Health Impacts of Burning Agricultural Crop Stubble

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Abstract

Health Impacts of Burning Agricultural Crop Stubble

Purpose of Study: Every year after harvest in Southeast Missouri a large percentage of the wheat and corn crop stubble is burned. This study examined possible health effects from the Particulate Matter < 2.5 μm ($PM_{2.5}$) that is generated from burning the wheat stubble.

Methods: A DataRAM-4 air monitor was used to record $PM_{2.5}$ levels from the burning of wheat stubble in Scott and Stoddard counties. Emergency room diagnoses at three hospitals in Southeast Missouri were obtained for each day of the burning season.

Results: Statistical testing showed that the three hospitals combined had statistically significant ($p<.01$) differences in number of emergency room visits resulting in respiratory diagnoses on days with $PM_{2.5}$ levels > 35 μg/cubic meter of air as compared to days with $PM_{2.5}$ < 35. Regression tests showed a strong positive correlation between number of fields burned and $PM_{2.5}$ levels ($r = .80$). A small positive correlation between $PM_{2.5}$ levels and number of respiratory diagnoses was shown ($r = .29$). This low correlation could be due to people developing symptoms before $PM_{2.5}$ values peaked

Conclusions: This is the first study to examine $PM_{2.5}$ levels in a rural area from agricultural fires and the $PM_{2.5}$ effects on hospital emergency room diagnoses. This study demonstrated an association between $PM_{2.5}$ levels from wheat stubble burning and hospital emergency room diagnoses of respiratory conditions. This study suggests that $PM_{2.5}$ monitors are needed in Southeast Missouri, that Missouri should consider either regulating or banning agricultural burning, and that alternatives to burning are needed.

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Reference Note regarding Figures: All figures (including photos) were created by Alex Heeb. Google Earth was used in creating Figure 7 and MODIS was used in creating Figure 8.

Introduction

Every year after corn (in late September and October) and wheat (in June) are harvested in Southeast Missouri, many fields are burned to clear off the remaining stubble. Agricultural burning is a quick and inexpensive way to clear thousands of acres of stubble. However, thousands of acres are burned, creating the possibility that resulting smoke and pollution could have unintended and detrimental consequences. Residents of towns and the surrounding countryside in the range of the smoke and pollution express concern about its effects on their health and their quality of life.

Many farmers believe that burning makes planting easier and kills pests. Other farmers are just as adamant that burning is unnecessary and harmful. A policy of the U.S. Department of Agriculture that sets a late June deadline for getting soybeans planted in Southeast Missouri in order for the soybeans to be eligible for crop insurance perhaps unintentionally encourages wheat stubble burning since some farmers claim they can get the field ready for planting the next crop quicker if they burn it.

As a historical note, my neighbor, a retired farmer with a good memory for dates, recalled that agricultural burning began in Scott County around 1970 when double-cropping began (planting soybeans in the same field after the wheat crop in that field is harvested) (as described by J. Dohogne, personal communication, June 15, 2007). Another person, who lived on a farm in Scott County as a boy in the 1930's, said that burning of fields was not done in the 1930's. He also said the stubble was used either as feed for cattle or was baled and taken to a paper-mill plant in Illinois. (as described by J. W. Groseclose, personal communication, June 3, 2007).

One agent produced by burning is fine particulate matter: particles 2.5 micrometers (microns) (μm) and smaller in diameter ($PM_{2.5}$). $PM_{2.5}$ particles have been tied to respiratory and cardiac ailments in other studies, but the other study only looked at urban areas. (Dominici et al. 2006)

Research Question: This study examines wheat stubble burning to see if it affects human health by the levels of $PM_{2.5}$ that are produced.

Study Population: The population studied in this research was the emergency room patients of the three area hospitals in Southeast Missouri during the wheat stubble burning period in June, 2007.

Potential Impact of Study Findings: The findings from this study should also apply to other rural areas where crop stubble is burned. This study's potential impact to farm operations, to air quality, and to the health of rural residents is considerable.

This study also compares the $PM_{2.5}$ levels from agricultural burning to the EPA standards. The EPA 2006 $PM_{2.5}$ 24-hour standard is 35 μg/m^3 (24-hour average, 98th percentile, averaged over 3 years). <The 98th percentile allows the worst 7 days for each year to be ignored>.

