Summary of Crop Production, Agricultural Burning, and Non-Burning Alternatives for the Western United States

TASK 1 DRAFT REPORT - REVISED

Prepared for:

The Fire Emissions Joint Forum of the Western Regional Air Partnership

July 17, 2001

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SUMMARY OF CROP PRODUCTION, AGRICULTURAL BURNING, AND NON-BURNING ALTERNATIVES FOR THE WESTERN UNITED STATES

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Prepared for:

The Fire Emissions Joint Forum of the
Western Regional Air Partnership

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ACRONYMS

AK	Alaska
ARMS	Agricultural Resource Management Study
ARS	Agricultural Research Service
AZ	Arizona
BAL	bales
BELD3.1	Biogenic Emissions Landuse Database, version 3.1
BU	bushels
CA	California
CARB	California Air Resources Board
CASS	California Agricultural Statistics Service
CDFA	California Department of Food and Agriculture
CGE	computable general equilibrium
CO	Colorado
CO_2	carbon dioxide
CWT	hundredweight (100 pounds)
DEQ	Department of Environmental Quality
EIIP	Emission Inventory Improvement Program
ERG	Eastern Research Group, Inc.
ETC	Enviro-Tech Communications
FEJF	Fire Emissions Joint Forum
FIPS	Federal Information Processing Standards
GIS	geographical information system
HI	Hawaii
ID	Idaho
KBG	Kentucky bluegrass
km	kilometer
MT	Montana
NASS	National Agricultural Statistics Service
ND	North Dakota
NM	New Mexico
NO_2	nitrogen dioxide
NV	Nevada
OR	Oregon
PEDB	Published Estimates Data Base
$PM_{2.5}$	particulate matter less than 2.5 microns in aerodynamic diameter
QA/QC	quality assurance/quality control
RIMSII	Regional Input Output Modeling System, version 2
SD	South Dakota
SJVUAPCD	San Joaquin Valley Unified Air Pollution Control District
USDA	United States Department of Agriculture
UT	Utah
WA	Washington
WESTAR	Western States Air Resources Council
WGA	Western Governors' Association

WRAP	Western Regional Air Partnership
WY	Wyoming

1.0 INTRODUCTION

Air emissions from burning agricultural residue, primarily consisting of fine particles, can be a significant source of air pollution on a short-term and intermittent basis. These emissions can directly impact visibility in Class I areas located near burns, or those Class I areas located far away through regional transport. The Western Regional Air Partnership (WRAP) and its Fire Emissions Joint Forum (FEJF) are sponsoring a project to conduct a thorough assessment of the non-burning alternatives to infield burning of agricultural residues, including their impacts on the environment, economy, health and safety, society, politics, and on the business and productivity of the agricultural industry.

In the context of this study, "agricultural burning" is defined as the burning of organic crop residue consisting of field crops, wood, and leaves. Also, the burning of ditch banks adjacent to, or associated with, crop production are included in this evaluation of alternatives to agricultural burning. The geographical scope of the project includes the 15 Western states of Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, North Dakota, New Mexico, Nevada, Oregon, South Dakota, Utah, Washington, and Wyoming. State, as well as tribal, jurisdictional issues will be addressed. The temporal scope of the data collected for this project was 1996, chosen to coincide with the WRAP base year emissions inventory effort. However, as described herein, it was necessary to use data from 1997 or other years in some cases when 1996 data were not available.

The overall project objectives include the following:

1. Identification of crops grown and the extent to which residue is disposed of through burning for the 15 Western states;
2. Display of the crop and residue/burning data in a database using a geographical information system (GIS);
3. Identification of potential alternatives to agricultural burning and characterization of their agronomic, environmental, health and safety, social, economic, and political impacts;
4. Development of criteria for selecting reasonable non-burning alternatives, cost-abatement curves (i.e., cost of alternative by crop) and examples of

how to apply the criteria and cost-abatement curves to evaluate alternatives;

5. Identification of existing and potential accountability mechanisms for tracking if, and which, non-burning alternatives are used by local, state, tribal, or federal entities;

6. Identification of existing and potential barriers to the use of alternatives, including non-statutory barriers (e.g., public acceptance, cultural practices, etc.), and recommendations on how these can be overcome;

7. Development of a plan for implementing a non-burning program based on the analysis, findings, and recommendations developed under this project.

The purpose of this report is to document the approach used and results of the work conducted to address Objectives 1, 2, and 3. (Work on the GIS database [Objective 2] is still in progress and only preliminary results are presented in this report. The final database containing both crop production and agricultural burning data will be included with the final Task 1 report.)

The work to address Objectives 1, 2, and 3 was performed under Task 1 of Western Governors' Association (WGA) Contract 30203-31 by Eastern Research Group, Inc. (ERG) and Enviro-Tech Communications (ETC). The focus of Task 1 is mainly on data collection and compilation to support future work to be conducted to address Objectives 4 though 7.

2.0 CROP PRODUCTION IN THE 15 WESTERN STATES

Information on the amount, type, and location of crops grown in the 15 Western states forms the foundation for quantifying the amount of agricultural burning that occurs, the basis for an analysis of the alternatives to burning, and their impacts. Quantification of crop production is followed by identification and quantification of residues, or fuels subject to agricultural burning. In this project we compiled crop production data into spreadsheets, then converted the spreadsheets into a geographic database for purposes of mapping crop production (and eventually agricultural burning) data at the county level for the 15 Western states. This section describes the sources of information used to develop the database of crop production statistics for 1996/1997, how they were compiled and checked, and the results of the compilation.

2.1 Sources of Crop Production Data

The three sources of data used to compile crop production data for the 15 Western states are described next. In general, all of these sources rely on surveys from a sample of farms and ranches within their geographical jurisdiction that result in county-level statistics. Crop production on tribal lands are included in these county-level statistics.

2.1.1 National Agricultural Statistics Service Database

The National Agricultural Statistics Service (NASS) Database was the first data source to be reviewed and compiled. The NASS is under the administrative jurisdiction of the U.S. Department of Agriculture (USDA). The NASS annual county data for 1996 were downloaded from the NASS "Published Estimates Data Base" (PEDB) (NASS, 1996a). The county-level data in the PEDB are based on surveys from a sample of farms and ranches. Surveys are conducted in a variety of ways including mailed questionnaires, telephone interviews, face-to-face interviews, and field observations. The types of information that were obtained from the PEDB for use in the project included:

- Commodity (crop type);
- Year (1996);

- State name;
- County name;
- State Federal Information Processing Standards (FIPS) code;
- District code (i.e., three-digit code for state-defined regions comprising multiple counties);
- County FIPS code;
- Harvested acres;
- Planted acres;
- Yield (quantity of crop produced per acre);
- Yield units (e.g., BU=bushels, CWT=hundred weight, BAL=bales, etc.);
- Production (Harvested acres x Yield); and
- Production units (generally the same as yield units).

Priority was given to collecting complete data for Harvested Acres. No attempt was made to search for and fill data gaps for Planted Acres, Yield, and Production since these data are not as relevant to the study as are Harvested Acres.

2.1.2 State Agricultural Statistics and Reports

Second, state agricultural statistics data and reports for 1996 were obtained from state links provided on the NASS website (NASS, 1996b). The state statistics and reports served as a secondary data source for identifying data on crops not reported by NASS. Additional data for California were obtained from "1996 Agricultural Commissioners' Data Report" (CDFA, 1997) and the reports link found on the California Agricultural Statistics Service (CASS) website (CASS, 1996). The state total production quantities for each crop from the state data were compared to the NASS state totals to help identify erroneous data or errors that may have occurred during data download or manipulation.

2.1.3 1997 Census of Agriculture

Third, the 1997 Census of Agriculture was reviewed (NASS, 1999). The NASS compiles the agricultural census every five years, with 1997 being the most recent year available. The census contains information on the market value of agricultural products sold, farms by market value, land use, selected crops harvested, and production expenses. The census data provided county-level crop data for crops not found in the PEDB or the state statistics publications; however, the census data were least preferred because they represented 1997 instead of 1996, which is the target year for this project.

2.2 Crop Production Data Compilation and Gap Filling

Crop data were collected by downloading electronic files and obtaining hard-copy reports from the NASS and state agricultural services. The steps for collecting crop data, along with filling data gaps were as follows:

1. Crop data for 1996 were downloaded from the NASS website for all crops, at the county level, for each of the 15 states;

2. Microsoft© Excel spreadsheets were developed from the NASS data for each state;

3. In some cases, crop totals were reported as "combined counties" totals. In these cases, the "combined counties" data were disaggregated to the county level according to the following procedure:

    a. When a district contained some county-level data and a "combined counties" total, then the harvested/planted/production quantities were distributed over the counties with no production shown. However, if distribution would have resulted in 100 or less acres harvested for a given county, then the harvested/planted/production quantities were added to these totals for the county in the combined county's district with the largest number of harvested acres.

    b. When a district contained only "combined counties" total (i.e., no county-level data were shown), then the harvested/planted/production quantities were distributed evenly over all counties in the district. However, if distribution would have resulted in 100 or less acres harvested for a given county, then the quantities were distributed evenly over the two, three, or four counties adjacent to counties in neighboring districts having the largest number of harvested acres.

c. Recalculated yields (e.g., bushel/acre, tons/acres) whenever production quantities were distributed.

4. Data from the individual states' databases and or hard-copy reports were compared to the NASS data to identify missing crops or incorrect values. Preference was given to state data if differences greater than 15% were found.

5. Data from the 1997 Agricultural Census were used in the absence of 1996 data to fill in any top 10 crops for each state (i.e., top 10 in terms of acres harvested in 1997) that may not have been collected by the NASS or states;

6. Crops (i.e., residues) known to have been burned since 1996 were identified from surveys made by the Western States Air Resources Council (WESTAR) and the WRAP/FEJF (WESTAR, 1999; WRAP, 2001a). Data from the 1997 Agricultural Census were used to fill in data gaps for crops burned for which state/county data were not previously collected.

7. Spreadsheets were imported into a single Microsoft© Access 1997 (hereafter Access) database. (Details on database development are described in Section 2.5, below.)

The following issue should be noted with regard to the individual wheat categories (i.e., all, winter, spring, and durum) and hay categories (i.e., all, alfalfa, and other) contained in the compiled database. The total of wheat/winter, wheat/spring, and wheat/durum acreage may not sum to the wheat/all acreage for a given county. This anomaly is due to the combined effect of two factors: First, some of the NASS data could not be reconciled on the county level. Second, data for "combined counties" were disaggregated to specific counties. The same situation applies to hay. Although the wheat and hay types may not sum to the wheat/all or hay/all at the county-level, they <u>do</u> sum at the district- and state-level. This issue was discussed with the WRAP/FEJF Project Manager and it was agreed that it is adequate to have reconciliation at the district-level (Jenkins, 2001). Also, it was decided that for GIS mapping purposes, the data for the individual wheat and hay types will be mapped, and not the data for wheat/all and hay/all.

