FINAL REPORT

Creating a Statewide Spatially and Temporally Allocated Agricultural Burning Emissions Inventory Using Consistent Emission Factors

ARB Contract Number: 99-714

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Acknowledgements

Completion of this project would not have been possible without the cooperation and assistance of various individuals in academia, private industry, and government.

The CAMFER group at UC Berkeley thanks Mr. Les Fife for his invaluable expert contribution that made this project possible and practical.

We are grateful for assistance, backing and partnership we have enjoyed from our project management including Patrick Gaffney, Mike FitzGibbon and Klaus Scott at the California Air Resources Board.

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1. Introduction and Executive Overview

For many regions in California, burning of agricultural residues can sometimes contribute significantly to episodic PM_{10} and $PM_{2.5}$ levels, as well as visibility reducing particles. In addition, federal and state land managers have plans to increase the levels of prescribed burning within California to reduce fire hazard and improve forest management. To better allocate and manage the air impacts of biomass burning, there is a need for better estimates of fire emissions, burn location, and when the burns occur.

The existing California Air Resources Board's emission estimates for agricultural burning must be improved for $PM_{2.5}$ emission inventories and visibility impact assessment. Current estimates lack (1) consistent, well documented emissions rate data, (2) consistent, statewide estimates of the quantities and types of agricultural residues actually burned, and (3) a consistent way of mapping crops and where burning occurs.

With the goal of addressing these inventory needs, this research project developed a prototype Agricultural Burning Emission Estimation System (ABEES). To generate a specific and high quality emission inventory, ABEES processes spatially and temporally specific burn activity data. This bottom-up approach is radically different from existing top-down allocation approaches employed statewide by the Air Resources Board.

Researchers collected year 2000 activity data from permit databases (71,000 records), developed digital maps to locate the burn activity, computed emissions, and compared the output with current ARB estimates. All of the data storage, computations and mapping techniques were scripted in a geographic information system (GIS).

In summary, the prototype Agricultural Burning Emission Estimation System was shown to be capable of creating a spatially and temporally specific emission inventory. When given high quality activity data, ABEES performed well. But when given an incomplete or non- spatially and temporally specific input, ABEES did not perform well. The ABEES approach is data intensive and therefore highly dependent on quality input. When given spatially and temporally resolved input data, a similarly high quality emission inventory can be achieved.

Decision makers at the California Air Resources Board demand an increasingly advanced state-of-the-science technique to answer complex environmental questions. Through this research project, the ABEES method is shown to be a sound approach. Furthermore, high quality activity data is already present in regions of California with advanced permitting systems. The State of California can press forward with both methodology advances (such as ABEES) and improved statewide data collection to support detailed emission inventory compilation and analysis.

This technical report documents the data collection and processing methods, analysis results, discussion evaluating the model output, and conclusions and recommendations for the next steps of the Agricultural Burning Emission Estimation System. All computer code and data central to the project is delivered as a CD-ROM companion to this report. A detailed account and analysis of the activity data collection is included as Appendix A.

2. Methods

2.1. Data collection – Creation of the California Ag Burn History Database

Ag burn permit data collection was performed by Les Fife of Fife Environmental. Fife Environmental's full report is included as Appendix A. Mr. Fife's task was to gather and assemble permit based agricultural residue burn history information from all areas of California with significant activity in calendar year 2000. He gathered records from 27 counties, became familiar with the data format, and then combined them into one statewide database.

2.1.1. Assembling permit data form California counties

To build a spatially and temporally resolved emissions inventory for California for year 2000, we obtained raw permit data from individual burn authorities in the State. Information recorded on burn permits is the most detailed and accessible governmental data source on agricultural burning activity. Individual counties and air districts of California each maintain their own permit databases. It was necessary to identify which authorities in California had pertinent information, obtain a copy of their year 2000 data, understand the structure and content of the database, then combine the separate databases into one statewide table.

This project's objective was to first assemble data from the Sacramento and San Joaquin areas then to expand the data gathering subject to available resources. We were able to obtain data from every California county that had significant burning in 2000. We received the data from counties and air districts mainly via electronic mail. In some instances, in-person visits to the agency were necessary.

The datasets from the various agencies were very different. Some were very intricate and detailed, while others were more of a summation. Some databases had a robust internal format, while others were inconsistent in their reporting techniques. Software file format, database field format and data values were all modified as necessary to meld the information into a common statewide data scheme. A summary of each county dataset obtained is in Appendix A, as well as complete details regarding data acquisition, processing, and normalizing issues.

From the collected information, we created a standardized database that could support emissions analysis, but also be a lowest common denominator for the diverse agency datasets. Our emphasis was in preserving data central to an emissions inventory. Information on time, location, amount and residue type involved in the burning generally existed in some form in each of the county databases. There were also voluminous other data that were not common between databases or not central to emissions estimation. These extraneous data were culled in the interest in maintaining a focused data product and in the interest of time.

The resulting California Agricultural Burning Database (caagb2000a.dbf) includes the following fields:

- County Name
- Burn Date
- Month Burned
- Residue Type
- Location
- Section Township and Range
- Acreage Burned
- Tonnage Burned

2.2. GIS integration – Creation of the California Ag Burn History Atlas

Following the compilation of tabular, statewide agricultural burning information, the next step was to convert the data into a format that can readily be used with GIS mapping and analysis software. Using the Ag Burn History Database, we created a "mappable" California Ag Burn History Atlas. The input database is a simple table of burn incidents. By design, each burn record has a space for location information. Using Geographic Information system (GIS) software we attempted to locate each of the burn permits in the database. We also encoded the date information. With the atlas established in the GIS, analysis could be performed for multiple counties over any date range.

2.2.1. Importing the Ag Burn History Database to GIS

A goal of this project was to locate, or geo-reference, burns based on the Public Land Survey System of Township Range and Section (TRS). TRS is a standardized legal description of location. The system is essentially a labeled one-by-one mile grid of the State. Given a TRS code, there is little ambiguity to its location. This is in contrast to street addresses or specialized "grower's field names".

Using the collected data, we identified and utilized as much Township Range and Section information as possible. The "location" field in the Database is the catch-all field for any spatial information from the various agency databases. For those records that included TRS, this data was extracted into a separate field (named "sectwnrng") that could ultimately be standardized and used for geo-referencing (i.e, mapping). Thus the "sectwnrng" field is a calculated field created by the project team to identify TRS data we can geo-reference.

Imperative to utilizing the location data in GIS software was to have the TRS values in a standardized format. The "sectwnrng" field contains appropriate data but not in a consistent format. There are many possible ways of citing a TRS location. Not surprisingly, the TRS data in the Ag Burn History Database was in different formats from different data providers.

For example, ways of codifying *Township 20 North, Range 30 East, Section 6* based on the *Mount Diablo meridian* may include: *20N30E6*, *T20NR30E06*, *20N30E06* or *R30ET20N06*.

To standardize the reported TRS data, we wrote an algorithm to parse the TRS data into a single format. We wrote the program in the ArcView GIS environment using the Avenue scripting language. The script looks in the "sectwnrng" field of the Ag Burn History Database, converts the data and writes the output to a new field called "trsteale". MTRS stands for *Meridian Township Range Section*.

Our new format expresses the previous example as: *M20.0N30.0E06*

Our MTRS data format is capable of uniquely identifying any Public Land Survey System parcel in the State. The practical outcome of the script is a new calculated field containing a universally identifiable and consistent TRS value. This was designed to interface with Public Land Survey System coverage available from the California Spatial Information Library (http://gis.ca.gov). The coverage implemented in this project includes sections "filled" into land grant and other non-surveyed area. The source code of the *parset.ave* script is provided on the companion CD.

2.2.2. Standardizing date format

As with the TRS data, formats for the reported burn dates were also standardized. We simplified the date value to a plain number field. The date format of the "date" field was calculated to an eight digit chronologically ascending number in the "date2" field. The format is year (four digits) then month (two digits) then day (two digits).

For example, the date *June 2, 2000* was converted to: *20000602*

2.2.3. ARB ag burn fuel loading and emission factors table

Recommended California Air Resources Board agricultural residue loading and emission factors were used in this project for our emission calculations. We obtained a table of loading and emissions factors from ARB staff (ARB 2000). An excerpt of the ARB document featuring the table is included as Table 1 below.

The table lists fuel loadings in tons per acre and emissions in pounds per ton for various pollutants. Reported agricultural burning data was predominantly reported in acres. The ARB emission factor table is appropriate for calculating emissions mass through the simple steps of multiplying acres times fuel loading times the emission factor. The table was converted to a dBase format (eftable.dbf) for import into the geographic information system emission estimation tool.

Table 1: Emission Factors for Open Burning of Agricultural Residues, California Air Resources Board.

Crop	PM_{10}[a] (lbs/ton)	$PM_{2.5}$[a] (lbs/ton)	NO_x[b] (lbs/ton)	SO_2[b] (lbs/ton)	VOC[c] (lbs/ton)	CO (lbs/ton)	Fuel Loading[d] (tons/acre)	Fuel Moisture[e] (% weight)	Source of Data
Row Crops									
Alfalfa	28.5	27.2	4.5	0.6	21.7	119.0	0.8	10.4	AP-42, Jenkins NOx & SO2
Barley	14.3	13.8	5.1	0.1	15.0	183.7	1.7	6.9	Jenkins (EF)[f]
Corn	11.4	10.9	3.3	0.4	6.6	70.9	4.2	8.6	Jenkins (EF)[f]
Oats	20.7	19.7	4.5	0.6	10.3	136.0	1.6	9.6	AP-42, Jenkins NOx & SO2
Rice	6.3	5.9	5.2	1.1	4.7	57.4	3.0	8.6	Jenkins (EF)[f]
Safflower	17.7	16.9	4.5	0.6	14.8	144.0	1.3	14.1	AP-42, Jenkins NOx & SO2
Sorghum	17.7	16.9	4.5	0.6	5.1	77.0	2.9	17.2	AP-42, Jenkins NOx & SO2
Wheat	10.6	10.1	4.3	0.9	7.6	123.6	1.9	7.3	Jenkins (EF)[f]
Orchard and Vine Crops									
Almond	7.0	6.7	5.9	0.1	5.2	52.2	1.0	18.3	Jenkins (EF)[f]
Apple	3.9	3.7	5.2	0.1	2.3	42.0	2.3	53.5	AP-42, Jenkins NOx & SO2
Apricot	5.9	5.6	5.2	0.1	4.6	49.0	1.8	33.7	AP-42, Jenkins NOx & SO2
Avocado	20.6	19.4	5.2	0.1	18.5	116.0	1.5	29.3	AP-42, Jenkins NOx & SO2
Bean/Pea	13.7	13.0	5.2	0.1	14.2	148.0	2.5	11.4	AP-42, Jenkins NOx & SO2
Cherry	7.9	7.4	5.2	0.1	6.0	44.0	1.0	36.2	AP-42, Jenkins NOx & SO2
Citrus	5.9	5.6	5.2	0.1	6.8	81.0	1.0	29.3	AP-42, Jenkins NOx & SO2
Date palm	9.8	9.3	5.2	0.1	3.8	56.0	1.0	13.3	AP-42, Jenkins NOx & SO2
Fig	6.9	6.5	5.2	0.1	6.0	57.0	2.2	30.1	AP-42, Jenkins NOx & SO2
Grape	4.9	4.6	5.2	0.1	3.8	51.0	2.5	31.5	AP-42, Jenkins NOx & SO2
Nectarine	3.9	3.7	5.2	0.1	2.3	33.0	2.0	32.0	AP-42, Jenkins NOx & SO2
Olive	11.8	11.1	5.2	0.1	10.3	114.0	1.2	33.5	AP-42, Jenkins NOx & SO2
Orchard	7.8	7.3	5.2	0.1	6.3	66.0	1.7	28.8	Average all tree EFs
Peach	5.9	5.6	5.2	0.1	3.0	42.0	2.5	15.7	AP-42, Jenkins NOx & SO2
Pear	8.8	8.3	5.2	0.1	5.1	57.0	2.6	34.3	AP-42, Jenkins NOx & SO2
Prune	2.9	2.8	5.2	0.1	4.6	47.0	1.2	25.3	AP-42, Jenkins NOx & SO2
Walnut	4.2	4.0	4.5	0.2	4.8	67.0	1.2	33.1	Jenkins (EF)[f]

2.2.4. Residue type label standardization

The California Air Resources Board has a succinct list of researched fuel loadings and emission factors associated with commonly burned agricultural residues. This table is described in the previous section. In contrast to this concise description of burning is the variable residue labeling information originally collected for the Agricultural Burning History Database. The statewide database is a collection of data from different burning authorities. The residue labels vary in their categorization, specificity and spelling. A complete list of all the different occurrences of labels in the "crop" field of the statewide database appears in Appendix A.

The ARB includes emission factors for only 25 specific residue types, but dozens of residue types were reported in the Ag Burn Database. This meant that we could not automatically match a fuel load and emission factors to each and every burn in the database. There were two specific obstacles. The first was clerical, where the residue information was clear but the labels were written differently. For example rice residue could be expressed in the database as *rice*, *Rice* and *rice stubble*. Syntactic differences include variations in spelling, capitalization and phrasing. The second and more complicated predicament was that the residue indicated in the permit information does not appear in the ARB table. Semantic differences may include ambiguous non-biotic labels such as *ditchbank and canal*, non-specific categories such as *orchard* or *field crops*, and even non-information such as *miscellaneous*.

In the final Agricultural Burning Database, residue type information was standardized such that every burn record links to an ARB emission factor. Original residue labels that were not compatible were either 1) reformatted to match the ARB labels, 2) reassigned to a similar crop category appearing in the ARB table, or 3) reassigned to a default crop category. Project management and researchers agreed that the best goal of this project was to provide a complete emissions inventory at the consequence of incorporating potential inconsistencies. Harmonizing the database residue information to the ARB emission factors table was lead by ARB project management and executed by the research staff and subcontractor.

A corollary to providing **completeness** was documenting **confidence**. Each residue assignment in the Ag Burn History Database and Atlas has a confidence value. This nominal code ranks the quality of the residue label assigned by researches and ultimately used in the emissions inventory. Burn records where the residue label clearly matched an ARB table entry were assigned a confidence of "1". Syntactic modifications of permit labels would fall into this category. With a confidence value of "1", researchers are confident an appropriate fuel loading and emission factor, as supplied by ARB, are being used in the calculation process. Confidence values of "2" were assigned to records that needed a minor reassignment from a crop present in the permit database to a similar category documented by ARB. This was most typical for 1) various pruning types being condensed into an averaged ARB "orchard" entry and 2) different grape related burning being condensed into a general ARB "grape" entry. All remaining database records that did not match an ARB crop category were given a single default value. The fuel loading and emission factors implemented for this default are from the "grassland" category. Permit data subject to this generalization received the lowest confidence ranking of "3". A summary of confidence values over the year 2000 activity dataset is presented below.

Table 2: Emission factor assignment confidence rating summary.

Confidence Code	Num Records	Percent Records	PM_{10} (tons)	Percent PM_{10}
1	50,282	70%	4,631	51%
2	2,981	4%	323	4%
3	18,194	25%	4,159	46%

2.2.5. Implementing ARB agricultural burn emissions estimation calculations

Emissions estimates were calculated for each burn incident in the Ag Burn History Atlas. We used the standard ARB method of multiplying together acreage, fuel loading and an emission factor. The formula is:

Emission Estimate (lbs) = Activity (acres) x Fuel Loading Factor (tons/acre) x Emission Factor (lbs/ton)

In the event that an acreage was not reported but tons of residue consumed was reported, the emission calculation formula was:

Emission Estimate (lbs) = Fuel Loading (tons) x Emission Factor (lbs/ton)

We applied this calculation for each pollutant to be included in the emissions inventory. Pollutants calculated for this project are:

- PM_{10} – Particulate matter less than 10 microns in size
- $PM_{2.5}$ – Particulate matter less than 2.5 microns in size
- NO_x – Oxides of nitrogen
- SO_2 – Sulfur dioxide
- VOC – Volatile organic compounds
- CO – Carbon monoxide

In preparing the emissions mapping, emission estimates for each pollutant are stored in a separate field in a temporary database. This temporary database is attached to the History Database in the GIS. Keeping the emissions calculations in a separate file from the activity database has two main advantages. First it reinforces that the derived calculations are a separate product from the activity database. For a historic emissions analysis, the activity information is likely to be fixed. The activity database can be kept "read only" and isolated from unintended edits in the calculations and queries taking place in the GIS. The second and related advantage of two separate files is to facilitate the update of the emissions calculations. If the emissions factors table is changed and the inventory is to be recalculated, only the separate emissions files needs to be altered. A "switch" in the eiserver.ave script is used to activate the recalculation of the emissions estimates. The switch is currently set to "off" and the emissions estimates are essentially static for the purposes of running the ABEES. Staff modifying the emissions calculations need not worry about the activity data itself. If the format of the History Database remains constant new pollutants or an improved calculation method can easily be implemented.

3. Results

3.1. The California Ag Burn History Atlas

The California Ag Burn History Atlas is a statewide database of individual burns and their location, date and crop specifics. The California Ag Burn History Atlas is implemented in ArcView GIS. The Atlas is essentially the Ag Burn History Database linked to a map of the Public Land Survey System of California. Using out-of-the-box tools in ArcView users can map particular emissions, for particular crops, for particular areas over a particular date range. The Atlas supports this flexible and low-level analysis by maintaining a simple format. The format is illustrated below.

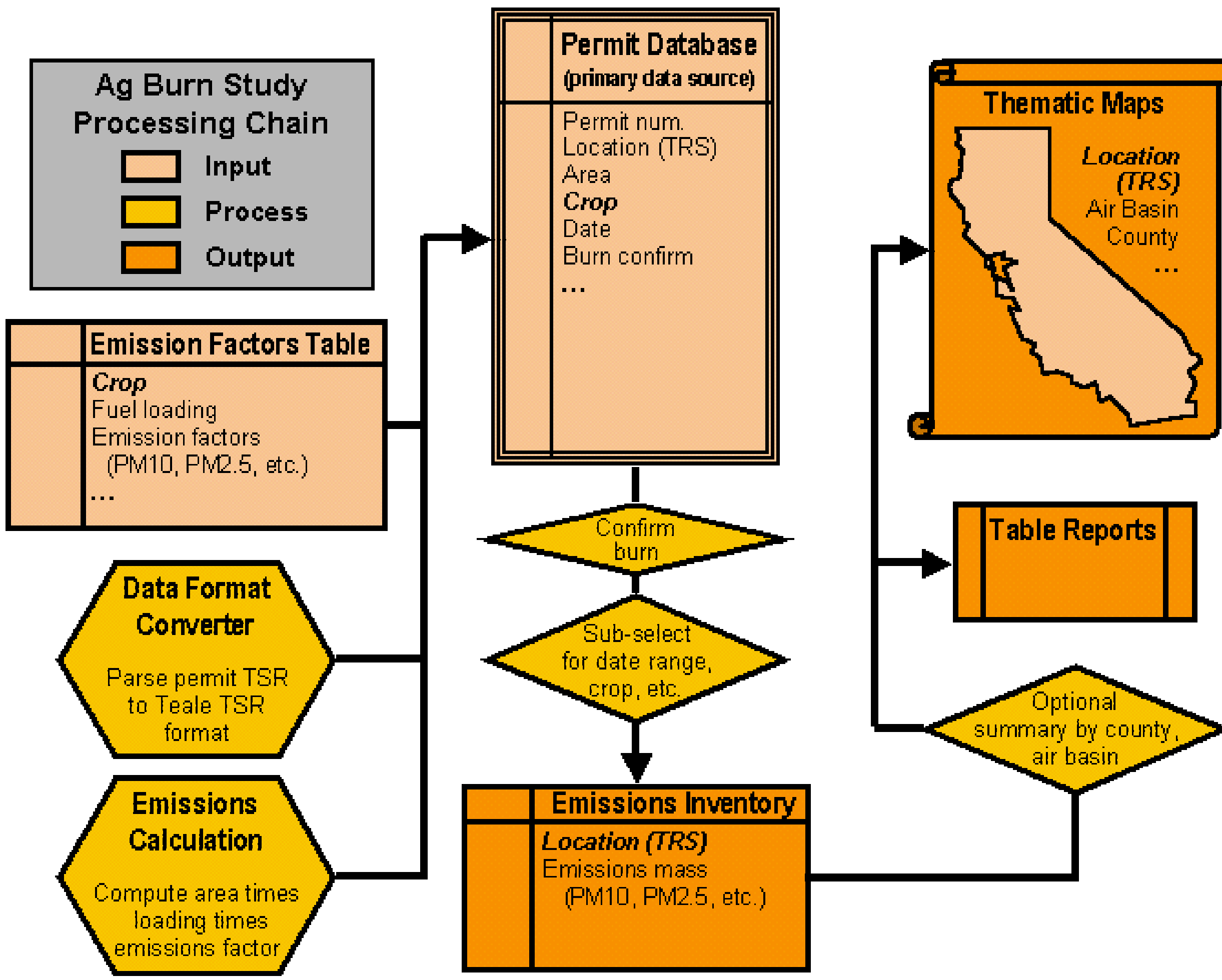


Figure 1 Ag Burn History Atlas flow diagram

The Atlas consists of three database files: The Ag Burn History Database, the ARB emission factors table and a new database to hold calculation output. The emission factors table is attached to the History Database via crop name. This database join effectively assigns fuel loading and per pollutant emission factors to each burn incident. GIS computer code performs the emissions calculations. Source code for these scripts is included on the companion CD. The one map in the Atlas is the Public Land Survey System (PLSS) coverage for California. This spatial dataset has a text label for each section depicted on the map. The History Database is linked to the PLSS map by TRS code. Each fire can therefore be located in the State of California and, conversely, each TRS location in California has an inventory of fire activity and emissions for the year.

This Atlas is designed to be queried for custom emissions inventories– either statewide or by county and for arbitrary time periods. A prototype interface for doing so via desktop-GIS is described in section 3.2.

The table below summarizes some of the agricultural burning activity data collected as part of this project. As shown, a large fraction of the reported burning occurs in January, and the two largest residue types burned are almond prunings and rice straw. Additional county and crop specific information is provided in Appendix A.

Table 3: Agricultural burning activity data summary.