Some impacts from agricultural burning are not covered in this study. These include: traffic accidents from smoke causing impaired visibility on nearby roads, possible relation to lung cancer incidence, compaction of soil, destruction of earthworms, thus depriving the soil of the benefit they bring, and creation of greenhouse gases. Crops are only a CO_2 sink (net absorption) if they were not burned, but with burning the crops are also a source (net emission) of CO_2

Relevant Scientific Literature

Other studies have covered the individual topics of agricultural burning. (McCarty, Justice, Korontzi, 2007), of $PM_{2.5}$ levels and their relation to human health in urban areas, (Dominici et al. 2006), (Dockery, Pope, Xu, Spengler,Ware, Fay et al. 1993), (Laden, Schwartz, Speizer, Dockery, 2006), (Pope, Burnett, Thun, Calle, Krewski, Ito, Thurston, 2002), at how $PM_{2.5}$ levels affected college students with asthma, (Wu, Jimenez, Claiborn, Gould, Simpson, Larson, Liu, 2006), at how the number of fields burned affected hospitalization rates, (Jacobs, Kreutzer, Smith, 1992), and at MODIS to detect agricultural fires.(McCarty et al. 2007), (Morisette, Giglio, Csiszar, Setzer, Schroeder, Morton, Justice, 2005), (Giglio, Descloitres, Justice, Kaufman, 2003). This appears to be the first study that combined many of these areas in a single study – examining MODIS and GOES agricultural fire detection, looking at $PM_{2.5}$ levels and their relation to hospital emergency room visits and diagnoses in a rural area.

Hypotheses

1. H_0) Null hypothesis: There will not be a strong positive correlation between the number of fires and the $PM_{2.5}$ level. Pearson's $r < 0.8$.

H_1) Alternate hypothesis: There will be a strong positive correlation between the number of fires and the $PM_{2.5}$ level. Pearson's $r > 0.8$.

2. H_0) Null hypothesis: There will not be a statistically significant difference between the mean number of emergency room diagnoses for respiratory conditions on days with low $PM_{2.5}$ days as compared to high $PM_{2.5}$ days. High $PM_{2.5}$ days are defined as days with $PM_{2.5}$ readings above 35 $\mu g/m^3$, which is the 24-hour EPA Standard.

$\mu_1 = \mu_2$ where μ_1 = mean number of E.R. diagnoses on high $PM_{2.5}$ days. μ_2 = mean number of E.R. diagnoses on low $PM_{2.5}$ days.

H_1) Alternate hypothesis: ($\mu_1 \neq \mu_2$) There will be a statistically significant difference between the mean number of emergency room diagnoses for respiratory conditions on days with low $PM_{2.5}$ days as compared to high $PM_{2.5}$ days.

Methods

Design of Study: An analytic, observational study design was used. This study consisted of two parts – collecting primary data on $PM_{2.5}$ levels during the wheat stubble burning period in Scott and Stoddard Counties in Missouri, and obtaining emergency room secondary data from three area hospitals for this period. Following data collection, statistical analysis was done. Corn stubble burning also occurs in this area, but since it occurs in the fall after school starts, I was unable to study its effects.

Source of Data: While wheat stubble burning occurs throughout Southeast Missouri and elsewhere in the U.S.A. (e.g. Northeast Arkansas, Eastern Oregon), as an individual researcher, I had my hands full just covering Scott and Stoddard Counties. The DataRAM 4 air monitor was my only option for collecting $PM_{2.5}$ readings as it was a free loaner and I couldn't afford anything else. It was also portable, thus allowing me to gather readings from throughout this area. For the E.R. data I used data from three area hospitals. There is a 4th area hospital at Dexter, Mo., but it has very little E.R. traffic.

Health Record Access: For the emergency room data, all three emergency room directors certified in writing that there was no individually identifiable data and that all HIPAA regulations were met.

Data Collection Procedures and Timeframe: Agricultural burning of wheat stubble began on June 12, 2007 and continued through June 22. During this period I documented as many fires in Scott and Stoddard Counties, Missouri as possible. Several times a day I drove to a spot from which a large portion of Scott and Stoddard Counties could be seen. On clear days smoke from fires could be seen from over 20 km away (Fig. 1), less so on days with high particulate levels. (Fig. 2) Upon seeing a smoke plume I drove to the fire and recorded date, time, and GPS coordinates. I also often took $PM_{2.5}$ readings, and photographed the burns. I also attempted to count smoke plumes when there were more fires burning than I could visit.

Figure 1 – Smoke Plume

Figure 2. Low and High PM 2.5 Days & Visibility

A portable DataRAM 4 (Fig. 3) air monitor, donated for one month from CleanAir Instrument Rental was used to measure $PM_{2.5}$ in units of $\mu g/m^3$. Measurements were taken several times daily from June 12 to July 6. Some readings were taken near fires, others were taken from random locations (away from fires) to get a better idea of how much $PM_{2.5}$ had dispersed throughout the area. Readings were also taken each evening from outside my home.

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Figure 3. DataRAM 4 Air Monitor

The $PM_{2.5}$ air intake nozzle was used on the DataRAM 4. The option on the DataRAM 4 to take into account the relative humidity and to not include any mass due to moisture was selected.

The DataRAM 4 provided maximum and average mass readings and maximum and average size of particles. The monitor while recording had both a current reading and a reading averaged over the entire recording interval. Whenever possible I attempted to take readings about five minutes long. At some fires, readings were not taken because of things such as no good place to set-up, no escape route if the fire got out of control, and too many curious onlookers.

