Atmospheric Environment 106 (2015) 154–164

Contents lists available at ScienceDirect

Atmospheric Environment

journal homepage: www.elsevier.com/locate/atmosenv

A comparative analysis of potential impact area of common sugar cane burning methods

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HIGHLIGHTS

- We measure two types of sugarcane burning practices.
- We compare the dispersion from each type of burn.
- Ground burning has less potential to impact offsite areas.

ARTICLE INFO

Article history:
Received 15 September 2014
Received in revised form
4 January 2015
Accepted 3 February 2015
Available online 4 February 2015

Keywords:
Lidar
Agricultural air quality
Smoke
Dispersion
Sugarcane

ABSTRACT

The negative effects of agricultural burning are well-known, although the actual impact area of different activities has not previously been quantified. An elastic backscatter lidar system was used to examine the impact-area size and dispersion of smoke generated from different types of sugarcane burning activities; pre-harvest (standing) burning and post-harvest (ground) burning. Experiments were conducted in the sugarcane harvest season of 2010 and 2011 at two locations in Louisiana, USA. Current dispersion theory would suggest that the primary difference between burn types would be primarily in the initial plume rise, but that the overall plume shape would remain the same. However, remotely sensed lidar data with the capability to measure plume dispersion and the short time dynamics of plume location showed pre-harvest (standing) burning produced a larger plume with greater rise and more spread within the 300 m of the plume, but a decrease in dispersion, but not concentration further downwind. Post-harvest (ground) burning produced a more traditional plume shape, but still exceeded impact area predictions near the source. Moreover, large changes in plume size can occur with small increases in wind speed. These are the first instrumented measurements of the meteorological effects of the different types of sugarcane burning. These results indicate that ground burning is preferable, but should be avoided in lower wind speed conditions.

1. Introduction

It is well recognized that there is a lack of information as to how agricultural production contributes to the air quality, and by extension, directly or indirectly affects human health (Aneja et al., 2008). One production practice of concern is sugarcane burning, where the particles and gases produced can affect the surrounding communities for six months out of the year (Arbex et al., 2007). Although the adverse health effects of sugarcane burning emissions on surrounding communities are well documented (Arbex et al., 2007; Cançado et al., 2006; Mazzoli-Rocha et al., 2008), the smoke emission at the source itself has not been quantified. Depending on the meteorological conditions, the resulting smoke plume can travel fairly far (>30 miles) and be considerably dense (causing limitations in visibility). The types of pollutants from emitted from agricultural burn practices include particulates (both PM10 and PM2.5), partially consumed fuel, carbon monoxide, hydrocarbons, nitrogen oxides, and other compounds (Jimenez et al., 2006), but a lack of data exists on sugarcane specifically (Dennis et al., 2002; Hays et al., 2005).

In the case of sugarcane burning activities, some modest guidelines exist to help burn managers avoid excessive smoke

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http://dx.doi.org/10.1016/j.atmosenv.2015.02.005
1352-2310/

impacts on the surrounding communities. These guidelines are based on traditional plume modeling techniques and use the underlying principles of the Gaussian model, treating the field as a point source (Carney et al., 2000), to determine a category day based on atmospheric stability conditions. Category days indicate no burning possible, burning any time, or recommend times for burns to occur (e.g. after surface inversion has lifted but before 4 pm) and are based on fire weather forecasts for the region and the type of burn to be performed. The projected impact area is determined as a simple cone of influence defined by the current wind direction $\pm 30^{\circ}$(Carney et al., 2000). Both of these metrics have the benefits of being simple to understand and are easily computed at the beginning of a burn event. Those benefits, however, may come at the cost of accuracy.

Published data on the atmospheric impacts of sugarcane production is very limited (Cheesman, 2004). An extensive review has indicated that much of the currently available literature has focused on sugarcane production in tropical regions such as Australia and Brazil (Allen et al., 2010; Weier, 1999). It is unlikely that the information from studies conducted in tropical regions can serve as basis for estimating atmospheric emissions from sugarcane production in other climatic regions. The cultivation and fertilization practices in tropical regions are quite different from those in the subtropical U.S. (Cheesman, 2004). For instance, in Australia, harvest residue is fully retained to conserve soil moisture needed for healthy sugarcane growth and N fertilizer is often split-applied 2–3 times a year (Wood, 1991). On the other hand, in Louisiana, the northern-most sugarcane production area in the U.S., residue needs to be carefully managed in order to avoid low sugar yields caused by negative soil water–temperature relation from cold, rainy weather that often prevails in the winter months (Kennedy and Arceneaux, 2006; Richard et al., 2001; Viator et al., 2009, 2008). The lack of adequate information for U.S. practices has resulted in uncertainty concerning the characterization of emission inventory of greenhouse gases as well as PM-related NH_3 from sugarcane (Dennis et al., 2002), and plume impact areas.

