

Note: This is a reference cited in *AP 42, Compilation of Air Pollutant Emission Factors, Volume I Stationary Point and Area Sources*. AP42 is located on the EPA web site at www.epa.gov/ttn/chief/ap42/

The file name refers to the reference number, the AP42 chapter and section. The file name "ref02_c01s02.pdf" would mean the reference is from AP42 chapter 1 section 2. The reference may be from a previous version of the section and no longer cited. The primary source should always be checked.

Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

OPEN BURNING
AP-42 Section 2.4
Reference Number
20

Florida Sugar Cane Factors

James H. Southerland, Chief
Source Analysis Section (MD-14)

Brian Mitchell
Air Programs Branch, Region IV

Enclosed is a brief report that Audrey McBath and I put together in response to the sugar cane factors question. As indicated therein, any conclusions are shaky but may be adequate for this purpose. I am going ahead with modifications to AP-42 but will be able to delete or change them if Region IV finds problems with the analysis.

Please advise Mike Martin (WPBHD) of the number(s) to use following your review as he awaits hearing from EPA prior to completing his current inventory. Also, I have not talked with FSCL, Inc. since our meeting in Atlanta. You may wish to send them a copy of this material or your letter to West Palm Beach.

Be sure to call if you have questions.

7 Enclosures

cc: J. Bosch, NADB
E. Lillis, AMTB
T. Helms, Region IV

AMTB/J.SOUTHERLAND/bc - Ext. 5474 (2-6-78)

Emission Factors and Field Loading for Sugar Cane Burning

James H. Southerland

and Audrey McBath

Purpose

As a result of inquiries from West Palm Beach County Health Department, Florida, the Florida Sugar Cane League, Inc., and EPA Region IV, the emission factors and field loading factors for pre-harvest burning of sugar cane crops has been reviewed. This report briefly discusses some of the associated problems uncovered as a result of that review and provides a medium to convey the status and conclusions made regarding these numbers.

History

In 1972-1973 a sampling and testing program was conducted to provide quantitative data on emission factors for burning of sugar cane in Hawaii. This was initiated at the request of the EPA Region IX and in support of the Hawaii Department of Health. The work was done by Dr. Ellis F. Darley at the University of California, Riverside, under a research grant with EPA's Office of Research and Development with a technical advisor (JHS) from the Office of Air Quality Planning and Standards. Funding was relatively minimal (a little over \$11,000), but due to the interest of Dr. Darley and the nature of the grant, the amount of work done was quite extensive.

Due to reorganization, and accompanying transfer of responsibilities, as well as a somewhat delinquent receipt of the report of the work, incorporation into AP-42 was done under separate contract with a new project officer. This contract called for a general update, of which sugar cane was only a small part.

Assisting and providing consultation on the project were representatives from EPA Region IX, Hawaii Department of Agriculture, Hawaii Department of Health (air pollution), the Hawaiian Sugar Planters Association, and other miscellaneous groups. The major concern of interest was the contention that the 225 lb/acre emission factor then in use (which we have not researched the basis for) was indicating sugar cane to be a major concern in the then impending State Implementation Plan revision for Hawaii.

The results of Dr. Darley's efforts were reported upon in Report EPA-450/3-75-071, "Air Pollutant Emissions from Burning Sugar Cane and Pineapple Residues from Hawaii." It should be noted, however, that the report only presents a brief summary of the data (Copies of raw data and related correspondence were retrieved for use in this review.). When the contractor, Pacific Environmental Services, updated the AP-42 section as documented in Report EPA-450/3-75-087, "Calculation of Emission Factors for Agricultural Burning Activities," some basic detail appears to have been lost or overlooked as unimportant. One such detail was that Darley's tests showed a field loading (quantity burned) averaging 15.8 tons per acre. By separate and prior determinations, (Enclosure 1) the Hawaii Department of Agriculture had determined a value of 17 tons/acre.

It should also be noted that, at the same time, duplicate field samples were taken by the Hawaiian Sugar Planters and presumably observed by the Hawaiian Departments of Health and Agriculture representatives. Burning of these plants or samples by means and procedures partially unknown and totally unclear, the 15.8 ton/acre average field loading was reduced (See Enclosure 2) to 10.9 (or 11.0). James Southerland was no longer associated with the project at this point and consequently does not

fully understand the justification and rationale used for that modification and the records of the project show no details. The letter from Ed Lui of HSPA to Bill Arlington (July 2, 1977) has been indicated to be supportive of the 10.9 figure, but there was difficulty in following the development of that conclusion. (It should also be noted that they use 8.4 lb/ton as an emission factor--the high end of Dr. Darley's 99.9% confidence range.) Using Darley's raw data sheets (Enclosure 3) for the shipments on Lui's enclosure, a 143 ton/acre (total cane) value may be calculated. No fires in Darley's tests showed weight gain!