On June 17, the internal rechargeable battery in the DataRAM 4 failed, although it could still be run using an external power source. CleanAir Instrument Rental provided a replacement DataRAM 4 monitor. Both monitors came with a paper certifying that they were correctly calibrated. I ran both monitors for 24 minutes while they were positioned next to each other on the screened-in porch of my home. (Fig. 4)

Figure 4. Comparing Readings of two DataRam4s

There was a difference in the readings. Monitor #1 had a maximum $PM_{2.5}$ reading of 45.19255 and an average $PM_{2.5}$ reading of 31.42493. Monitor #2 had a maximum $PM_{2.5}$ reading of 26.283480 and an average $PM_{2.5}$ reading of 20.296650. Thus, Monitor #1 may have reported readings that were higher by approximately 11 for the same conditions. However, even if Monitor #1 was reporting readings 11 units higher than was the actual case, this still would not have affected the results of the t-tests to see if levels of $PM_{2.5}$ > 35 had statistically significant differences between the mean number of ER visits for respiratory conditions for days above and below these values. The t-test results would not have been affected because on the days when Monitor #1 readings were used for the last daily $PM_{2.5}$ reading the readings were for 23, 114, 56, and 69 (on June 12-15), which if adjusted downward by 11 would be 12, 103, 45, and 58. The correlation results were likewise not affected. But since both monitors had been certified as correctly calibrated, perhaps they were both accurate.

Data from satellite fire detection systems, the Moderate Resolution Imaging Spectroradiometer (MODIS) system on the Aqua and Terra satellites and also from the Geostationary Operational Environmental Satellites (GOES), was also examined. Data from the satellites was retrospective (4 hour lag) and could not be used to locate active fires, but was useful for several other purposes (locating missed fires, estimating fires, etc.). Accuracy of the satellites was also examined.

Three local hospitals provided data on emergency room visits with respiratory diagnoses. Since the first data I received from the three hospitals did not use consistent formats, I specifically requested a second set of data that provided consistent use of the ICD9 diagnosis codes for respiratory conditions. All three hospital emergency room directors stated in writing that the data provided to me for this study was de-identified/anonymous data and in compliance with all privacy and HIPAA laws. This data was compared to $PM_{2.5}$ levels that had been collected over the time frame of June 12 through June 30. Lag days of 0, 1, and 2 were tested for time between high $PM_{2.5}$ levels and day of visit to emergency room. Number of fires was also compared to $PM_{2.5}$ levels with correlation analysis to see if there was a relation.

June 12 – June 30 was the comparison period used for statistical analysis. That was the only period of time for which I had data from all three hospitals and also $PM_{2.5}$ data from the air monitor. I also decided to combine the ER counts for the three hospitals, rather than test each individually. By combining the data from all three hospitals, the results from the statistical tests would be more robust because more values could be compared than if done individually.

Statistical tests were run using the program InStat. Data was examined in InStat with T-tests and correlation analysis

Because they often work in close proximity with burning fields, exposure of farmers to $PM_{2.5}$ was also quantified. No farmers who I observed while they were burning fields wore any protective masks (Fig. 5)

Figure 5. Farmer & Young Child Near Burning (with faces concealed to protect their identify)

Weather maps were examined for each day to see if high pressure areas or wind direction affected $PM_{2.5}$ levels. The weather maps were obtained from the National Weather Service at http://www.hpc.ncep.noaa.gov/ . Wind direction reports were obtained from the Weather Underground web site: http://www.wunderground.com. The

U.S. government web site “Airnow” at http://airnow.gov/ was used to view ozone readings in Southeast Missouri, but the nearest $PM_{2.5}$ readings were from reporting stations in Southern Illinois and St. Louis.

I looked into possibly using the MODIS 1 km Land Cover Dataset and the MODIS 250m Normalized Difference Vegetation Index to detect fields which had been blackened with fire. (Fig. 6) However, these require that you have access to remote sensing software packages, which I did not have available.

Figure 6. Blackened field after burning stubble.

I also examined using Google Earth images for this area to determine acreage of burned wheat fields. The Digital Globe date stamp for the Google Earth images in Southeast Missouri shows as 2007-07-22 for images east of the Benton Hills and east of a line running about 5 miles west of U.S. Hwy 61, and as 2007-08-09 for images west of the Benton Hills and west of the line about 5 miles west of U.S. Hwy 61. The photos would have been taken around a month after harvest. I used the blackened fields

(Fig.6, 7) in the Google Earth images as a cross-check of the relative accuracy of my ground-level surveys of burned areas. I also came up with a method using Adobe Photoshop to determine precise size of irregularly-shaped fields as shown on Google Earth. Here is the Google Earth Image of this area with the date stamp:

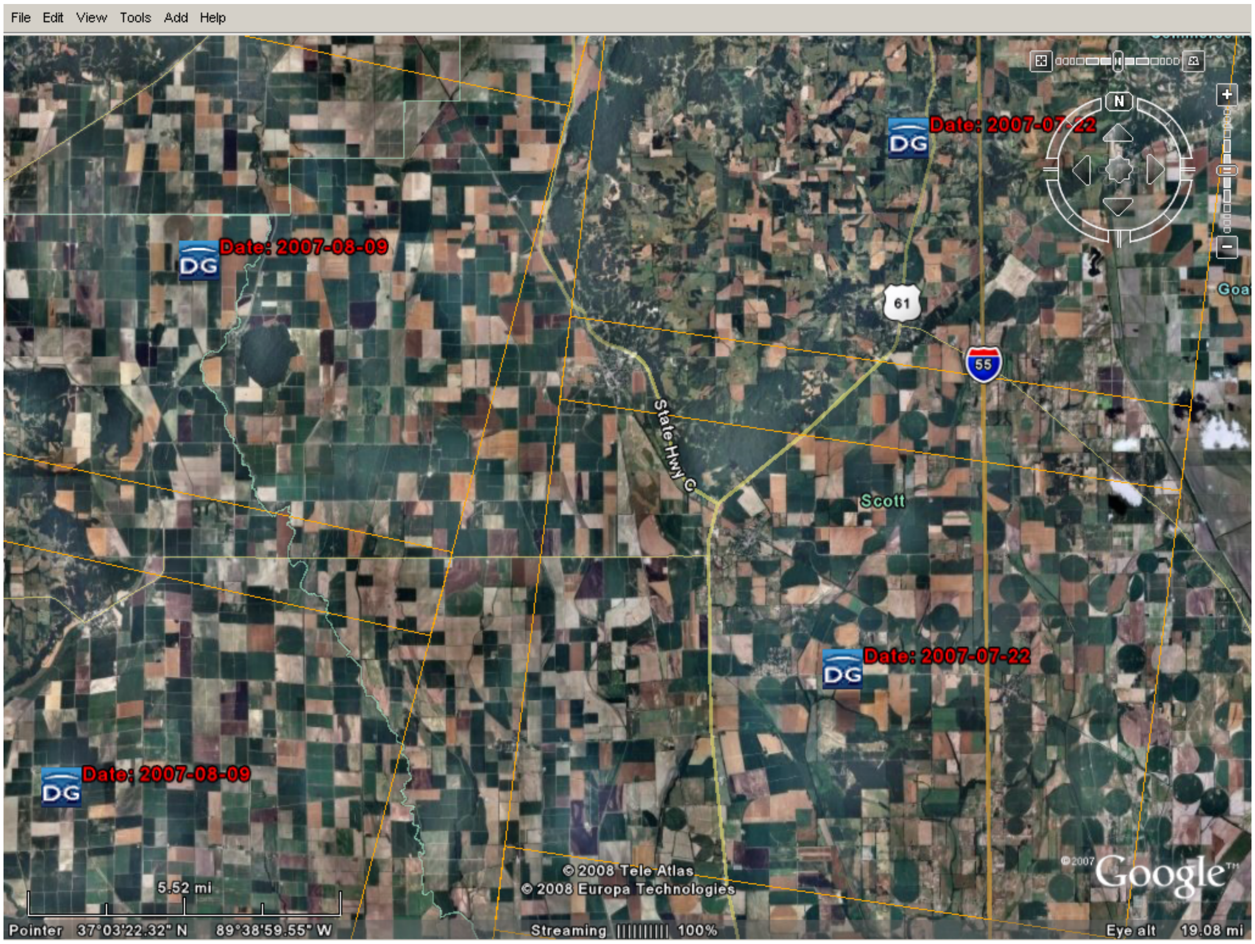


Figure 7. Google Earth Image of part of Scott Co.

Primary Outcome Measure

Two primary outcome measures are used in this study:

1) the correlation between the number of fires and the $PM_{2.5}$ level and

2) mean number of emergency room diagnoses for respiratory conditions on days with $PM_{2.5} < 35$ as compared to days with $PM_{2.5} > 35$.

Analytic Methods Used

Using the statistical software program Instat, I ran t-tests on primary outcome measure #1 and correlation tests on primary outcome measure #2.

Results

From June 12 to June 22, 73 fires were visually confirmed and marked with a GPS. An additional 49 fields that had been burned were found during drive-by surveys after the burning season, making for a total of 122 fields burned. Most fields were at least 40 acres in size with some fields as large as 160 acres. Only 32 fields were not burned and instead planted using no-till methods. These totals just cover the area and the fires that I was actually able to observe in person. I am certain that many additional fires occurred in Scott and Stoddard Counties that I missed, but I speculate that my in-person observations are valid samples that represent accurately the overall fires that occurred in this area.