Table 2-1 shows the crop production data collected for each of the 15 Western states. This table represents the universe of crop production data and includes the top 10 crops grown in each state (i.e., most acres harvested) as well as other crops (i.e., data available in NASS and/or known to be burned but not necessarily part of the top 10 category). Table 2-2

Table 2-1. Crops Harvested During 1996/1997 in the 15 Western States

Crop Types	AK	AZ	CA	CO	HI	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Field Crops:															
Barley	✔	✔	✔	✔		✔	✔	✔		✔	✔	✔	✔	✔	✔
Beans, Dry Edible			✔	✔		✔	✔	✔					✔	✔	✔
Canola														✔	
Corn for Grain		✔	✔	✔		✔	✔	✔	✔		✔	✔	✔	✔	✔
Corn for Silage		✔	✔	✔		✔	✔	✔	✔			✔	✔	✔	✔
Cotton, Upland and American Pima		✔	✔						✔						
Flaxseed								✔				✔			
Hay, All	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Hay, Alfalfa	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Hay, All Other	✔	✔	✔	✔			✔	✔	✔	✔	✔	✔	✔	✔	✔
Hops														✔	
Lentils						✔									
Oats	✔		✔	✔		✔	✔	✔			✔	✔	✔	✔	✔
Peas, Dry Edible			✔			✔								✔	
Proso Millet				✔								✔			
Rice			✔												
Rye								✔				✔			
Safflower			✔												
Sorghum		✔	✔	✔					✔			✔			
Soybeans								✔				✔			
Wheat, All		✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Wheat, Durum		✔	✔				✔	✔				✔			
Wheat, Other Spring				✔		✔	✔	✔		✔		✔	✔	✔	✔
Wheat, Winter All		✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Orchard Crops:															
Almond			✔												
Apple		✔	✔						✔		✔		✔	✔	
Apricot			✔												
Avocado			✔												
Cherry			✔								✔		✔	✔	
Citrus		✔	✔												
Fig			✔												
Filbert											✔				
Grape		✔	✔								✔			✔	
Kiwi			✔												
Macadamia Nut					✔										
Nectarine			✔												
Olive			✔												
Peach		✔	✔								✔		✔	✔	
Pear		✔	✔								✔			✔	
Pecan			✔						✔						
Persimmon			✔												
Pistachio			✔												

Table 2-1. Continued

Crop Types	AK	AZ	CA	CO	HI	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Plum and Prune			✔								✔			✔	
Walnut			✔												
Fruits and Vegetables:															
Asparagus			✔											✔	
Blueberries														✔	
Pineapple					✔										
Other[1]	✔	✔	✔		✔				✔	✔	✔		✔		
Grasses and Seeds:															
Alfalfa, Seed		✔	✔	✔		✔	✔			✔	✔	✔	✔	✔	✔
KBG, Seed						✔	✔				✔			✔	
Other, Seed[2]		✔	✔	✔		✔	✔				✔	✔	✔	✔	✔
Other:															
Coffee					✔										
Mint						✔					✔				
Peanuts			✔						✔						
Potatoes	✔	✔		✔		✔	✔	✔	✔	✔	✔		✔	✔	✔
Sugarcane					✔										
Sugarbeets			✔	✔		✔	✔	✔			✔			✔	✔
Sunflowers				✔				✔				✔			

Sources: See Table 2-2
[1]Fruits/vegetables "other" = cabbage, carrots, lettuce, tomatoes, green peas, sweet corn, snap beans, dry onions, melons
[2]Field/Grass seed "other" = fescue, red clover, ryegrass

Table 2-2. Sources of Data for Main Crops Harvested in 1996/1997 in the 15 Western States

	AK	AZ	CA	CO	HI	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY
Field Crops:															
Barley	1	1	1	1		1	1	1		1	1	1	1	1	1
Beans, Dry Edible			1	1		1	1	1					1	1	1
Canola														4	
Corn for Grain		1	1	1		1	1	1	1		1	1	1	1	1
Corn for Silage		1	1	1		1	1	1	1			1	1	1	1
Cotton, Upland and American Pima		1	1						1						
Flaxseed								1				1			
Hay, All	4	1	4	1	1	1	1	1	1	1	1	1	1	1	1
Hay, Alfalfa	4	1	4	1	1	1	1	1	1	1	1	1	1	1	1
Hay, All Other	4	1	4	1	1		1	1	1	1	1	1	1	1	1
Hops														1	
Lentils						4									
Oats	1		1	1		1	1	1			1	1	1	1	1
Peas, Dry Edible			3			4								4	
Proso Millet				4								4			
Rice			1												
Rye								1				1			
Safflower			3												
Sorghum		1	3	1					1			1			
Soybeans								1				1			
Wheat, All		1	1	1		1	1	1	1	1	1	1	1	1	1
Wheat, Durum		1	1				1	1				1			
Wheat, Other Spring		1	1	1		1	1	1		1		1	1	1	1
Wheat, Winter All															
Orchard Crops:															
Almond			2												
Apple		4	3						4		4		4	2	
Apricot			3												
Avocado			3												
Cherry			3								4		4	4	
Citrus		4	3												
Fig			3												
Filbert											3				
Grape		2	3								4			4	
Kiwi			3												
Macadamia Nut					2										
Nectarine			3												
Olive			3												
Peach		4	3								4		4	4	
Pear		4	3								4			4	
Pecan			3						4						
Persimmon			3												
Pistachio			2												

Table 2-2. Continued

Plum and Prune			3											4	
Walnut			2								4				
Fruits and Vegetables:															
Asparagus			3											4	
Blueberries														4	
Pineapple					2										
Other	1	4	3		2				4	4	1		4	4	
Grasses and Seeds:															
Alfalfa, Seed		4	3	4		4	4			4	4	4	4	4	4
KBG, Seed						4	4				4			4	
Other, Seed		4	3	4		4	4				4	4	4	4	4
Other:															
Coffee					2										
Mint						4					4				
Peanuts			3						1						
Potatoes	1	1		1		1	1	1	1	1	1		4	1	4
Sugarcane					1										
Sugarbeets			1	1		1	1	1			1			1	1
Sunflowers				1				1				1			

Data Sources:

1 = 1996 NASS Published Estimates Database (NASS, 1996a)

2 = State statistics database (NASS, 1996b)

3 = Other state data and reports (CASS, 1996; CDFA, 1997)

4 = 1997 Agricultural Census (NASS, 1999)

shows the sources of the data used for each crop for each state according to the compilation procedure described above.

2.3 QA/QC Procedures

The quality assurance/quality control (QA/QC) procedure was developed based on U.S. EPA's QA/QC document (EIIP, 1997). The purpose of this procedure is to ensure that the following data quality objectives for the crop database for the 15 Western states are met:

- To account for the major crops grown in each state, at the county level for 1996. *Metric*: collect county-level data for the top 10 crops (based on total acres harvested) in each state. For states with fewer than 10 crop types (e.g., Alaska and Hawaii), collect data for all of the crops comprising 90% of all acres harvested.
- To account for all crops subject to agricultural burning in each state, at the county level for 1996. *Metric:* Collect county-level data for all crops that are subject to agricultural burning.
- To account for acres harvested and production quantities for crops meeting objectives 1 and 2. *Metric:* Acres harvested compare across alternative data sources within ±15% accuracy.

The applicable functions of the types of QA/QC methods employed are shown in Table 2-3. The QA/QC methods shown on Table 2-3 were employed both before and after the crop production spreadsheets were converted into Access. How these methods were used to evaluate the crop data are described below.

2.3.1 Reality Checks: Compare Data to Standard Reference Value

The crop data compiled from the 1996 NASS were compared to the 1996 data in the state agricultural statistics annual reports. Any NASS data more than ±15% different from state data will be corrected to the state value(s).

Table 2-3. Summary of QA/QC Methods Used to Evaluate Crop Production Data

Method	Ensure Completeness of Data	Ensure Reasonableness of Data	Ensure Validity of Data and Assumptions	Ensure Mathematical Correctness	Ensure Accuracy of Data
Reality checks	✓	✓			
Peer Review	✓	✓	✓		
Sample Calculations			✓	✓	✓
Computerized Checks			✓	✓	✓
Independent Audits	✓	✓	✓	✓	
Validation	✓	✓	✓		✓

For each state, Table 28 of the 1997 Agricultural Census (i.e., "Specified Crops by Acres Harvested") was used to rank the top 10 crops based on acres harvested during 1997. These data were compared to the NASS data to ensure that the top 10 crops for each state are consistent between 1996 and 1997. If any top 10 crops are missing, we obtained data for the missing crops based on the following data sources (in order of preference):

- State agricultural statistics reports for 1996;
- Other references for 1996; and
- 1997 Census of Agriculture.

The WESTAR agricultural burning survey and FEJF agricultural burning survey (WESTAR, 1999; WRAP, 2001a) were reviewed to determine the types of crops burned since 1996. New crops' production were added to the data set in order to account of all burned crops grown in a state, even if they are not among the top 10.

2.3.2 Peer Review: Checklist or Written Comments by Reviewer

Notes were kept on the data sources used to compile each state's crop data, gap-filling techniques, and corrected errors. Notes were made on hard copies of the draft crop data spreadsheets for future review. A complete listing of data sources used are included within this Task 1 draft report. Additionally, information on data sources will be included in the metadata files describing the details of the crop database to be used in the GIS (see Section 2.5, below).

To ensure the completeness and reasonableness of the data collected (i.e., top 10 crops in each state and all crops that could potentially be burned), the database was distributed to members of the FEJF for review of their respective states. A "Peer Reviewers Checklist" was provided to facilitate consistent and useful comments from the reviewers. The peer review is still underway, and any changes resulting from peer reviewer comments will be reflected in the final version of the crop production database.

2.3.3 Sample Calculations: Replication of One Set of Calculations

Generally, calculations related to the crop data were not performed; however, some simple calculations were performed to ensure mathematical correctness and accuracy of data. For example, county-level crop data were summed to ensure that county totals sum to district and state totals reported in the data sources.

2.3.4 Computerized Checks: Electronic Methods of Checking or Verifying Data

Completeness and consistency checks were performed on the crop data. These were conducted on specific data elements as follows:

- County and state names and FIPS codes were checked against those included in the GIS database to ensure consistency of spelling and codes;
- Tables indexing crop names were developed and compared to ensure consistency in crop names among states; and
- After spreadsheets were imported into one database, the totals for acres harvested and production quantity were summed to ensure these totals matched the "State Total" data for each crop by county.

2.3.5 Independent Audits: Systematic Evaluation to Determine the Quality of the Database

The WRAP/FEJF Project Manager is currently conducting an independent audit of the crop database to:

- Evaluate the effectiveness of the technical and quality assurance procedures used to develop the data;
- Help ensure the completeness and accuracy of the data;
- Determine whether data quality objectives are being met; and
- Determine the need for additional QA/QC measures.

The WRAP/FEJF Project Manager will report the findings of his audit to the FEJF and ERG/ETC. We will make changes to the data or procedures as deemed necessary to meet the data quality objectives.

2.3.6 Validation: Comparison of Estimates to Real-World Measurements (or Surrogates)

Validation of the crop data compiled under this project can be conducted in two ways:

1. The crop data could be compared to actual field observations. However, this is not a feasible exercise considering the time and budget constraints of this project.
2. The knowledge possessed by many of the state representatives on the FEJF could be used in lieu of actual field observations to:
    a. Ensure the major crops are accounted for;
    b. Ensure the crops that could potentially be burned are accounted for; and
    c. Provide additional reality checks on the values of acres harvested, acres planted, production, and the location of the crops by county.

The review shown in the second step is currently being conducted by FEFJ and states' representatives. Any changes resulting from comments received by the reviewers will be reflected in the final version of the crop production database.

2.4 Results of Compiled Crop Data

Table 2-4 shows the number of acres harvested for the top 10 crops within each of the states. The crops shown on Table 2-4 are grouped by the categories of "Cereals and Grains," "Orchard Crops," "Grasses and Seeds," and "Other." These categories, which are different than those shown in Table 2-1, are used to facilitate development of fuel categories to be used in later analyses. Table A-1 in Appendix A shows state crop production data in terms of acres harvested for all crops for which data were collected.

As Table 2-4 shows, the greatest production of crops in terms of acres harvested is in the "cereals and grains" category, with hay and wheat varieties comprising the most acres. Although orchard crops and grasses and seeds make up a relatively smaller portion of the top 10 crops harvested, these are important crops to consider with regard to non-burning alternatives since their residues are widely burned in the West. The states of North Dakota, South Dakota,

Table 2-4. Summary of Acres Harvested of the Top 10 Crops Within the 15 Western States for 1996/1997

	AK	AZ	CA	CO	HI	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY	TOTAL
Grains and Hay:																
Barley	6,900	54,000		92,000		730,000	1,150,000	2,600,000		5,000	150,000	145,000	100,000	440,000	120,000	**5,592,900**
Corn; For Grain		40,000		890,000			15,000	600,000	84,000		37,000	3,650,000	20,000	120,000	50,000	**5,506,000**
Corn; For Silage			275,000	90,000		68,000	39,000		44,000			320,000	40,000		33,000	**909,000**
Hay; Alfalfa	3,801	160,000	944,056	860,000		1,000,000	1,700,000	1,700,000	250,000	250,000	460,000	2,500,000	545,000	490,000	620,000	**11,482,857**
Hay; All Other	20,222	19,000	754,717	650,000			900,000	1,200,000	100,000	230,000	610,000	1,800,000	160,000	310,000	600,000	**7,353,939**
Oats	700						50,000	380,000			35,000	360,000	9,000		32,000	**866,700**
Proso Millet				125,765												**125,765**
Rice			500,000													**500,000**
Sorghum		45,000		260,000					225,000			145,000				**675,000**
Wheat; Durum		164,000					280,000	2,940,000								**3,384,000**
Wheat; Other Spring						700,000	4,100,000	9,500,000		10,000	105,000	2,250,000	25,000	395,000	26,000	**17,111,000**
Wheat; Winter All			550,000	2,200,000		860,000	1,980,000		110,000	9,000	815,000	1,580,000	160,000	2,350,000	210,000	**10,824,000**
Orchard Crops:																
Almonds			400,692													**400,692**
Apples														154,930		**154,930**
Citrus		37,900	284,790													**322,690**
Grapes			721,505													**721,505**
Pecans									23,188							**23,188**
Grasses and Seeds:																
Seeds; Alfalfa										11,731						**11,731**
Seeds; Other											513,246					**513,246**
Other:																
Fruits and Vegetables	343	28,800	777,358		13,120				38,375	4,415			6,695	189,269		**1,058,375**
Beans; Dry Edible				125,000		93,000		570,000					5,201		31,000	**824,201**
Coffee					5,400											**5,400**
Cotton; Upland		314,000	995,000						55,000							**1,364,000**
Cotton; American Pima		41,900														**41,900**
Lentils						65,540										**65,540**
Macadamia Nuts					20,200											**20,200**