Monthly Summary			**Major Crop Summary**	
Month	**Acres Burned**	**Tons Burned**	**12 Major Residue Types**	**Acres Burned**
January	152,252	40,130	Almond	261,681
February	69,585	5,148	Rice	174,062
March	90,441	8,896	Grape	89,821
April	58,189	7,948	Wheat	55,922
May	33,698	9,564	Walnut	54,736
June	38,046	4,277	Tumbleweeds	30,831
July	35,648	5,959	Raisin	29,770
August	26,784	4,674	Bermuda	26,933
September	65,803	6,626	Brush	23,919
October	103,914	9,371	Ditchbank/Canal	20,819
November	137,017	13,216	Chaparral/Chemise	17,906
December	100,865	8,213	Prunes	12,521
TOTALS	**912,242**	**124,022**		**798,921**

The figure below maps the number of activity records collected for each county in the state for the study period.

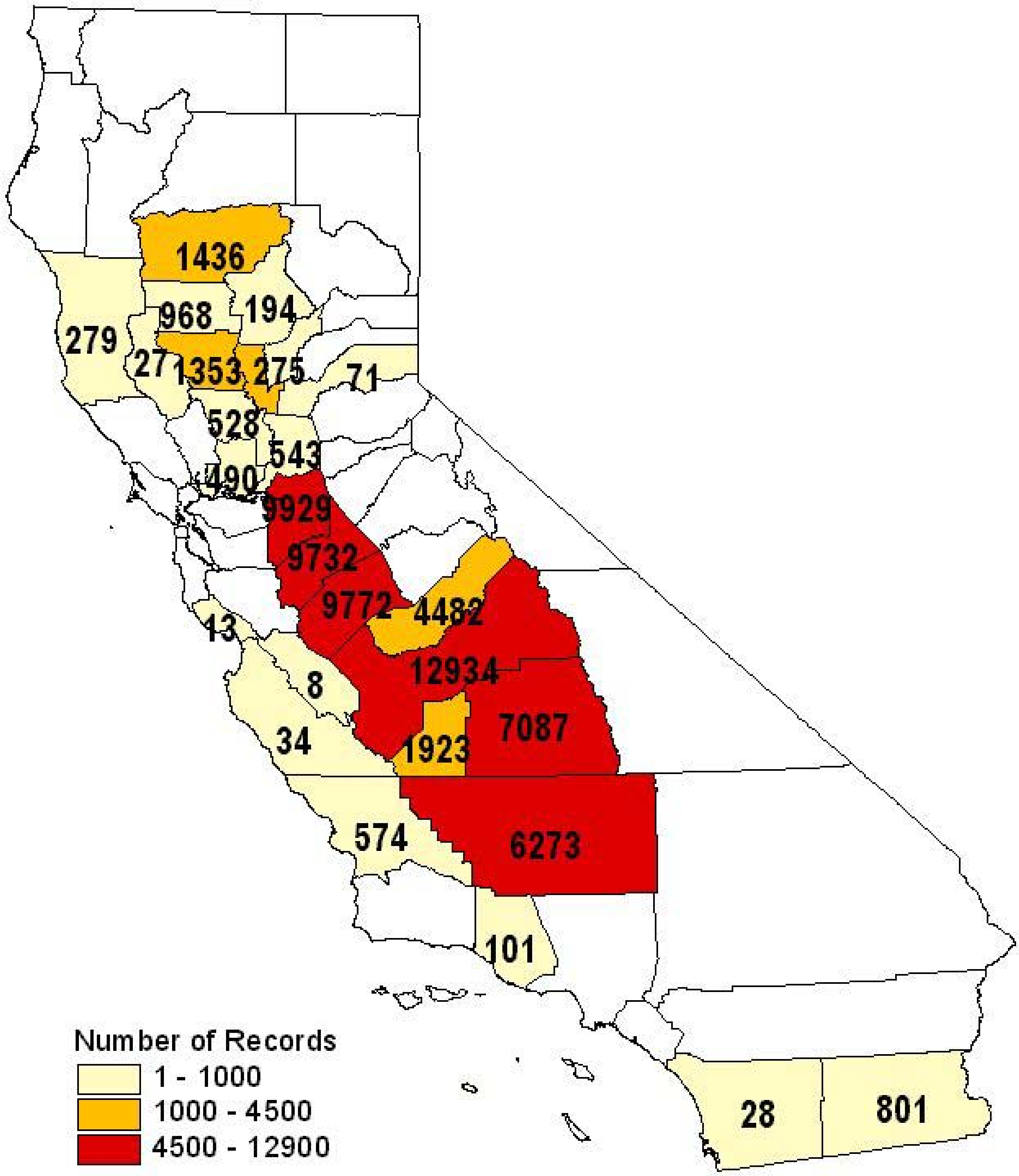


Figure 2: Activity records collected by county.

3.2. The Ag Burn Emissions Estimation GIS

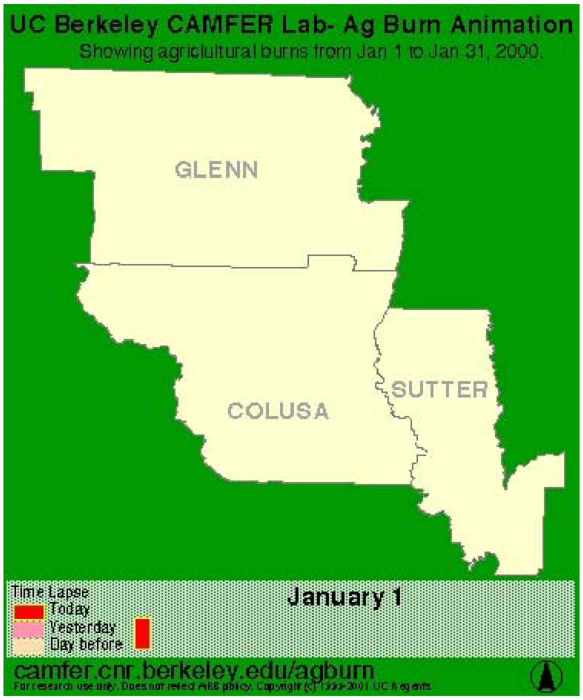
The Ag Burn Emissions Estimation Geographic Information System is a collection of data and scripts for analyzing and presenting the data. The overall concept and design of the GIS is very straightforward. Detailed programming code and cartography bring about the automated processing and summary of thousands of records of activity data. The Ag Burn GIS is implemented as an ESRI ArcView GIS 3.2 Project File (ABEES.apr).

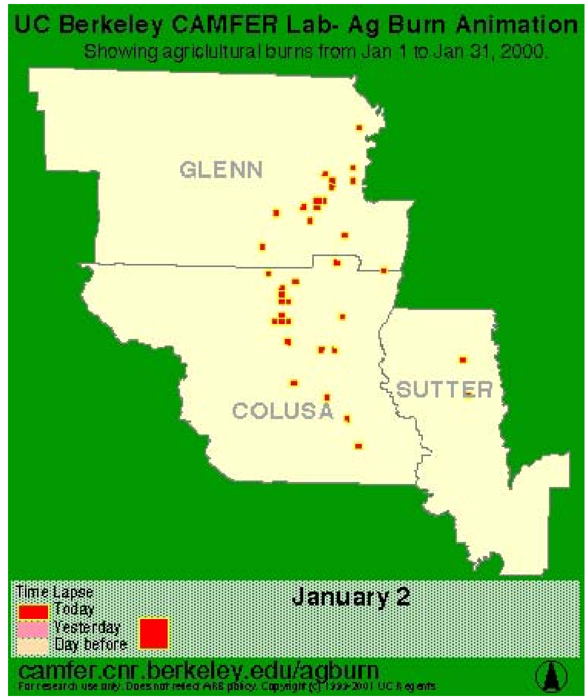
The three main data elements of the Ag Burn Emissions Estimation GIS are 1) the California Ag Burn History Atlas for year 2000, 2) the Public Land Survey System digital map of California and 3) the ARB emission factor table for agricultural burning residue. The Ag Burn History Atlas is a dBase database with 71,457 records and 13 fields and is referenced in the APR file as a table document. The PLSS digital map is the single spatial data layer in the GIS. It is an ArcInfo coverage originally from the Teale Data Center consisting of 157,285 Township Range and Section polygons and associated attribute data for the entire state. The ARB emission factor table is stored as a dBase file on disk and displayed as an ArcView table document.

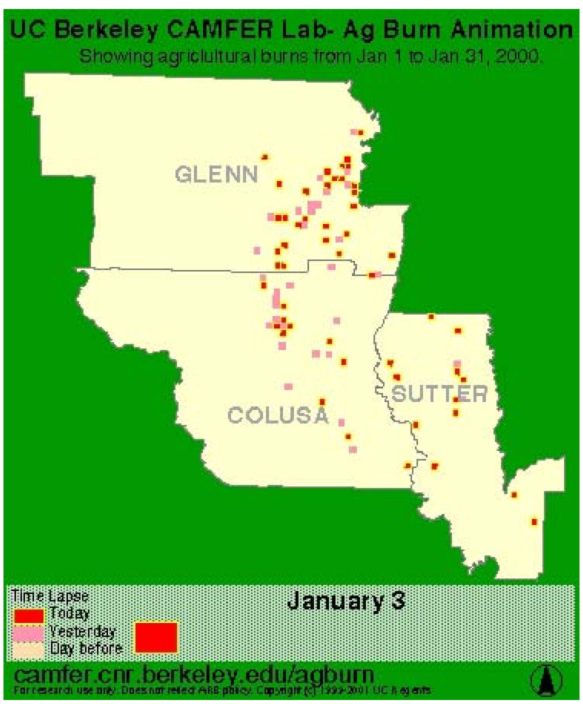
The three datasets relate to each other through particular fields. The emission factors can join to the Ag Burn History Atlas by crop name. That is, each activity record has a residue value that can be "looked up" in the emission factor table. This is a many-to-one relationship where many activity records will link to a particular crop emission factor. The History Atlas can link to the PLSS coverage through Township Range and Section code. That is, each geo-referenced activity record can be tied to its Section on the map. The "link" in the GIS is actually implemented in the other direction where each PLSS record will link to several activity records. This is a one-to-many relationship where one Section will tie to several burn incidents through the year.

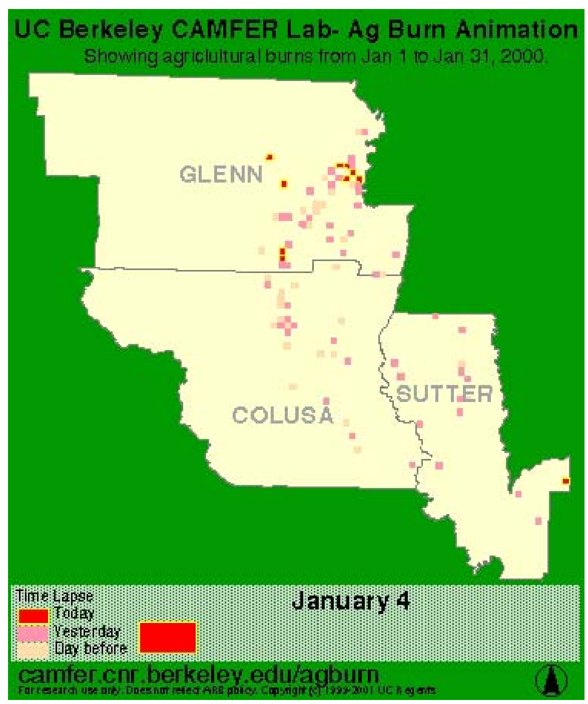
On the following pages is a collection of images displaying an excerpt of ABEES activity data by Township Range and Section. Each image shows new agricultural burn events for that day along with previous days' fires "fading away." These images demonstrate both the fine spatial resolution and fine temporal resolution of the Agricultural Burning Emission Estimation System.

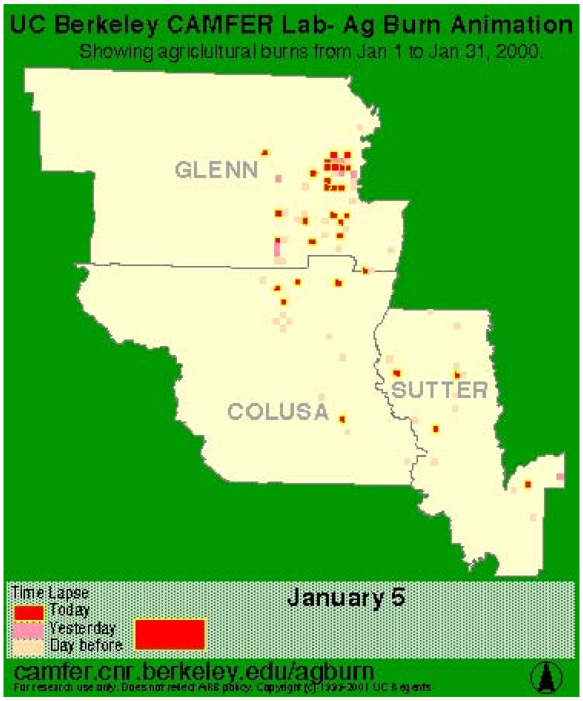
Figures 3(a) – 3(l): Series of “time lapse” maps showing ABEES recorded agricultural burn events for Glenn, Colusa and Sutter Counties from January 1 to January 12, 2000.

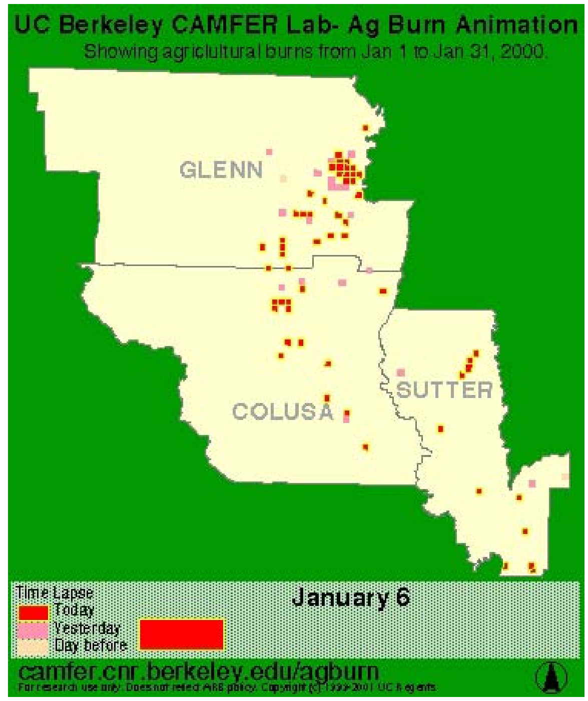









UC Berkeley CAMFER Lab- Ag Burn Animation
Showing agriclultural burns from Jan 1 to Jan 31, 2000.
GLENN
COLUSA
SUTTER
Time Lapse
Today
Yesterday
Day before
January 5
camfer.cnr.berkeley.edu/agburn


UC Berkeley CAMFER Lab- Ag Burn Animation
Showing agriclultural burns from Jan 1 to Jan 31, 2000.
GLENN
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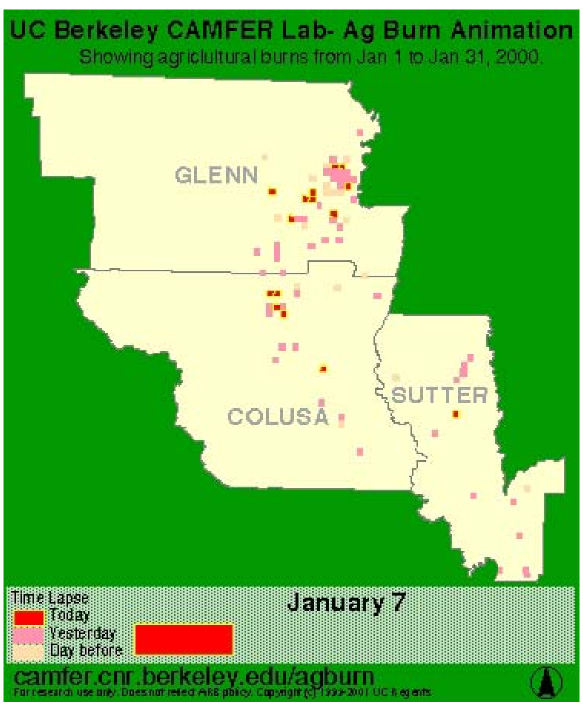
SUTTER
Time Lapse
Today
Yesterday
Day before
January 6
camfer.cnr.berkeley.edu/agburn


UC Berkeley CAMFER Lab- Ag Burn Animation
Showing agriclultural burns from Jan 1 to Jan 31, 2000.
GLENN
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Time Lapse
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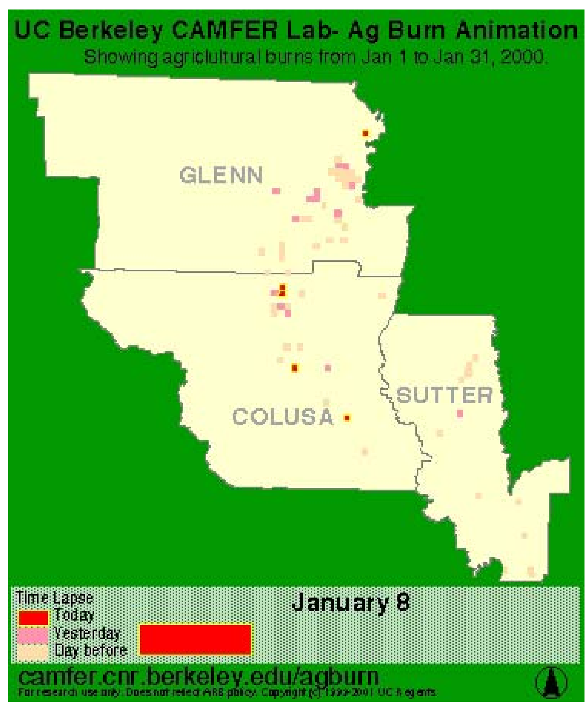
January 7
camfer.cnr.berkeley.edu/agburn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Showing agriclultural burns from Jan 1 to Jan 31, 2000.
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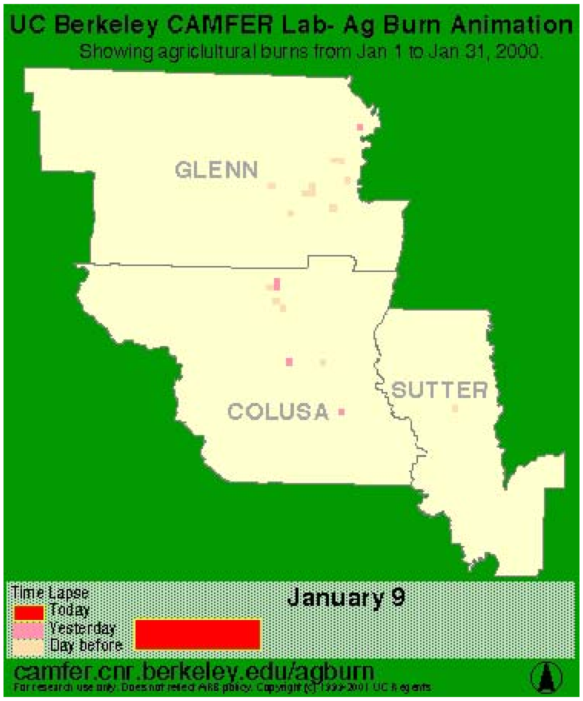
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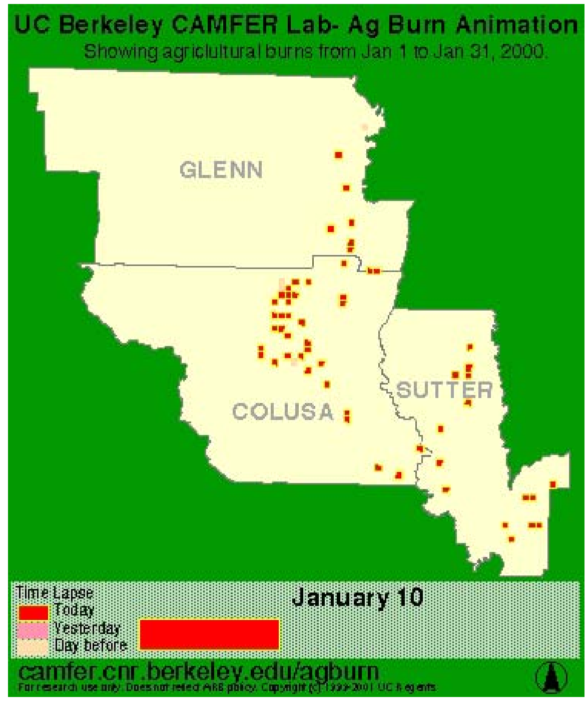
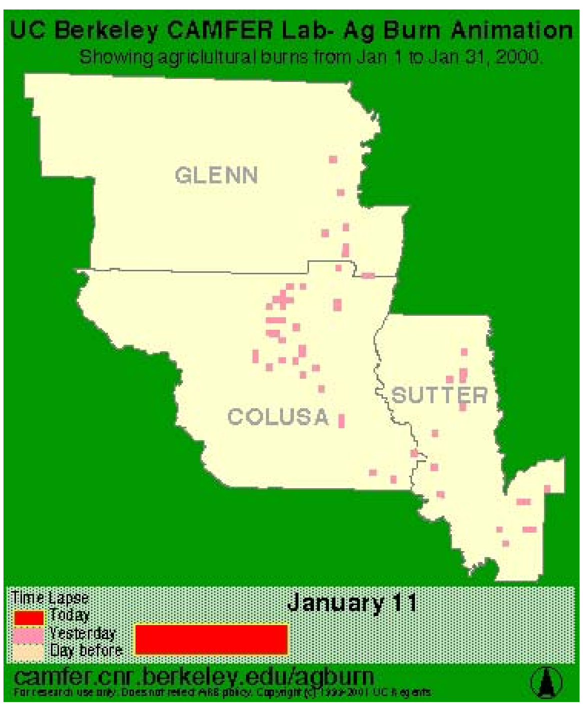
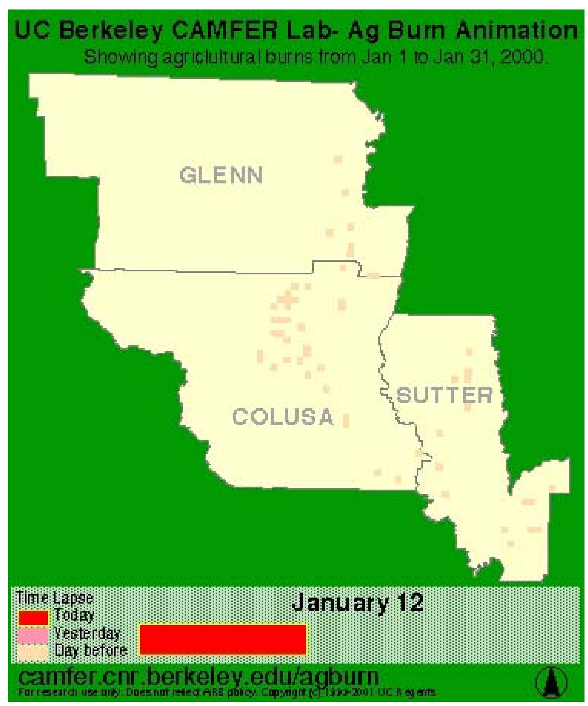

UC Berkeley CAMFER Lab- Ag Burn Animation
Showing agricultural burns from Jan 1 to Jan 31, 2000.
GLENN
COLUSA
SUTTER
Time Lapse
Today
Yesterday
Day before
January 10
camfer.cnr.berkeley.edu/agburn


UC Berkeley CAMFER Lab- Ag Burn Animation
Showing agricultural burns from Jan 1 to Jan 31, 2000.
GLENN
COLUSA
SUTTER
Time Lapse
Today
Yesterday
Day before
January 11
camfer.cnr.berkeley.edu/agburn


UC Berkeley CAMFER Lab- Ag Burn Animation
Showing agricultural burns from Jan 1 to Jan 31, 2000.
GLENN
COLUSA
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Time Lapse
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January 12
camfer.cnr.berkeley.edu/agburn

3.3. Year 2000 Emission Estimates from the Ag Burn Emissions Estimation GIS

We used the Emission Estimation GIS to summarize emission estimates for calendar year 2000. The summaries are illustrated in the maps and tables included below. The true utility of the GIS-based system is for analyzing spatially resolved daily data at the county level. These annual summaries emphasize, despite the fine resolution data involved, the method's statewide and yearlong scope.