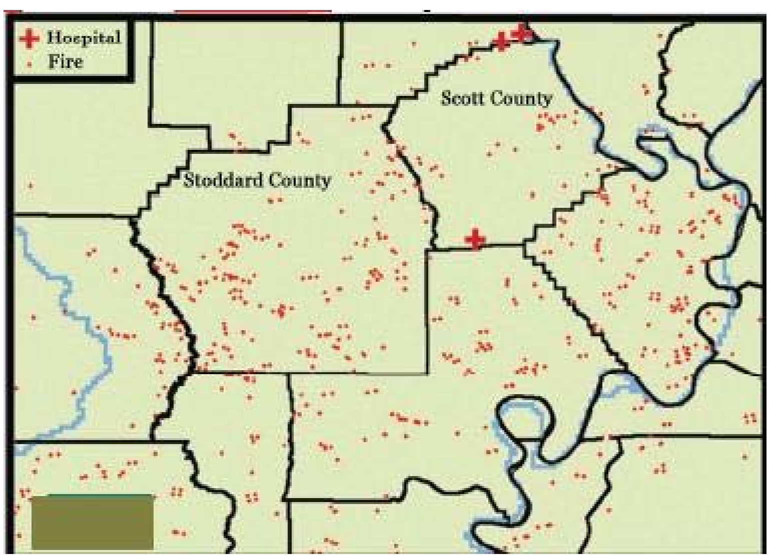


Figure 8. Location of Fires by MODIS

The accuracy of MODIS and GOES Satellites was quantified. MODIS (1 km^2 resolution) performed very poorly in detecting fires, even when it was making a pass over a burning field. Less than half of all field burns in Scott County were detected. One reason for the low detection is that the Aqua and Terra satellites which carry the MODIS onboard, are in a polar sinusoidal orbit and each only pass over this area twice a day in a brief 10-15 minute passover. Thus, most of the time there is not a MODIS equipped satellite in range.

But even at times when the MODIS Overpass Predictor predicted either Aqua or Terra was making a pass overhead, the MODIS on that satellite did not detect some fires. As an example, consider the fire in the over 40 acre field at 37°02'08.45" N and 89°48'04.54" W (near Bell City, Missouri) on June 17. (Fig. 9) The time stamp on the DataRAM monitor showed I was taking $PM_{2.5}$ readings at the road next to this field from 12:49-13:33 CDT. These times correspond to the time stamp of the first (12:47) and last (13:23) photos I took of these fires. MODIS Overpass Predictor showed that on June 17 that Aqua would rise at 13:15:38 CDT, peak 13:22:26, set 13:28:41 CDT, with peak elev. of 29.1 for LAT/LONG of 37.036 N 89.8 W. Also, there was a MODIS detected fire by Aqua at 18:25 GMT (or 13:25 CDT) just a few miles away. There was no cloud cover during this time. I speculated that perhaps the heavy smoke was being detected by MODIS as clouds.

Figure 9. Burn missed by MODIS.

The GOES Satellite proved to be much more adept at detecting fires but limited resolution (16 km^2) made it impossible to pinpoint the origin of fires. Together, MODIS (Fig. 8) and GOES located almost the same number of fires as daily ground searches found, but were not as precise.

The total number of field burns (known from both satellite detection and ground surveys) was compared to air quality data gathered during the study. $PM_{2.5}$ was strongly correlated with the number of fields burned that day (r = 0.81) when two rainy days and the first full day of burning were accounted for. (Fig. 10) On the first full day of burning, $PM_{2.5}$ reached high levels, but only for a short time late at night. After the burning season ended, it took circa four days to return to levels recorded before the study.