Table 2-4. Continued

	AK	AZ	CA	CO	HI	ID	MT	ND	NM	NV	OR	SD	UT	WA	WY	TOTAL
Mint											45,221					**45,221**
Peanuts									16,500							**16,500**
Peas; Dry Edible						71,507								126,975		**198,482**
Pineapple					20,000											**20,000**
Potatoes	630					413,000				6,999	61,000			161,000		**642,629**
Soybeans								845,000				2,670,000				**3,515,000**
Sugarbeets						184,000	57,500								56,800	**298,300**
Sugarcane					42,900											**42,900**
Sunflower				107,000				1,165,000				690,000				**1,962,000**
Total	**32,596**	**904,600**	**6,203,118**	**5,399,765**	**101,620**	**4,185,047**	**10,271,500**	**21,500,000**	**946,063**	**527,145**	**2,831,467**	**16,110,000**	**1,070,896**	**4,737,174**	**1,778,800**	**76,599,791**

Data Sources:

1996 NASS Published Estimates Data Base (NASS, 1996a)
State statistics databases (NASS, 1996b)
Other state data and reports (CASS, 1996; CDFA, 1997)
1997 Agricultural Census (NASS, 1999)

and Montana have the most acres harvested, primarily wheat. Although California ranks fourth in terms of top 10 crops harvested, it is an important state with regard to the individual top 10 crops harvested because their residues are widely burned (e.g., residues from orchard crops, especially almonds and walnuts).

2.5 Development of the Geographic Database

The first step in the development of the geographic database was to import the crop production data. As noted in Section 2.2, Excel spreadsheets containing county-level crop production data (based on data from NASS and state agricultural services) were imported into Access. Before they were imported, a check was performed to ensure that all the Excel spreadsheets had the same fields (those listed in Section 2.1), as well as a field indicating whether data had been disaggregated from a district total or combined-counties total to individual counties. After the files were imported, a check was performed to ensure that the number of records present in the Access database was equal to the number of records in the Excel spreadsheets.

A field called FIPS was then added to each record in the database, representing a concatenation of the two-digit state FIPS code and the three-digit county FIPS code. The reason for this is because the ArcView GIS software associates each state and county with a 5-digit FIPS code. The addition of the 5-digit FIPS code to the Access database allows each record in the database to be linked to ArcView geographic data files representing the locations of each state and county. Then an Access query was used to compare the state name, county name, and 5-digit FIPS codes used in ArcView to the state name, county name, and 5-digit FIPS codes present in the Access database. Discrepancies were corrected using the U.S. EPA's master list of FIPS codes (USEPA, 2001c).

Additional QA/QC procedures that were performed included the following:

- Access queries were used to sum the total acres planted, acres harvested, and production for an individual crop in all the counties within a state and to compare this sum to the record in the database showing the state total acres planted, acres harvested, and production. In cases where discrepancies arose, they were corrected by referring to the source data.

- Access queries were used to verify that only one record for each crop type in each individual county was present in the database. In cases where discrepancies arose, they were rectified based on consulting the source data.

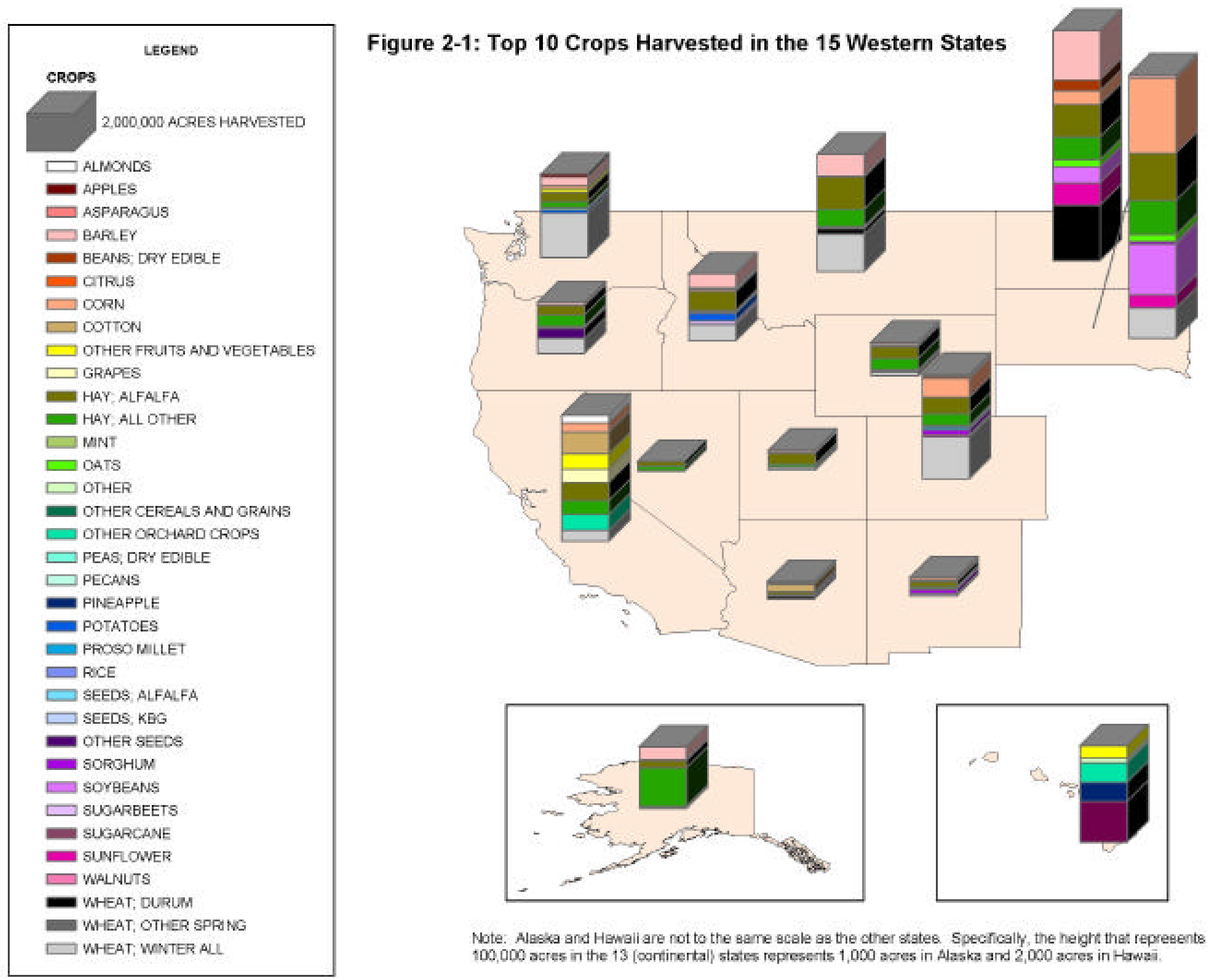
The final Access crop production database will be included in Appendix A of the Task 1 final report (i.e., after peer review comments are addressed; see Section 2.3, above). Also, a complete metadata file describing the data sources, gap filling techniques, and other relevant details of the database will be included with the final version.

In order to develop maps that would show the top 10 crops in each state and county, Access was programmed to generate a "GIS crop production summary table" that listed each state and county down the rows and all the available crops for which data was collected across the columns, filling the cells with the number of acres harvested for the appropriate crop in the appropriate county (or state as a whole) with the data present in the Access database. A version of this table (the "GIS Top 10 table") was created that showed only the acres harvested for the Top 10 crops grown in a county (or state as a whole), leaving the remaining cells blank. This second table was imported into ArcView and linked to the program's geographic data files representing the locations of each state and county based on matching 5-digit FIPS codes.

A draft map showing the top 10 crops in all 15 Western states is included as Figure 2-1. This map (as well as the state-specific maps that show the Top 10 crops in each county) uses the "GIS Top 10 table" to generate legends that show the relative number of acres harvested for each state (or county). Any comments received on Figure 2-1 will be addressed before the 15 maps (one for each WRAP state) showing the top 10 crops harvested in each county are produced.

Also, the crop production data will be used in development of the estimates of total residue and total residue burned (described in detail in Section 3.0 of this report). The "GIS crop production summary table" will be combined with agricultural burning data, imported into ArcView, and linked to the program's geographic data files. The resulting database will contain a complete set of crop production and agricultural burning activity data for the 15 Western states.

Figure 2-1: Top 10 Crops Harvested in the 15 Western States



Note: Alaska and Hawaii are not to the same scale as the other states. Specifically, the height that represents 100,000 acres in the 13 (continental) states represents 1,000 acres in Alaska and 2,000 acres in Hawaii.

3.0 AGRICULTURAL BURNING ACTIVITY IN THE 15 WESTERN STATES

An important goal of this project is the development of an agricultural burning database for the 15 Western states. This database, which will be linked to the crop production database, will provide information on crop residues (total generated and total burned) by county for two purposes:

1. To identify the extent to which agricultural burning occurs, types of crops burned, and the location (i.e., county, region, state) and time (i.e., season, month, and day if feasible) when burning occurs and facilitate the evaluation of alternatives to burning and their impacts;
2. To provide county-level and sub-county level (if feasible) data on residue burned for estimating emissions from agricultural burning in the 15 Western states.

This section describes the sources of information available to develop the agricultural burning database of crop production statistics for 1996/1997, how they are being compiled, gap-filled, and checked. The design for the database is provided, and the data collected to date are presented. It is anticipated that the agricultural burning database will be completed during July 2001. The completed database will be presented in the final version of this report.

3.1 Sources of Agricultural Burning Data

The types of data needed to characterize agricultural burning include amount of residue burned and/or number of acres burned, by crop. The time of the burn is necessary, with the day of the burn being most desirable, but the season and/or month of the burn is sufficient. Also, the location of the burn is required; address or section (township and range) is best, but county location is sufficient.

Obtaining agricultural burning data presents a significant challenge. First, only a few states have organized smoke management programs that track actual burn activity. Some states can provide agricultural burning activity data based on information collected for their emissions inventories. Also, anecdotal information is available for a few other states in the form of responses to surveys conducted by the WESTAR and the WRAP/FEJF (WESTAR, 1999; WRAP, 2001a), and on-going research being conducted by ERG/ETC.

The agricultural burning data compiled to date are from the following sources, in order of completeness and relevancy to this project:

- Agricultural burning database for San Joaquin Valley of California compiled by the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) (SJVUAPCD, 2001);
- Agricultural burn permit database and summary spreadsheet for Washington State compiled by the Washington State Department of Ecology (WDOE, 2001a, WDOE, 2001b);
- Emissions inventories for agricultural burning (containing data on acres or residue burned by crop, by county) developed by the state Departments of Environmental Quality in Oregon, Idaho, and Utah (ODEQ, 2001; IDEQ, 2001; UDEQ, 2001);
- Agricultural acres burned in the Sacramento Valley (Fife, 2001);
- Information (e.g., state-wide totals of acres burned by crop, seasons, or months when certain crops are burned, etc.) taken from the WESTAR Agricultural Burning Survey (WESTAR, 1999) and the WRAP/FEJF Agricultural Burning Smoke Management Program Survey (WRAP, 2001a);
- Information related to agricultural burning on tribal lands (i.e., whether or not agricultural burning occurs on reservations within the WRAP region) taken from the draft WRAP/FEJF report entitled "Tribal Emissions Inventories and Air Quality Data Gathering and Assessment Project" (WRAP, 2001b); and
- Anecdotal information gathered during telephone interviews of various state environmental and agricultural agencies by ERG/ETC, which are on-going. (A complete list of agencies and individuals contacted will be provided in the Task 1 final report.)

As mentioned above, efforts pertaining to agricultural burning data collection are still underway. However, we estimate that we have obtained nearly all of the data, including anecdotal information, that are available. For this reason, we devised a data gap filling procedure to provide the necessary data to complete the database. Any additional information obtained through our investigation that is relevant to other tasks under this project will be incorporated into the database as appropriate. The results of the data compilation and the gap filling techniques are discussed next.

3.2 Agricultural Burning Data Compilation

Agricultural burning data were collected by downloading electronic files provided by the various agencies listed above, and augmented with anecdotal information from our research efforts. A summary of the data collected to-date are shown in Table 3-1.