Emission estimates are summarized by county in the table below. The system records emission estimates in pounds to preserve the precision of the event-by-event emission calculations. Also noted in the summary table is the number of records in the Ag Burn Atlas per county to yield the estimates.

Table 4: Annual emissions (lbs/year) as estimated by the Ag Burning Emissions Estimation GIS.

County	Records	PM10	PM2.5	CO	NOx	SO2	VOC
BUTTE	194	799,687	753,483	7,067,156	575,933	106,087	593,364
COLUSA	1,353	1,038,903	977,135	9,353,059	740,271	152,694	768,573
FRESNO	12,934	3,061,123	2,913,454	23,977,213	1,674,115	110,428	2,192,036
GLENN	968	858,003	803,527	7,817,363	708,193	149,810	640,098
IMPERIAL	801	1,518,623	1,450,462	12,660,707	477,710	76,059	1,038,651
KERN	6,273	1,089,542	1,039,754	8,945,056	570,193	39,261	777,318
KINGS	1,923	435,689	415,590	4,055,634	192,028	22,085	316,878
KINGS COUNTY	1	42	40	313	35	1	31
LAKE	27	524,697	500,925	3,981,880	185,904	19,078	362,568
MADERA	4,482	982,547	933,209	8,024,807	642,345	24,691	729,772
MENDOCINO	279	1,627,475	1,551,691	12,426,694	645,886	57,160	1,118,753
MERCED	9,772	888,337	847,434	6,828,243	491,849	35,585	635,243
MONTEREY	34	456,171	436,088	3,270,660	129,105	17,214	306,983
PLACER	71	81,602	76,521	733,485	64,560	13,543	60,501
SACRAMENTO	543	159,634	151,342	1,168,925	79,780	10,318	101,167
SAN BENITO	8	342,645	327,560	2,456,700	96,975	12,930	230,585
SAN DIEGO	28	209,659	200,134	1,521,241	63,281	7,259	147,294
SAN JOAQUIN	9,929	987,247	939,826	8,047,787	551,943	48,048	707,179
SAN LUIS OBISPO	574	308,935	293,540	2,505,815	155,294	9,692	221,311
SANTA CRUZ	13	35,139	33,592	251,940	9,945	1,326	23,647
SOLANO	490	118,008	112,747	883,790	47,183	4,581	76,493
STANISLAUS	9,732	597,011	569,706	4,969,300	461,186	18,313	454,454
SUTTER	1,601	689,680	651,388	6,311,166	454,870	80,633	519,681
TEHAMA	1,436	67,784	64,450	758,558	55,719	1,985	65,104
TULARE	7,087	831,981	791,316	7,924,598	467,277	31,484	646,355
VENTURA	101	192,469	182,552	2,070,091	122,467	3,359	195,287
YOLO	528	141,091	133,518	1,313,171	88,350	14,564	110,970
YUBA	275	182,058	171,167	1,599,067	133,439	27,001	133,846

As can be seen in the map below, most agricultural burning emissions are produced in the Sacramento Valley, San Joaquin Valley and Imperial County regions of California.

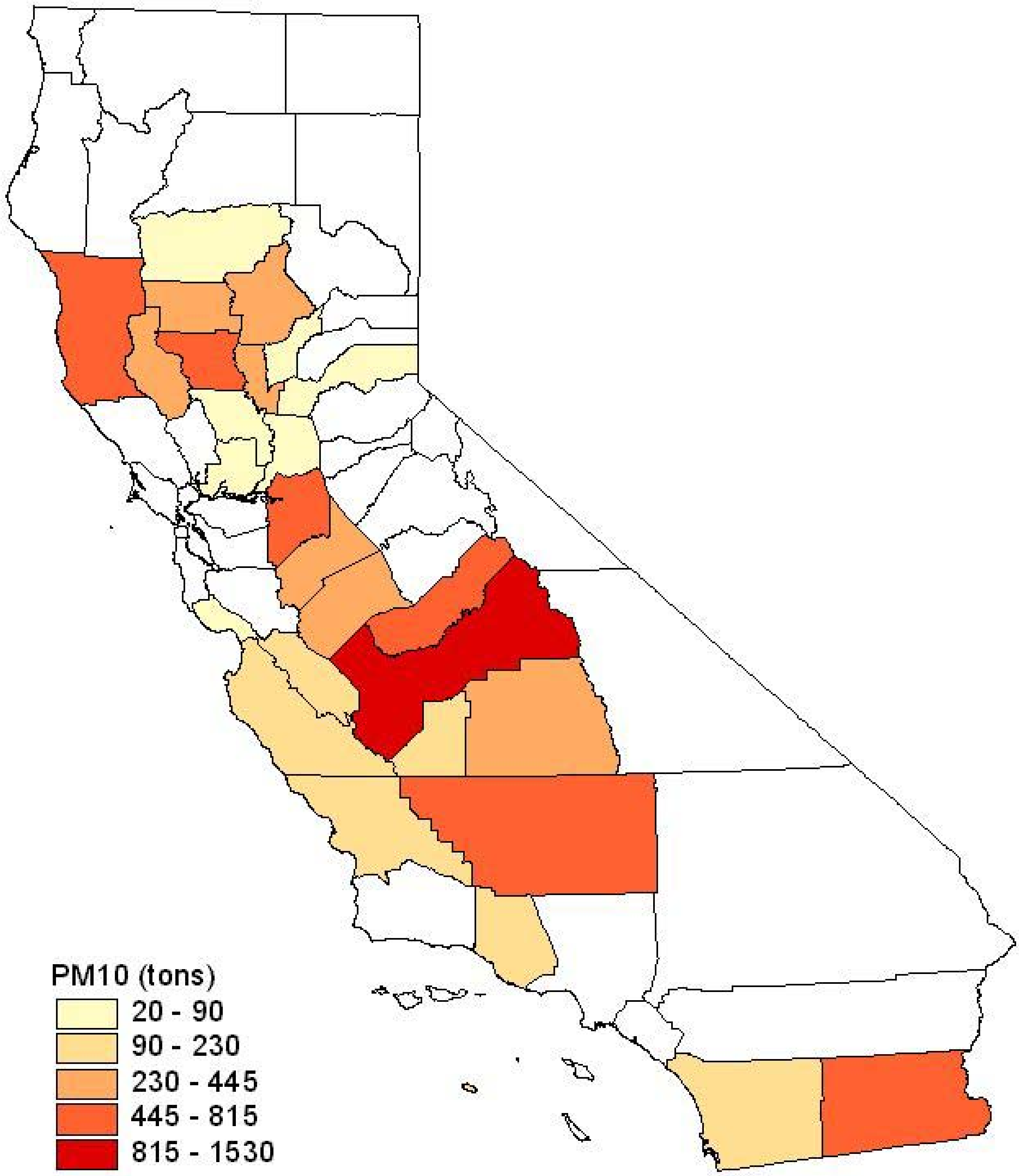

Figure 4: Calculated annual emissions for PM_{10} by county.

4. Discussion

4.1. Comparison of ABEES Output to Current ARB Estimates

The Agricultural Burning Emissions Estimation System developed in this project relates to emission estimates from California Emission Inventory Data Analysis and Reporting System (CEIDARS). The CEIDARS system is considered the official emission inventory system for the State of California. We compared annual county estimates for CEIDARS to ABEES over calendar year 2000 for particulate matter (PM_{10}).

The purpose of this comparison is simply to evaluate the estimated emissions using the two very different methodologies. The scope of the project does not allow for a detailed analysis of the specific reasons for differences observed between the two methods. Instead, the comparison allows an evaluation of the potential strengths and shortcomings of each approach, as well as providing a rough 'reality-check' of the emissions data sets. Specific recommendations for implementing the new ABEES approach are discussed in detail in Section 5.

Figure 4 (below) graphs PM_{10} emissions per county in tons for CEIDARS and ABEES. The sources tallied for CEIDARS include *Agricultural Burning – Field Crops*, *Agricultural Burning – Prunings*, and *Weed Abatement*. We did not include the wildland fuel categories. The GIS based estimates include all records collected as part of the Agricultural Burning Database. For the entire state, the ABEES emissions are 56 percent of the CEIDARS totals. In most counties where there is significant agricultural burning, the ABEES estimates are lower than the CEIDARS estimates.

Colusa, Glenn, Merced, San Joaquin, Stanislaus, and Sutter counties all had over 1000 tons of PM_{10} reported in CEIDARS and less than half that amount recorded using the ABEES approach. Burn Atlas records for Colusa and Glenn Counties mainly indicated rice burning while Merced, San Joaquin and Stanislaus Counties were dominated by orchard pruning removal. Sutter County contained a combination of both types of burning. Most of those counties also had records for weed abatement burns. But the GIS records for these counties were of relatively good quality: Generally speaking they contained location information and emission factor assignments resulting in high confidence.

In these examples, where ABEES produces the higher emission, it is hard to speculate a reason for the discrepancy. The records going into the calculation seem to be of good quality. If it is a question of lower activity, then we could hypothesize that ABEES is not capturing all the burning. But if we presume the permit activity is complete, then there could be a difference in the emission calculation methods.

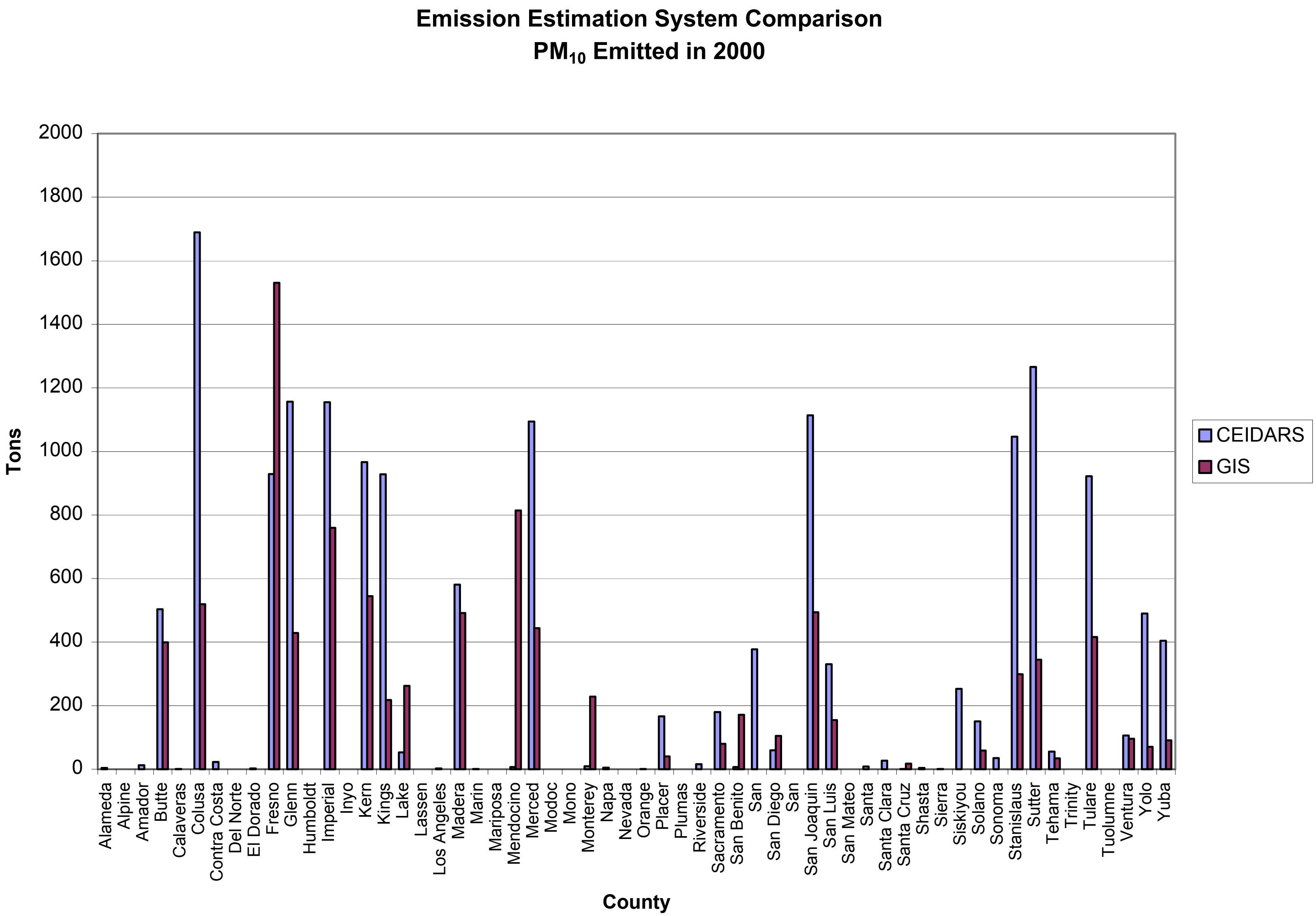

Figure 5: CEIDARS to ABEES annual by county comparison.

The comparisons of Lake, Mendocino, and Monterey Counties showed permit based ABEES emissions higher than CEIDARS. The records going into the GIS for these counties were of poorer quality. Activities included wildland fuel types such as "brush" and "wildfire". There were relatively few records driving these emission totals. The records generally had a low emission factor look-up confidence ranking and poor temporal specificity.

The cases of Lake, Mendocino and Monterey Counties can be typified in that ABEES is using the wrong type of input. The agricultural residue emission estimates will be inflated if intense wildland burning activity is inadvertently included.

The Fresno County emission estimates were far greater in ABEES compared to CEIDARS. This was in fact the most active county in the ABEES report with 1530 tons of PM_{10} emissions. CEIDARS reports under 930 tons of PM_{10} for year 2000. There were almost 13,000 records in the Ag Burn History Atlas driving the GIS emission estimates for Fresno. Half of these records had a crop look-up confidence value of 3 while the other half were 1 and 2. That is, half of the records for Fresno County were assigned the default fuel loading and emissions factors of "grassland". These records were made up of crops unknown to the ARB emission factor table as well as weed abatement burns. Also in this category was an ambiguous crop code of "vegetable crops". The middle confidence ranking records were largely "grape stumps/stakes" and were assigned the ARB "grape" emission values. The high confidence matches were orchard pruning burns.

The Fresno activity data included in the Ag Burn History Atlas is by far the most varied in residue type. There were many burns of over 100 acres of many different types of residue from records with all three confidence rankings. It is not clear how the amount of activity or fuel loading and emission factor assignments are specifically affecting the new emission estimates. A detailed examination of the data is needed to understand the quality of the ABEES estimates for Fresno County.

Butte and Madera Counties are examples where ABEES and CEIDARS nearly agree for year 2000. The records for Butte County are all monthly estimates; daily permit records were not available. It could be the case that ABEES and CEIDARS are working with the same input data in this case. Records for Madera County were true daily activity data. There was a mix of confidence in the fuel loading assignments including weed abatement and bonafide residue burning. Orchard removal was the dominant activity in Madera County. These two counties were mid-range emitters for PM_{10} with estimates between 400 to 600 tons.

The reason the estimates for these three counties are about the same for the two systems may again be explained in the input data for ABEES. The activity data for Butte County is not individual permit information. These summaries may in fact be the same input data to CEIDARS. ABEES input data for Imperial and Madera Counties are typical low-level permit based data. But the activity records for these counties are not voluminous. Perhaps, given the scale of agricultural burning and the dominance of certain crops in these areas, the permit-based estimates more easily converge with a top-down CEIDARS style estimate. An optimistic speculation is that the smallish dataset is complete and therefore matches expert estimates for the county. It could also be that a combination of the overestimates and underestimates, as hypothesized for previous cases, combine to cancel each other out.

4.2. Data Deficiencies in the Ag Burn Emissions Estimation GIS

The comparison of ABEES emission estimates to the contemporary CEIDARS system highlights the need for better input data to successfully implement the ABEES approach for statewide emission estimates. Two types of problems expose the dependence of a precise emission calculation method on complete and detailed input data.

First, there are definitely counties where appropriate data were not available. The examples of Lake, Mendocino and Monterey Counties show that including the wrong type of activity information, in this case wildland burning, will inflate the emission estimates. Therefore, the results for these counties computed using the ABEES approach for the year 2000 do not represent actual agricultural burning emissions. In this case, non-agricultural burning activity information was commingled in the agricultural burn input data.

Second, each activity record in the Ag Burn History Database had fuel loading and emission factors assigned to it by crop type. For some records, crop identity was not clear and approximate fuel loading and emission factors where assigned. The analysis in the previous section showed that the confidence of this look-up was not distributed evenly between counties. Some counties that warranted examination because of the difference in ABEES and CEIDARS emission estimates had many low confidence records as input. Fresno County had a significant percentage of records where loading and emission factors had to be approximated. The success of emission factor assignments was recorded for the express purpose of gauging quality in the process. While a failure to match crop descriptions to emission factors specific to each crop does not necessarily produce emission estimation errors, it does highlight the need for standardization of crop residue naming when using a statewide emission estimation approach. Naturally, where the input data do not precisely match the estimation methods or available emissions data, the emissions estimates for such counties will have an additional level of uncertainty.

In summary, both the input data (e.g., crop names, acres burned, tons burned) and emission factor lookup tables (by crop type) must be consistent to ensure the most reliable emission estimates for agricultural burning. The vulnerability of a precise method that utilizes crop specific activity information is that either crop specific emission factors must be available or a good “crosswalk” between the available limited emission factors and the many reported crop residue types. For this project, there were several counties where the data gathered perfectly fit the new method. But where appropriate and detailed were not available, the data intensive processing fails or at best produces uncertain results.

4.3. Input Data Validation Needs of a Permit Based System

The open ended and inconsistent nature of the existing permit-based agricultural burn activity data collection shows a potential weakness of ABEES when using existing data sets. Thousands of individual permit records go into this type of bottom up emission estimation system. The vulnerability is that, using this method alone, one does not know if the input dataset is complete. By merely asking for and collecting permit databases, it is hard to account for potential data omission.

Omission error is considered in the CEIDARS and ABEES comparisons for Colusa, Glenn, Merced, San Joaquin, Stanislaus, and Sutter Counties. The Ag Burn History Atlas seems to contain records with clear and detailed information. Yet the annual county estimates for these regions are below those of CEIDARS. Perhaps the ABEES estimates, being based on precise permit information are of higher quality. But maybe CEIDARS is more accurate for the year and ABEES is simply missing input data. As stated above, discovering the true reason for discrepancies for year 2000 comparisons is not pursued in this report. Even so, an undeniable vulnerability of the ABEES system (and any emission estimation approach) is that it depends on complete activity data to provide complete results. This emission estimation system depends on an activity data collection scheme to feed it complete input data. It the activity data is complete, we can be confident that the emission estimate will be of reasonable quality. Conversely, if the activity data collection is not controlled for omission and other factors, the emission estimation quality will suffer proportionately.

5. Conclusion

The resources spent in developing the Agricultural Burning Emissions Estimation System have gone further than providing a temporally and spatially refined emission inventory for year 2000. Development of the tool and the associated analysis clearly show where improvements are needed to develop consistent and statewide emission estimates for agricultural burning. The developed bottom-up method is straightforward enough to be applied by the Air Resources Board to future years emissions estimates, provided credible and consistent input data can be collected. As discussed previously, the fundamental method is sound, and considering input data limitations, the results are comparable to existing ARB emission estimates.

Using the newly developed approach, spatially precise and temporally refined agricultural emission inventories may be developed for future use in smoke management plans, dispersion modeling, State Implementation Plan development, and control strategy assessment. We recommend the ARB pursue the ABEES model and work to improve its input data.

5.1. Reason to Pursue an Agricultural Burning Emissions Estimation Type System

The primary reason to pursue the ABEES model is that it is the best way to achieve a spatially and temporally allocated burning emission inventory. This potential of ABEES is undeniable *despite* its requirement for good quality and consistent input data to perform effectively. This type of system requires spatially and temporally explicit activity information in order to create a spatially and temporally specific emission inventory. The year 2000 run was hampered by some incomplete and inconsistent input data. This data, which has generally been adequate for the air districts to perform their regulatory duties, was not always sufficient for the detailed emissions mapping performed in this project.

ABEES is the tool to harness an evolving permitting system in the State and yield an emission inventory for policy development. If the regulatory challenges are increasingly specific (exposure studies, burn/no burn decisions, SIP modeling), decision makers will need commensurately sophisticated tools. Only a system that processes spatially and temporally specific activity data can produce this type of high quality information.

A top-down methodology, such as the one employed for open burning by CEIDARS, can only go so far to fuel the regulatory process in California. Deriving "precise" information by allocating CEIDARS emissions below county or within a month hits a wall in its accountability. A system based on top-down allocation is inherently built on generalization. This is in contrast to the concepts of specificity and accuracy sought in a modern regulatory environment. The transition must be made from *allocation* techniques to *location* techniques to build a truly fine-scale emission inventory.

The most significant attribute of ABEES is that the *method* is inherently accurate. That is, generalization is not built into the system as a rule. Given a date, location, activity rate, fuel loading and emission factors, ABEES will create an emission inventory. In this type of system, location, time and activity rates are dealt with explicitly and individually. This ability to handle data at a low-level is paramount to creating a spatially and temporally refined emission inventory.