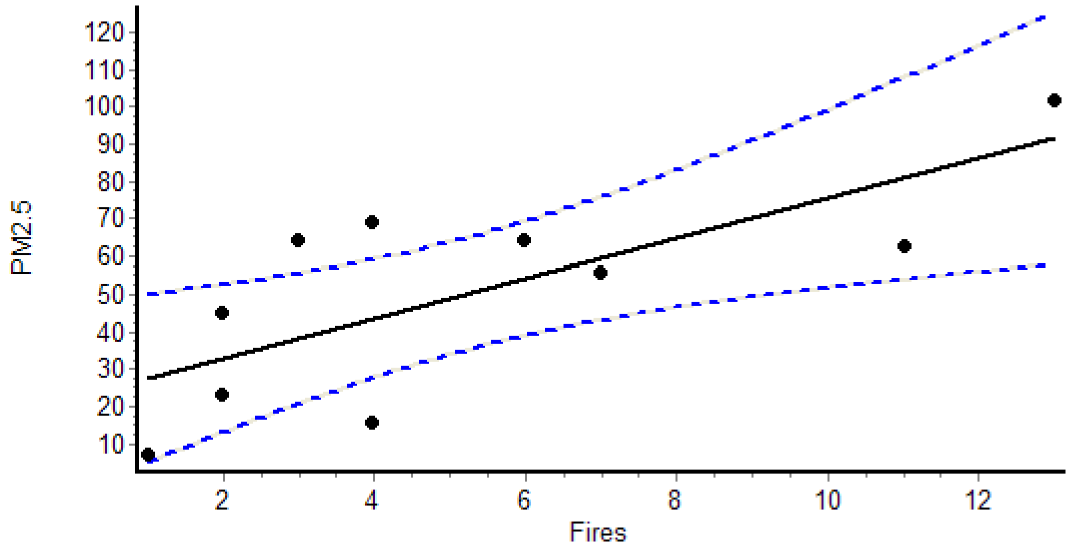


Figure 10. Fires per Day - PM 2.5 Levels

The $PM_{2.5}$ levels remained high during the period from June 13-June 18 when a high pressure system was keeping the air stagnant. When a thunderstorm rolled through on the evening of June 18th, $PM_{2.5}$ levels plunged from 45 to 15. Another high pressure system became centered over the area on June 20th and June 21st and $PM_{2.5}$ readings rose to 64 during this time.

Figure 11. Fire at Twilight on 1st Day of Burning

Two tornado-like vortexes were observed during fires. One became fairly large in size and lasted for several minutes. (Fig. 12)

Figure 12. Vortex Created from Stubble Burning

Wind direction may also have affected $PM_{2.5}$ readings. For example, I observed a very large fire (Fig. 13) behind one school with the smoke plume headed in a northerly direction. I took $PM_{2.5}$ readings about 10 minutes later from a location about five miles south of this fire, and the $PM_{2.5}$ readings were not elevated.

Figure 13. Burning Near School

Hospital emergency room visits with a respiratory diagnosis were significantly greater on days when $PM_{2.5}>35$ ($p = 0.0386$). (Fig. 17) The number of emergency room patients diagnosed in the three hospitals combined, the number of fires spotted by satellite each day, and the $PM_{2.5}$ value are given in the following charts: (Fig. 14, 15)

EMERGENCY ROOM RESPIRATORY DIAGNOSES & $PM_{2.5}$ LEVELS																				
ICD9	PRINCIPAL DIAGNOSIS	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
466.0	Acute Bronchitis		2	1	1	1	2	3	1	1	1	3	5	4	1	1	1		1	1
477.9	Allergic Rhinitis NOS	1											1	1						
490	Bronchitis, NOS			1	1									1		1				1
491.21	Obstructive Chronic Bronchitis & acute exacb.		1	2	2	2		2		1	1	3	1		1	1	1	1	4	3
491.22	Chronic Bronchitis with acute Bronchitis												1							
493.90	Asthma, Unspecified acute						1		1						1					
493.92	Asthma, Unspecified with acute exacerbation			1		1					1								1	
518.81	Acute Respiratory Failure				1		1	2								1				
518.84	Acute & Chronic Respiratory Failure			1																
TOTALS		1	3	6	5	4	4	7	2	2	3	6	8	6	3	4	2	1	6	5
DATE - JUNE		12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
PM < 35	PM > 35	23	114	56	69	65	102	45	7	13	64	18	40	25	31	19	24	15	49	26

Figure 14. ER Diagnoses & PM 2.5 Level

DATE - JUNE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
FIRES	2	3	7	4	11	13	2	1	12	6	4	0	0	0	0	0	0	0	0

Figure 15. Number of Fires for each day of study.

PM2.5 Reading	Nearest City
1381	Bell City
649	Benton
442	Randles
378	Bell City
372	Morley
355	Bell City
347	Chaffee
273	Chaffee
246	Chaffee
117	Randles

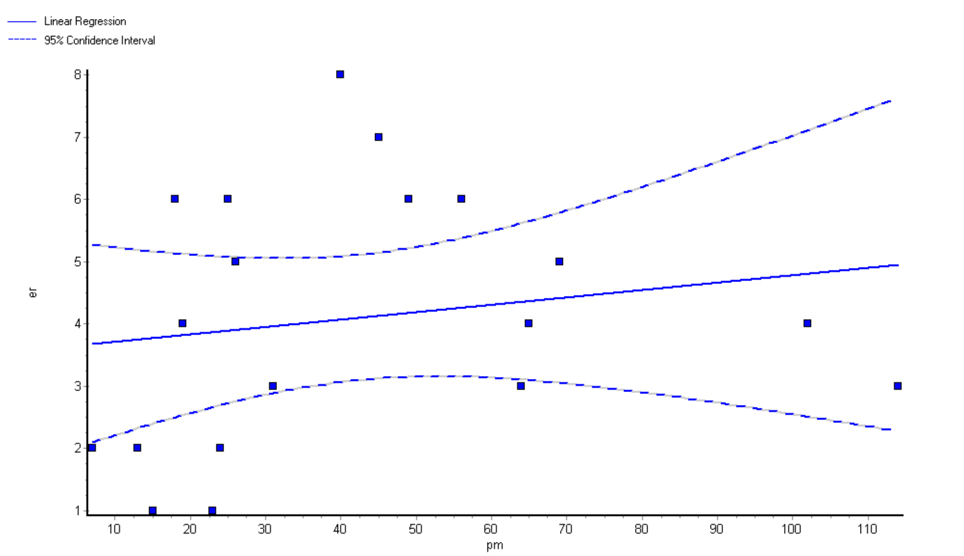
Table 2. Ten highest average readings near fields.

