sample of producers in Arkansas who burn crop residue and a sample of non-producers who resided in the same counties as the producers. Non-producers may not be willing to compensate producers at an amount that would reduce the use of CBR. Non-producers do not fully understand some of the benefits of CRB, like reduced tillage or equipment savings cost, and producers are less likely to perceive increased greenhouse gas (GHG) emissions as a negative externality associated with CRB. A multi-stakeholder approach can provide more depth and breadth to understanding complex decisions about farm management practices, and these results have implications for policies that incentivize adopting best farm management practices.

Keywords Crop residue burning · Residue management · Agricultural conservation · Public perception

1 Introduction

In preparation for the next seeding season, agricultural producers can select crop residue management methods with various social costs and benefits. Crop residue burning (CRB) is often a relatively inexpensive management method compared to other options, like mechanical tillage, and is time-efficient by allowing for earlier planting of the next seed round [1]. Moreover, CRB is an effective weed and pest management tool [2].

While CRB may be the most affordable, convenient, or effective management method for crop residue in some contexts, there are several environmental and social externalities imposed on local non-producers. The black carbon emitted from CRB has a global warming impact of 460 to 1500 times stronger than carbon dioxide [3] Smoke emitted from CRB can threaten local air quality and the respiratory health of surrounding residents [4]; for example, emergency department visits due to respiratory conditions are often higher in surrounding counties during burning seasons [5]. CRB is

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also associated with increased driving time and vehicle accidents [6]. Thus, reducing CRB is a climate-smart agricultural practice for agricultural producers [7] that also improves air quality and health conditions for non-producers.

CRB is a particularly common practice in rice-producing areas, as rice residue potentially jeopardizes the seedling health and growth health of future plantings [8]. About 58% of rice production in the United States (U.S.) occurs in the Arkansas (AR) Delta Region [9], and it is estimated that about 40% of AR rice fields use CRB in years when conditions are conducive [8]. AR has been estimated to be the second state most reliant on CRB in the U.S. [10], and around 25% of Arkansans live in counties where crop residue is burned [11]. To mitigate some of the harm associated with CRB, the AR Voluntary Smoke Management Guidelines were developed to outline criteria for safe burning [12].

This study aims to determine the opinions of producers and non-producers in AR to better understand the positive and negative factors associated with CRB. Published research examining the factors associated with CRB in the U.S. is lacking. Previous studies exploring the factors of CRB use have been conducted in Pakistan [13], India [14], Nepal [15], the Philippines [16], China [17], and Bangladesh [18]. Financial, labor, time, and information constraints play a role in the decision to burn [13–15, 19]. While these studies provide useful context regarding motivating factors associated with CRB, the results may not apply to the U.S. due to differences in farm size and income. This study contributes to the CRB literature gap in the U.S. by using a unique multi-stakeholder approach that considers the experiences of both producers in the AR Delta Region and the surrounding residents who were not agricultural producers (henceforth referred to as non-producers).

To complete the objective of this study, data were first collected from AR producers using a survey that asked a series of questions exploring their motivations for using CRB and opinions about the associated externalities. To contrast the results from the producer survey, a survey asking a similar set of questions was then distributed to non-producers residing in the same counties as producers. The goal of a multi-stakeholder approach is to include representation from multiple stakeholder categories [20], which can create a mutual understanding between stakeholders and increase the adoption of agricultural production practices [21, 22]. The results of this study are a first step to understanding why U.S. producers use CRB and the extent to which non-producers are affected by this crop residue management method.

2 Survey overview and data analysis

This study was approved by the Institutional Review Board at the University of Delaware [1497680–4]. The procedures used in this study adhere to the tenets of the Declaration of Helsinki, and informed consent was obtained from respondents before completing the survey.

Data were collected from web-based surveys distributed to agricultural producers and non-producers in the AR Delta Region. Respondents were asked their opinions about the perceived benefits of CRB, the perceived negative effects of CRB, and the compensation to reduce CRB. The survey was piloted by experts at the University of Arkansas (i.e., extension agents and agricultural economists) in July 2021 to receive feedback on the questions and response options provided to respondents. Question wording had to vary slightly between the producer and non-producer surveys; more details about the specific questions asked and wording are provided below in Sects. 2.1, 2.2, and 2.3.