5.2. Recommendations for Improving Agricultural Burning Emissions Estimation

The utility of ABEES is its ability to create a spatially and temporally located emission inventory. Its Achilles' heal is that is requires spatially and temporally location activity data as input. The best way to improve ABEES output is to improve its input. State of California agricultural burning activity data could be improved through both its format and accuracy.

5.2.1. Consistent data format

A consistent data format is necessary for an automated and statewide emission inventory tool. A hurdle encountered by researchers in this study, as documented in Section 2 of this report, was obtaining and federating permit based data across California. But the data elements required for ABEES input are not numerous. Standardizing and coordinating District permit databases to allow the data to be combined would create a smooth path for use by an inter-District emission inventory tool such as ABEES. This report, including the detailed subcontractor report on data integration, can serve as a preliminary assessment of data formatting needs.

It is encouraging to note that year 2000 data was indeed federated and successfully used in this particular research project. Achieving an inter-District standard to facilitate an ongoing statewide emission inventory is certainly possible and is highly recommended.

5.2.2. Consistent data quality

The second and more challenging requirement of ABEES input is consistently high quality data. As the analysis above shows, ABEES estimates are sensitive to a both a complete and specific input. Permit records that do not match the emission estimation system of lookup tables (for emission calculations) or do not record specific time and location information undermine the utility of the system. Less subtly, patent omission of known activity will also reduce the credibility of the output.

Fortunately, California already has an active system of high quality agricultural permitting systems. The records from the more developed District systems, as employed for year 2000 in this study, performed well under ABEES. The state of the art emission estimation techniques themselves leave a lot of room for improvement. In light of this, the high quality records obtained for this study were sufficient to achieve the goals of temporal and spatial specificity for the regions with complete data.

Examples of quality spatial and temporal activity information already exist throughout the State. The Air Resources Board and Districts could make rapid gains by identifying 1) where improvements are necessary in the State then 2) what lessons can be learned from the other areas to make the improvements. This aspect of quality coordination could be performed in tandem with the coordination necessary for data formatting.

5.3. Recommendations for Deploying an Agricultural Burning Emissions Estimation

Establishing the data environment for an ABEES type system and establishment of the final system itself could take the form of an evolution rather than an instant deployment. It will be gradual in 1) different areas of the State have varying capacities to contribute permit data and 2) there are likely priority areas where refined estimates are needed. That is to say, both the need for the system and the capability to support it vary over the State of California. The deployment could be done on a "cost effective" basis; where obtaining and quality controlling input is emphasized in particular areas. This study explored some concepts of quality control and documentation in terms of confidence ratings of emission factors and algorithms for identifying location information (see Section 2). The concept of rating data and recording that information could be carried forward to an operational system. Rather than letting low quality data discolor the whole Statewide system, utilize the encoded quality information when interpreting the results. While working to achieve a universal quality, the deployment and utilization of a temporally and spatially explicit system can move forward.

ABEES may be best evolved using CEIDARS as a complementary emission inventory technique. The fundamental difference of the two systems could be leveraged by the Air Resources Board to improve the agency's emission estimation tools at large. ABEES is a bottom-up estimation routine while CEIDARS is a top-down inventory database. The two systems can be allowed to co-exist to serve as a system of checks and balances on each other. It is hard to assure completeness in ABEES, while near impossible to ascertain the completeness, precision, and accuracy, and data timeliness in CEIDARS. However, the breadth and history of CEIDARS can possibly be used as a check for completeness in ABEES while the detail inherent to ABEES can critique the precision of CEIDARS. To have two largely independent systems at the ARB's disposal may be useful for demonstrating quality and transparency in the intricate arena of agricultural burning emissions estimation.

5.4. Summary

The California Air Resources Board has increasing demands for spatial and temporally specificity in its emission inventories of agricultural residue burning. This challenge is best met with the Agricultural Burning Emission Estimation System explored in this research study. Combining this method with coordinated statewide activity reporting can yield the high quality environmental information needed by the State of California to minimize agricultural smoke impacts, while allowing the agricultural community to perform traditional burning practices.

6. References

California Air Resources Board, Emission Factors for Open Burning of Agricultural Residues, Memorandum, August 17, 2000. Patrick Gaffney, Planning and Technical Support Division, pgaffney@arb.ca.gov

California Mapping Coordinating Committee, Public Land Survey System (Land grants filled), ArcInfo Coverage, December 1999, http://gis.ca.gov/.

7. Appendices

7.1. Companion CD-ROM: Project Databases and Scripts

Attached is a computer CD-ROM documenting the databases and software developed in this research project. All databases used as input and generated as output are included. Processing scripts are written in the ESRI ArcView 3 AVENUE scripting language and are commented in-line. A bare-bones ArcView 3 project file (ABEES.apr) is also on the disk. This project file allows the scripts to execute using the database and map files.

7.2. Appendix A: Subcontractor Report

Following is the subcontractor report by Fife Environmental delivered to researchers at the University of California at Berkeley.

FINAL REPORT
2000 CALIFORNIA AGRICULTURAL BURNING DATABASE

Submitted to:

Peng Gong
James Scarborough
CAMFER Lab
University of California, Berkeley

By:

Les Fife
Matthew Fife
Fife Environmental

29 September 2001

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EXECUTIVE SUMMARY

Agricultural burning can be a significant source of particulate and gaseous pollutant emissions. However, this emission inventory category usually does not receive the same level of analysis as traditional stationary sources.

The purpose of the project in "Creating a Statewide Spatially and Temporally Allocated Agricultural Burning Emission Inventory Using Consistent Emission Factors" was to: collect the most recent burn data for key agricultural counties, conduct data analyses, develop a consistent data format, compile the information into a single database, evaluate the data using geographic information system (GIS) software, and develop a prototype web page to display the results on the Internet.

For many years there have been reporting requirements for air districts involving agricultural burning. The basic data required to be reported were the number of burn permits, date of permit issuance, permittee, and estimate of the amount of burning. The general description of the data to be reported lead to many different formats. Data were submitted to the Air Resources Board in paper and electronic form and at different intervals, such as quarterly or annually. The Sacramento and San Joaquin Valleys have an extensive agricultural industry and, therefore, were required to report on a more frequent basis. The remaining areas of the State submitted annual reports.

Fife Environmental was to contact air districts throughout California that had potentially significant agricultural burning and request electronic agricultural burning data files. Our approach to contacting and obtaining electronic files of agricultural burning information was to first get a letter of introduction from the ARB Emission Inventory Branch. Upon contacting the districts we explained the joint Air Resources Board (ARB) and UC Berkeley (UCB) project and described the basic burn data that were necessary to fulfill the project needs. Our explanations also included the preferred format of the electronic data. Most of the data files were e-mailed to us. In two cases we had to travel to the district offices and assist them in extracting the pertinent data. We received a variety of file types including databases, spreadsheets, word processing files and ASCII delimited text files. Most files were from Windows/DOS based computers, although we did work with Apple Computer files also. For calendar year 2000, we obtained electronic burn records for 27 of California's 58 counties. In total, there were over 71,400 individual burn records covering 240 different types of residue burned.

Of the many data formats (i.e., database, spreadsheet, text file) the databases had the most detailed information. Data were available on type of residue, date of burn, location of burn, section-township-range, and acres or tons burned. Files received in spreadsheet format were generally a monthly summary of burning without location information. Text files contained even less information and were sometimes difficult to interpret.

In performing the data analyses we employed various methods. When we received the data files we converted the data, if necessary, into a spreadsheet format for better analyses. We sorted the burn records by residue type. Then we summed the amount of burning by acres and/or tons for each residue type. After exporting the files into databases we further analyzed the data. We looked for information gaps in the records and other anomalies. The content was sorted by burn date or burn month and by location. We joined multiple fields for section township and range into a single field. Information on residue types and locations were edited for spelling using the find and replace option.

Our next task was to create a standard, integrated database file. The challenge is converting all types of data files into a coherent format. There were problems with different field lengths, different field formats (e.g., numeric, alphanumeric, date, memo), inconsistent residue descriptions, and missing fields. After analyzing the various data files we decided on the standard format for the record fields. A county name field was needed. Data fields necessary to conduct the temporal and spatial analyses were critical. For the temporal analysis both burn date and month were included. For a spatial analysis a section-town-range field was created separate from a general location field. Lastly we added database fields for acres and tons burned.

When the statewide database format was finished, we began importing agricultural burning records from the 27 counties into the integrated database. We had already converted many of the disparate county file formats we had received into both spreadsheet and then database files. Then each of the county database files were further modified to eliminate superfluous fields that did not match the statewide database format. After this was accomplished the importing of records was done. At the conclusion of the importing phase another review was performed on the entire integrated database. Data were checked for accuracy and completeness. Some additional, minor editing was done on this final database. The database was then e-mailed to UCB in a zipped format for their review.

In conclusion, there were several problems compiling a coherent statewide agricultural burning database. The problems included different data file types, multiple data formats, inconsistent information on crop residues, burn locations, and burn times. However, the issues can be resolved with appropriate education, planning, coordination and assistance from the Air Resources Board. The ARB must inform and assist air districts in developing a consistent agricultural burning database program which will be a useful tool in managing burning and easily blend with GIS analysis. The ARB should schedule regional meetings to explain the proposal and work jointly with districts in developing specifics for the database. The ARB should also provide assistance in converting relevant, existing data into the new database.

There are many potential air quality benefits of a standardized, statewide, agricultural burning database. With geographic information system (GIS) analysis and internet access, a better understanding and management of agricultural burning is possible. Complete and accurate burn data can be correlated with meteorological and air quality factors. Information on burning that might affect adjacent districts or air basins can be analyzed more thoroughly and coordination and communication improved among agencies.

DATA SUMMARY

The following two tables contain key information that was collected. Table I lists the counties included in the consolidated statewide database with total crop value ($1,000) for 1999 and the main residues burned (acres/tons) in calendar year 2000.

Table I - Agricultural Burning Summary Information			
County	Crop Value	Acres/Tons Burned[1]	Main Residues Burned
Butte	257,393	45,967 / 0	rice, almond, walnut
Colusa	351, 278	52,065 / 0	rice, wheat, safflower
Fresno	3,559,604	189,162 / 26	almond, grape, raisin
Glenn	253,474	45,397 / 0	Rice
Imperial	1,045,092	55,102 / 0	bermuda, wheat, asparagus
Kern	2,128,896	65,731 / 4	almond, tumbleweed, wheat
Kings	901,627	24,577 / 13	almond, tumbleweed, ditchbank/canal
Lake	49,173	20,960 / 0	wildfires, walnuts, land clearing
Madera	700,241	76,001 / 19	almond, grape, pistachio
Mendocino	127,674	63,069 / 45	brush, grape, slash
Merced	1,534,020	60,367 / 78	almond, ditchbank & canal, rice
Monterey	2,369,144	12,301 / 10,059	Chaparral/chamise, grassland &oak
Placer	58,124	4,207 / 0	rice, sudan
Sacramento	293,859	5,863 / 0	rice, pear, corn
San Benito	179,848	10,750 / 862	chaparral, chamise
San Diego	1,242,535	3,370 / 7,023	brush, grass, citrus
San Joaquin	1,352,672	54,375 / 18	almond, walnut, rice
San Luis Obispo	393,023	13,319 / 32	grape, brush, prunings
Santa Cruz	248,234	1,036 / 327	pine, redwood, fir, eucalyptus

Table I, Cont. - Agricultural Burning Summary Information

County	Crop Value	Acres/Tons Burned[1]	Main Residues Burned
Solano	195,483	5,096 / 0	corn, walnut, prune
Stanislaus	1,210,211	67,815 / 32	almond, walnut, rice
Sutter	347,651	38,974 / 0	rice, wheat, walnut
Tehama	97,221	9,072 / 0	prune, walnut, almond
Tulare	3,075,978	51,238 / 13	walnut, wheat, almond
Ventura	1,059,057	0 / 23825	citrus, avocado, other
Yolo	339,937	8,776 / 0	rice, safflower, walnut
Yuba	108,220	9,147 / 0	rice, other field crops

[1]The values shown are reported values. Some counties report the quantity of residue burned in either tons or acres, or sometimes both. This is why some counties have zero listed for tons, even though acres are reported. For the emission calculations, fuel loadings were used to convert acres burned to tons burned.

Table II describes agricultural burning in the counties included in the database on a calendar month basis and the 12 residue types with the most acres burned.

Month	Acres Burned	Tons Burned	12 Major Residue Types	Acres Burned
January	152,252	40,130.3	Almond	261,681
February	69,585	5,147.9	Rice	174,062
March	90,441	8,895.5	Grape	89,821
April	58,189	7,948.3	Wheat	55,922
May	33,698	9,564.2	Walnut	54,736
June	38,046	4,277.3	Tumbleweeds	30,831
July	35,648	5,959.0	Raisin	29,770
August	26,784	4,674.0	Bermuda	26,933
September	65,803	6,626.1	Brush	23,919
October	103,914	9,370.7	Ditchbank/Canal	20,819
November	137,017	13,216.4	Chaparral/Chemise	17,906
December	100,865	8,213.3	Prunes	12,521
TOTALS	912,242	124,022.8		798,921

PROJECT DESIGN

The project proposal described the general goals and methodology of "Creating a Statewide Spatially and Temporally Allocated Agricultural Burning Emissions Inventory Using Consistent Emission Factors". To achieve those goals, the research team held initial meetings to discuss the project. In meetings with UC Berkeley and Air Resources Board staff, we explained the Sacramento Valley Air Basin Agricultural Burning Management Program and the extent of agricultural burning data that this Program requires to be successful.

We provided an example of the Colusa County Air Pollution Control District agricultural burning database. Colusa County has the most growers and rice acres in the Sacramento Valley. The integrated database has a Grower file, Field file, Activities file, Trading file, Crop file, etc. There are 26 data fields per record in the Field file alone. Colusa's database contains the largest number of burn records.Maintaining the Sacramento Valley database files demands considerable time and resources.

At another meeting we distributed an analysis of the Fresno County agricultural burning database. The handout showed the number of crop residues burned and a count of the number records for each residue along with totals for acres and tons burned. We discussed the issue of overlapping categories and residue types that were atypical of agricultural operations. It was decided that all residues would be included within the consolidated database.

The project proposal specifically stated that the Sacramento and San Joaquin Valleys would be included in the data collection and analysis. It also stated that, if resources allowed, other counties in California would be contacted to obtain agricultural burning data. First, we did a cursory review of crop statistic reports and annual crop revenues to determine which additional counties should be contacted. That process identified seven other counties: Imperial, Lake, Mendocino, Monterey, San Diego, San Luis Obispo, and Ventura. Second, we contacted staff in the Sacramento Valley with which we regularly work. Then we contacted the data processing staff in the central office of the San Joaquin Valley Air Pollution Control District. Last, we contacted other air district offices by phone with several follow-up calls to obtain the electronic files. In two instances we traveled to district offices to help them extract the data.

A statewide agricultural burning database that could be spatially and temporally allocated required that certain fields be present in the records. We needed to explain to all districts the basic data that we were interested in and discuss the content and structure of their databases. Data fields referencing geographic location of the burning were necessary. In some cases burning is done in a farmer's field. Other times burning may be for weed control on open grazing land. Agricultural burning may also take place in a small family orchard. Each of these examples could have a different type of location description. Temporal information would be in the form of a specific burn date or in summarized records by month or even season. We discussed these issues with the air districts during our contacts.

After reviewing the data files that we received, we decided upon the standard database fields and data formats that would allow the project goals to be achieved. The combined California agricultural burning database for the year 2000 has the following record fields for all counties:

- County Name
- Burn Date
- Month Burned
- Residue Type
- Location
- Section Township and Range
- Acreage Burned
- Tonnage Burned

However, not all counties have data reported in each record field. The data analysis section that follows describes the agricultural burning information we received in more detail.

DATA ANALYSIS

Data Formats

We knew that California air districts used different computer hardware platforms and software to maintain databases. Our task was to develop a flexible database program that could accept data from many formats. Electronic files were received as standard databases, spreadsheets, word processing files, and ASCII delimited text files. We often needed to convert files from one format to another and even from Apple to DOS files. The importing, exporting and joining of disparate file types was time consuming.

Database files contained the most complete burning information. Data were available on type of residue, date of burn, location of burn, section-township-range, and acres or tons burned. However, there were many different types of database program files such as dBase, FoxPro, Dataflex, Access, and FileMaker Pro.

Data received in spreadsheet files were mainly either Excel or Lotus 123. Spreadsheet files were generally a monthly summary of residue burning but without location information. To process the information, we worked mostly in Lotus and reviewing and editing the data prior to exporting it to our standard database.

Files were also received in word processing and ASCII text file formats. These files were the most difficult to work with, requiring more editing and analysis. From the edited file we imported the data into a Lotus spreadsheet and did more numeric analysis. We then exported the data into our standard database.

As electronic data files were received, they were evaluated for structure and content. Information reviewed included type of residue burned, quantification of burning, location of burn site, and time of burning by date, month or season. All agricultural burning data from all counties were imported to separate Lotus spreadsheet files to enable better analysis and sorting. Burn dates and months were sorted to evaluate chronological data. Acres and tons burned were summed, compared and analyzed by residue types.

Data Fields

The data provided by the 27 counties was a combination of specific, individual, burn records and generalized burn summaries by month and residue type. Counties with the most complete data were located in the Sacramento and San Joaquin Valleys. The least detailed information was received from Lake, Mendocino, and San Diego counties.

As noted the key fields needed to build a standardized and usable database were county name, burn date, month burned, residue type, location, section-township-range, acreage burned, and tons burned. The following discussion elaborates on selected data fields.

Residue Type:

The databases contained many different types of residues. Sometimes the residues were not typical of agricultural burning. Some examples of unusual residues are driftwood, firewood, and poultry feathers. All residues were incorporated into the consolidated database at the request of ARB and UCB staff.

Below is a list of types of residue burned (240 total) that were reported in the county files. No changes in this list were made for spelling errors or abbreviations.

Acacia, French Broom
Alfalfa
Alfalfa Hay
Almond
Almond Pruning
Almond Prunings
Almonds
Aloe
Apple
Apple Orch Rmvl
Apple Pruning
Apple Prunings
Apples
Apricot
Apricot Pruning
Apricot Prunings
Artichoke Stubble
Asparagus
Avocado
Avocado Pruning
Barley
Barley Stubble
Bean
Berms
Bermuda
Bermuda Grass
Blackberries
Broccoli Seed Stubble
Brooder Paper
Brush
Brush/Oak Tree Debri
Bushberry

Canola
Celery
Central Chaparral
Chamise and Grass
Chamise, Chaparral, Grass, Down Trees
Chamise, Grass
Chamise, Grass, Oak Woodland
Chaparral
Chaparral 90%, Live Oak Woodland 10%
Chaparral and Star Thistle
Chaparral, Grass, Oak Woodland
Chaparral, Grass/Oak Woodland
Chaparral-Chamise and Timber Understory
Cherry
Cherry Pruning
Christmas Trees
Citrus
Citrus Pruning
Clover
Corn
Cotton
Dead Citrus Trees
Diseased Bee Hives
Diseased Hives
Ditch
Ditchbank
Ditchbank & Canal
Ditchbank & Canal (1 Ton/Mile)
Ditch-Bank-Canal
Ditchbanks
Dodder Weed
Douglas Fir
Driftwood
Dry Eucalyptus
Eucalyptus
Eucalyptus and Pine
Eucalyptus Slash
Eucalyptus Slash and Stumps
Fence Rows
Fert/Pesticide Sacks
Fertilizer Sacks
Fig
Fig Pruning
Firewood
Flax
Flood Debris
Flood Debris (Plant)
Forest Mgmt. Timber
Forest Mgmt. USFS
Forest Slash Piles
Goat
Grains
Grape
Grape Prunings
Grape Stakes
Grape Stakes/Stumps
Grape Stumps/Stakes
Grape Vines/Canes
Grapes
Grass
Grass (Grass, Orchard)
Grass and Scrub
Grass, Scrub
Grassland, Oak Savannah
Grasslands
Grasslands and Chaparral
Hay
Kiwi
Kiwi Pruning
Knobcone Pine/Chaparral
Land Clearing
Land Mgmt. LRA
Land Mgmt. SRA/CDF
Lemon Grass
Macadamia
Macadamia Nuts
Madrone, Oak, Chamise
Milo
Natural Vegetation,
Nectarine
Nectarine Pruning
Noxious Weeds
Nursery
Nursery Trimmings
Nursury Pruning
Nursury Prunings
Nursury Trimming
Nursury Trimmings

Oak
Oat
Oat Stubble
Oats
Olive
Olive Pruning
Olive Prunings
Onion
Orch Removal
Orchard Removal
Other
Other Field
Other Field Crop
Other Field Crops
Other Hay
Other Prunings
Other Vegetable
Other-Field Crops
Other-Miscellaneous
Other-Prunings
Palm
Pasture
Pasture Shade Trees
Pasture/Corral Trees
Pea Vines
Peach
Peach Pruning
Peach Prunings
Peaches, Etc.
Pear
Pear Orch. Rmvl
Pear Pruning
Pear Prunings
Pears
Pecan
Pecan Pruning
Pepper
Perennial Crop Rem
Persimmon
Persimmon Pruning
Pest/Fertilizer Sack
Piled Brush from 30 Acres of Cleared Land
Piles of Tree Limbs, Branches, and Clippings
Pine
Pine Slash
Pistachio
Pistachio Pruning
Plum
Plum Pruning
Plum Prunings
Pluot
Pomegranate
Pomegranate Pruning
Pond/Levee Banks
Ponding/Levee Banks
Poultry Feathers
Prescription Burn
Prune
Prune Pruning
Prunes
Prunings
Qiunce
Raisin Trays
Raisin, Date Trays
Rangeland Browse
Redwood and Douglas
Residential Vegetation
Rice
Rice Stubble
Rose Prunings
Safflower
Slash
Slash Piles from Brush and Trees and Driftwood
Slash Piles from Douglas Fir Harvest
Slash Piles from Eucalyptus Groves
Sorghum
Sorghum (Milo)
Standing Brush

Star Thistle
Straw
Sudan
Sugar Cane
Sugar Cane Leaves
Sugar Cane Stubble
Sugar Pea
Thistle
Timothy Grass
Tobacco
Tules
Tumble Weeds
Tumbleweed
Tumbleweeds
T-Weeds
Typha Spp. & Scirpus
Vegetable Crops
Vegetables
Vegetation
Vines
Vineyard Removal
Walnut
Walnut Pruning
Walnut Prunings
Walnut Trees
Walnuts
Weeds
Weeds (Ditches)
Weeds (Field)
Weeds (Levees)
Weeds (Woody Shrubs)
Weeds/Brush
Weeds/Tulies & Catails
Wheat
Wheat Stubble
Wild Hay
Wild Rice
Wildfires
Willow and Cottonwood Saplings
X-Mas Trees
Yellow Starthistle

Without a comprehensive, standardized list of residue types, there is a tendency to have multiple descriptions of residues, overlapping categories and subsets of general categories. In Fresno County the list of residue types illustrates some common problems. Certain residue types are unclear and imprecise. Vineyard removal, grape vines/canes and grape stumps/stakes all imply the same residue (grape), but are slightly different. This makes it difficult to determine the correct emission factor to use. Brush, other field crops, orchard removal, and vegetable crops are too general. Residue types such as "other" provide no information with which to assign an emission factor. Berms, ponding/levee banks and ditchbank & canal merely describe a location, not the residue type. There is also a category for noxious weeds, yet there were separate listings for weeds such as goat grass, lemon grass, and dodder.