Following the initial inquiries from West Palm Beach officials and the Florida Sugar Cane League, the data was somewhat superficially reviewed and it was determined that the numbers given in AP-42 were of Hawaiian derivation and that there is reason to believe that the Florida (or other) cane might differ significantly. It was also agreed that in the absence of other information, it would be reasonable to assume that the emission factors themselves would not differ significantly (See Enclosure 4). A point should be made that emission factors are estimates or averages and usually some circumstances will exist which will prevent hard and fast agreement with any single actual situation. Also, since we are not "expert" in growing or burning sugar cane, the technical judgements of those who are considered expert were heavily depended on and their judgement was coupled with our judgement and knowledge of the purposes and limitations of emission factors and inventories in general.

Current Analysis

After arrangements were made to meet with officials from West Palm Beach, EPA Region IV, The Florida Sugar Cane League, and James Southerland,

a letter (Enclosure 5) was received (at the meeting) from the Florida Sugar Cane League recommending the use of loading factors ranging from 3.9 to 4.4 tons/acre. Subsequent studies by Mr. Michael Martin of West Palm Beach and his local contacts with the Department of Agriculture, produced additional estimates of 5 to 6 tons/acre. A fairly limited time was spent reviewing these data and more questions were uncovered than can conclusively or scientifically be answered. However, the following discussion relates to the values received for consideration.

December 9 Letter from FSCLI (Enclosure 5)

The information presented in this letter, as developed by Dr. Orsengio, a reputable and experienced director of research for FSCLI, is fairly internally consistent and the numbers derived and presented are not beyond belief, although the basic studies were not developed with air pollution factors in mind.

1. The first argument (page 2, paragraph 2) supports a value of 3.9 tons/acre. The rationale is that of using the same ratios as for Hawaiian cane but using Florida Production figures. The Hawaii field values from the Department of Agriculture (enclosed letter from Mel Dollar) indicate a 17 ton/acre loading in Hawaii or 12% of the total crop (including trash). This corresponds to 142 tons/acre total crop. If this figure of 12% is used then $44 \times .12 = 5.3$ tons/acre for Florida.

Also going back to Dr. Darley's original data sheets for the same (corresponding) plot used in Ed Lui's letter, an average of 164.1 lb/25 sq. ft. test plot (143 tons/acre) was calculated. If the 12% "disappearance" figure from the Hawaiian Studies were used, 17.2 tons burned would result. Then $143 - 92 - 17 = 34$ tons/acre unburned trash where 92 tons/acre is yield. This incidently means that 17/51 about 33%

of the trash is consumed, where many of the Florida estimates are around 50% of the trash consumed. Due to the differences, a 5.3 value would seem to be closer to reality than a 3.9 ton/acre value (assuming 11 tons/acre total trash in Florida).

2. The Clayton and Churchill value in the FSCL letter (page 2, paragraph 5) sounds reasonable and consistent with several references, even though based on personal communications. Ten percent of 44 tons/acre = 4.4 tons/acre.

3. Also the Clayton and Churchill values on page 3 substantiate the 4.4 tons/acre value and seem reasonable and consistent.

4. If the Irvine data on page 3 of (Paragraph 2) of the FSCL letter are adjusted to a 44 tons/acre average base then the value is again $4.0 \times 44/40 = 4.4$ tons/acre. The question of 1.5% (assumed) added for unrecovered leaves is an obvious unknown.

5. There is no real problem with the 4.4 value of Orsenigo's (paragraph 3, page 3) from the "green vs. burned" study.

January 13, 1978 Letter from Michael Martin West Palm Beach Health Department
(Enclosure 6)

USDA and West Palm Beach did some limited studies as reported in Mr. Martin's letter.

1. Martin's value is 5.01 from the tests with USDA. An arbitrary 1.0 ton/acre would be added for use of chemicals, for a total of 6.0 tons/acre. Although, the number of stalks used was limited, the work was done with air pollution factors in mind.

2. Also attached to Mr. Martin's letter was unreferenced methodology based on 11 of 44 tons being trash and 50% of that being combustible. This gives 5.5 tons/acre. The assumptions are within the range of those given in various papers, etc. submitted by Martin and FSCL.

EPA 450/3-74-062, "Emissions Inventory from Forest Wildfires, Forest Managed Burns and Agricultural Burns," November 1974.