Table 3-1 shows the availability of data documenting actual burn activity is very limited. The most complete set of data is CA(1) because it contains information on the exact location (address) and day of each specific burn. In fact, the CA(1) data also give the time of the burn. CA(1) covers seven (and a portion of an eighth) counties within the San Joaquin Valley Air Basin. Other fairly complete sets of data include CA(2) (covering 10 counties within the Sacramento Valley Air Basin), and the ID, OR, UT, and WA data sets, all of which provide county-level acres or residue (OR only) burned by month. The AZ, CA(3), and NV data are only for one county within each state, and the HI and WY data provide statewide acres burned by crop (HI is for sugarcane, only).

The timeframes for the burn data vary from 1996 only, to data for 1996 through 2001. Priority is given to 1996 data because that is the year of the crop production data and the WRAP's base year emissions inventory. However, it will be necessary to use other years if 1996 data do not exist or are thought to be incomplete or less accurate than later years. For example, we know from conversations with SJVUAPCD, that although 1996 data are available in the CA(1) data set, 1999 data are much preferred due to improvements in data collection and management procedures. The magnitude of agricultural burning has been fairly constant during the years 1996-2000 based on the data sets reporting multiple years. Therefore, mixing years of burn data will not introduce significant error into the resulting emissions calculations. We will document the years of the data used within the final database.

Even though the survey of burning activity by tribes in the WRAP region provided insight into the types of burning that occur on tribal lands (i.e., range, agricultural, and wildland), the survey does not provide sufficient detail to allow quantification of burning in terms of acres or residue. However, the survey results show that of the 76 tribes that conduct prescribed burning, only 45 conduct agricultural burning. Of the 45 respondents/reservations

Table 3-1. Summary of Agricultural Burning Data Available for the 15 Western States

		Available Agricultural Burning Activity Data										
Type of Data	**Units/ Format**	**AZ**	**CA(1)**	**CA(2)**	**CA(3)**	**HI**	**ID**	**NV**	**OR**	**UT**	**WA**	**WY**
Acres Burned	Acres	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Year Burned	YY	1997	1999	1996-2000	1997	1996	1996	1996	1996	1996	1996-2000	1996
Month Burned	MM	✓	✓	✓	✓	✓	✓	✓		✓	✓	
Day Burned	DD		✓									
Residue Burned	Tons								✓			
Spatial Resolution		County	Address	County	County	State	County	County	County	County	County	State

Source List:
AZ: WESTAR, 1999 (Yuma County, only).
CA(1): Agricultural burning database for San Joaquin Valley (SJVUAPCD, 2001).
CA(2): Agricultural burning spreadsheet for Sacramento Valley (Fife, 2001).
CA(3): WESTAR, 1999 (Lake County, only).
HI: WESTAR, 1999 (statewide, but distribution to counties/islands can be made based on acres harvested).
ID: 1996 Agricultural burning emissions inventory (IDEQ. 2001).
NV: WRAP, 2001a (Lovelock County); grain stubble and alfalfa seeds, only.
OR: 1996 Agricultural burning emissions inventory (ODEQ, 2001).
UT: 1996 Agricultural burning emissions inventory (UDEQ, 2001).
WA: Agricultural Burning Permit Database and spreadsheet (WDOE, 2001a; WDOE, 2001b).
WY: WESTAR, 1999 (statewide, but distribution to counties can be made based on acres harvested).
✓ Data are available.
Blanks indicate that data are not available.

conducting agricultural burning, the survey categorizes the reasons for burning as weed abatement and ditch and canal clearing. Only one survey respondent mentioned a crop type (i.e., “stubble”). Thus, it can be concluded that agricultural burning on tribal lands is relatively insignificant compared to agricultural burning on public or private lands.

Another important type of data that is needed to estimate quantities of residues burned is residue loading factors. By multiplying the acres harvested of a particular crop (acres) times the residue loading factor for that crop (tons/acres), a reasonable estimate of residue (tons) remaining after harvest can be made. A summary of these factors, which are based on various studies and research into the yields of residue by harvest of specific crops, is shown in Table 3-2. The factors shown on Table 3-2 come from several sources including research by CARB (CARB, 2001), Jenkins and Sumner (1986), and references provided by Idaho Department of Environmental Quality (DEQ) (i.e., Idaho Mint Growers Association and Intermountain Grass Growers Association). ERG/ETC is still attempting to obtain residue loading factors for hops, blueberries, canola, and pineapple. If these factors are ultimately not available, then we will make reasonable assumptions to assign factors from similar crops.

3.3 QA/QC Procedures

A QA/QC procedure similar to that employed for the crop production data is being developed for the agricultural burning data. (see Section 2.3 of this report). The purpose of this procedure is to ensure that the following data quality objectives for the agricultural burning database:

- To account for all crop residues that were actually burned within states in the WRAP region based on actual burn data compiled by state agencies at the county level for 1996 or other years (1997-2000). *Metric:* Collect available county-level data for all crops that are subject to agricultural burning that represents at least 90% of the data available.
- Develop a procedure to estimate crop residues burned within states in the WRAP region for which data do not exist. *Metric:* Estimates of crop residues burned compare to estimate by state peer reviewers within ±25% accuracy.

Table 3-2. Residue Loadings (Tons/Acre) for Crops Burned in the 15 Western States

Crop Type	States Where Crops are Burned	Residue Loading (tons/acre)	Comments/Sources
Field Crops:			
Barley	CA, ID, MT, UT, WA, WY	1.70	
Corn	CA, UT, WA	4.20	
Hay, All	CA, UT, WA	0.80	Assume same as hay; alfalfa
Hay, Alfalfa	WA	0.80	
Hay, All Other	CA	0.80	Assume same as hay; alfalfa
Hops	WA		To be determined
Oats	CA, UT, WA	1.60	
Rice	CA	3.00	
Sorghum	CA	2.90	
Wheat, Other Spring	UT, WA	1.90	Assume same as wheat
Wheat, Winter All	UT	1.90	Assume same as wheat
Wheat, Unspecified	AZ, CA, ID, MT, ND, WA	1.90	
Grains/Cereals, Unspecified	CA, NV, OR, SD, WA	1.90	Assume same as wheat
Orchard Crops:			
Almond	CA	1.00	
Apple	CA	2.30	
Apricot	CA	1.80	
Avocado	CA	1.50	
Cherry	CA	1.00	
Citrus	AZ, CA	1.00	
Fig	CA	1.70	Average of all trees
Grape	CA, WA	2.50	
Kiwi	CA	1.70	Average of all trees
Nectarine	CA	1.70	Average of all trees
Olive	CA	1.70	Average of all trees
Peach	CA	2.50	
Pear	CA	2.60	
Pecan	CA, NM	1.70	Average of all trees
Persimmon	CA	1.70	Average of all trees
Pistachio	CA	1.70	Average of all trees
Plum and Prune	CA	1.20	
Walnut	CA	1.20	
Orchard residue, Unspecified	WA	1.70	Average of all trees
Fruits and Vegetables:			
Asparagus	WA	1.50	
Beans, Dry Edible	CA, WA	2.50	
Blueberries	WA		To be determined
Canola	WA		To be determined
Mint	ID, OR	0.50	Idaho Mint Growers Association via IDEQ

Table 3-2. Continued

Crop Type	States Where Crops are Burned	Residue Loading (tons/acre)	Comments/Sources
Other fruits and vegetables	CA, WA	1.47	Jenkins and Sumner, 1986 (average of all vegetables)
Peanuts	CA	1.20	Assume the same as potatoes
Peas, Dry Edible	CA, WA	2.50	
Pineapple	HI		To be determined
Potatoes	UT, WA	1.20	Jenkins and Sumner, 1986
Safflower	CA	1.30	
Sugarcane	HI	14.00	Midpoint of AP-42 (11-17 tons/acre)
Vegetables, Unspecified	CA	1.47	Jenkins and Sumner, 1986 (average of all vegetables)
Grasses and Seeds:			
Alfalfa, Seed	ID, NV, WY	0.80	1996 Agricultural Emissions Inventory by Idaho DEQ
KBG, Seed	ID, NV, WY	2.00	(Idaho) Intermountain Grass Growers Association
Other, Seed	WA, WY	2.00	Assume same as KBG
Bermuda Grass	AZ, CA	2.00	Assume same as KBG
Grass Seed, Unspecified	*WA*	2.00	Assume same as KBG
Grasses, Unspecified	OR	2.00	Assume same as KBG
Other:			
Ditches and ditch banks	AZ, CA, ID, NM, NV, WY	3.20	"Used weeds, unspecified" loading

Sources:
Residue Loading Factors: CARB, 2000 except where otherwise noted.
States where crops are burned: WESTAR, 1998; WRAP, 2001a; SJVUAPCD, 2001; WDOE, 2001a; ODEQ, 2001; IDEQ, 2001, UDEQ, 2001; Fife, 2001.

We have employed the following QA/QC procedures during the burn data collection process:

(This section to be completed for the final report)

3.4 Development of the Geographic Database

The first step in the development of the agricultural burning database was to identify the types of data to be included in the database and how they would be used to generate estimates of residue burned by crop type at the county level or sub-county level. Table 3-3 shows the data fields to be included in the agricultural burning database. These data will facilitate the calculation of amount of residue by crop by county using crop production data from the crop database and residue loading factors to be provided in a table within the database.

3.4.1 Gap Filling Techniques

For the states and counties with available burn data (see Table 3-1), records will be created for individual counties by crop with the acres burned, and the year and month of burn (day of burn available from only CA(1)). Calculations will be made to estimate percentage of acres burned and/or amount of residue burned (except for Oregon for which actual residue burned data are available). Next, a statewide average of percentage residue burned by crop will be calculated. Finally, a crop average percentage residue burned will be calculated based on the average of the statewide averages by crop.

In the cases when crop averages (i.e., average percentage residue burned for each crop) are applied to the states for which burn data do not exist, then other types of information also will be considered in order to make the application of the averages as accurate as possible. Anecdotal information from surveys (WESTAR, 1998; WRAP, 2001a), and reasonable assumptions when necessary, will be used in combination with the crop averages to populate the database for the states for which actual burn data do not exist. For example, the actual crops burned and the seasons (and months) in which burning occurs are known from the surveys for nearly every state; thus, the crop averages will be applied to each state (and county) for each crop type and month as applicable.

Table 3-3. Description of the Agricultural Burning Database for the 15 Western States

Database Fields		**Units/ Format**	**Data Source or *Calculation***		
COMM	Commodity or crop		Crop database		
YR_HAR	Year harvested	YY	Crop database		
STATE	State name		Crop database		
StFips	State FIPS code	##	Crop database		
COUNTY	County name		Crop database		
CoFips	County FIPS code	###	Crop database		
AH	Acres harvested	Acres	Crop database		
RL	Residue loading	Tons/Acre	AP-42, ARB, other		
RES[1]	Amount of residue	Tons	*AH x RL*		
			For: CA(1), CA(2), WA, ID, UT, Partial States[2]	**For: OR**	**For: Remaining States**
A_BURN	Acres burned	Acres	Actual data	N/A	N/A
%BURN	% of acres burned		*A_BURN/AH*	N/A	N/A
Year	Year burned	YY	Actual data	Actual data	Anecdotal information or assumption
Month	Month burned	MM	Actual data	Actual data	Anecdotal information or assumption
Day	Day burned	DD	CA(1) only	N/A	N/A
R_BURN[1, 3]	Residue burned	Tons	*RL x A_BURN*	Actual data	*RES x CR_AVG_%BURN*
ST_AVG_%BURN	State average % burned by crop		Average of all %_BURN by crop[4]		
CR_AVG_%BURN	Crop average % burned		Average of all ST_AVG_%BURN by crop[4]		

Notes:
[1]Data will be mapped on a county or sub-county basis (if feasible) for the states of CA, ID, OR, WA, and UT.
[2]Partial states include acres burned for specific counties and/or crops in AZ, CA(3), HI, NV, and WY. See Table 3-1 for details on the types of data available for these states.
[3]Data will be linked with BELD3.1 data to resolve to 1km parcels or sub-county regions (if feasible) for all states. Resulting dataset will be submitted to the FEJF/Emissions Task Team in an Excel spreadsheet.
[4]ST_AVG_%BURN and CR_AVG_%BURN will be calculated based on data from CA(1), ID, OR, UT, and WA because these are the most complete data sets available and will most likely provide the best averages of residue burned by crop.
N/A: Not applicable

Also, surveys and other information collected under this project will be used to identify any state or county bans on burning to ensure that crop averages are not applied inappropriately. Finally, regional similarities (or differences) in agricultural burning activity will be considered before applying the crop averages. For example, crop averages developed from UT and WY may be more appropriate to apply to CO than crop averages developed from the other sets of data. Also, when anecdotal information is available for one state (e.g., South Dakota) but not for a neighboring state (e.g., North Dakota) then available information for the first state would be assumed to be the same for the neighboring state.