The producer sample was reached via email listservs maintained by the University of Arkansas Cooperative Extension Service. A primer email about the survey was sent to AR producers on August 18, 2021, the survey link was sent on August 26, 2021, and data were collected through October 27, 2021. In total, 40 responses were received from producers using CRB. While AR is the largest rice-producing state in the U.S., the number of rice farms in AR decreased from around 4365 in 1997 to 1877, a 57% decrease [23]. There are no estimates on the number of farms per county or whether the number of farms continued to decrease from 2017 to the time of data collection in 2021. Nevertheless, using the estimated 1877 farms in 2017 and the estimate that about 40% of AR rice fields use CRB in years when conditions are conducive [8], a sample size of 40 producers results in a margin of error of 15% with a 95% confidence level. While a lower margin of error would be preferred, small samples relative to the population size of a producer group are common [24–26] because recruiting agricultural producers to participate in research is difficult [27].

A survey was then distributed to non-producers residing in the same AR counties via a panel maintained by Qualtrics. Data were collected from 309 non-producers from July 26 to August 7, 2022. According to the 2020 U.S. census, there were 376,700 adults over the age of 18 residing in the AR counties sampled [28]. Thus, a sample size of 309 non-producers results in a margin of error of 6% with a 95% confidence level. A list of the counties and the proportion of respondents sampled from each county is shown in Appendix Table 1.

2.1 Perceived benefits of CRB

Opinions about the most beneficial aspects of CRB were collected separately for the agronomic and economic benefits. The framing of questions asked to producers and non-producers differed slightly. Producers were asked, "what are the benefits of burning crop residue" and non-producers were asked, "what are the benefits that cause producers to burn crop residue." Respondents were provided with seven possible agronomic benefits of CRB and asked to provide a ranking for the most beneficial aspect; the benefits provided were nutrient management, insect control, weed management, disease management, irrigation management, crop rotation, and reduced tillage. Four possible economic benefits were provided to respondents including labor cost savings, equipment cost savings, and personal time savings. A 'no benefits' and 'I don't know' response options for each question were also provided.

The data from the questions were stacked, so there was a row to reflect each response option per respondent. The response option ranked as the most beneficial was coded as one, and the other response options were coded as zero. These data were used to estimate a multinomial logistic regression model [29], that included an indicator variable for producers that can be specified by:

$$\mathrm{PR}\left(MB_{ni}\right) = \alpha_{1i} + \beta_{1i}P_n \tag{1}$$

where MB_{ni} is equal to one if the ith benefit was ranked as most beneficial by the nth respondent and zero otherwise, P_n is an indicator variable equal to one if the nth respondent was a producer and zero if a non-producer, α_{1i} are specific constants for each benefit, and β_{1i} are the coefficients of interest that estimate differences in benefit ranking between producers and non-producers. Standard errors were clustered by a respondent to account for repeated measures from stacking the data. The marginal effects for β_{1i} are reported in the Results section that represent the differences in the proportions a benefit was ranked as most beneficial (i.e., non-producers minus non-producers) and test for differences between producers and non-producers.

2.2 Perceived negative effects of CRB

To determine which negative effects producers and non-producers associated with CRB, producers were prompted to select any negative effects from their experience with CRB, and non-producers were asked to select any negative effects they associated with CRB. The negative effects provided were local air quality, increased greenhouse gas (GHG) emissions, impacts on human health, increased car accidents, and increased driving times. Respondents were also provided "other" and "no negative effects" as response options. "No negative effects" was an exclusive response option, so respondents who selected this could not select any other negative effects in the question.

The data from this question were also stacked, and a binary logistic regression model was estimated because respondents could select multiple options. Selected response options were coded as one, and unselected options were coded as zero. Like Eq. 1, an indicator variable for producers was included as an independent variable to determine differences between producers and non-producers that can be specified by:

$$\mathrm{PR}\left(NE_{ni} = 1\right) = \alpha_{2i} + \beta_{2i}P_n \tag{2}$$

where NE_{ni} is equal to one if the nth respondent selected negative effect i and zero otherwise, and β_{2i} are the coefficients of interest. Standard errors were clustered by a respondent to account for stacking the data. The marginal effects for β_{2i} are reported to estimates the differences in the proportions that negative effects were selected (i.e., non-producers minus non-producers) and statistically test for differences.

2.3 Compensation to reduce CRB

Lastly, respondents were asked about the compensation level needed not to burn crop residue. Again, the framing of questions varied slightly between non-producers and producers. Producers were asked, 'how much would you have to be compensated to not burn crop residue' and non-producers were asked, 'how much should producers be compensated to not burn crop residue.' Five response options were provided for per acre compensation: \$0, \$1 to \$20, \$21 to \$30, \$31 to \$40, \$41 to \$50, and more than \$50. The censored categorical response options were used as the dependent variable to estimate an interval regression model that can be specified by.