The report above references the Florida Department of Agriculture and Consumer Services as the source of a fuel loading value of 7 ton/acre for Florida cane. The method of calculation, assumptions, etc. are not available. The value could not be, therefore, discounted or verified. Therefore

Assuming that values that were submitted and not disqualified, (We cannot scientifically qualify any values achieved by using ratios, any other non-field tested data, or any data where gross/net crop weight is not included with trash weight [in same article] since gross/net crop weight varies by 50% or more among varieties of cane, however, this was overlooked due to availability of better information), should receive equal weight and consideration, we would have:

$$\frac{5.3 + 4.4 + 4.4 + 4.4 + 4.4 + 6.0 + 5.5 + 7.0}{8}$$

or 5.2 tons/acre, as a "reasonable" but not totally defensible average value.

Emissions vs. Loading

The information in the letters supplied by FSCLA and WPBHD rely somewhat upon articles and papers which were put together for some other purpose. The trash portion that is assumed to be burned is primarily

the dry trash. In looking at Darley's data sheets, it becomes obvious that the combustion is not just of the dry leaves, but of the green leaves also. Also, as the proportion of green leaves increases, the emissions per acre or per ton also increase, suggesting pyrolysis.

If the Florida cane has a larger proportion of green material per plant or per acre than the Hawaiian cane, then perhaps the emission factor is indeed larger for Florida cane than that tested in Darley's samples from Hawaii.

Conclusions and Recommendations

There are many unknowns and variables unaccounted for. Florida cane obviously has lower loading per acre than Hawaiian. However, the emissions per ton burned may well be higher. More actual field study warrants consideration. This study should, if possible, include simulated burns similar to Darley's to verify that the factors are also appropriate.

The cost of such an undertaking might be considerable, especially since Darley's set-up is quite unique and he is retiring almost immediately. The gain, other than a "nice set of numbers" might be minimal. The impact of different numbers, the need to precisely identify the source of non-attainment for SIP revision purposes, etc., are all factors to be considered in determining whether funds should be expended toward further revising or "fine tuning" the numbers. In the interim, it is recommended that emission factors be used which give conservative (high) ranges and that loading factors be used which are lower than the Hawaiian but not the lowest extreme one might find in Florida. The proposed modification to AP-42 (Supplement 8) is geared to provide these interim values (recommending use of high value in range).

Emission Factors 1b/ton Fuel Loading, tons/acre

Particulate	CO	HC	HA	11-17
6 - 8.4	60-81	5-16	FL	4-7
			LA	3-5

FEF

OFFICE OF AIR QUALITY PLANNING AND STANDARDS
Research Triangle Park, North Carolina 27711

OPEN BURNING
AP-42 Section 2.4
Reference Number
20

Florida Sugar Cane Factors

James H. Southerland, Chief
Source Analysis Section (MD-14)

Brian Mitchell
Air Programs Branch, Region IV

Enclosed is a brief report that Audrey McBath and I put together in response to the sugar cane factors question. As indicated therein, any conclusions are shaky but may be adequate for this purpose. I am going ahead with modifications to AP-42 but will be able to delete or change them if Region IV finds problems with the analysis.

Please advise Mike Martin (WPBHD) of the number(s) to use following your review as he awaits hearing from EPA prior to completing his current inventory. Also, I have not talked with FSCL, Inc. since our meeting in Atlanta. You may wish to send them a copy of this material or your letter to West Palm Beach.

Be sure to call if you have questions.

7 Enclosures

cc: J. Bosch, NADB
E. Lillis, AMTB
T. Helms, Region IV

AMTB/J.SOUTHERLAND/bc - Ext. 5474 (2-6-78)

Emission Factors and Field Loading for Sugar Cane Burning

James H. Southerland

and Audrey McBath

Purpose

As a result of inquiries from West Palm Beach County Health Department, Florida, the Florida Sugar Cane League, Inc., and EPA Region IV, the emission factors and field loading factors for pre-harvest burning of sugar cane crops has been reviewed. This report briefly discusses some of the associated problems uncovered as a result of that review and provides a medium to convey the status and conclusions made regarding these numbers.

History

In 1972-1973 a sampling and testing program was conducted to provide quantitative data on emission factors for burning of sugar cane in Hawaii. This was initiated at the request of the EPA Region IX and in support of the Hawaii Department of Health. The work was done by Dr. Ellis F. Darley at the University of California, Riverside, under a research grant with EPA's Office of Research and Development with a technical advisor (JHS) from the Office of Air Quality Planning and Standards. Funding was relatively minimal (a little over \$11,000), but due to the interest of Dr. Darley and the nature of the grant, the amount of work done was quite extensive.