The following list was compiled from records of all counties. It includes residue names, acres and tons burned, with associated problems described.

RESIDUE NAME	ACRES	TONS	PROBLEM
Berms	5282	14	describes location onlv
Brush	23919	17178	too general to assign emission factor
Christmas Trees	25	32	types of trees could be fir, pine, cedar
Ditch	524	0	describes location onlv
Ditch-Bank-Canal	0	1	describes location only
Ditchbank	0	15.5	describes location only
Ditchbank & canal	19060	54.5	describes location only
Ditchbanks	1235	0	describes location only
Fence Rows	226	3	could be fence posts or vegetation along nce row
Fert/Pesticide Sacks	85	9	could be paper or plastic
Firewood	760	0	could be oak, pine, walnut, almond etc
Flood Debris	16	3	could be wood, brush, weeds etc
Forest Management Private	528	0	forest burning has wide range of fuel ading
Forest Management USFS	852.1	0	forest burning has wide range of fuel ading
Grain	113	0	could be corn, oats, wheat, rice etc
Hay	3	106	could be alfalfa, oat, grass etc
Land Clearing	2660	0	too general to assign emission factor
Land Management LRA	203.5	0	too general to assign emission factor
Land Management SRA/CDF	298.6	0	too general to assign emission factor
Noxious Weeds	1494	48	there are hundreds of weeds in this category
Nursery	15	0	too general to assign emission factor
Nursery Pruning	10	0	too general to assign emission factor
Nursery Prunings	69	1.2	too general to assign emission factor
Nursery Trimmings	66	19	too general to assign emission factor
Nursery and Flower Crops	0	165.15	too general to assign emission factor
Orchard Removal	5152	37	orchard pushouts have wide range of fuel ading
Other	242	127	too general to assign emission factor
Other-Miscellaneous	861	0	too general to assign emission factor
Other Hay	57	0	could be alfalfa, oat, grass etc
Other Vegetable	15	0	many types but no emission factors or fuel

			ading
Pasture	446	12	too general to assign emission factor
Pasture Shade Trees	22	14.1	too general to assign emission factor
Pasture/Corral Trees	267	32	too general to assign emission factor
Perennial Crop Removal	600	0	too general to assign emission factor
Pest Prevention (Typha spp scirpus)	1	1	lacks identification of specific residue
Ponding/Levee Banks	120	0	describes location only
Pond/Levee Banks	41	0	describes location only
Prescription Burn	237	0	could be forest, grassland, wildland mixed
Rangeland Browse	795	0	too general to assign emission factor
Residential Vegetation	320	0	could be tree limbs, bushes, weeds
Slash	7081	26	too general to assign emission factor
Standing Brush	9299	12	too general to assign emission factor
Straw	15	0	could be oat, wheat, rice etc
Thistle	58	8	many types but no emission factors or fuel ading
Vegetable Crops	2290	92	many types but no emission factors or fuel ading
Vegetables	2	0	many types but no emission factors or fuel ading
Vegetation	2509	39	many types but no emission factors or fuel ading
Vines	44	0	could be grape, blackberry, raspberry etc
Weeds	9160	70	many types with wide range of fuel loading
Weeds (Ditches)	8.23	0	many types with wide range of fuel loading
Weeds (field)	169.5	0	many types with wide range of fuel loading
Weeds (Levees)	10	0	many types with wide range of fuel loading
Weeds (Woody Shrubs)	8.7	0	too general to assign emission factor
Weeds/Brush	37	0	too general to assign emission factor
Weeds/Tules & Catails	4	0	no specific emission factor or fuel loading
Wildfires	7300	0	could be forest fire or grass fire
Wildland Vegetation [anagement	396	0	too general to assign emission factor
X-mas Trees	0	37.1	types of trees could be fir, pine, cedar

Location

Location data for burning included several different types of descriptions. Location information sometimes referred to grower fields, street addresses, multiple sections of a township and range, nearest crossroads, landmarks, and irrigation canals and gates. Some county databases included more than one type of location description. One reason for using different location descriptions was the type of residue burned. The location of tumbleweed burning on open land was often described by sections-township-range while orchard residue was located at a street address. Examples of counties with various location descriptions are shown below.

Location Type	Source	Data
grower field ID	(Glenn County)	A7
street address	(Fresno County)	8772 E Lincoln
multiple TRS	(Kern County)	Secs19-30/T31S/R26E
nearest crossroads	(Colusa County)	Lurline and Cortina
landmark	(Monterey County)	Pinnacles National Monument
irrigation canal, gate	(Imperial County)	Ash 84

Conventional location information is valuable to an air district in managing agricultural burning. This enables a district inspector to easily find the burn site. A grower field identification (ID) conveys precise location information about a field when compared to a grower's map of his or her fields. The canal and gate location data used in Imperial County is also very accurate in locating an individual field. Fields are irrigated from named canals through a specific gate number. Street addresses are also good location references. These are valid location descriptors, although they are incompatible with developing the consistent data sets needed for GIS analysis tools.

Location references of multiple sections, nearest crossroads, and landmarks may cover hundreds or even thousands of acres and be too vague to pinpoint an actual burn site.

Section- Township-Range:

If conventional location information are supplemented with a specific section-township-range data field, as in the Colusa County database, the spatial mapping of burning through GIS tools is an easier task. A section is comprised of 640 acres which most likely contains many smaller fields that are burned separately. The individual fields also may have different crop residues to be burned. Another advantage of a section-township-range data field is the ability to sum the acres burned in a section and check the total acreage against the 640 acre standard. Unfortunately, these data were reported in different formats by different jurisdictions. Therefore, prior to using the spatial data in the emission estimation system, the values were standardized as described in Section 2.2.1 of the main report.

Acreage/Tons Burned:

Reports of agricultural burning information provided to the ARB have historically been submitted in either acres or tons burned. For growers reporting burning to an air district, acres burned is likely to be the most accurate figure. Growers must provide acreage information to many government agencies to receive pesticide use permits, for farm subsidy programs, water allotments, et cetera. For this reason, growers are very familiar with the acreage in each field and assign unique IDs to each field as part of their record keeping.

Information on tons burned would be more useful than acres for computing emission estimates. Orchard growers might report burning in this way after they have pruned their trees in part of an orchard and piled the material to be burned. Depending on the type and age of trees, an orchardist may selectively prune some trees, prune heavily one year and only lightly for several other years. Some trees are rarely pruned. Other types of burning in an orchard could be a selective pushout of diseased or old non-productive trees. In pushouts, it is common practice to cut up the larger limbs and trunk for firewood before burning smaller branches and the stump and roots. Also after harvest there is sometimes cleanup burning of broken limbs and harvest trash (e.g., hulls and shells). The reporting of orchard burning might require more detailed information from the grower to get an accurate tonnage or fuel loading number.

In the consolidated database there were numbers reported for some categories of residue in both acres and tons within the same air district. As an example, Fresno County reported both acres and tons burned for almonds, apple, citrus pruning, nectarine pruning, peach pruning, and walnut pruning. They also reported a significant amount of acres and tons burned for grape stumps/stakes. All San Joaquin Valley counties reported residue burning in both acres and tons. Monterey, San Diego and Ventura reported most of their burn numbers in units of tons.

Burn Date/Month:

Temporal burning data were reported as either a specific burn date or in summarized spreadsheet files as monthly burning. Lake County, reported burning by a calendar season or several seasons (e.g., fall and spring). Although many air district databases contained exact burn dates, the districts that submitted summarized monthly burning should also be able to provide specific burn dates.

Data Acquisition and Consolidation Problems

There are inherent problems in assembling a coherent, statewide, agricultural burning database from air districts that have no standardized data reporting format to follow. Inconsistencies arise due to differences in computer hardware and software used. Variability in the quantity and type of agricultural burning from one county to another results in differences in the content and detail of the information. The effort and resources required to create and maintain an agricultural burning database are significant. Staff time is spent getting pertinent data from growers or public agencies that conduct burning, data entry time into the database, data review and producing reports.

We thoroughly explained the project data needs to all of the air districts and were able to obtain most of the critical information to build the database. The districts provided the data either in their original data file or exported the data into a standard format that we could use. Most files were e-mailed to us although in two instances we had to travel to the districts (Imperial and Glenn counties) to assist them in extracting the data.

Imperial County has a diverse and extensive agricultural industry. The agricultural burning database was in a Dataflex format that was unfamiliar to the air district staff. We decided it was essential to travel to retrieve the data because of the significant amount of burning in the County. Their field location information (irrigation canal and gate) is unique in California and we also wanted to become more familiar with that system.

The Glenn County agricultural burning data resides in a custom Filemaker Pro database on a network of Apple Computers. They have an out-of-town consultant that developed the database and maintains the computer network. We are familiar with Apple Computers and traveled to the District office to collect the data. After locating the appropriate data file and selecting the records we were able to export them to a comma delimited text file that could then be saved on a diskette readable by our computer system.

Some of the information we received in data files, while useful to district staff, was unsuitable for our project purposes. These data would have overwhelmed and unnecessarily complicated the statewide agricultural burning database. Data such as codes, contact names, phone numbers, and comment fields, were considered extraneous for the consolidated database and were deleted from our converted files.

Key information regarding residue type, burn date or month, burn location, and acreage or tons burned were essential. Even the files that contained these key data required careful review, editing, and often format conversion to be imported to the consolidated database. Each burn record consists of data fields. Each data field is created in a specific format. Data can be in formats such as alphanumeric, numeric, date, boolean, memo et cetera. These data formats are not always convertible to another type.

Besides data format types, the length of the data fields varied significantly from one file to another. It was critical to set up field lengths in the consolidated database, especially for residue type and location, that would include as much of the reported information as possible. The main problem was the information from word processing text files tended to be exceedingly long. Most database and spreadsheet files had more succinct descriptions. We had to compromise on some field lengths to allow for easier screen editing. There was extensive time spent in standardizing, joining, and converting the data that was provided by districts.

Our data review suggests that data entry was by various district staff. Descriptions of residue types were inconsistent. There were general residue categories, subcategories of those categories, and misspellings of residues. We corrected spelling errors and, in our analyses, grouped residue burning into fewer categories.

Data reporting in both acres and tons for individual burns creates a question of redundancy. The following counties reported some burns in both: Mendocino, Monterey, San Benito, Santa Cruz, and San Luis Obispo. Many San Joaquin Valley counties reported both tons and acres for the same residue categories but not for the same burns. This adds to inconsistencies and uncertainties. San Diego and Ventura counties reported data almost exclusively in units of tons burned. Most counties reported burns in terms of acres.

In the agricultural burning files that we received, many of the residue types burned were either overly general or merely indicated the location of a burn without describing the material burned. Also fuel loading and emission factors are unavailable or not sufficiently refined for many of the residues that are burned in California. These are common problems that should be eliminated from an agricultural burning inventory.

COUNTY INFORMATION

This section of the report provides summaries of the reported residue burning in the calendar year 2000. Table III shows the total number of county records and other details reported and included in the in the consolidated California agricultural burn database developed for the project. The following pages provide detailed county information for the burned crop residues and the acres and tons burned, as applicable.

Table III – Number of Collected Records for Agricultural Burning

County	Total Records	Crop Records	Acres Records	Tons Records	Date Records	Month Records	Location Records	TRS Records
Butte	194	194	194	0	0	194	0	0
Colusa	1,353	1,353	1,353	0	1,353	0	1,285	1,033
Fresno	12,934	12,934	11,476	877	12,934	0	12,934	1,149
Glenn	968	968	968	0	968	0	967	967
Imperial	801	801	801	0	801	0	800	0
Kern	6,273	6,273	3,630	2,468	6,273	0	6,273	1,985
Kings	1,924	1,924	1,448	319	1,924	0	1,924	0
Lake	27	27	25	0	0	27	0	0
Madera	4,482	4,482	3,833	494	4,482	0	4,482	0
Mendocino	279	279	277	277	28	0	0	0
Merced	9,772	9,772	7,126	2,303	9,772	0	9,772	0
Monterey	34	34	19	23	34	0	34	0
Placer	71	71	71	0	71	0	71	71
Sacramento	543	543	409	0	543	0	543	0
San Benito	8	8	7	3	8	0	8	0
San Diego	28	28	1	28	0	0	0	0
San Joaquin	9,929	9,929	4,860	4,901	9,929	0	9,929	0
San Luis	574	574	132	454	574	0	0	574
Santa Cruz	13	13	8	12	13	0	13	0
Solano	490	490	454	0	490	0	489	0
Stanislaus	9,732	9,732	8,278	1,145	9,732	0	9,731	0
Sutter	1,601	1,601	1,576	0	1,601	0	339	339

Table III, Cont.– Number of Collected Records for Agricultural Burning

County	Total	Crop	Acres	Tons	Date	Month	Location	TRS
Tehama	1,436	1,436	1,425	0	0	1,436	1,431	1,436
Tulare	7,087	7,087	3,372	3,433	7,087	0	7,087	38
Ventura	101	101	0	101	0	101	0	0
Yolo	528	528	492	0	528	0	527	0
Yuba	275	275	275	0	275	0	262	0

BUTTE
Air District: Butte County Air Quality Management District

Crop	Acres
Almond	6080.2
Apple	35
Apricot	0.5
Brush	1438.3
Corn	57.1
Ditch	522.3
Grape	2
Grass	947.3
Kiwi	38.7
Oats	58
Olive	201.8
Orchard Removal	74.5
Other Field Crop	636.6
Other Prunings	180.4
Other Vegetable	14.2
Peach	186.9
Pecan	3
Persimmon	36.5
Pistachio	63
Prune	1395.4
Rice	29509
Safflower	50
Slash	225.8
Vines	42.7
Walnut	2633.5
Weeds	535.8
Wheat	754
Wild Hay	1
Wild Rice	221

COLUSA
Air District: Colusa County Air Pollution Control District

Crop	Acres
Bean	48
Corn	446
Grass	434
Pea Vines	178
Rice	42768
Safflower	2411
Walnut	1
Wheat	3285

FRESNO
Air District: San Joaquin Valley Air Pollution Control District

Crop	Acres	Tons
Alfalfa	6680.5	13
Almond Pruning	65791.6	181.2
Apple Pruning	1158	42
Apricot Pruning	167.7	1
Asparagus	1376	0
Avocado Pruning	20	0
Barley Stubble	125	0
Bean	12.4	0
Berms	2995.3	11.5
Bermuda Grass	1	0
Brush	125.8	12
Bushberry	52.5	0
Cherry Pruning	340.6	12
Christmas Trees	23.1	0
Citrus Pruning	2038.6	164.9
Cotton	10.2	1.9
Diseased Bee Hives	0	2.6
Ditchbank & Canal	1327.4	11
Dodder Weed	1420	1.3
Driftwood	0	8
Eucalyptus	211.9	4.3
Fence Rows	81.8	2
Fert/Pesticide Sacks	82	9.3
Fig Pruning	2270.5	6
Goat Grass	0.1	0.3
Grape Stumps/Stakes	33627.3	1446
Grape Vines/Canes	4862	60.2
Grass	0.2	0
Kiwi Pruning	1.7	0
Lemon Grass	143.9	0
Nectarine Pruning	1518.5	77.1
Noxious Weeds	737	37.8
Nursery Prunings	39	0
Oat Stubble	156	0.6
Olive Pruning	186.5	12.5
Orchard Removal	2987.1	103.4
Other	201.1	10.1
Other Field Crops	70	0
Pasture	178.7	3.1
Pasture/Corral Trees	264	32.2
Pea Vines	6.1	0
Peach Pruning	2543	90.5
Pear Pruning	207.1	1
Pecan Pruning	864.9	7.9
Persimmon Pruning	146.2	2.8
Pistachio Pruning	416.9	11
Plum Pruning	2223.2	81.1
Pomegranate Pruning	201.9	3
Ponding/Levee Banks	44.6	0.5
Prune Pruning	1823.6	8.3
Raisin Trays	23848	7.6
Rice Stubble	7557.2	0
Sugar Cane	8.4	0
Tules	45	0
Tumbleweed	9279.7	93.3
Vegetable Crops	1530.8	22
Vineyard Removal	2255.1	37.2
Walnut Pruning	3302.4	44.9
Wheat Stubble	747.5	1

GLENN
Air District: Glenn County Air Pollution Control District

Crop	Acres
Rice	45602

IMPERIAL
Air District: Imperial County Air Pollution Control District

Crop	Acres
Alfalfa	335
Artichoke Stubble	1
Asparagus	4108
Bermuda	26922
Broccoli Seed	15
Brush	12
Canola	162
Celery	30
Corn	109
Citrus Trees	7
Flax	3
Grass	115
Oats	205
Onion	244
Straw	15
Sudan	2658
Sugarcane Leaves	5
Sugarcane Stubble	9
Timothy Grass	155
Weeds/Brush	37
Weeds/Tules	4
Wheat	19951

KERN
Air District: San Joaquin Valley Air Pollution Control District

Crop	Acres	Tons
Alfalfa	213.7	0
Almond	33945.1	9551.8
Apple	719.7	168.5
Apricot	91	33.7
Asparagus	311	0
Barley	152	0
Bean	247	1
Berms	2	0
Brush	0	2.8
Cherry	117	8
Citrus	768.9	821.4
Corn	244	6
Cotton	2.5	1
Ditchbank & Canal	3330.1	202.7
Dodder Weed	4	0
Eucalyptus	19	81.1
Fence Rows	80.5	0
Grape	3297.8	892.9
Grape Stakes/Stumps	584	802.9
Grass	42	9.5
Kiwi	0.2	4.2
Nectarine	53	160
Noxious Weeds	2	5
Nursery Trimmings	7	0.5
Oats	50	0
Olive	2	3.5
Other Field Crops	0	4
Pasture	0	0.5
Pasture Shade Trees	2	2.1
Peach	148.5	16.5
Pear	16.5	3
Pecan	314	12
Pistachio	804.5	239
Plum	587.5	304
Pomegranate	35	1.5
Pond/Levee Banks	36	0
Prescription Burn	70	0
Prune	0	5
Raisin, Date Trays	505.5	13.7
Rose Prunings	392.5	84.9
Safflower	374	0
Tumbleweed	8301.3	818
Vegetable Crops	248	1
Walnut	329	48.9
Weeds	1108.2	65.5
Wheat	7992.3	0.2
X-mas Trees	0	4

KINGS

Air District: San Joaquin Valley Air Pollution Control District

Crop	Acres	Tons
Alfalfa	13.5	0
Almond Pruning	3089.5	399.6
Apple Pruning	0	15
Apricot Pruning	14.5	10
Asparagus	14	0
Barley Stubble	1.5	0
Bean	220	150
Berms	55.3	0
Cherry Pruning	45.5	0.5
Citrus Pruning	1	0
Cotton	16.8	0
Diseased Bee Hives	0	1.1
Ditchbank & Canal	1489.9	9.9
Dodder Weed	33.4	0
Eucalyptus	35.7	18.5
Fence Rows	28.7	0.5
Fig Pruning	0.2	0
Goat Grass	4	0
Grape Stumps/Stakes	234.1	43.3
Grape Vines/Canes	281.3	3
Lemon Grass	4	0
Nectarine Pruning	61.9	6.5
Noxious Weeds	721.4	5.2
Nursery Pruning	0	0.2
Oat Stubble	2.2	0
Olive Pruning	68	0
Orchard Removal	795.8	104
Other	40	0
Pasture/Corral Trees	3	0
Peach Pruning	394.9	67.8
Pecan Pruning	112	3.5
Persimmon Pruning	71	0
Pistachio Pruning	524.3	35.5
Plum Pruning	161.7	0.5
Pomegranate	98	9
Ponds/Levee	48.7	0
Prescription Burn	157	0
Prune Pruning	16	5
Raisin Trays	38	0
Safflower	43	0
Tumbleweed	2998.4	65.4
Vegetable Crops	1.8	0
Vineyard Removal	0.1	0
Walnut Pruning	5779.7	315.2
Wheat Stubble	6807	50

LAKE

Air District: Lake County Air Quality Management District

Crop	Tons
Alfalfa Hay	62.4
Almonds	7
Apples	51.8
Barley	22.2
Firewood	760
Forest Management Private	528
Forest Management USFS	852.1
Grain	112.5
Grapes	1760
Kiwi	0.9
Land Clearing	2660
Land Management LRA	203.5
Land Management SRA/CDF	298.6
Nursery	14.5
Other Hay	57
Pasture	16
Peaches	3.6
Pears	800
Perennial Crop Removal	600
Prunes	4
Rangeland Browse	795
Residential Vegetation	320
Vegetables	1.5
Walnuts	3663
Wheat	61.5
Wild Rice	80
Wildfires	7300

MADERA

Air District: San Joaquin Valley Air Pollution Control District

Crop	Acres	Tons
Alfalfa	100	0
Almond Pruning	36026.2	1039.2
Apple Pruning	377.9	16
Apricot Pruning	18	81.3
Berms	1986.5	1.5
Bermuda Grass	10	0
Brooder Paper	0	17
Brush	5.5	0
Bushberry	9	1
Citrus Pruning	76	8.5
Corn	0.5	0
Diseased Bee Hives	4.5	2.1
Ditchbank & Canal	1193.2	0.1
Dodder Weed	92.6	0
Eucalyptus	105.8	29.8
Fence Rows	20.5	0
Fig Pruning	6098	37.5
Grape Stumps/Stakes	11308.1	242.1
Grape Vines/Canes	899.7	24.4
Grass	0.5	0
Kiwi Pruning	2	0
Nectarine Pruning	52	0
Noxious Weeds	30	0.1
Nursery Prunings	30	1
Oat Stubble	412	10
Olive Pruning	138.2	3
Orchard Removal	535.6	23.5
Other Prunings	5	0
Peach Pruning	217	82
Pear Pruning	5	0
Pecan Pruning	52	0
Pistachio Pruning	8082.1	252
Plum Pruning	23	23
Pomegranate Pruning	49	0
Ponding/Levee Banks	21	0
Poultry Feathers	1	1
Prune Pruning	535	40
Raisin Trays	4352	4.6
Rice Stubble	108	0
Safflower	0.3	0
Tumbleweed	791.2	15.7
Vegetable Crops	0	2
Vineyard Removal	380.1	5
Walnut Pruning	424	19.3
Wheat Stubble	1373.8	0