3.4.2 Integration of BELD3.1 Database

It is desirable to determine the location of agricultural burning on a sub-county level in order to provide the basis for a spatially accurate emissions inventory and eventual ambient air quality modeling analysis. The agricultural burning database described above has been designed to report amounts of residues produced and burned by crop on the county level. However, data contained within the Biogenic Emissions Landuse Database (BELD), version 3.1 can be used to estimate agricultural land use at a 1 kilometer (km) resolution.

The percentage of agriculture in each 1 km parcel will be multiplied by the percentage of all agricultural activity in a county devoted to each single crop (based on the crop production data for 1996/1997 collected for this project). This will be an improvement over the existing crop distribution data currently within BELD3.1 that is based on the 1992 Agricultural Census.

The resulting estimates of the types of crops grown at the 1 km parcel level will allow the burning activity to be applied to the 1 km parcel level using the data in the agricultural burning database. Also, it may be feasible (and necessary to limit the size of the resulting database) to combine 1 km parcels into sub-county regions that depict areas of significant agricultural activity.

A 3-step process will be used to integrate the BELD3.1 data into the agricultural burning database:

1. Process the BELD3.1 data by downloading 9 tiles (13 states; BELD3.1 data for Alaska and Hawaii are not available) and forming 1 file;

2. Apply the BELD3.1 data to the crop distributions from the agricultural burning database to estimate agricultural burning activity at the 1 km parcel level.

3. Perform sensitivity analysis to determine the feasibility of grouping 1 km parcels into sub-county regions based on percentage of agriculture. If this process cannot be automated and designed to account for multiple sub-county regions within a single county, then it may be too time consuming to attempt this process at this time. If determined to be feasible, we will consult with the WRAP/FEJF prior to assigning 1 km parcels to sub-county regions.

3.4.3 Mapping of Agricultural Burning Activity

Two GIS maps for the combined states of California, Idaho, Oregon, Utah, and Washington (the states for which actual burn activity data exist) will be generated from the data in the agricultural burning database. These maps will include the following:

- One map of crop residue amounts (total tons by crop); and
- One map of burned amounts (total tons of residue burned by crop).

These maps will be developed at the county-level. If grouping 1 km parcels into sub-county regions is determined to be feasible, and it is decided to proceed with the refinement of the data as described in Section 3.4.2 above, then these maps will be generated at the sub-county level instead of at the county level.

3.5 Deliverables

In summary, the deliverables related to agricultural burning that are in progress and will be provided according to the process described above in this section include the following:

- An Access database containing the types of data shown in Table 3-3. These data will actually be linked within one overall database that includes the crop production database described in Section 2.0 of this report.

- Excel spreadsheets with residues burned (tons) by crop, by county, by 1 km parcel. If determined to be feasible the residue quantities may be provided at the sub-county level (groupings of 1 km parcels).
- Two maps depicting total residue amounts and total residue burned at the county level for the states of California, Idaho, Oregon, Utah, and Washington. If determined to be feasible the maps may show data at the sub-county level.

4.0 IDENTIFICATION OF NON-BURNING ALTERNATIVES

This section describes the strategies used to identify non-burning alternatives to infield burning of agricultural residues. In this section, we also identify which non-burning alternatives are currently in use, or have been used in the recent past, by crop residue (i.e., fuel type) for each of the 15 Western states. Where possible, we have identified and defined the non-burning alternatives available for potential application to the various crop type residues and subsequent fuel types for the 15 Western states. Investigation into the alternatives is still underway. The results of this investigative effort to date are presented in Table 4-1.

4.1 Non-Burning Alternatives Research Strategy

As expected, the identification of existing non-burning alternatives is a complex and challenging task. In some states there are formal requirements to consider alternatives to infield agricultural burning of residues prior to conducting field burning activities; however, there are typically no formal requirements to actually implement non-burning alternatives. Information regarding the availability, applicability, and cost effectiveness of non-burning alternatives is typically not provided by the states in any comprehensive or coordinated fashion. If alternatives are routinely used, the degree to which non-burning alternatives are implemented is often not formally tracked. To collect the depth and variety of information desired and to address the expectedly wide distribution of information sources, the ERG/ETC team developed a systematic strategy to collect the data needed.

A comprehensive three-tiered approach was employed to identify and research the various potential sources of information. The three-tiered approach includes contacting and/or researching the availability of information from three different levels of information sources.

The first level of sources investigated included state environmental agencies, boards and departments, their respective published reports and documents, and articles and summary information posted on official state level websites. It was expected that if any

Table 4-1. Non-Burning Alternatives Applicable by Fuel (Residue) Type

Fuel/Residue	Leave Residues in Place				Scientific Improvements			Alternative Land Use			Cut or Collect Residues and Haul											
	Cut & Drop Residue in Place	Soil Incorporation: Wet or Dry	Soil Incorporation: Fallow Field, Crop Rotation	Cut, Mulch & Drop in Place	Genetic Selection: Less Fuel Residual	Genetic Selection: Disease/ Pest Resistance	Genetic Selection: Other Tolerance	Plant Crops That Do Not Need to be Burned	Land Conversion to Non-Agricultural Use	Conservation Tillage Practices	Cut, Mulch & Haul Residue	Haul to: Waste or Landfill Facility	Haul to: Permitted Burn Facility	Haul to: Power Generation Facility	Haul to: Ethanol Production	Haul to: Redistribution Facility	Haul to: Manufacturing/Use Other[5]	Haul to: Fiberboard Facility	Haul to: Particleboard Facility	Haul to: Use as Compost or Mulch[6]	Haul to: Use as Animal Feed	Haul to: Use as Erosion Control[7]
Grains and Hay																						
Barley	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•	•		•	•	•
Corn (All)				•	•	•	•	•	•	✔	•	•	•	•	•	•	•			•		
Hay; alfalfa	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•			•	•	•
Hay; All Other	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•			•	•	•
Oats	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•	•		•	•	•
Rice	•	CA	•		CA	CA	•	CA	CA	✔		CA	CA	CA	CA	CA	CA	CA		CA	CA	CA
Sorghum	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•			•	•	•
Wheat (All)	•	CA, WA	•		•	CA, WA	•	CA	CA	✔		•	CA	CA	CA	CA	CA	ND	WA	CA	CA	CA
Wheat; Winter All	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•	•		•	•	•
Wheat; Other Spring	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•	•		•	•	•
Grain Other[1]	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•	•		•	•	•
Grasses and Seeds																						
Seeds; Alfalfa	•	•	•		•	•	•	•	•	✔		•	•	•	•	•	•	•		•	•	•
Seeds, Kentucky Bluegrass	•	•	WA, OR, ID	WA, OR, ID	•	WA, OR, ID	WA, OR, ID	•	•	✔		•	•	•	•	•	•			WA, OR, ID	WA, OR, ID	•
Seeds; Other[2]	•	•	WA, OR, ID	WA, OR, ID	•	OR	•	•	•	✔		•	•	•	•	•	•			WA, OR, ID	WA, OR, ID	•

Table 4-1. Continued

Fuel/Residue	Leave Residues in Place				Scientific Improvements			Alternative Land Use			Cut or Collect Residues and Haul											
	Cut & Drop Residue in Place	Soil Incorporation: Wet or Dry	Soil Incorporation: Fallow Field, Crop Rotation	Cut, Mulch & Drop in Place	Genetic Selection: Less Fuel Residual	Genetic Selection: Disease/ Pest Resistance	Genetic Selection: Other Tolerance	Plant Crops That Do Not Need to be Burned	Land Conversion to Non-Agricultural Use	Conservation Tillage Practices	Cut, Mulch & Haul Residue	Haul to: Waste or Landfill Facility	Haul to: Permitted Burn Facility	Haul to: Power Generation Facility	Haul to: Ethanol Production	Haul to: Redistribution Facility	Haul to: Manufacturing/Use Other[5]	Haul to: Fiberboard Facility	Haul to: Particleboard Facility	Haul to: Use as Compost or Mulch[6]	Haul to: Use as Animal Feed	Haul to: Use as Erosion Control[7]
Orchard																						
Almond				CA		•	•	•	•		•	CA	CA	CA		•	•	•	CA	•		
Apple				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Apricot				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Avocado				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Cherry				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Citrus				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Grapes				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Nectarines				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Olive				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Peach				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Pear				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Pecan				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Plum and Prune				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Walnut				•		•	•	•	•		•	CA	CA	CA		•	•	•	•	•		
Orchard Other[3]				•		•	•	•	•		•	•	•	•		•	•	•	•	•		
Other																						
Asparagus	•	•	•		•	•	•	•	•	✔												
Beans, Dry Edible		•	•		•	•	•	•	•	✔												
Blueberries										✔												
Canola										✔												
Cotton (All)		•	•		•	•		•	•	✔												
Mint	•	•	•		•	•	•	•	•	✔												

Table 4-1. Continued

Fuel/Residue	Leave Residues in Place				Scientific Improvements			Alternative Land Use			Cut or Collect Residues and Haul											
	Cut & Drop Residue in Place	Soil Incorporation: Wet or Dry	Soil Incorporation: Fallow Field, Crop Rotation	Cut, Mulch & Drop in Place	Genetic Selection: Less Fuel Residual	Genetic Selection: Disease/ Pest Resistance	Genetic Selection: Other Tolerance	Plant Crops That Do Not Need to be Burned	Land Conversion to Non-Agricultural Use	Conservation Tillage Practices	Cut, Mulch & Haul Residue	Haul to: Waste or Landfill Facility	Haul to: Permitted Burn Facility	Haul to: Power Generation Facility	Haul to: Ethanol Production	Haul to: Redistribution Facility	Haul to: Manufacturing/Use Other[5]	Haul to: Fiberboard Facility	Haul to: Particleboard Facility	Haul to: Use as Compost or Mulch[6]	Haul to: Use as Animal Feed	Haul to: Use as Erosion Control[7]
Peas, Dry Edible		•	•		•	•	•	•	•	✓												
Peanuts										✓												
Pineapple		HI		•	•	•	•	•	•	✓	•	•	•	•		•	•					
Potatoes										✓												
Safflower		•	•	•	•	•		•	•	✓	•											
Soybeans		•	•		•	•	•	•	•	✓												
Sugarcane				•	•	•	•	•	•	✓	•	•	•	•		•	•				•	•
Other Fruits/Vegs[4]										✓												
Agricultural Related Fuels																						
Ditches	•			•																		
Land Clearing																						
Rangeland																						
Sagebrush	•	•		•																		
Weeds	•	•		•																		

• = Potentially Applicable
✓ = Currently in practice in most of the 15 Western states
WA, OR, etc. (i.e. State) = In practice to some degree currently or has been in practice in the past
[1]Includes undefined grain and hay crops
[2]Includes bermuda, fescue, rye, red clover and other grasses for seed production
[3]Includes pistachio, nectarine, persimmon, kiwi, fig and other undefined orchard crops/fuels
[4]Includes cabbage, carrots, lettuce, tomatoes, green peas, dry onions, melons & coffee
[5]Includes cement products, building materials, paper packaging & cardboard manufacturing
[6]Includes food production such as mushroom composting, compost for dairy facilities manure composting, animal bedding
[7]Includes wind and soil erosion control, forestry rehabilitation & landfill covering

requirements to implement non-burning alternatives were in place at the state level—and if any non-burning alternatives were identified, available and in use—it would be known to and reported by those at the state environmental agency who had responsibility for implementing the agricultural burning programs.

For states with aggressive mandates to reduce agricultural burning, such as Washington, Oregon and California, quality information on non-burning alternatives was readily available. For those states with less aggressive smoke reduction programs or no formal requirements to address agricultural burning, little or no direct information on non-burning alternatives was readily available. In these cases, additional contact persons and/or potential sources of related information were obtained by talking with contact persons at the state environmental agency, board and department level. The additional contact persons and/or information sources identified were typically directly affiliated with state or federal agricultural agencies. These comprised our second level of information sources. The second level sources included state and federal agricultural research centers, state university agricultural extension services offices, individual university agricultural researchers, officially published research documents and reports, articles and summary information posted on agricultural research related websites. For some states, the second level sources extended to official state sanctioned, or in some cases mandated, agricultural burning or non-burning alternatives working groups. These working groups were usually comprised of representatives from the agricultural community, as well as state agricultural and state environmental agencies.