Due to reorganization, and accompanying transfer of responsibilities, as well as a somewhat delinquent receipt of the report of the work, incorporation into AP-42 was done under separate contract with a new project officer. This contract called for a general update, of which sugar cane was only a small part.

Assisting and providing consultation on the project were representatives from EPA Region IX, Hawaii Department of Agriculture, Hawaii Department of Health (air pollution), the Hawaiian Sugar Planters Association, and other miscellaneous groups. The major concern of interest was the contention that the 225 lb/acre emission factor then in use (which we have not researched the basis for) was indicating sugar cane to be a major concern in the then impending State Implementation Plan revision for Hawaii.

The results of Dr. Darley's efforts were reported upon in Report EPA-450/3-75-071, "Air Pollutant Emissions from Burning Sugar Cane and Pineapple Residues from Hawaii." It should be noted, however, that the report only presents a brief summary of the data (Copies of raw data and related correspondence were retrieved for use in this review.). When the contractor, Pacific Environmental Services, updated the AP-42 section as documented in Report EPA-450/3-75-087, "Calculation of Emission Factors for Agricultural Burning Activities," some basic detail appears to have been lost or overlooked as unimportant. One such detail was that Darley's tests showed a field loading (quantity burned) averaging 15.8 tons per acre. By separate and prior determinations, (Enclosure 1) the Hawaii Department of Agriculture had determined a value of 17 tons/acre.

It should also be noted that, at the same time, duplicate field samples were taken by the Hawaiian Sugar Planters and presumably observed by the Hawaiian Departments of Health and Agriculture representatives. Burning of these plants or samples by means and procedures partially unknown and totally unclear, the 15.8 ton/acre average field loading was reduced (See Enclosure 2) to 10.9 (or 11.0). James Southerland was no longer associated with the project at this point and consequently does not

fully understand the justification and rationale used for that modification and the records of the project show no details. The letter from Ed Lui of HSPA to Bill Arlington (July 2, 1977) has been indicated to be supportive of the 10.9 figure, but there was difficulty in following the development of that conclusion. (It should also be noted that they use 8.4 lb/ton as an emission factor--the high end of Dr. Darley's 99.9% confidence range.) Using Darley's raw data sheets (Enclosure 3) for the shipments on Lui's enclosure, a 143 ton/acre (total cane) value may be calculated. No fires in Darley's tests showed weight gain!

Following the initial inquiries from West Palm Beach officials and the Florida Sugar Cane League, the data was somewhat superficially reviewed and it was determined that the numbers given in AP-42 were of Hawaiian derivation and that there is reason to believe that the Florida (or other) cane might differ significantly. It was also agreed that in the absence of other information, it would be reasonable to assume that the emission factors themselves would not differ significantly (See Enclosure 4). A point should be made that emission factors are estimates or averages and usually some circumstances will exist which will prevent hard and fast agreement with any single actual situation. Also, since we are not "expert" in growing or burning sugar cane, the technical judgements of those who are considered expert were heavily depended on and their judgement was coupled with our judgement and knowledge of the purposes and limitations of emission factors and inventories in general.

Current Analysis

After arrangements were made to meet with officials from West Palm Beach, EPA Region IV, The Florida Sugar Cane League, and James Southerland,

a letter (Enclosure 5) was received (at the meeting) from the Florida Sugar Cane League recommending the use of loading factors ranging from 3.9 to 4.4 tons/acre. Subsequent studies by Mr. Michael Martin of West Palm Beach and his local contacts with the Department of Agriculture, produced additional estimates of 5 to 6 tons/acre. A fairly limited time was spent reviewing these data and more questions were uncovered than can conclusively or scientifically be answered. However, the following discussion relates to the values received for consideration.

December 9 Letter from FSCLI (Enclosure 5)

The information presented in this letter, as developed by Dr. Orsengio, a reputable and experienced director of research for FSCLI, is fairly internally consistent and the numbers derived and presented are not beyond belief, although the basic studies were not developed with air pollution factors in mind.

1. The first argument (page 2, paragraph 2) supports a value of 3.9 tons/acre. The rationale is that of using the same ratios as for Hawaiian cane but using Florida Production figures. The Hawaii field values from the Department of Agriculture (enclosed letter from Mel Dollar) indicate a 17 ton/acre loading in Hawaii or 12% of the total crop (including trash). This corresponds to 142 tons/acre total crop. If this figure of 12% is used then $44 \times .12 = 5.3$ tons/acre for Florida.