MENDOCINO

Air District: Mendocino County Air Quality Management District

Crop	Acres	Tons
Brush	20401.78	1457.85
Grape	19273.75	2221
Orchard Removal	110	3225
Pear	293	119.5
Prunings	5041	111.5
Slash	7616.7	25740
Standing Brush	10497	12429
Vegetation	2549.3	39.7

MERCED

Air District: San Joaquin Valley Air Pollution Control District

Crop	Acres	Tons
Alfalfa	47.5	0
Almond	37110	4356.3
Apple	266	12.5
Apricot	45.8	125.5
Asparagus	80	0
Barley	30	0
Bean	70	25
Berms	232	1
Brush	4	7
Bushberry	8.3	54
Cherry	6.3	51.3
Christmas Trees	0	23
Citrus	0	5
Cotton	0.5	1
Diseased Bee Hives	0.9	22.9
Ditchbank & Canal	6319	269.3
Dodder Weed	694.8	10
Eucalyptus	29.3	96.3
Fertilizer Sacks	0	0.1
Fig	833.6	125.5
Grape	472	95
Grass	1382	62.4
Hay	3	106
Nectarine	40	57.5
Oats	109	8.5
Olive	22.5	5.5
Other Field Crops	256	3
Other Prunings	53.3	107.3
Peach	492.8	95
Pear	0	3
Pecan	51.4	0
Pistachio	780	166.5
Plum	53	12
Pomegranate	3	5
Prune	56	62.5
Raisin, Date Trays	80.5	13
Rice	3682	5
Sorghum (Milo)	1	0.5
Thistle	36	2
Tules	458	1
Tumbleweed	1893.5	201.3
Vegetable Crops	88.5	31.5
Walnut	2063.4	1392.8
Weeds	1887.5	256
Wheat	331.4	0

MONTEREY

Air District: Monterey Bay Unified Air Pollution Control District

Crop	Acres	Tons
Brush	46	49
Chamise, Grass	500	1
Chamise, Grass, Oak Woodland	1000	0
Chaparral	8156	4333
Chaparral, Grass/Oak Woodland	1000	500
Eucalyptus Slash	0	105
Forest Slash Piles	0	20
Grasslands	100	0
Grassland, Oak Savannah, Chaparral	972	4564
Grass, Scrub	20	20
Madrone, Oak, Chamise Slash	0	8
Pest Prevention	1	1
Pine, Pine Slash	0	258
Redwood/Fir Slash	700	80
Wildland Vegetation Management	396	0
Willow & Cottonwood Saplings	0	20
Yellow Starthistle	10	0

PLACER

Air District: Placer County Air Pollution Control District

Crop	Acres
Clover	162
Rice	4045

SACRAMENTO
Air District: Sacramento Metropolitan Air Quality Management District

Crop	Acres
Alfalfa	2.3
Almond	3.5
Apple	3.4
Apricot	0.5
Blackberry	0.3
Corn	1360.0
Ditchbank	0.5
Flood Debris	14.8
Grape	138.5
Milo	50.0
Oats	40.0
Olive	8.0
Peach	0.5
Pear	1584.6
Plum	1.8
Rice	1997.3
Safflower	26.3
Sudan	1.5
Walnut	16.5
Weeds (Ditches)	8.2
Weeds (field)	169.5
Weeds (Levees)	10.0
Weeds (Shrubs)	8.7
Wheat	342.0

SAN BENITO
Air District: Monterey Bay Unified Air Pollution Control District

Crop	Acres	Tons
Chamise, chaparral	2000	0
Chaparral	8750	812
Walnut trees	0	50

SAN DIEGO
Air District: San Diego County Air Pollution Control District

Crop	Acres	Tons
Aloe		0.75
Apple		15.5
Apricot		1
Avocado		690.9
Brush		4,769.75
Citrus		924.15
Ditch-Bank-Canal		1
Eucalyptus		44
Grape		5
Grass		10
Kiwi	3370	4
Macadamia Nuts		8.2
Nursery/Flowers		165.15
Oak		6
Olive		16
Other Field Crops		10.8
Other Prunings		326.15
Palm		7
Peach		1.9
Pecan		3
Persimmon		3.7
Plum		1
Pomegranate		2.5
Slash		2
Tumble Weeds		1.5
Vegetable Crops		0.5
Walnut		1.7
Weeds		0.5

SAN JOAQUIN
Air District: San Joaquin Valley Air Pollution Control District

Crop	Acres	Tons
Alfalfa	7	3
Almond	21029.6	3619.2
Apple	111.1	288
Apricot	195	205.5
Asparagus	50	0
Barley	320	0
Bean	12.2	1
Bushberry	1.8	7
Cherry	1918.6	3589.3
Chirstmas Trees	1.3	7.5
Corn	4992	4
Diseased Bee Hives	1.7	2.4
Ditchbank & Canal	1271.1	134
Eucalyptus	1.8	19.5
Fertilizer Sacks	0	1
Fig	0	1
Grape	2358.5	1773.1
Grass	2829.8	13
Kiwi	4	0
Oats	176.4	4
Olive	66.5	14.9
Other field Crops	230	12.5
Other Prunings	317.2	233.2
Peach	90.7	250.3
Pear	5	133
Pecan	0	1
Persimmon	44	8
Pistachio	40	4
Plum	0	8
Pluot	1.5	2
Prune	0	19
Rice	5796.5	0
Safflower	130	0
Thistle	16	6
Tules	5	0
Tumbleweed	1754.9	97.6
Vegetable Crops	337.3	2.5
Walnut	7240.4	7652.6
Weeds	536.8	112.6
Wheat	2344.8	25

SAN LUIS OBISPO
Air District: San Luis Obispo County Air Pollution Control District

Crop	Acres	Tons
Almond	128	345
Apple	15	41
Avocado	1.5	15
Barley	11	0
Brush	2514.5	556.25
Bushberry	0	1.75
Citrus	25	20.5
Ditchbank & canal	2	0
Grape	5414	486.25
Grass	2.5	6
Kiwi	0	4
Oats	0	3.5
Olive	9	0
Orchard Removal	105	123.5
Other field crops	96	81.75
Other Prunings	1462.5	1049
Peach	0	2
Pear	25	0
Pistachio	112.5	0.5
Safflower	400	0
Slash	7	97
Sugar Pea	29.15	92.5
Tumbleweed	160	0
Walnut	83	161.25
Weeds	1401.5	136
Wheat	90	21
Wild Hay	1200	2.5

SANTA CRUZ

Air District: Monterey Bay Unified Air Pollution Control District

Crop	Acres	Tons
Acacia, frenchbroom, redwood slash	0	20
Brush	30	103
Douglas Fir	323	113
Eucalyptus	303	103
Pine, pine slash, chaparral	380	8

SOLANO

Air District: Yolo-Solano Air Quality Management District

Crop	Acres
Almond	1203.2
Apple	5.0
Apricot	44.6
Cherry	0.3
Corn	1938.3
Olive	0.5
Peach	8.0
Pear	133.5
Prune	567.4
Rice	10.0
Safflower	20.0
Walnut	1416.2
Wheat	481.0

STANISLAUS

Air District: San Joaquin Valley Air Pollution Control District

Crop	Acres	Tons
Almond	49359.6	1766.7
Apple	65.6	20.5
Apricot	1805.6	158
Avocado	0	1
Barley	70	0
Bean	30	3
Brush	24.9	9.3
Bushberry	4.4	9
Cherry	189.4	38
Chirstmas Trees	0	2
Citrus	19.5	3
Corn	0.3	0.5
Diseased Bee Hives	1.5	3.5
Ditchbank & Canal	1242.1	48.2
Eucalyptus	26.9	4
Fig	10	0
Grape	976.3	93.4
Grape Stakes	0	0.5
Grass	248	6
Kiwi	17	0
Nectarine	22	0
Oats	79	0
Olive	0.4	0
Orchard Removal	0.4	0
Other Field Crops	1.5	0
Other Prunings	231.6	51.2
Peach	931.2	94
Pear	0.5	1
Pecan	13	0
Persimmon	31	0
Pistachio	44.3	2
Plum	0.5	14
Prune	21	4.5
Rice	1838	0
Tumbleweed	536	63
Vegetable Crops	4.8	2
Walnut	8939.2	795.2
Weeds	671	28.6
Wheat	153.4	1

SUTTER

Air District: Feather River Air Quality Management District

Crop	Acres
Almond	838
Ditchbank	1581
Orchard Removal	457
Peach	1126
Prune	2809
Rice	23252
Safflower	2134
Walnut	3388
Weeds	1924
Wheat	3568

TEHAMA
Air District: Tehama County Air Pollution Control District

Crop	Acres
Almond	2016
Fig	5
Oats	25
Olive	1577
Peach	56
Pecan	85
Pistachio	10
Prune	2622
Rice	47.4
Sorghum	35
Walnut	2319
Wheat	275

TULARE
Air District: San Joaquin Valley Air Pollution Control District

Crop	Acres	Tons
Alfalfa	94.7	0
Almond	4588.4	1878.9
Apple	310.5	57.9
Apricot	23.6	14.4
Avocado	13.5	11
Barley	240.5	0
Bean	90	1
Berms	0.5	0
Brush	1.4	8.5
Bushberry	0	0.7
Cherry	152.5	28.7
Citrus	3421.8	2424.1
Citrus Pruning	103	12
Corn	1	0
Cotton	1	1.5
Diseased Bee Hives	1	21.6
Ditchbank & Canal	2665.6	27.5
Eucalyptus	49.5	194.4
Fence Rows	11.2	0.5
Fig	5	5
Flood Debris	0	3
Grape	3043.2	631.8
Grape Stakes/Stumps	1272.2	415.6
Grass	73.2	2.5
Kiwi	14	28.2
Nectarine	479.3	255
Nursery Trimmings	65.4	197.6
Oats	102	0
Olive	2438.6	1857.3
Orchard Removal	39	19.1
Other	0.5	7.3
Other Prunings	3.5	2.7
Pasture	267.2	125
Pasture Shade Trees	20	12
Peach	1935.7	299.2
Pear	43.9	27.6
Pecan	380.2	92.7
Persimmon	42.9	53.6
Pest/Fertilizer Sack	0	0.8
Pistachio	691.8	286.5
Plum	2508.2	539.7
Pomegranate	73	66.9
Pond/Levee Banks	5	0
Prescription Burn	10	0
Prune	1508.1	861.4
Quince	20	20.3
Raisin, Date Trays	916.3	40.5
Star Thistle	0	4
Sudan	110	0
Tumbleweed	4478.5	187.1
Vegetable Crops	15.7	31
Vineyard Removal	16	0
Walnut	1642.5	2429.9
Weeds	452.9	82.9
Wheat	6653	23.6
X-Mas Trees	0	33.1

VENTURA
Air District: Ventura County Air Pollution Control District

Crop	Tons
Apple	2
Apricot	21.25
Avocado	2209.75
Brush	318.75
Chaparral	238.5
Citrus	19510.75
Ditchbank	15.5
Grape	2.25
Kiwi	5
Macadamia	0.5
Oak	46.25
Olive	43
Other	1253.75
Peach	1.75
Pear	0.75
Pepper	12.5
Plum	0.25
Tobacco	10
Tumbleweeds	10
Walnut	99.5
Weeds	23

YOLO
Air District: Yolo-Solano Air Quality Management District

Crop	Acres
Almond	704.5
Apricot	76.0
Cherry	5.0
Corn	167.0
Fig	40.0
Pear	42.0
Prune	680.4
Rice	3396.0
Safflower	1544.0
Walnut	1313.5
Wheat	771.5

YUBA
Air District: Feather River Air Quality Management District

Crop	Acres
Ditchbanks	5
Orchard Removal	214
Other-Field Crops	362
Other-Miscellaneous	298
Peach	66
Pears	19
Plum	9
Prune	216
Rice	7923
Walnut	25
Weeds	137

TABLE of COUNTY FILE INFORMATION

Consolidated Agricultural Burning Database - 2000				
County Name	Contacts	Data Format	Data Completeness	Data Issues
Butte	Stephen Ertle	Excel ss	all crops, monthly, acres	no locations, sectwnrge (what exactly is sectwnrge? TRS data?)
Colusa	Charles Price	FoxPro db	most crops, daily, acres, locations & sectwnrge	not all data
Fresno	Wayne Clarke Ted Strauss	dBase db	all crops, daily, acres, tons, locations	mix sectwnrge data w/locations
Glenn	Candis Woods Trudy Silveira	FilemakerPro Ascii	rice, daily, acres, location is field ID, sectwnrge	no other crops or location data
Imperial	Jeanette Bryant Martin Fitzurka	Dataflex db Ascii	all crops, daily, acres, location is canal&gate	no sectwnrge
Kern	Wayne Clarke Ted Strauss	dBase db	all crops, daily, acres, tons, locations	mix sectwnrge data w/locations
Kings	Wayne Clarke Ted Strauss	dBase db	all crops, daily, acres, tons, locations	mix sectwnrge data w/locations
Lake	Robert Reynolds	Text file Ascii	all crops, seasonal, acres, tons	no locations, sectwnrge
Madera	Wayne Clarke Ted Strauss	dBase db	all crops, daily, acres, tons, locations	mix sectwnrge data w/locations
Mendocino	Ronda Gott	Excel ss	few crops, few daily, acres, tons	no locations, sectwnrge limited data
Merced	Wayne Clarke Ted Strauss	dBase db	all crops, daily, acres, tons, locations	no sectwnrge
Monterey	Isabel Navoa Teresa Sewell	Text file Ascii	few crops, daily, acres, tons, locations	mix sectwnrge data w/locations
Placer	Ann Hobbs	FoxPro db	mostly rice, daily, acres, locations, sectwnrge	not all data
Sacramento	Susan Engstrom	FoxPro db Lotus ss	all crops, daily, acres, field ID is location	no sectwnrge

San Benito	Isabel Navoa Teresa Sewell	Text file Ascii	few crops, daily, acres, tons, sectwnrge is location		not all data
San Diego	Bill Reeves Ralph Decianni	Word file	all crops, mostly tons		no location, sectwnrge no date or month
San Joaquin	Wayne Clarke Ted Strauss	dBase db	all crops, daily, acres, tons, locations		no sectwnrge
San Luis Obispo	Karen Brooks	Excel ss	all crops, daily, acres, tons, sectwnrge is location		no other location data
Santa Cruz	Isabel Navoa Teresa Sewell	Text file Ascii	few crops, daily, acres, tons, location		mix sectwnrge data w/locations
Solano	Dave Smith	Excel ss FoxPro db	all crops, daily, acres, fire district is location		no sectwnrge
Stanislaus	Wayne Clarke Ted Strauss	dBase db Excel ss	all crops, daily, acres, tons, locations		no sectwnrge
Sutter	Jeff Citron	FoxPro db Lotus ss	all crops, daily, acres, location & sectwnrge rice		no location or sectwnrge other crops
Tehama	Gary Bovee	Excel ss	all crops, daily, acres, location, sectwnrge		date field conversion problem - put in month
Tulare	Wayne Clarke Ted Strauss	dBase db	all crops, daily, acres, tons, locations		mix sectwnrge data w/locations
Ventura	Kent Field	Excel ss	all crops, monthly, tons		no locations, sectwnrge
Yolo	Dave Smith	Excel ss FoxPro db	all crops, daily, acres, fire district is location		no sectwnrge
Yuba	Jeff Citron	FoxPro db	all crops, daily, acres, location		not all data - only fall no sectwnrge

CONCLUSIONS AND RECOMMENDATIONS

Several air districts in California have staff and computer resources needed to develop and maintain detailed agricultural burning databases. Districts with significant agricultural industries currently collect data and generate databases. There is considerable knowledge in those districts of their agricultural burning operations. The districts understand the need to effectively regulate burning for air quality purposes. However, this project shows that the agricultural burning data files statewide need to be more uniform in format and in the data collected. This will enable more sophisticated temporal and spatial analyses and thus better burning management.

We recommend six improvements that to the agricultural burning reporting data to better support spatially and temporally resolved emission estimates.

1. There needs to be a standardized data file structure instead of multiple computer file formats.
2. Data fields need to include minimum information to allow for enhanced temporal and spatial analyses.
3. Inconsistencies in residue types need to be resolved eliminating general descriptions and overlapping categories.
4. More complete information is needed in fuel loading and emission factor data.
5. Information on burn sites should include both conventional location descriptions and section-township-range data.
6. Temporal information on burning should be referenced by date and not just month or season.

It is recommend that the Air Resources Board should establish statewide standards of minimum burning information. But equally important as data structure is the validity of the information reported in the database. Advanced planning needs to be invested into standardizing the residue categories and training in the collection of pertinent data. The ARB should provide guidance and meet with air districts to jointly develop the database format and discuss its use. The Board staff must assist air districts in maintaining a consistent agricultural burning database program which will be useful in managing burning and easily adapt to GIS analytical tools. The ARB should also provide assistance in converting relevant, existing data into the new database. Most importantly the Air Resources Board should hold educational meetings to explain the proposal to districts and the agricultural community so mutual cooperation and understanding is fostered from the beginning.

The potential benefits of a standardized database are numerous. It will be possible to easily merge compatible county databases into a statewide database. Complete and accurate burn information can be correlated with computer files of meteorological and air quality data. Through the use of GIS tools, temporal and spatial burn maps can be created and made accessible on the Internet. Information on burning in adjacent air districts or air basins can be analyzed more thoroughly and coordination and communication improved among agencies. With a standardized agricultural burning database, GIS analyses and Internet access, a better understanding and management of agricultural burning is possible.

7.3. Appendix B: Assessment of Agricultural Burns using NOAA-14 AVHRR Data

7.3.1. Overview

A relatively small component of the overall project was to explore the viability of using satellite imagery to detect agricultural burns either while they occur or after the fact. In summary, it was determined that the available satellite data are not readily usable for agricultural burn detection. This is due to several factors including the short duration of the fires, the relatively low intensity (heat) of the fires, the small size of many agricultural fires, and because a previously vegetated field can be cleared either by fire, or by land preparation activities, all of which presently make agricultural fire detection using the available NOAA-14 AVHRR satellite data impractical.

7.3.2. Data sources

In performing the analysis, the following data sources were used:

<u>Field Data</u>
Original field data for agricultural burning (abfield.dbf) obtained from Air Resources Board (ARB) include:

- Permitnum - burn permit number for an individual grower
- Fieldnum - ID number that the grower assigns to an individual field
- Fieldsub - not often used
- Location - physical location of field (nearest crossroads etc.)
- APN - assessor's parcel number (another way of locating a field) not often used
- SecTwnRng - section township and range location of field provided by grower
- Zone - burning management zone location for county purposes
- Acres - number of acres in field
- Crop - type of crop residue to be burned
- Basincode - basin crop code alpha
- Statecode - state crop code numeric
- Burn_NB - designation by grower whether field is to be burned or not
- Hazard - note if field is adjacent to roadway, populated area, etc.
- Windneed - if smoke could create hazard what wind direction needed to avoid
- Disease - note if field has experienced disease problems
- Status - what is status of field, Ready to burn, Burned, etc.
- Reportday - day field was reported to county for adding to database
- Harvstday - day harvesting was finished for field
- Disposal - method other than burning that was used to dispose of residue
- Method - rice straw spread or windrowed behind harvester
- Readyday - calculated day based on drying times straw is ready to burn
- Waitday - if grower wants to wait until a later date to burn can be specified
- Filenum - record number in database
- Filenum2 - not often used

Burndate - date the field was burned
Comments - any additional comments needed to describe the field

Satellite Image Data
Remotely sensed Advanced Very High Resolution Radiometer (AVHRR) data are available on a daily basis, at no cost. The AVHRR data has spatial resolution of approximately 1.1 km at the satellite nadir from the nominal orbit altitude of 833 km. The AVHRR data has 5 channels, 1 visible, 1 near-infrared and 3 thermal channels. Various vegetation indices derived from the first 2 channels are used to detect vegetation changes, and the 3 thermal channels are suitable for monitoring fire events based on temperature changes.

7.3.3. Objectives

The objectives of this component of the study were:

a) To assess the possibility of using remotely sensed Advanced Very High Resolution Radiometer (AVHRR) data to detect the field size of agricultural burn.
b) To validate the occurrence validation of AVHRR detected agricultural burning
c) To estimate air pollution caused by agricultural burns

7.3.4. Methodology

Three counties (Colusa, Glenn and Sutter) were selected for analysis in this component of the study. The numbers of acres burned, from the collected agricultural burn database, were sorted for each of the selected 3 counties, and the burn dates were recorded for those burn areas greater than 150 acres ($\cong 0.607\ km^2$). By using the MTRS field in the burn database as a join item, the Public Land Survey polygon coverage of California sections was used to establish spatial locations of each agricultural burning event. The GIS data layer of agriculture burns was then used to create polygons, referenced by date, for those burn areas greater than 0.6 km^2 (figure1). AVHRR images were obtained for the burn date, the following day, and the two days prior to the burn. Therefore, a total of five AVHRR images were needed for analysis of each fire event.

The required AVHRR data were downloaded from the Satellite Active Archive website (www.saa.noaa.gov). The level 1b AVHRR data were processed using PCI Goematica software. The channels 1 and 2 were transferred to top-of-atmosphere (TOA) reflectance in percentage, and the 3 thermal channels were converted into brightness temperatures in degrees K.

Each satellite image was geo-referenced and the GIS layer showing the burn locations and sizes was overlaid on the top of the satellite images for investigation. The goal of this analysis was to investigate whether fires reported in the agricultural burning database could be observed using the satellite data

7.3.5. Results and Discussion

Five out of 3900 fire events in the selected 3 counties had areas greater than 200 acres (≅ 0.81 km^2), and 34 of them had areas between 150 and 200 acres. For the 5 large fire events, only one had cloud-free AVHRR data for the time period of the burn. More than half of the 34 middle-sized fire events occurred on cloudy days. For those burns having cloud-free satellite images, when comparing the images before and after the burn, the measured land brightness levels of channels 3, 4 and 5 were not affected by the agriculture burns. In effect, the satellite could not detect the change in the land due to the action of the burn.