Figure 16. Highest PM 2.5 Readings.

raw data	raw data	t-test results comparing means of days with PM<35 vs. days with PM>35	
PM < 35	PM > 35	Do the means differ significantly? Yes	
1	3	two-tailed P value	0.0386
2	6		
2	5	t-value used to compute P	2.242
6	4	degrees of freedom	17
6	4	mean difference	1.911
3	7	Two assumptions should be met to use the t-test: 1)the differences in standard	
4	3	deviation are not statistically significant & 2) the data must pass normality test.	
2	8	INSTAT tested assumption 1 with the F-test and reported:	
1	6	Are the differences in standard deviation statistically signficant? No	
5		INSTAT tested assumption 2 with the Kolmogorov-Smirnov test and reported:	
3.2	5.111	MEAN	PM < 35 pass normality test? Yes
1.932	1.764	STD. DEV.	PM > 35 pass normality test? Yes
10	9	SAMPLE SIZE	t-test using InStat statistical software
0.611	0.5879	STD .ERR.MEAN	
1.818	3.755	LOWER 95% CI	
4.582	6.467	UPPER 95% CI	

Figure 17. t-test of ER diagnoses & PM 2.5

Data from three hospital emergency rooms combined for respiratory diagnoses



showed a low positive correlation with $PM_{2.5}$ levels (r=0.27) (Fig. 18). However, after some additional

Figure 18. Correlation-PM2.5/ER DIAGNOSES WITH ZERO LAG DAYS

testing on the data, I found that if you allowed one lag day between the $PM_{2.5}$ level and the ER diagnoses just used the 10-day fire period, that r=0.8369. The p-value was .0025. The regression analysis produced the following graph.(Fig. 19)

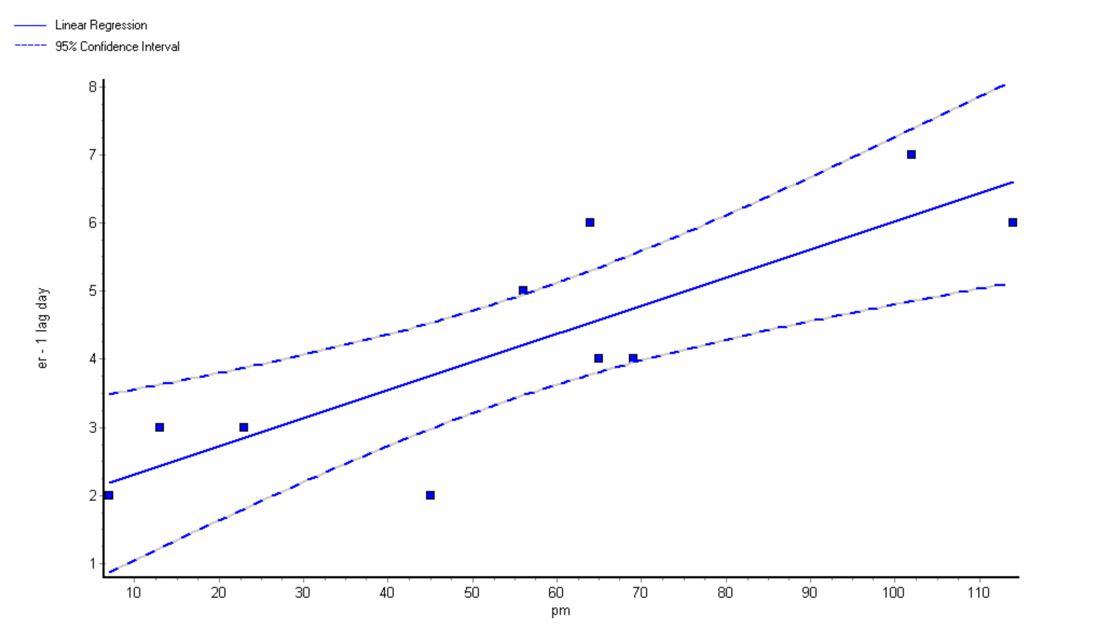


Figure 19. Correlations of PM level to ER diagnoses with one lag day.