Also going back to Dr. Darley's original data sheets for the same (corresponding) plot used in Ed Lui's letter, an average of 164.1 lb/25 sq. ft. test plot (143 tons/acre) was calculated. If the 12% "disappearance" figure from the Hawaiian Studies were used, 17.2 tons burned would result. Then $143 - 92 - 17 = 34$ tons/acre unburned trash where 92 tons/acre is yield. This incidently means that 17/51 about 33%

of the trash is consumed, where many of the Florida estimates are around 50% of the trash consumed. Due to the differences, a 5.3 value would seem to be closer to reality than a 3.9 ton/acre value (assuming 11 tons/acre total trash in Florida).

2. The Clayton and Churchill value in the FSCL letter (page 2, paragraph 5) sounds reasonable and consistent with several references, even though based on personal communications. Ten percent of 44 tons/acre = 4.4 tons/acre.

3. Also the Clayton and Churchill values on page 3 substantiate the 4.4 tons/acre value and seem reasonable and consistent.

4. If the Irvine data on page 3 of (Paragraph 2) of the FSCL letter are adjusted to a 44 tons/acre average base then the value is again $4.0 \times 44/40 = 4.4$ tons/acre. The question of 1.5% (assumed) added for unrecovered leaves is an obvious unknown.

5. There is no real problem with the 4.4 value of Orsenigo's (paragraph 3, page 3) from the "green vs. burned" study.

January 13, 1978 Letter from Michael Martin West Palm Beach Health Department
(Enclosure 6)

USDA and West Palm Beach did some limited studies as reported in Mr. Martin's letter.

1. Martin's value is 5.01 from the tests with USDA. An arbitrary 1.0 ton/acre would be added for use of chemicals, for a total of 6.0 tons/acre. Although, the number of stalks used was limited, the work was done with air pollution factors in mind.

2. Also attached to Mr. Martin's letter was unreferenced methodology based on 11 of 44 tons being trash and 50% of that being combustible. This gives 5.5 tons/acre. The assumptions are within the range of those given in various papers, etc. submitted by Martin and FSCL.

EPA 450/3-74-062, "Emissions Inventory from Forest Wildfires, Forest Managed Burns and Agricultural Burns," November 1974.

The report above references the Florida Department of Agriculture and Consumer Services as the source of a fuel loading value of 7 ton/acre for Florida cane. The method of calculation, assumptions, etc. are not available. The value could not be, therefore, discounted or verified.

Therefore

Assuming that values that were submitted and not disqualified, (We cannot scientifically qualify any values achieved by using ratios, any other non-field tested data, or any data where gross/net crop weight is not included with trash weight [in same article] since gross/net crop weight varies by 50% or more among varieties of cane, however, this was overlooked due to availability of better information), should receive equal weight and consideration, we would have:

$$\frac{5.3 + 4.4 + 4.4 + 4.4 + 4.4 + 6.0 + 5.5 + 7.0}{8}$$

or 5.2 tons/acre, as a "reasonable" but not totally defensible average value.

Emissions vs. Loading

The information in the letters supplied by FSCLA and WPBHD rely somewhat upon articles and papers which were put together for some other purpose. The trash portion that is assumed to be burned is primarily

the dry trash. In looking at Darley's data sheets, it becomes obvious that the combustion is not just of the dry leaves, but of the green leaves also. Also, as the proportion of green leaves increases, the emissions per acre or per ton also increase, suggesting pyrolysis.

If the Florida cane has a larger proportion of green material per plant or per acre than the Hawaiian cane, then perhaps the emission factor is indeed larger for Florida cane than that tested in Darley's samples from Hawaii.

Conclusions and Recommendations

There are many unknowns and variables unaccounted for. Florida cane obviously has lower loading per acre than Hawaiian. However, the emissions per ton burned may well be higher. More actual field study warrants consideration. This study should, if possible, include simulated burns similar to Darley's to verify that the factors are also appropriate.

The cost of such an undertaking might be considerable, especially since Darley's set-up is quite unique and he is retiring almost immediately. The gain, other than a "nice set of numbers" might be minimal. The impact of different numbers, the need to precisely identify the source of non-attainment for SIP revision purposes, etc., are all factors to be considered in determining whether funds should be expended toward further revising or "fine tuning" the numbers. In the interim, it is recommended that emission factors be used which give conservative (high) ranges and that loading factors be used which are lower than the Hawaiian but not the lowest extreme one might find in Florida. The proposed modification to AP-42 (Supplement 8) is geared to provide these interim values (recommending use of high value in range).

Emission Factors lb/ton Fuel Loading, tons/acre

Particulate	CO	HC	HA	11-17
6 - 8.4	60-81	5-16	FL	4-7
			LA	3-5