Table 1 Multinomial logistic regression estimates for the differences in the most beneficial agronomic aspects associated with CRB

Agronomic issues	Marginal effects for the producer indicator variable	Standard errors
Nutrient management	– 0.187***	(0.049)
Insect control	– 0.104***	(0.017)
Weed management	– 0.009	(0.045)
Disease management	– 0.037	(0.028)
Irrigation management	– 0.039***	(0.011)
Crop rotation	– 0.026	(0.051)
Reduce tillage	0.549***	(0.077)
No benefit/I don't know	– 0.147***	(0.041)
Log likelihood	– 643	
Number of observations	349	

***significance at a *p*-value < 0.01

$$C_n^* = \alpha_3 + \beta_3 P_n \tag{3}$$

whereC_n^* is the per acre compensation response category selected by the *n*th respondent. Due to the inclusion of the indicator variable for producers (P_n), the intercept (α_3) estimates the mean compensation that non-producers indicated producers should be compensated to eliminate CRB, and β_3 estimates the difference between the mean compensation required by producers and what non-producers indicated producers should be compensated.

3 Results

The proportions of agronomic factors that were selected as the most beneficial aspect of using CRB are presented in Appendix Table 2. The most beneficial selections by producers and non-producers differed significantly for some of the agronomic benefits selected. For example, reduced tillage was selected by approximately 68% of producers as the most beneficial aspect of CRB and by about 13% of non-producers. Crop rotation was the agronomic benefit selected second-most by producers (10%). Nutrient management was selected the most by non-producers (26%), whereas nutrient management was only selected by about 8% of producers. "I don't know" was selected the second most by non-producers (14%). The marginal effects in Table 1 estimate the differences between producers and non-producers and indicate which differences were significant. For example, the marginal effect for reduced tillage was 0.55, which is the difference between the 68% of producers and 13% of non-producers selecting reduced tillage mentioned previously. On average, producers were significantly less likely than non-producers to select nutrient management, insect control, irrigation management, and no benefit / I don't know, while producers were significantly more likely to select reduced tillage.

The proportions that each economic factor was selected as the most beneficial aspect are displayed in Appendix Table 3. Equipment cost savings was selected the most by producers (60%), and labor cost savings was selected the second most (23%). Labor cost savings was selected the most by non-producers (32%), and "I don't know" was selected the second most (24%). The marginal effects in Table 2 show the differences in proportions that the most beneficial economic aspects of using CRB were selected. Equipment cost savings was selected by about 44% more of the producer sample than the non-producer sample, and no benefit / I don't know was selected by 27% more of the non-producer sample. Both of these differences were significant, while there were no significant differences in labor cost savings or personal time savings.

The proportions of the negative effects associated with CRB selected by respondents are shown in Appendix Table 4. Approximately 72% of non-producers selected local air quality, more than half selected impacts to human health, and more than a third selected increased GHG emissions as negative effects of CRB. A high proportion of producers also selected local air quality (75%) and impacts on human health (35%). Table 3 presents the marginal effects that estimate the differences between producer and non-producer selection of negative effects. Producers were significantly less likely than non-producers to select increased GHG emissions and impacts on human health

Table 2 Multinomial logistic regression estimates for the differences in the most beneficial economic aspects associated with CRB

Economic issues	Marginal effects for the producer indicator variable	Standard errors
Labor cost savings	– 0.099	0.071
Equipment cost savings	0.438***	0.080
Personal time savings	– 0.069	0.057
No benefits/I don't know	– 0.270***	0.044
Log likelihood	– 457	
Number of observations	349	

Standard errors are presented in parentheses

***significance at a p-value < 0.01

Table 3 Binary logistic regression estimates for the differences in selected negative effects associated with CRB

Negative effects	Marginal effects for the producer indicator variable	Standard errors
Local air quality	0.019	0.057
Increased GHG emissions	– 0.118**	0.060
Impacts to human health	– 0.110**	0.051
Increased car accidents	0.060	0.058
Increased driving times	– 0.081	0.110
Other	0.161*	0.089
No negative effects	0.110	0.067
Log likelihood	– 1104	
Number of observations	2443	
Number of clusters	349	

Standard errors were clustered. ** and *denote significance at p-values < 0.05 and 0.10

Table 4 Interval regression estimates for the compensation levels to reduce crop residue burning

	Coefficients	Standard errors
Constant	30.346***	1.605
Producer indicator variable	16.195***	4.851
Log likelihood	– 555	
Number of observations	349	

***denotes significance at a p-value < 0.01

as negative factors associated with CRB. Otherwise, there were no differences between non-producers and producers at a p-value less than 0.05.