The main reasons burns could not be detected is that 1) many of the burns occurred on cloudy days, making a complete analysis difficult, 2) most of the burns were not large enough to be detectable by the 1.1 km x 1.1 km resolution of the satellite, 3) the reported burn data included spatial resolution down to a township (1 square mile), the exact latitude and longitude location of the burn was unavailable, and 4) the short duration and low temperature of the burns makes them difficult to detect using just a flyover 'snapshot' image.

7.3.6. Conclusion

Although the AVHRR images are available at daily basis, due to the relatively short duration of agricultural burning and cloud contaminations for the year of study, the data are not suitable for detecting agriculture burns in California. In addition, most agriculture burns were too small to be detectable by using images with pixel size of 1.21 km^2.

Due to the inability to use the AVHRR satellite data to detect agricultural fires, it could not be used to validate the collected tabular agricultural burn data or for performing emission estimates. Possibly, higher resolution daily images such as MODIS or SPOT Vegetation data in combination with AVHRR data may hold more promise for future study as they have morning overpasses that can complement the afternoon overpasses of NOAA satellites. Use of this additional resolution information could increase the chance of capturing the burning events in the morning, as well as help to detect the small, relatively quick, and low intensity fires produced by agricultural burning.

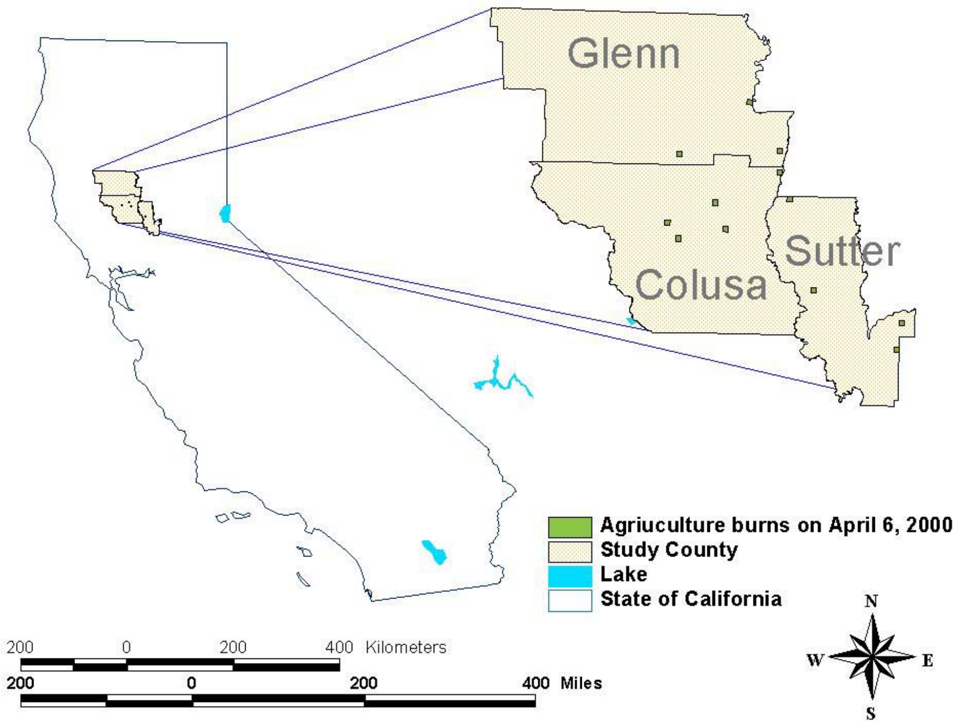


Figure 1. Reported agriculture Burns on April 6, 2000

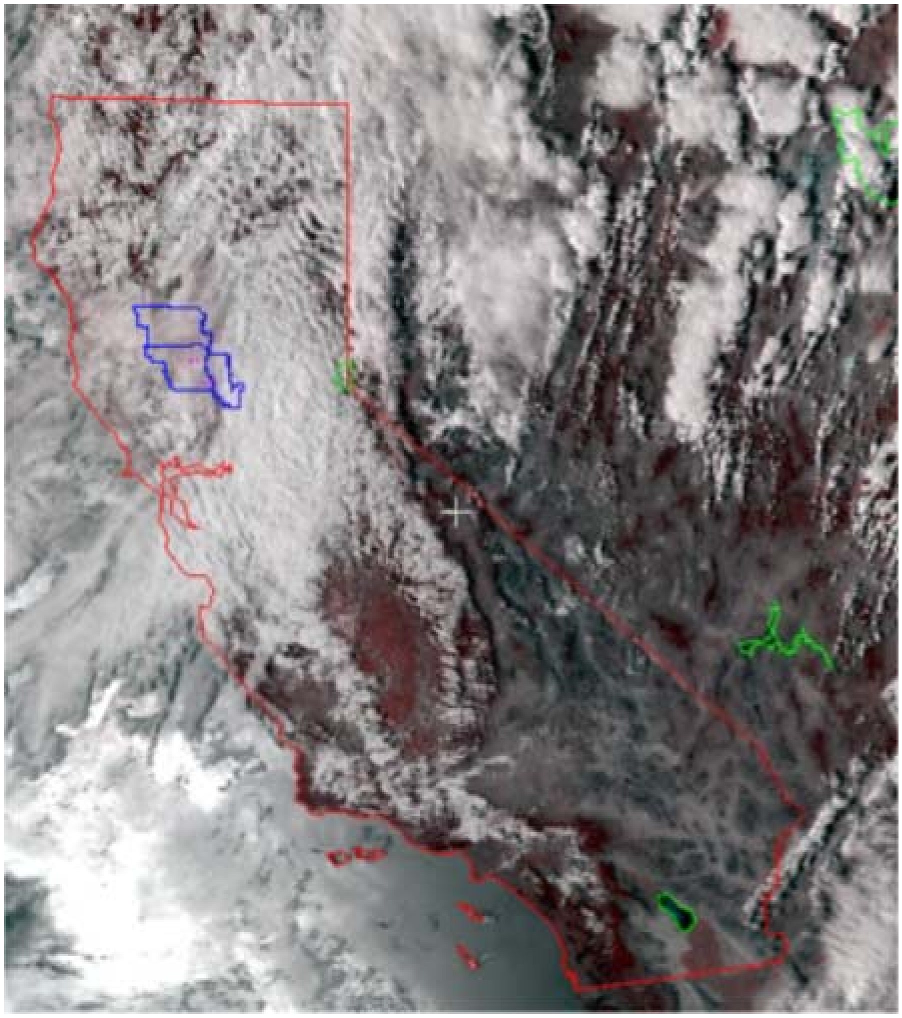
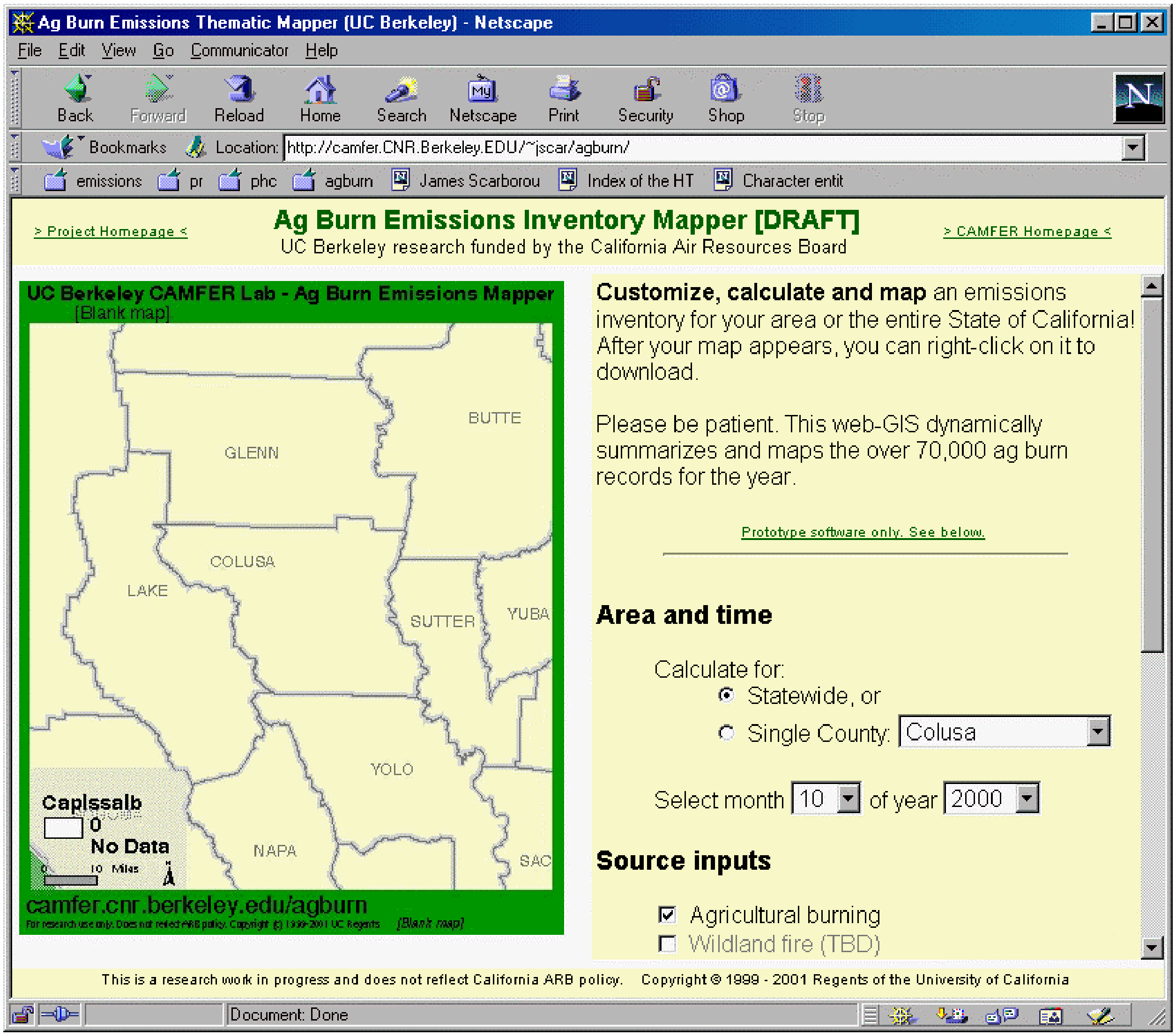
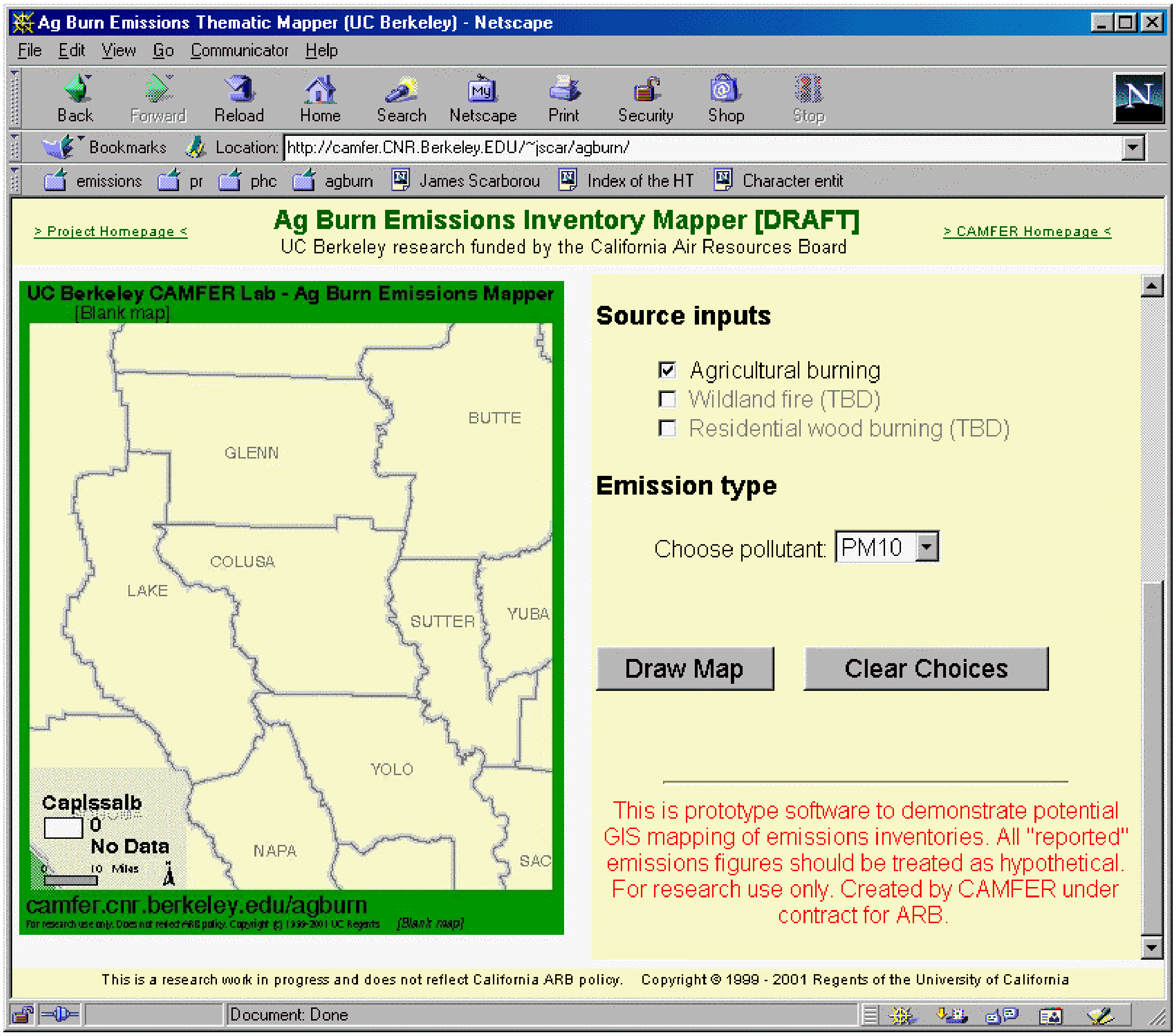


Figure 2. Agriculture burns on August 31, 2000 were overlaid on an AVHRR image of September 1, 2000

7.4. Appendix C: Prototype Web-GIS Screen Captures

Following are screen captures from the prototype web-GIS developed to illustrate real-time online emissions summaries and mapping using ABEES. The series of four images follows a user interaction to summarize PM_{10} estimates for October 2000 first statewide then by one-mile Sections in Colusa County, California.




Ag Burn Emissions Thematic Mapper (UC Berkeley) - Netscape
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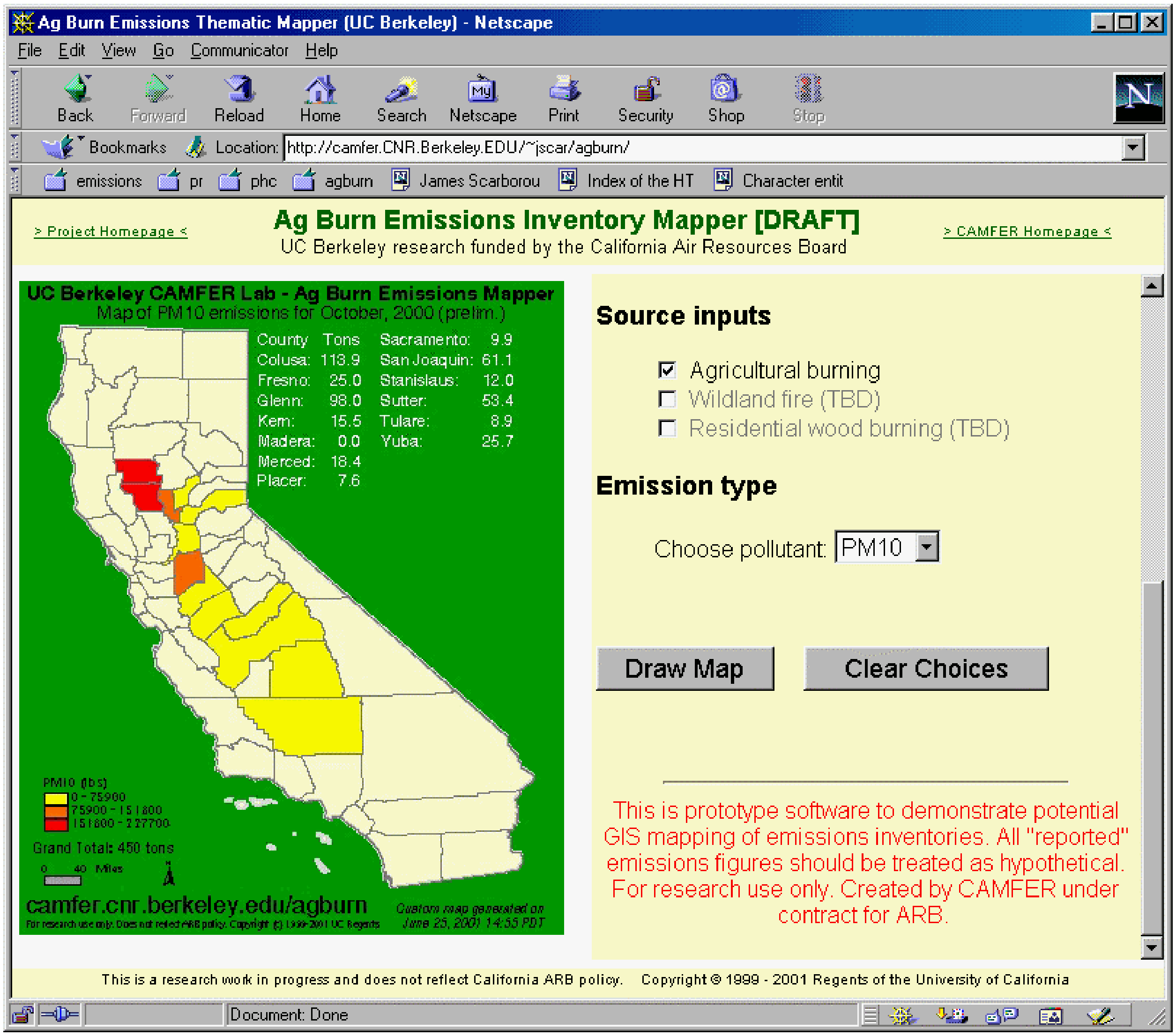
Ag Burn Emissions Inventory Mapper [DRAFT]
UC Berkeley research funded by the California Air Resources Board
> CAMFER Homepage <
UC Berkeley CAMFER Lab - Ag Burn Emissions Mapper
[Blank map]
BUTTE
GLENN
COLUSA
LAKE
SUTTER
YUBA
YOLO
NAPA
SAC
Caplssalb
0
No Data
10 Miles
camfer.cnr.berkeley.edu/agburn
Source inputs
Agricultural burning
Wildland fire (TBD)
Residential wood burning (TBD)
Emission type
Choose pollutant: PM10
Draw Map
Clear Choices
This is prototype software to demonstrate potential GIS mapping of emissions inventories. All "reported" emissions figures should be treated as hypothetical. For research use only. Created by CAMFER under contract for ARB.
This is a research work in progress and does not reflect California ARB policy. Copyright © 1999 - 2001 Regents of the University of California
Document: Done


Ag Burn Emissions Thematic Mapper (UC Berkeley) - Netscape
File Edit View Go Communicator Help
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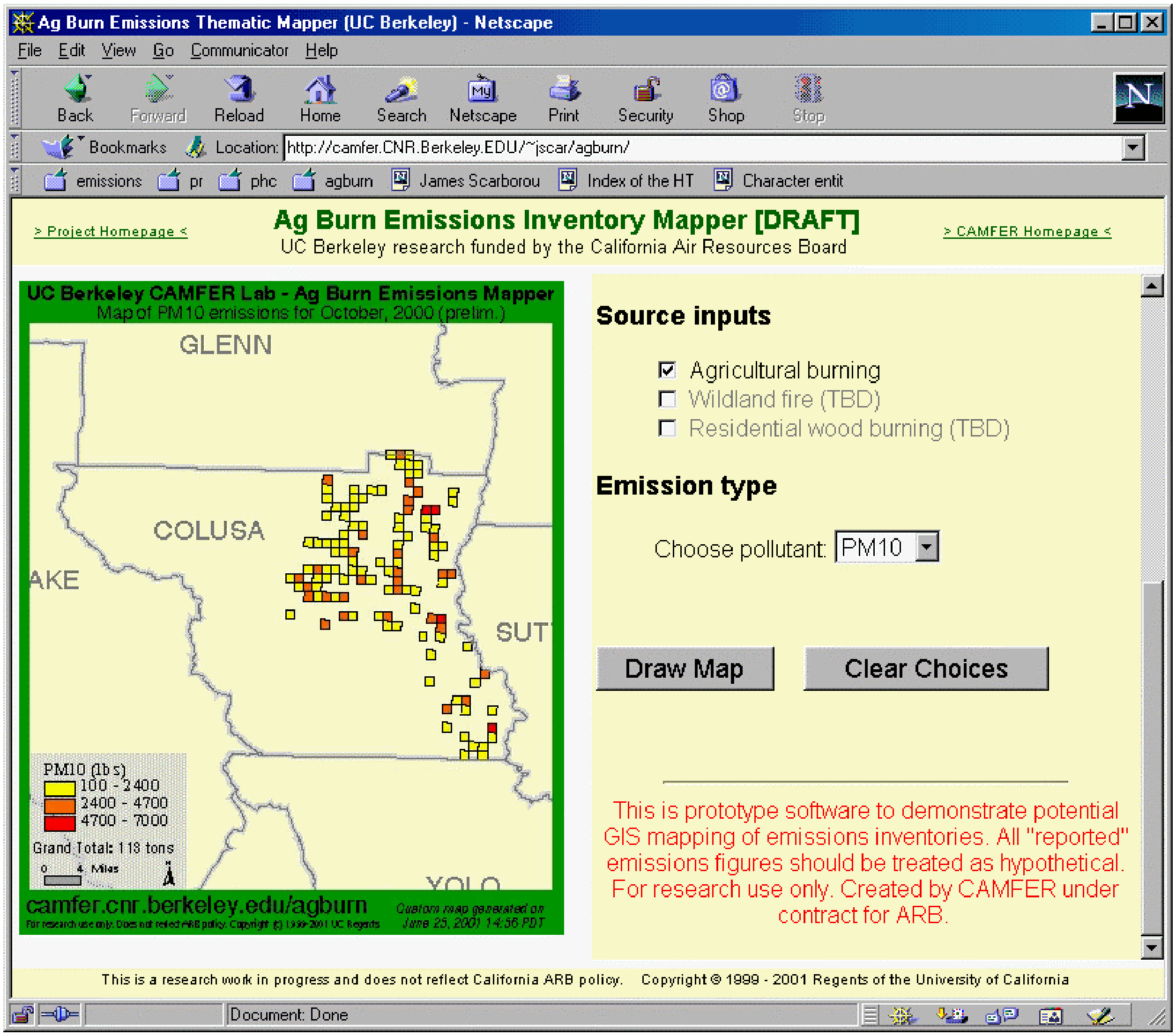
> Project Homepage <
Ag Burn Emissions Inventory Mapper [DRAFT]
UC Berkeley research funded by the California Air Resources Board
> CAMFER Homepage <
UC Berkeley CAMFER Lab - Ag Burn Emissions Mapper
Map of PM10 emissions for October, 2000 (prelim.)
County Tons
Colusa: 113.9
Fresno: 25.0
Glenn: 98.0
Kern: 15.5
Madera: 0.0
Merced: 18.4
Placer: 7.6
Sacramento: 9.9
San Joaquin: 61.1
Stanislaus: 12.0
Sutter: 53.4
Tulare: 8.9
Yuba: 25.7
PM10 (lbs)
0 - 75900
75900 - 151800
151800 - 227700
Grand Total: 450 tons
0 40 Miles
camfer.cnr.berkeley.edu/agburn
Custom map generated on June 25, 2001 14:55 PDT
Source inputs
Agricultural burning
Wildland fire (TBD)
Residential wood burning (TBD)
Emission type
Choose pollutant: PM10
Draw Map
Clear Choices
This is prototype software to demonstrate potential GIS mapping of emissions inventories. All "reported" emissions figures should be treated as hypothetical. For research use only. Created by CAMFER under contract for ARB.
This is a research work in progress and does not reflect California ARB policy. Copyright © 1999 - 2001 Regents of the University of California
Document: Done