As of the date this document was drafted, the ERG/ETC research team is still in the process of following-up leads obtained from the first level information sources and actively researching the second level sources. As expected, as the first and second level sources were investigated, a few third level sources were identified. The third level information sources include various private businesses and alternative agricultural information clearinghouses. These information sources will also be investigated as part of the remaining Task 1 effort. As available, any relevant information obtained from the third level information sources, as well as the first and second level sources will be summarized in the Task 1 final report.

4.2 Non-Burning Alternatives Information Sources

The first and second level sources which have provided information pertaining to the identification and use of non-burning alternatives in each of the 15 Western states, including tribal lands, include (to date) the following:

- ERG/ETC personal communications with phone survey respondents to the WRAP/FEJF Non-Burning Management Alternatives on Agricultural Lands project survey (12 states responded to date).
- California Air Resources Board:
  - "Alternative Uses of Rice-Straw in California" (CARB, 1997a);
  - "The Economic Impacts of Alternatives to Open-Field Burning of Agricultural Residues" (CARB, 1993);
  - "Progress Report on the Phase Down of Rice Straw Burning in the Sacramento Valley Air Basin 1995-1996: 1997 Report to the Legislature" (CARB, 1997b); and
  - "Rice Straw Diversion Plan" (CARB, 1998).
- USDA Agricultural Research Services:
  - "ARS Helps Grass Seed Growers Produce Seed Without Field Burning" (USDA, 1997a).
  - "Less Fire, More Science for Grass Growers" (USDA, 1997b).
- Washington State Department of Ecology:
  - "Cereal Grain Crops Best Management Practices" (WDOE, 2001c).
  - Washington Department of Ecology Agricultural Burning Task Force (Pfeifer, 2001).
- Other sources:
  - "Advisory Committee on Alternatives to Rice Straw Burning Report" (SCAC, 1995).
  - "Kentucky Bluegrass (KBG) Seed Crops--Agricultural Methodologies for Reducing Air Emissions," (USEPA, 2001b).

– “Best Management Practices When Harvesting Surplus Cereal Straw,” (GOS, 2000).

– “Western States Agricultural Burning Survey”, (WESTAR, 1998).

– “Agricultural Burning Smoke Management Program Survey”, 2001, Draft Final Report, Contract No. 30202-11, (WRAP, 2001a).

– “Earth Saver: Your Runoff and Sediment Control Solution”, (Earth Saver, 2001).

As our research identifies other information sources they will be included in the Task 1 final report.

4.3 Non-Burning Management Alternatives Identified to Date

Historically the types of non-burning agricultural management alternatives available and/or in use have fallen into two categories: soil incorporation of residues in place, and off-site residue disposal (CARB, 1993). At this stage in the research effort, ERG/ETC have found that the non-burning alternatives available and in use today typically fall into four different categories. These categories are more broadly defined than the prior categories and they include:

- Leaving residues in place either with or without infield residue treatment,
- Improved management practices and scientific advancement in horticulture,
- Alternative land uses; and
- Residue collection and hauling for use offsite.

4.3.1 Leaving Residues in Place

This category of non-burning alternatives includes simple cut and drop in place residue treatments, more complex cut, mulch and drop in place methods and traditional both wet and dry soil incorporation of residues. It also includes more complex field management strategies which utilize soil incorporation techniques coupled with deliberate non-burning crop rotation or fallow field practices. Non-burning alternatives in this category, if applicable to a given crop or fuel type, have the distinct advantage of being expeditious and typically less expensive initially; however, increased incidence of insect pest and disease leading to reductions in crop quality and overall decreased profits have been cited as problematic for the implementation of these alternatives.

Hidden costs associated with potential decreases in crop yields and increased use of fertilizers and pesticides have also been cited as drawbacks to widespread use of these non-burning alternatives. While more creative and complex field management strategies such as deliberate fallow field or crop rotation practices to increase soil nutrients or break disease and pest cycles offer promising improvements in the implementation of alternatives, factors such as these will be addressed more completely as we continue to assess impacts and barriers to the implementation of these and other alternatives in Tasks 2, 3, 4 and 5 of this project.

4.3.2 Improved Management Practices and Scientific Advances

Non-burning management alternatives in this category include scientific advances in horticulture which have led to the development of genetically distinct types of crops that have been genetically selected because they offer a variety of desirable traits. The desirable traits in this case can decrease the need to burn subsequent crop residues. Such traits include increased plant resistance to pests and disease. The development of crop varieties with increased resistance to pests and disease increases the potential feasibility of implementing non-burning alternatives such as soil incorporation.

These desirable traits also include genetic selection for less fuel residue. Scientific advances such as this has made it possible to produce high quality grain, such as rice in California, on crop varieties with shorter stalks. When harvested, these short stalk varieties leave less residue in the field. Scientific advances in horticulture have also led to the genetic selection for such practical traits as increased tolerance to shade. For grass seed production in states such as Washington and Oregon this reduces or eliminates altogether the need to burn grass seed production crops. Historically agricultural burning was conducted to remove previous years' leafy residues and allow sunlight to reach the crown new growth areas.

This category of alternatives is fairly new in its application to non-burning settings. It will likely change greatly over time but it offers several of the most promising alternatives available to date. As these non-burning alternative are more clearly defined and perhaps others are identified, non-burning alternatives in this category will be addressed more extensively as we continue to assess impacts and barriers to the implementation of these and other alternatives in Tasks 2, 3, 4 and 5 of this project.

4.3.3 Alternative Land Use

This category includes the use of alternatives to burning that actively change how the agricultural land has been or will be used. In some cases, growers and producers simply choose to plant crops that do not require burning. In these cases a variety of economic, social and political factors may play a role in the growers' and producers' decision. Such activity may come about in response to a variety of factors, only some of which may be related to environmental concerns and the need to reduce air pollutants from the burning of agricultural residues. This category also includes non-burning strategies which may take agricultural land completely out of crop production. Again, these practices may or may not come about in response to the need to reduce agricultural burning.

Based on our experience with agricultural burning practices and related issues throughout the West and our ongoing research on this project, the ERG/ETC team concludes that non-burning alternatives in this category are being implemented. However, it has not yet been determined or documented to date, for what ultimate purpose and to what extent these non-burning alternative strategies are being implemented. This category is presently much less defined than the other three categories. Alternative agricultural non-burning land use decisions are expected to be more tightly bound to economics and crop production environments, as well as land use pressures such as urban growth and development, than they are to environmental pressures. However, to the extent possible within the scope of this effort, as we continue to research the existence and use of non-burning alternative management practices in the 15 Western states, non-burning alternatives in this category may be addressed more extensively as we assess impacts and barriers to the implementation other alternatives in Tasks 2, 3, 4 and 5 of this project.

4.3.4 Residue Collection and Hauling for Use Offsite

This category of non-burning alternatives is quite broad in its applicability and potential for widespread implementation. All non-burning alternatives in this category are based on the premise that the crop residues, which remain after harvesting, are cut and/or otherwise collected from the field and then mechanically hauled offsite. Alternatives in this category are largely defined by what happens to the crop residue once it leaves the field. Non-burning management alternatives that fall in this category include the following:

- General cut and haul to some unspecified destination,
- Haul to a waste or landfill facility,
- Haul to a permitted burn facility,
- Haul to a power generation facility,
- Haul to an ethanol production facility for use in automotive fuels production,
- Haul to a redistribution facility,
- Haul to a manufacturing or other use facility such as for cement, building materials, paper packaging or card board,
- Haul to a fiberboard production facility,
- Haul to a particle board facility,
- Haul to use as compost or mulch for food production or horticultural practices,
- Haul to use as animal feed or bedding, and
- Haul to use for erosion control either as bales or as manufactured erosion control products.

A number of these non-burning alternatives have been identified as either being in use currently, or in use in the past, in Washington, California, North Dakota, Oregon and Idaho. Decisions to implement alternatives from this category are expected to be tightly bound to economics, reliability of residue production, consistent quality of residues available, and market demands for products produced or the residue uses. It is expected that some of the non-burning alternatives in this category will be addressed more extensively as we assess feasibility, economics, impacts and barriers to the implementation of these and other alternatives in Tasks 2, 3, 4 and 5 of this project.

5.0 ASSESSING IMPACTS OF NON-BURNING ALTERNATIVES

There is a need to understand the impacts non-burning alternatives will have on farms, the environment, and the regional society in order to assess the reasonableness of adopting non-burning alternative practices. Often, in environmental policy, what seems like a good idea to address one problem creates numerous unforeseen consequences in other areas. Adoption of conservation tillage, for example, addressed soil conservation and surface water quality issues. But, the increased use of herbicides and the diminution of surface runoff that the change in tillage practice entailed created a threat to groundwater quality. Impacts will be assessed in several dimensions to develop reasonable criteria for adoption of non-burning alternatives.

Changing agricultural practices affect not only the agronomy of the farm and its economic well-being but reverberate through the environment as the landscape changes and through society as economic relationships shift and adjust. A shift to non-burning alternatives may have profound effects on sub-regions and cultures. To keep the assessment manageable, consideration of the impacts will be restricted in two ways.

First, changing land use may be a significant contributor to reduced particulate emissions, but it raises large issues about the character of rural areas and the future of rural development. The grower’s decision to change crops or take land out of agriculture is complex. The decision depends on local conditions, the economics of substitute crops, the individual firm’s investment in machinery and equipment, and the owner’s attitude toward rural life. Analysis of the decision requires different analytical tools than assessment of marginal changes in current practices. The decision analysis would entail modeling of all of the grower’s options. These vary from crop to crop and region to region. Thus, likely price and production possibilities for many substitute operations in many different locations would need to developed. To make a complete assessment, estimates of the likely environmental impacts of the new crop’s production process would also be needed. This analysis will be confined to the marginal changes in growing practices which can be addressed with simpler analytical tools.

Second, 22 alternative practices having applicability to crops grown in the Western states with implications for agricultural burning were identified (See Table 4-1). Section 4.0 showed a large subset of these 990 possible combinations are feasible non-burning alternative options. It is not possible to perform a detailed assessment of the impacts of all of the feasible options with the time and resources available. A "broad brush" assessment of the implications of adoption for all of the feasible combinations of crops and practices identified in Section 4.0 will be developed. This summary level analysis will provide a largely qualitative assessment of the issues that would arise from promoting that crop-practice combination. The summary analysis will give WRAP/FEJF an indication of what may or may not work and its implications.

Table 5-1 is a draft table shell that indicates the severity of each feasibility factor in relation to each alternative to burning rice straw on a scale from one to three, with three being the least feasible. A similar table will be developed for each fuel/residue based on our survey responses and economic modeling. As impacts are very site specific, estimates must be considered as broad averages. The factors in Table 5-1 are phrased in the negative so that a high number in the table always indicates a stronger degree of negative consequences for that alternative. (i.e., an alternative with many 3s in its column is probably not a viable option.)

Also, the impacts of non-burning alternatives for several crops will be examined more closely. Detailed studies of non-burning alternative practices for rice and grass seed culture (CARB, 1993; WDOE, 1998) will serve as models for our work. We will seek the FEJF's advice on which crop impacts to study in more depth within the limits of the available data.

For discussion of the possible impacts, we break the issues into workable categories, describe what each impact is, and explain how we expect to assess its potential effects at the summary and more detailed levels.

5.1 Agronomic Impacts

The first consideration is what happens to the agricultural production unit. How does changing to a non-burning alternative change what the grower must do on the land and how

Table 5-1. Rice – Impacts of Non-Burning Alternatives

Feasibility Factors [1]	Cut and Drop Residue			Cut and Haul Residue to:											Genetic Selection for:			Alternative Land Uses		
	Mulch Residue	Soil Incorporation: Wet or Dry	Soil Incorporation: Fallow Field	Waste Facility	Permitted Burn Facility	Power Generation Facility	Ethanol Production Facility	Redistribution Facility	Manufacturing or Use Facility	Fiberboard Facility	Particleboard Facility	Use as Compost or Mulch	Use as Animal Feed	Use For Erosion Control	Less Fuel Residual	Disease / Pest Resistance	Other Tolerances	Plant Crops That Are Not Burned	Land Conversion to Non-Agriculture Use	Conservation Tillage
Agronomic:																				
Soil compression	1	3	2	2	2	2	2	2	2	2	2		2	2						
Increased water use		3																		
Increased herbicide use	2	2	2																	2
Increased pesticide use																				
Land constraint				2	2	2		2	2				2	2						
Time or equipment constraint				2	2	2		2	2				2	2						
Environmental:																				
Countervailing air emissions				2	1	1				2	2									
Negative wildlife impacts																				
Water quality degradation		1		3	3	2													2	
Health and Safety:																				
Increased equipment use				2	2	2		2	2				1							
Energy:																				
No contribution to energy production	1	1	1	1	1			1					1	1						1
Economics:																				
Not cost-effective																				
Moderate farm stress																				
Substantial farm stress																				
Negative regional impacts																				
Social and Equity Issues:																				
Raises Tribal issues																		3	3	3
Raises small business issues																		2	2	
Impacts low resource farms																				1
Political Issues:																				
Agricultural objections																		3	3	3
Environmental objections				2																

[1]Feasibility factors are phrased to indicate a negative outcome. Higher ratings indicate worse consequences for that impact and alternative.
Blank = no problem or not relevant.
1 = some problem may exist.
2 = definite problem.
3 = a major problem.

does that change affect the productivity of the land? Farms may not have adequate land for storage of crop residue or labor time to transport it. The basic logistics of the alternatives will need to be assessed along with growers' resources to accomplish them. When ash is no longer left on the land, soil nutrient levels may be reduced. Burning also reduces weeds and plant pathogens as well as removing refuges for insect pests. The alternative practice may require more passes over fields with heavy equipment and so may compact the soil. Growers may need to increase application of chemical fertilizers and pesticides to counteract these effects and maintain productivity over the long term.