Discussion

$PM_{2.5}$ has been linked to respiratory ailments in other studies. However, its effects have mainly been studied in urban areas, where it is mostly a result of auto and factory emissions. Very little research has examined agricultural burning and $PM_{2.5}$ in rural areas.

This study is the only one I'm aware of where a portable air monitor was used to detect $PM_{2.5}$ values near the fields that were burned, and also at a variety of other locations. Other studies (Dominici 2006) (Wu 2006) used readings from a stationary air monitor.

$PM_{2.5}$ was strongly correlated to burning ($r = 0.81$) when rainy days and the first full day of burning were not counted. Following rains on June 19 and June 22, $PM_{2.5}$ levels fell from 45 to 7 and from 64 to 15, respectively. The day following the rains resulted in the two most significant outliers on the regression analysis. Even though there were many burns on these days, the $PM_{2.5}$ levels remained low. I hypothesize that because the rains cleansed the air, the $PM_{2.5}$ levels did not reach high levels because there was little $PM_{2.5}$ from the previous day. A third outlier occurred on the first day full day of burning. On this day, $PM_{2.5}$ levels reached high levels, but only for a short time late at night.

Emergency room data for respiratory diagnoses showed a low positive correlation with $PM_{2.5}$ levels ($r = 0.27$) (Fig. 18). However, days with $PM_{2.5} > 35$ had significantly more ER respiratory diagnoses ($p = 0.036$) than days when $PM_{2.5} \leq 35$. (Figs. 14 & 17) The EPA 24-hour standard for $PM_{2.5}$ is 35 $\mu g/m^3$. I hypothesize that the majority of people needing treatment developed symptoms before $PM_{2.5}$ levels peaked, which could explain why the correlation is not tighter. The data seems to support this. Environmental data such as this also has shortcomings (e.g., some people may use a private doctor instead of the ER, other may just "tough it out"). However, the t-test of $PM_{2.5}$ >35 strongly suggests that levels over 35 do cause more respiratory ailments.

GOES proved to be more adept at detecting fires than MODIS satellites. There are several major differences between the satellites. MODIS satellites are in polar orbit and only cross the Southeast Missouri area twice daily, whereas GOES satellites are in a fixed geostationary orbit and scan every 15 minutes. The satellites also use different sensors and algorithms for detecting fires. The large gap when there is no MODIS satellite passing over calls into question MODIS's usefulness for detecting agricultural fires unless additional satellites with MODIS were placed into orbit.

Conclusions

For hypothesis #1, the null hypothesis can be rejected because Pearson's R = .081 and P-value = 0.0007 and the alternate accepted. For hypothesis #2, the null hypothesis can be rejected because $\mu_1 \neq \mu_2$ (p=.0386) and the alternate accepted.

The results of this study suggest that agricultural burning significantly affects air quality and $PM_{2.5}$ levels. Elevated $PM_{2.5}$ levels was associated with more patients with respiratory ailments making visits to the emergency room. Although it was impossible to determine what groups were most at risk, it is probable that farmers are among the highest risk group because of exposure to direct smoke, which was up to 120 times higher than what is considered safe levels by the EPA. Studies on such groups would be particularly useful.

Further research is needed to examine the correlation between $PM_{2.5}$ and ER diagnoses in rural areas. Additional research needs to be done on the corn stubble burning in Southeast Missouri. The results and statistical analysis showed a strong tendency for ER visits for respiratory complaints to increase when $PM_{2.5}>35$. The results suggest that a large portion of Southeast Missouri is out of compliance with the current EPA $PM_{2.5}$ 24-hour standard. Additional $PM_{2.5}$ air monitors are needed to provide coverage for Scott, Stoddard, and counties of the Missouri Bootheel as the nearest $PM_{2.5}$ air monitor is located in Ste. Genevieve County (about 70 miles away) and had a high reading for $PM_{2.5}$ in 2007 of 34.3 for a 24-hour period.

To prevent unnecessary respiratory ailments, I recommend that farmers should not burn during high pressure systems or when $PM_{2.5}>35$. If burning could be done several hours before a heavy rain, then it probably would not have much effect because $PM_{2.5}$ would be removed by the rain. A better solution would be for a plant to be constructed that uses agricultural stubble. Such a plant could produce ethanol or straw-based particleboard using stubble that would otherwise be burned, thus providing another viable and financially rewarding product for farmers while reducing the need for burning. It may be necessary for Missouri to establish regulations regarding agricultural burning if voluntary efforts by farmers are not sufficient to reduce the $PM_{2.5}$ levels. Farmers, to protect their own health, should wear masks capable of filtering $PM_{2.5}$ from the air they breathe when working near agricultural burns.

Since the original presentation of this paper, my state representative contacted me concerning this issue, and is having the Missouri Department of Natural Resources look into the possibility of locating a permanent $PM_{2.5}$ air monitor in this area.

Figure 20. Another Field Burning in Southeast Missouri

Impacts of Burning Agricultural Crop Stubble

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