Louisiana is a major producer of sugarcane in the United States, with ~400,000 acres in the state dedicated to sugarcane farming (U.S. Department of Agriculture (2010)), and a yearly direct economic value of the crop exceeding $2 billion (Gravois et al., 2011). The sugarcane production cycle requires prescribed burning in the harvesting process. The sugarcane plant is 75–80% cane stalks, which is the desired product, and 20–25% extraneous leafy material (Gravois et al., 2011). The leafy "trash" that is not wanted is usually burned either before or after the cane is harvested. Pre-harvest burns, or "standing burns" are performed to remove the extra leafy material to both eliminate the waste and aid the efficiency of the harvesting equipment. Post-harvest burning, or a "ground burn" is performed days or longer after the harvesting process. In this case, the material that is leftover from the harvest is allowed to dry out and then burned to remove it from the field in order to promote good soil respiration while the field is between crop cycles. Without being burned, the leftover trash can both decrease the following year's crop yield and put economic burdens on the industry. If the layer of leafy material remains on the field, it will dry out the soil, as well as release allelochemicals while it decays, which will prevent the germination of the sugarcane seed the following season. Alternatively, moving the leafy material from the field would cost the industry an estimated $24 million for transportation and processing (Gravois et al., 2011). Burning sugarcane fields reduces the energy expenditure of the farmers, eliminates unnecessary wear of field and factory machinery, decreases the amount of material that factories process, and shortens the harvest season by 10% (Carney et al., 2000). Until an equally economically efficient way to eliminate the trash is discovered, sugarcane burning will remain a necessary harvesting method, meaning that smoke and ash management, or the act of conducting a prescribed burn during recommended atmospheric conditions, will be used to mitigate the effects on the nearby community (Carney et al., 2000).

Outside the U.S., multiple studies have evaluated the impact of sugarcane burning pollution on the health of nearby communities (Arbex et al., 2007; Cançado et al., 2006). A relationship between biomass burning and an increase in emergency room visits for inhalation therapy in Araraquara, Brazil was discovered by Arbex et al.(2007). Cancado et al. (2006) also found a strong relationship between hospital admissions due to respiratory diseases by the elderly and children during sugarcane burning season. The content of the smoke and ash plume was studied by Mazzoli-Rocha et al. (2008), who found sugarcane burning emissions to be at least as toxic as traffic emissions, and possibly even more so. Given these important societal aspects, it is desirable to have a better understanding of the short-term plume dynamics to aid in prediction and subsequent exposure prevention efforts. Here we present results of a field study in Louisiana to compare the size, shape, and dispersion of smoke plumes generated by pre-harvest and post-harvest burning practices. Results are compared to the theoretical dispersion patterns used by prescribed burn managers in the field. To our knowledge these are the first measurements of sugarcane smoke plume transport available.

2. Field data collection

Experiments were conducted in the harvest season of 2010 and 2011 at two locations in Louisiana, USA. In 2010, one standing burn and one ground burn were performed following current best management practices at the Louisiana State University (LSU) AgCenter Iberia field station in Jeanerette, LA. Due to a wet winter season, multiple points of burning were started around the field. In 2011, the experiment was repeated and additional burns were conducted at the LSU AgCenter St. Gabriel Research station in St. Gabriel, LA. These burns were more typical, the downwind side of the field was lit to let the fire work against the wind and then the field was ringed with fire around the edge. In both years, each burn area was approximately 1 acre. These fields are much smaller than a typical commercial plot, but represent a more controlled experiment. To the extent possible all factors, such as fuel usage and plot size were kept consistent for each burn even to minimize the effect on the measured plumes. A summary of the four burn events is found in Table 1.

Table 1
Summary of burn events.

Date	Type of burn and location	Burn time (LST)	Burn duration (minutes)	Scan sequence	Mean wind speed (standard deviation)	Mean wind direction (standard deviation)
17 Nov 2010	Standing Jeanerette	13.20 to 14.15	55	HORZ1	1.4 m/s (0.6)	181.6 (27.1)
18 Nov 2010	Ground Jeanerette	13.38 to 14.20	42	COMB1	2.2 m/s (0.7)	351.6 (15.6)
05 Dec 2011	Ground St. Gabriel	13.04 to 13.46	42	HORZ2	6.1 m/s (0.9)	209.1 (9.6)
12 Dec 2011	Standing Jeanerette	14.49 to 16.31	102	HORZ1	1.3 m/s (0.5)	272.4 (30.7)