The summary assessment of agronomic impacts will be largely qualitative. To the extent non-burning alternative practices have been adopted or field trials have been conducted, we will use the results of that experience to assess the impact of wider adoption of the practice. For many possible alternatives, however, the assessment may be based on untested, anticipated changes and experience with similar technologies. Information will be collected from agronomists, agricultural engineers, and other experts to assess the field-level impacts of each alternative. We will work with members of the FEJF to develop qualitative criteria to avoid unacceptable agronomic impacts.

The more detailed assessment will require specific information from field trials of the alternative practice in the crop of interest. Long term information would be especially useful as long run productivity is the central agronomic impact. Quantified rates of decline in productivity and added pesticide requirements will improve the multi-year crop budgets that we will use for the financial impact analysis.

5.2 Environmental Impacts

The goal of promoting non-burning alternatives for agricultural activities is to reduce the environmental impact of burning on visibility and air quality. However, it is expected that the non-burning alternatives will entail new practices which may have their own environmental consequences. For example, with increased tractor operations and transportation of field and orchard debris, more diesel fuel will be burned. This may increase overall carbon dioxide (CO_2), nitrogen dioxide (NO_2), and particulates in the air. If power plant emissions are poorly controlled, burning orchard or field crop wastes as fuel for electricity generation could reduce the benefits of decreased open burning. As a summary approach, we will discuss reductions in emissions released from each non-burning alternative vis-à-vis current practices. Also, the implications of using agricultural waste for animal feed, mulch, and other uses will be assessed by discussing the environmental consequences of these alternatives with appropriate experts.

Fire is a powerful agent of ecological change. Wildlife adapts to the agricultural practices in their environment. The timing of hay cutting, for example, has a tremendous effect on the survival of ground-nesting birds. Any changes in burn practices are likely to alter these adaptations. Follow-on effects from increased fertilizer and pesticide applications may have negative water quality effects in surface or groundwater. These effects will be noted in discussions with people who have experience with alternatives and highlighted where appropriate for all alternatives.

Environmental impacts present a challenge for more detailed case studies. Standard engineering data will be used to estimate emissions increases from residue use that offset emission reductions, in a mass balance sense. For other types of impacts, we will identify which non-burning alternatives raise the greatest environmental concerns.

5.3 Health and Safety Impacts

Alternatives must not increase the health or safety risks relative to current burning practices. Through literature review and interviews with local experts to assess qualitative changes in health and safety factors associated with current burning practices and the major alternatives. Safety impacts are unlikely to be strong criteria as we do not anticipate any of the alternatives will be unusually hazardous compared to other types of agricultural work.

5.4 Energy Impacts

Recent experience with the deregulation of the California power supply system has highlighted the vulnerability of the region to energy shortfalls and the need to find new sources of electricity. Crop residues can provide a renewable source of biomass for power generation. Sugarcane bagasse and nutshell fuelled furnaces have been added to sugar mills and nut processing plants for many years. Existing stand-alone biomass power plants rely on urban and lumber mill wood waste. They are capable of mixing in orchard prunings, but avoid non-woody crop residues.

Field crop residues present several challenges for electricity generation. First, they have a low heat content. It requires a large volume of straw to generate as much energy as a cubic foot of natural gas. Collection is, therefore, often costly. Large volume also creates handling problems in getting fuel into furnaces efficiently. Second, crop residues are seasonal. Large amounts of straw need to be removed from fields at certain times of the year and may not be available during the remainder of the year. Orchard pruning provides cuttings in late winter but not at other times. As a consequence, large quantities of fuel will typically need to be stored for considerable periods to keep a power plant operating continuously. Third, some residues must be dried, chipped, or otherwise pre-processed to be efficient fuels. If energy must be expended to process the residue, the possibility exists that it may require more energy to process the fuel than the fuel provides when it is burned. Fourth, crop residues leave ash when they are burned which may be regulated as hazardous waste with correspondingly high disposal costs. Rice straw, for example, has an ash content of 14 to 18 percent, compared to wood which typically has an ash content of less than 2 percent.

Even with these management issues, persistent high wholesale electricity prices may make an agricultural residue burning power plant a viable option for some locations. CARB (1993) and other sources have evaluated the prospect for new biomass power plants. Crop's suitability as a fuel will be scored for the broad brush assessment. The more detailed assessment will consider the feasibility of power plants for the specific crop given the characteristics of the residue and prior experience using it as a fuel. Power generation potential is likely to be a strong positive criterion for any alternative practice.

5.5 Economic Impacts

The economic impact of adopting non-burning alternatives is an important consideration. One criterion for selecting the preferable options will be cost effectiveness, e.g., the lowest cost per ton of particulate emissions reduced, such as particulate matter less than 2.5 microns in aerodynamic diameter ($PM_{2.5}$). This is a useful standard since it can be used to directly compare the agricultural non-burning alternatives with industrial and automotive $PM_{2.5}$

source reduction programs. Costs of adopting a non-burning agricultural alternative are measured by the difference in the cost of agricultural operations between the traditional burning operation and the new alternative approach. Each alternative will be assessed at the enterprise, firm, and regional level. While the cost of implementing an alternative for a given farm field is a component of the selection among alternatives, the viability of any alternative also depends on the firm's ability to remain profitable given the new labor, capital, and land requirements of the new technology. The ability of firms to finance the change and continue in business must be assessed. Regionally, the non-burning alternatives may shift employment and supply relationships.

In the summary assessment, these evaluations will be requested from our survey respondents. This will be a simple answer to the questions of whether the alternative is cost-effective, affordable, and regionally sustainable in the respondent's opinion. The detailed assessment will include comparative enterprise budgets, financial ratio analysis, and regional impact analysis.

5.5.1 Cost-Effectiveness – Enterprise Level Assessment

Engineers can estimate the tonnage of $PM_{2.5}$ released from agricultural burning of different crops each year. Each fuel source has a characteristic profile of burn products. While the profile varies with weather conditions, average values will be used to estimate emissions per ton of fuel burned. This rate of emission can be expanded to an acreage basis using average fuel production per acre harvested. Burn reduction programs in Washington and Oregon have significantly reduced human exposure to particulates without eliminating burning by permitting burns when the wind will carry pollutants away from population centers (WDOE, 1998). A detailed GIS system combined with regional wind pattern and population information could conceivably develop estimates of expected population exposed to smoke under different permitting scenarios. For alternative development, however, we perceive the goal as overall reduction in particulate emissions and so will consider cost effectiveness in terms of reduced tonnage of emissions rather than reduced human exposures.

Crop production budgets will be used to estimate the incremental costs per acre of the alternatives. Basically, a farmer has four options:

1. Leave the residue in place,
2. Haul it somewhere else,
3. Use varieties selected for characteristics that reduce the need to burn; or
4. Use the land for some other purpose that does not require burning, either a different crop or a non-agricultural use.

The first three options may be considered marginal changes to operations. While they may be costly changes to the grower, the rice producer continues to produce rice and most of his operation remains unchanged. The fourth option is much more consequential. Although changing crops may be a significant contributor to reduced particulate emissions, it raises large issues about the character of rural areas and the future of rural development. As discussed above, we believe changing land use is beyond the scope of this analysis and will offer only a cursory assessment of its possible impacts.

Crop production budgets for current agricultural practices show all of the necessary tasks to raise the crop and their costs per acre by expenditure category for a well-run operation. Budgets do not represent the average but generally show an idealized production operation using the best practices suggested by the state cooperative extension service. Budgets have also been produced for some non-burning alternative practices.

Many enterprise budgets show a loss whether or not the crop is actually viable. A more accurate measure of profitability is revenues minus variable costs. Many growers will continue to operate at a paper loss as long as their cash flow is adequate to cover variable costs and the essential fixed costs, e.g. debt service. If the additional costs of the alternative practice make the variable costs greater than revenues, then that alternative is definitely not affordable. If the alternative practice reduces net income considerably, growers will reassess the profitability of that enterprise and may switch to another crop or to a different non-burning alternative.

Table 5-2 shows a budget for producing tall fescue seed. The propane burn alternative assumes straw is baled, stacked, and later burned or composted elsewhere on the farm. It incurs additional variable costs of $28 and additional fixed costs of $18 over the current

Table 5-2. Enterprise Budget for Tall Fescue Seed, Willamette Valley, Oregon (Dollars per Acre)

Budget Element	Alternative			Difference from Conventional	
	Open Burn	Propane Burn	Crew-Cut	Propane Burn	Crew-Cut
Total Gross Income	542.75	542.75	542.75	0	0
Total Variable Cost	278.75	306.91	304.24	28.16	25.49
Gross Income - Variable Cost	264.00	235.84	238.51	-28.16	-25.49
Total Fixed Cost	213.52	231.99	242.67	18.47	29.15
Total of All Costs	492.27	538.9	546.91	46.63	54.64
Net Projected Returns	50.48	3.85	-4.16	-46.63	-54.64

Source: Cross, et al.,1992.

open burn practice. Propane burn continues to have a positive net income and so is a viable alternative. Crew-cutting also involves baling excess straw followed by one pass over the field with a crew-cutter. The additional pass involves more equipment for a longer time period so fixed costs are higher than the other alternatives. Although variable costs are slightly lower than propane burning, the crew-cut alternative has a negative net income. However, crew cut gross income minus variable costs is greater than the propane burn approach so crew cut is also a viable option. This budget assumes yield is unchanged through time no matter which option is selected so a simple analysis of an annual budget is appropriate.

We can generate other budgets in consultation with experts in the field by adding the costs of new activities, such as cutting and hauling straw. The alternatives differ in terms of what happens to the residue after it is cut. We will ask our expert contacts to characterize the operations necessary for each alternative and make assumptions based on their responses.

Several alternatives have the possibility of producing revenue from new by-products. Markets for many of these products are not yet well developed. We will use current prices of similar products to indicate the possible net revenues given current market conditions. Where the alternative practice has long term effects on the productivity of the land, such as by promoting pest survival, we will annualize costs over the cropping cycle to ensure that we capture the costs in terms of yield as well as the direct costs of the alternative. Annualization converts a flow of unequal payments through a period of time to an equivalent series of equal annual flows.

Cost effectiveness will be measured as the change in budgeted expenditures to implement the alternative per ton of $PM_{2.5}$ avoided by adopting the alternative practice. Most costs of the alternative practices are variable and emissions will be defined per acre, so abatement cost curves will be essentially linear. Key assumptions will be tested by sensitivity analysis.

5.5.2 Affordability – Farm Level

Growers will not adopt a new technology or practice unless it makes economic sense for their firm as a whole. We will need to assess the impact of the alternatives on the agricultural production firm’s profitability and financial stability. This is often evaluated in terms of changes in the firm's income and financial ratios. If income falls significantly, or financial ratios fall into a range where banks will hesitate to loan money, then the alternative may not be affordable and will not be widely adopted. We will use the crop budgets to assess whether a typical well-managed operation would confront financial difficulties in implementing the alternative technologies. Balance sheets and other information from the USDA Agricultural Resource Management Study (ARMS), an annual survey, can serve as a baseline for analysis (USDA, 2001).

The most intuitively direct measure of affordability is net income. As most firms are privately held and only report financial information for tax purposes, they have a disincentive to report positive net income. We will set percentage change limits such that a change in average revenues minus variable costs of a given percentage is considered to indicate a moderate affordability problem. U.S. EPA typically uses changes of 3 or 5 percent as indicators of moderate stress. Negative net revenue indicates severe stress (USEPA, 2001c).