Finally, the proportions of compensation levels selected by producers and non-producers are shown in Appendix Table 5. The distributions for non-producers were somewhat bimodal, with relatively high proportions of respondents selecting the lowest or highest compensation values. The compensation level most frequently selected by producers was more than $50 (the response option with the highest dollar amount); this is perhaps unsurprising given that most producers indicated that either equipment or labor cost savings were the most beneficial economic aspect of CRB. Table 4 presents the coefficients estimated by the interval regression model. On average, non-producers responded that producers should be compensated $30.35 per acre not to burn crop residue, while producers would require $46.55 per acre (30.35 + 16.20). The difference of 16.20, estimated by the coefficient for the producer indicator variable, was statistically significant.

4 Conclusions

The results of these surveys provide insight into the perceptions of CRB by producers and non-producers and how they align and contrast. Understanding the disparities in producer and non-producer sentiments towards a production practice with significant externalities can be insightful in policy scenarios seeking to improve outcomes for all stakeholders involved. Multi-stakeholder engagement can be crucial in promoting climate-smart agricultural practices, like reducing CRB [7]. Agricultural extension personnel are routinely asked to consult on the economic impact assessments of natural disasters and weather-related events [30–32]. These assessments use data from producer surveys, and a multi-stakeholder survey and analysis might provide more complete estimates by including non-producers in data collection.[1] Many other problems in agriculture would benefit from a multi-stakeholder approach to understanding perceptions, attitudes, and economic impacts. For example, virtually all the research on sustainable agriculture focuses on producer adoption [33, 34] or consumer perceptions and preferences [35–39].

In this study, producers showed a clear trend of using CRB to reduce the necessity of tillage and the associated equipment costs. Over two-thirds of producers selected reduced tillage as the most beneficial agronomic aspect of CRB, and the next popular answer choice was only selected by 10% of producers. Equipment cost savings was an important benefit of CRB for producers, which is likely also directly related to the burden of extensive tillage. This result makes intuitive sense considering the extensive tillage needed to maintain rice fields without CRB and the state's high share of rice production. When asked about the benefits of CRB, non-producers' responses were more evenly split across response options, potentially indicating an overall lack of understanding of the practice.

In terms of the negative factors associated with CRB, producers and non-producers were both most concerned with the impact on local air quality. However, impacts to human health was selected significantly less frequently by both groups, which is counterintuitive considering the connection between air quality and human health. Still, responses to this question show a trend of concern for environmental and health-related factors over inconveniences like road closures. Producers were almost twice as likely than non-producers to select "no negative effects."

On average, AR non-producers were willing to pay about $16 per acre less than producers would accept as compensation to forgo CRB. Producers and non-producers showed the most similarities in identifying the negative factors associated with CRB, but responses differed significantly when asked to select the agronomic and economic benefits of the practice. These inconsistencies likely contribute to the gap between non-producers' willingness to compensate producers for not burning crop residue versus the amount producers require. Our findings will help address the gap in the literature concerning U.S. producers' perceptions of CRB, with the added component of non-producer sentiments also included. The disparity in compensation levels has important policy implications as it indicates that policies seeking to tax non-producers to subsidize producers to reduce CRB may not be feasible. However, some form of a cost-share policy would likely be a more acceptable and economically feasible solution for both parties. Surveying both stakeholder groups gives policymakers an estimate of what a potential cost-share policy would need to look like to reduce CRB.

This study set out to provide some baseline information about the perceptions and use of CRB in the U.S. While these results provide some insight into the motivations of producers and concerns of non-producers, there are limitations to this study. Notably, the sample sizes and differences in sample sizes. There is a relatively large margin of error associated with the sample size for producers; however, recruiting agricultural producers to participate in research is difficult. For example, a recent paper examining producer response rates for five research studies showed that two of the five studies had a response rate of 0%, and the other studies had response rates of 1%, 4.1%, and 6.5% [27]. Another limitation is the difference in sample sizes (i.e., 40 producers and 309 non-producers). While the population size of non-producers is also much larger than the population size of producers, the difference in sample sizes has implications for estimates, as standard errors are influenced by the number of observations. Thus, the sample sizes and differences in sample sizes should be considered when interpreting study results.

Author contributions J.H. wrote the main manuscript. R.B. wrote the main manuscript. B.R.M. designed the survey instruments, collected data, estimated the statistical analysis, and revised the main manuscript. A.M.S. designed the survey instruments, collected data, and revised the main manuscript. J.M. wrote the main manuscript.

[1] Mitchell, Tonsor, and Schulz (2021) were the first to adopt a multi-stakeholder approach to analyze cost-share policies [26].

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Data availability All data and the Stata code used for this study are available at: https://osf.io/m6rwq/?view_only=488a7b0bf0e14edeb631601b4bda2d89.

Declarations

Competing interests The authors declare no competing interests.

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