Ag Burn Emissions Thematic Mapper (UC Berkeley) - Netscape
File Edit View Go Communicator Help
Back Forward Reload Home Search Netscape Print Security Shop Stop
Bookmarks Location: http://camfer.CNR.Berkeley.EDU/~jscar/agburn/
emissions pr phc agburn James Scarborou Index of the HT Character entit
> Project Homepage <
Ag Burn Emissions Inventory Mapper [DRAFT]
UC Berkeley research funded by the California Air Resources Board
> CAMFER Homepage <
UC Berkeley CAMFER Lab - Ag Burn Emissions Mapper
Map of PM10 emissions for October, 2000 (prelim.)
GLENN
COLUSA
AKE
SUT
YOLO
PM10 (lbs)
100 - 2400
2400 - 4700
4700 - 7000
Grand Total: 118 tons
0 4 Miles
camfer.cnr.berkeley.edu/agburn
Custom map generated on June 25, 2001 14:56 PDT
Source inputs
Agricultural burning
Wildland fire (TBD)
Residential wood burning (TBD)
Emission type
Choose pollutant: PM10
Draw Map
Clear Choices
This is prototype software to demonstrate potential GIS mapping of emissions inventories. All "reported" emissions figures should be treated as hypothetical. For research use only. Created by CAMFER under contract for ARB.
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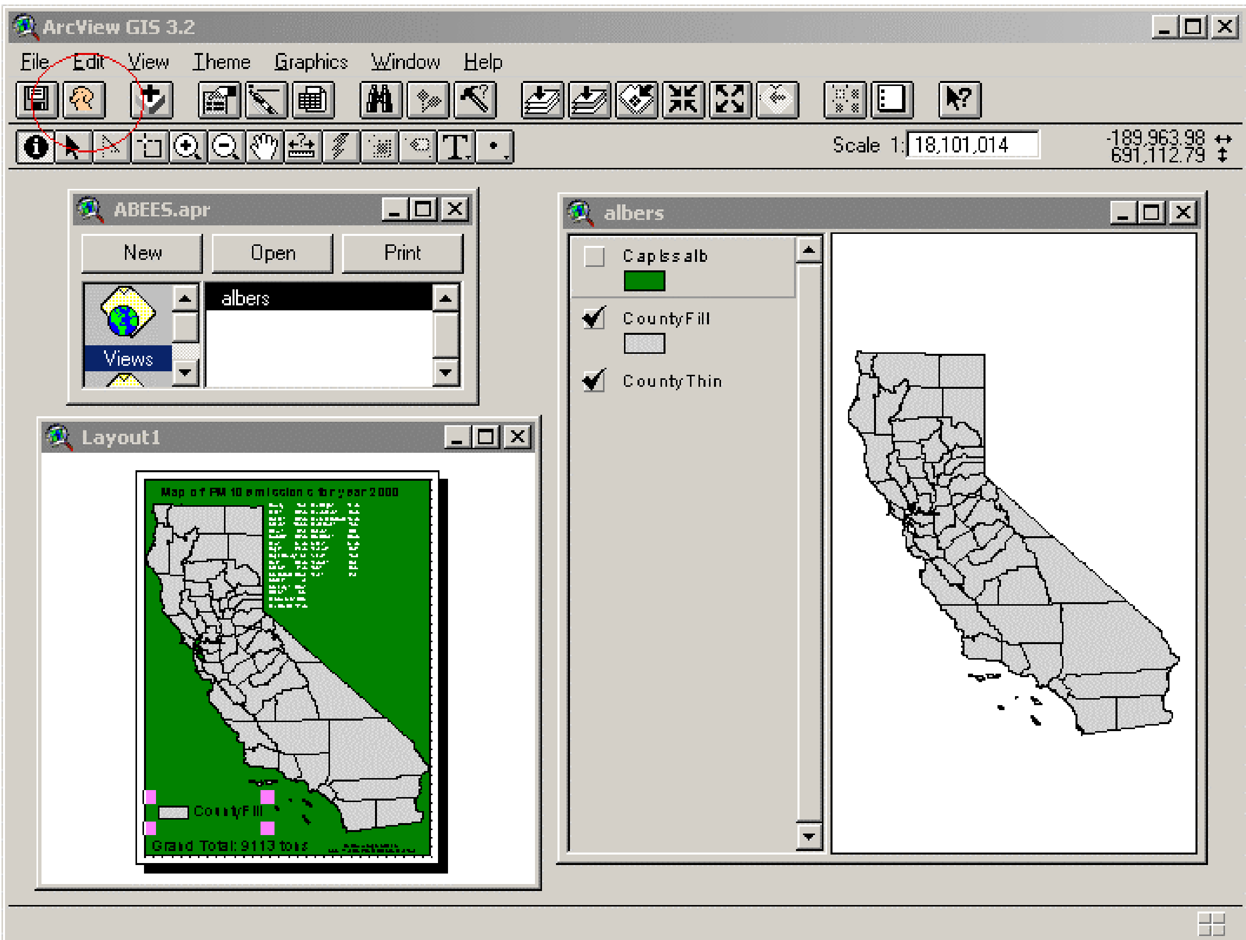
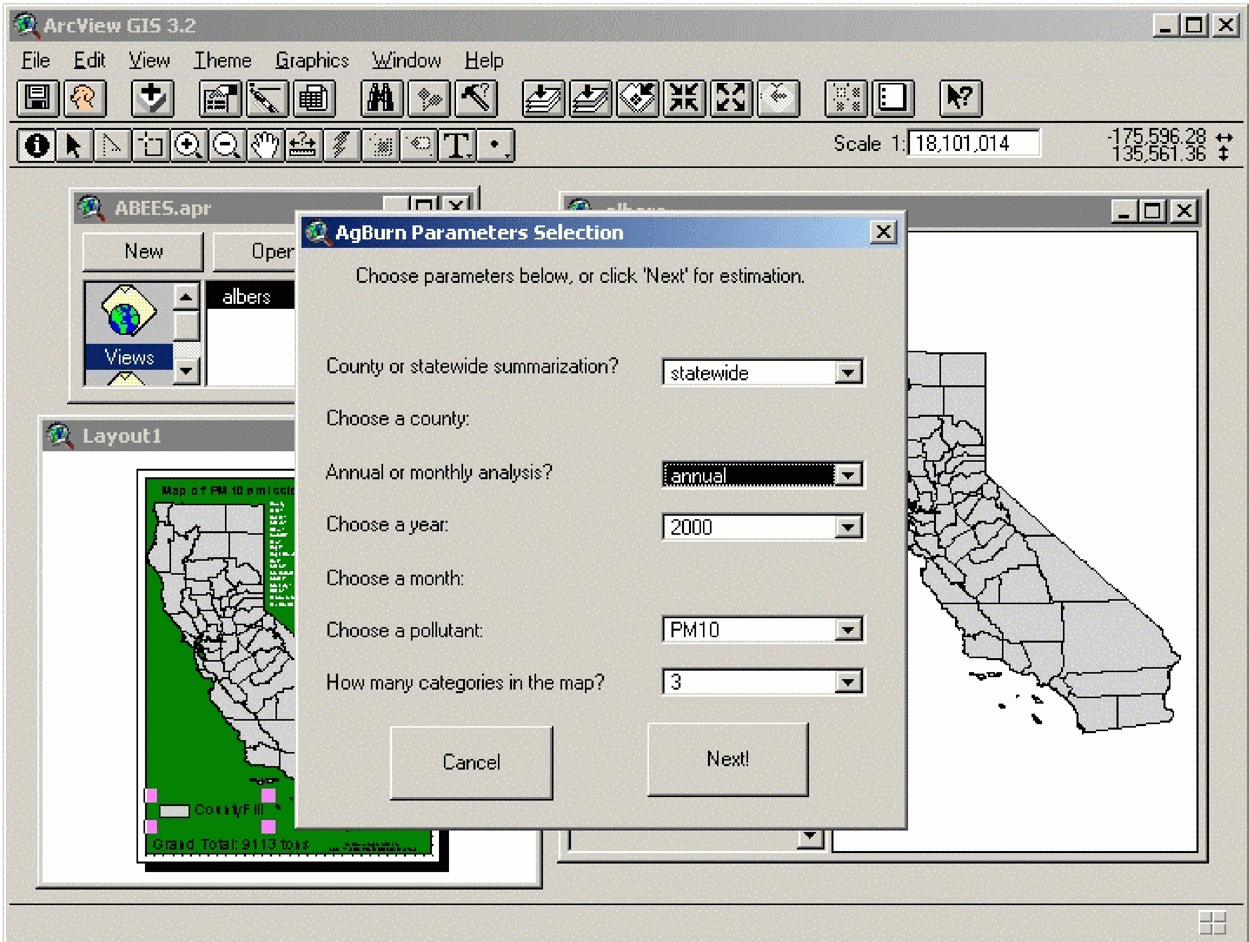
Document: Done

7.5. Appendix D: Prototype Desktop-GIS Screen Captures

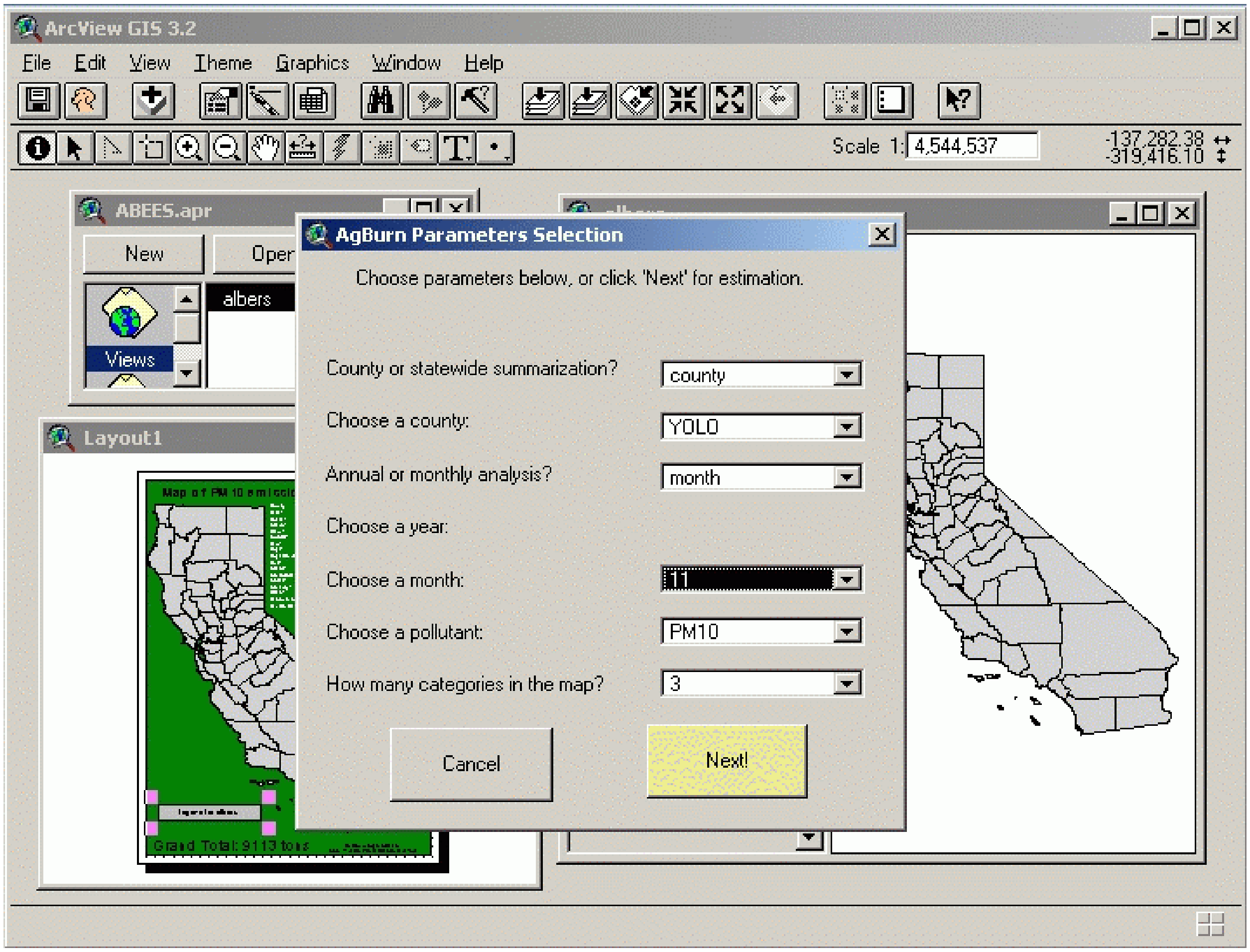
Following are screen captures from the prototype desktop-GIS developed to illustrate mapping and reporting functionality using the ABEES project included on the companion CD. The series of images is designed to illustrate the use of the emission estimation tool and the sequence of dialogs that will be displayed.



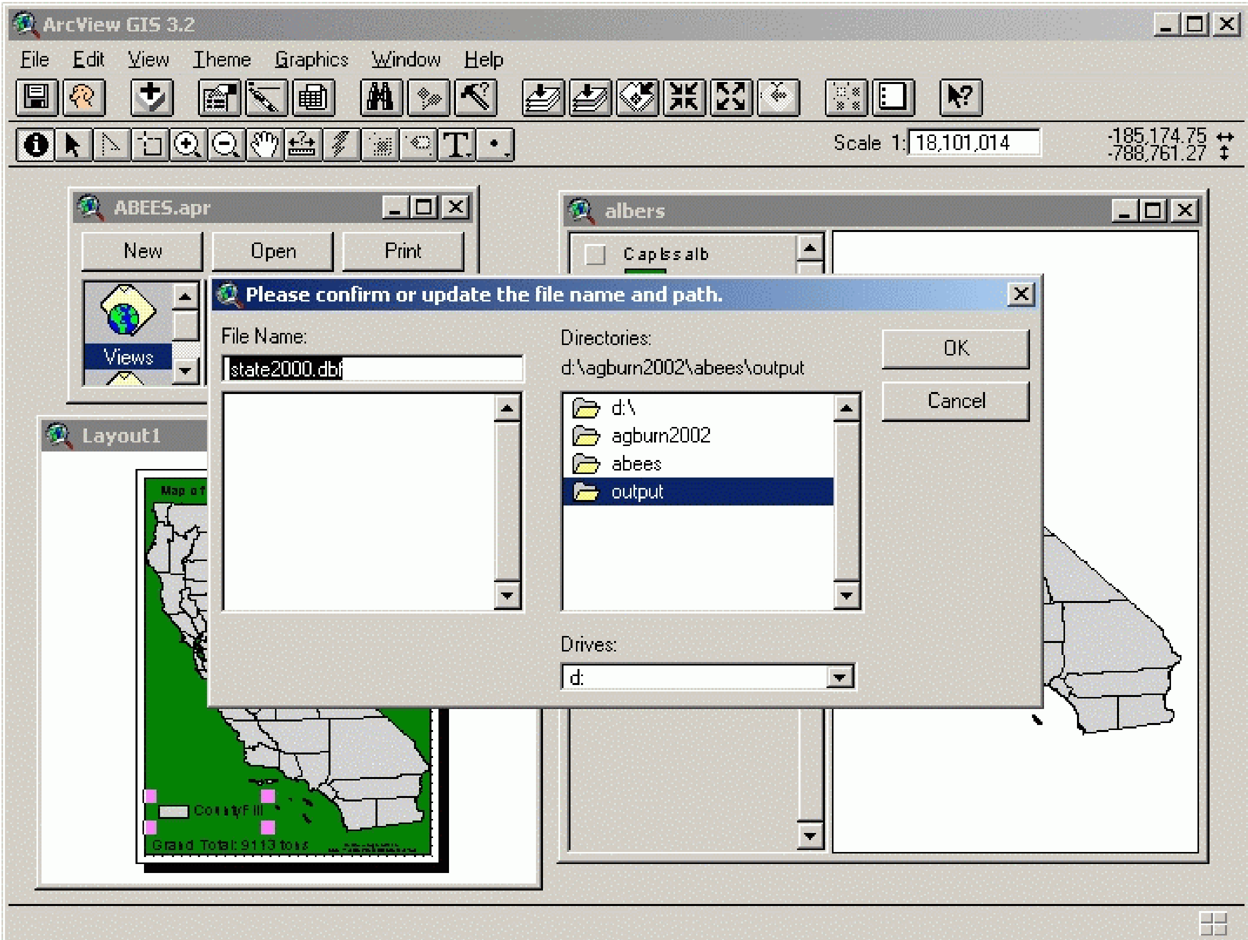
This image shows the ABEES desktop system with the View menu. The button in the upper left of the image, circled in red launches the ABEES dialog that allows the user to interactively choose the summary parameters.



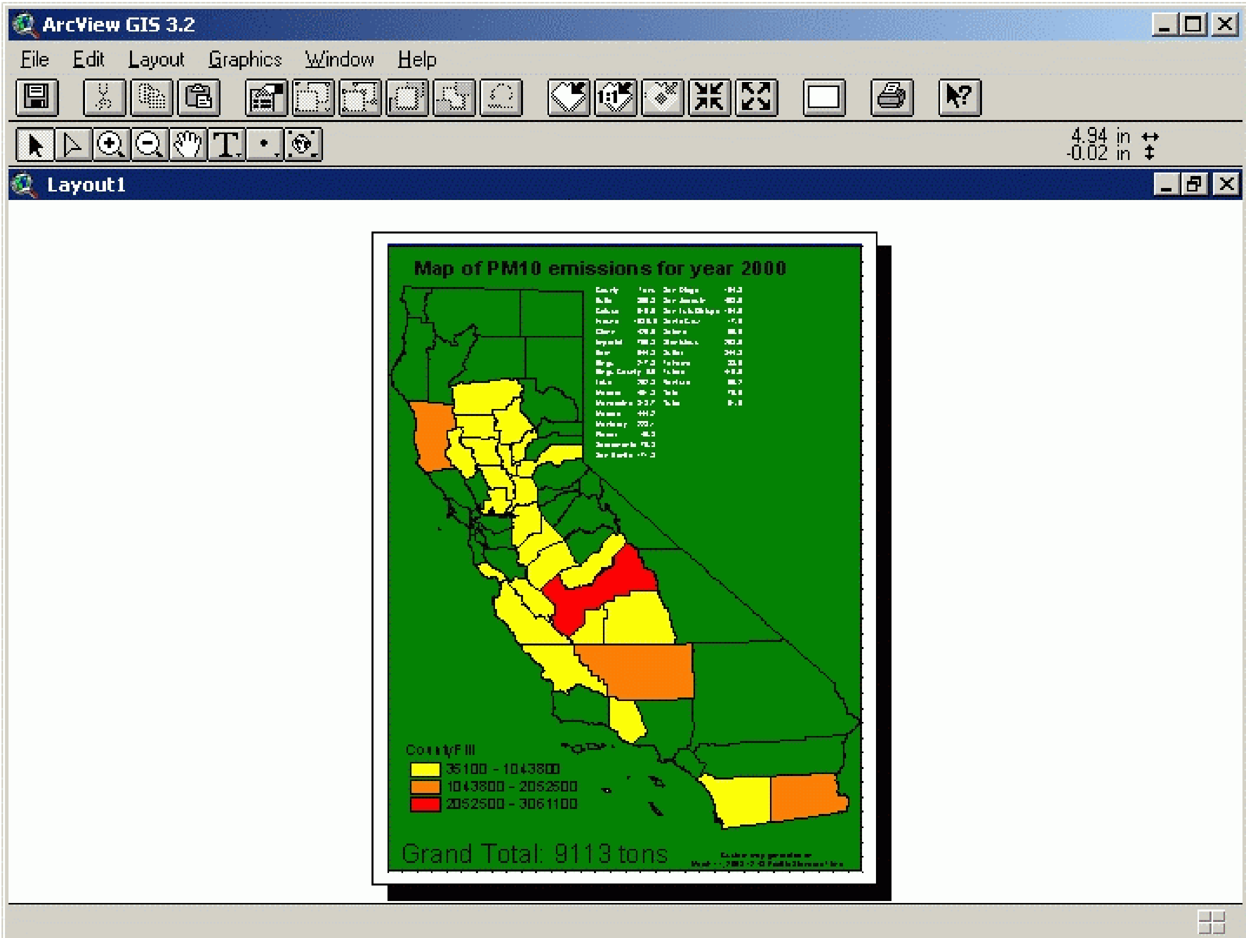
Upon launching, the ABEES will display this dialog. The user is prompted to pick some summary parameters such as annual or monthly emission estimation and statewide or county geographic scope.



This image shows the same dialog as the previous image, except with county and monthly estimation parameters. When the parameters have been set, the Next button should be pressed (highlighted in the above image) to continue with the estimation.



The ABEES will prompt the user for output file name and location. The default is a directory in the ABEES folder.



The ABEES will create a default layout of the data specified in the startup dialog. These layouts can be manipulated for presentation ready quality or export to web pages. The layout will appear slightly different depending on summary parameters.