We will also consider changes in debt-to-asset ratios. Banks and other lenders have criteria for lending to agricultural firms which include the levels of various asset ratios. If a firm's debts become too high in proportion to its total assets, the long term burden of debt can require a large share of cash resources. The higher probability of default discourages banks from lending additional funds to the firm, making equipment replacement costly and difficult. The USDA considers a debt-to-asset ratio higher than 0.40 an indicator of financial distress (USDA, 1999).

5.5.3 Indirect Impacts – Regional Level

Changes in farm operations can have impacts in the regional economy. Collecting and transporting crop residue may require extra labor which may generate more income for farm workers. New equipment that might be needed or faster depreciation of old equipment may increase sales at agricultural implement dealers. Such effects generate ripple effects throughout the regional economy. The California Air Resources Board (CARB, 1993) used a computable general equilibrium (CGE) model to trace the impact on prices and quantities of adopting different policy options for burning crop residue. CGE is particularly useful in assessing agricultural income changes from switching crops or exiting agriculture. Only rice straw burning in the Sacramento Valley was assessed with CGE in the CARB report. Preliminary assessment of changes for other crops showed the regional impacts were unlikely to be significant and did not merit a full CGE analysis. Similarly, we do not foresee significant regional dislocations from adoption of non-burning alternative practices.

In those case studies where alternatives appear to generate changes that may ripple through the economy, we will apply publicly available multipliers from the Regional Input-Output Modeling System, Version 2 (RIMS II) (USDC, 1997) to derive a first approximation of the impact. The multiplier analysis will estimate indirect and induced changes in employment and output for all sectors of the economy from output changes in the farm sector. CGE modeling is more sophisticated than multiplier analysis and can answer a variety of questions about possible outcomes and the effects of changing assumptions. CGE analysis may be useful at a later stage to assess more detailed regulatory options.

5.6 Social and Equity Issues

There may be burning practices or non-burning alternatives that have implications unique to certain groups beyond simple cost considerations, such as small growers, culturally diverse groups, or residents of tribal lands. We will ask our expert survey respondents if they are aware of any special considerations as we research non-burning alternatives.

If it is determined that non-burning alternatives have significant potential to reduce visibility impacts when applied to these groups, we will note the nature of the issue. In the more detailed analyses, we will indicate likely air quality results with and without the group's adoption of non-burning alternatives and will explore state options to address the issue. ERG will consult with FEJF to make additional reasonableness determinations on a case-by-case basis.

5.7 Political Issues

Promotion of non-burning alternatives by government, even on a voluntary basis, has the potential to antagonize agricultural interest groups. Most growers, producers, and distributors are politically well organized. They routinely advocate their concerns in state legislatures through crop specific organizations and more general agricultural lobbies.

Environmental and recreation interests are also well organized. Any effort to induce change may face political pressure on several fronts. We will ask our survey respondents if they are aware of any specific groups with strong positions on agricultural burning. The strength and willingness to compromise of the various interest groups varies from state to state. While we can indicate potential pitfalls, FEJF and WRAP member governments will need to make their own assessments of the political viability of any alternatives on a case-by-case basis.

5.8 Summary

Table 5-3 summarizes the sources, methods, and expected outcomes of the detailed analysis described above. Our goal will be to develop information for establishing criteria to assess the reasonableness of alternative practices that reduce agricultural burning in the 15 Western states. These methods and criteria will be applied to two or three major crops to demonstrate their use. Abatement cost curves will also be developed from the alternatives' costs and abatement effectiveness. More cursory impact assessment methods will be applied to all crops identified as contributing to agricultural burning.

Table 5-3. Summary of Methods to Assess Impacts of Non-Burning Alternatives

Impact		Sources	Methods	Expected Results
Agronomic:				
	Soil compression	Prior Trials; Agronomic experts	Apply results from prior trials to prospective sites	Problem for some crops; long term decline in productivity and/or additional work
	Increased water use			Little incremental water use
	Increased herbicide use			Likely problem as weeds proliferate without burning
	Increased pesticide use			Likely problem for some alternatives as pests shelter in unburned fields
	Land constraint			May be problem for smaller farms
	Time or Equipment constraint			May be problem for smaller farms
Environmental:				
	Offsetting air emissions	Burning facilities emissions history	Compare emissions from burned fields with emissions from facilities	Burning at a power plant or disposal facility is less polluting than field burning
	Negative wildlife impacts	Prior Trials	Anecdotal evidence of changes in habitat	Little change in effect from burning
	Water quality degradation	Prior Trials	Qualitative assessment of likely changes	Little change anticipated
Health and Safety:				
	Increased equipment use	Crop Budgets; Agricultural Injury database	Budgets will indicate extra equipment passes; apply injury rates per hour and compare with injuries from burning	Small increased risk of injury; largely from increased highway driving
Energy:				
	No contribution to energy production	Alternative Description	Use engineering information to estimate energy produced by using residue as fuel	Some opportunity to increase energy output if prices are high enough
Economics:				
	Not cost-effective	Crop Budgets; engineers' emissions estimates	Estimate costs of farming practice changes per unit of emissions reduced	Reducing agricultural burning is comparatively cost effective in many situations
	Moderate farm stress	Crop Budgets; ARMS Survey data	Estimate impact of changes in farm costs on farm financial ratios	Minor impacts on some farms
	Substantial farm stress	Crop Budgets; ARMS Survey data	Estimate impact of changes in farm costs on farm financial ratios	Very few farms seriously affected
	Negative regional impacts	RIMS Multipliers; aggregated costs	Estimate employment and other changes from multiplier changes	Small regional impacts
Social and Equity Issues:				
	Raises Tribal issues	Survey	Qualitative assessment	Unknown
	Raises small business issues	Survey	Anecdotal evidence	Some problems possible
	Impacts low resource farms	Survey; Crop Budgets; ARMS data	Anecdotal evidence and estimated impacts from farm costs	Some small farms may be affected
Political Issues:				
	Raises agricultural objections	Survey	Anecdotal evidence	Some objections are likely
	Raises environmental objections	Survey	Anecdotal evidence	Some objections are possible

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APPENDIX A

CROP PRODUCTION AND AGRICULTURAL BURNING DATABASE

(A summary spreadsheet is included for this Task 1draft report. A diskette of the completed database will be included in the Task 1 final report.)

State	Commodity	Acres Harvested
AK	barley	6,900
AK	fruits and vegetables; other	343
AK	hay; alfalfa	3,801
AK	hay; all	24,023
AK	hay; all other	20,222
AK	oats	700
AK	potatoes	630
AZ	apples	2,230
AZ	barley	54,000
AZ	citrus	37,900
AZ	corn; for grain	40,000
AZ	corn; for silage	16,937
AZ	cotton; amer. pima	41,900
AZ	cotton; upland	314,000
AZ	fruits and vegetables; other	28,800
AZ	grapes	4,300
AZ	hay; alfalfa	160,000
AZ	hay; all	179,000
AZ	hay; all other	19,000
AZ	peaches	192
AZ	pears	18
AZ	potatoes	9,000
AZ	seeds; alfalfa	2,667
AZ	seeds; other	3,556
AZ	sorghum	45,000
AZ	wheat; all	178,000
AZ	wheat; durum	164,000
AZ	wheat; winter all	14,000
CA	almonds	400,692
CA	apples	39,981
CA	apricots	21,314
CA	asparagus	34,121
CA	avocado	56,335
CA	barley	190,000
CA	beans; all dry edible	123,000
CA	cherries	17,438
CA	citrus	284,790
CA	corn; for grain	220,000
CA	corn; for silage	275,000
CA	cotton; amer. pima	164,000
CA	cotton; upland	995,000

State	Commodity	Acres Harvested
CA	figs	14,564
CA	fruits and vegetables; other	777,358
CA	grapes	721,505
CA	hay; alfalfa	944,056
CA	hay; all	1,698,773
CA	hay; all other	754,717
CA	kiwi	5,242
CA	nectarines	36,634
CA	oats	30,000
CA	olives	34,409
CA	peaches	71,823
CA	peanuts	750
CA	pears	21,884
CA	peas; dry edible	697
CA	pecans	1,905
CA	persimmons	2,479
CA	pistachio	65,373
CA	plums and prunes	133,068
CA	rice; all	500,000
CA	safflower	156,801
CA	seeds; alfalfa	53,799
CA	seeds; other	77,499
CA	sorghum	18,855
CA	sugarbeets	82,200
CA	walnuts	168,298
CA	wheat; all	688,000
CA	wheat; durum	138,000
CA	wheat; winter all	550,000
CO	barley	92,000
CO	beans; all dry edible	125,000
CO	corn; for grain	890,000
CO	corn; for silage	90,000
CO	hay; alfalfa	860,000
CO	hay; all	1,510,000
CO	hay; all other	650,000
CO	oats	35,000
CO	potatoes	87,600
CO	proso millet	125,765
CO	seeds; alfalfa	1,232
CO	seeds; other	6,879
CO	sorghum	260,000
CO	sugarbeets	51,100
CO	sunflower	107,000

State	Commodity	Acres Harvested
CO	wheat; all	2,268,000
CO	wheat; other spring	68,000
CO	wheat; winter all	2,200,000
HI	coffee	5,400
HI	fruits and vegetables; other	13,120
HI	macadamia nuts	20,200
HI	pineapple	20,000
HI	sugarcane	42,900
ID	barley	730,000
ID	beans; all dry edible	93,000
ID	corn; for grain	40,000
ID	corn; for silage	68,000
ID	hay; alfalfa	1,000,000
ID	lentils	65,540
ID	mint	23,790
ID	oats	25,000
ID	peas; dry edible	71,507
ID	potatoes	413,000
ID	seeds; alfalfa	31,210
ID	seeds; KBG	32,796
ID	seeds; other	17,629
ID	sugarbeets	184,000
ID	wheat; all	1,560,000
ID	wheat; other spring	700,000
ID	wheat; winter all	860,000
MT	barley	1,150,000
MT	beans; all dry edible	10,300
MT	corn; for grain	15,000
MT	corn; for silage	39,000
MT	hay; alfalfa	1,700,000
MT	hay; all	2,600,000
MT	hay; all other	900,000
MT	oats	50,000
MT	potatoes	10,200
MT	seeds; alfalfa	13,122
MT	seeds; KBG	259
MT	seeds; other	8,965
MT	sugarbeets	57,500
MT	wheat; all	6,360,000
MT	wheat; durum	280,000
MT	wheat; other spring	4,100,000

State	Commodity	Acres Harvested
MT	wheat; winter all	1,980,000
ND	barley	2,600,000
ND	beans; all dry edible	570,000
ND	corn; for grain	600,000
ND	corn; for silage	140,000
ND	flaxseed	77,000
ND	hay; alfalfa	1,700,000
ND	hay; all	2,900,000
ND	hay; all other	1,200,000
ND	oats	380,000
ND	potatoes	131,000
ND	rye	16,000
ND	soybeans	845,000
ND	sugarbeets	225,300
ND	sunflower	1,165,000
ND	wheat; all	12,515,000
ND	wheat; durum	2,940,000
ND	wheat; other spring	9,500,000
ND	wheat; winter all	75,000
NM	apples	1,192
NM	corn; for grain	84,000
NM	corn; for silage	44,000
NM	cotton; amer. pima	14,000
NM	cotton; upland	55,000
NM	fruits and vegetables; other	38,375
NM	hay; alfalfa	250,000
NM	hay; all	350,000
NM	hay; all other	100,000
NM	peanuts	16,500
NM	pecans	23,188
NM	potatoes	10,300
NM	sorghum	225,000
NM	wheat; all	110,000
NM	wheat; winter all	110,000
NV	barley	5,000
NV	fruits and vegetables; other	4,415
NV	hay; alfalfa	250,000
NV	hay; all	480,000
NV	hay; all other	230,000
NV	potatoes	6,999
NV	seeds; alfalfa	11,731

State	Commodity	Acres Harvested
NV	wheat; all	19,000
NV	wheat; other spring	10,000
NV	wheat; winter all	9,000
OR	apples	6,658
OR	barley	150,000
OR	cherries	8,804
OR	corn; for grain	37,000
OR	filberts	26,678
OR	grapes	5,800
OR	hay; alfalfa	460,000
OR	hay; all	1,070,000
OR	hay; all other	610,000
OR	mint	45,221
OR	oats	35,000
OR	peaches	705
OR	pears	15,090
OR	plums and prunes	1,462
OR	potatoes	61,000
OR	seeds; alfalfa	9,465
OR	seeds; KBG	18,798
OR	seeds; other	513,246
OR	sugarbeets	16,300
OR	wheat; all	920,000
OR	wheat; other spring	105,000
OR	wheat; winter all	815,000
SD	barley	145,000
SD	corn; for grain	3,650,000
SD	corn; for silage	320,000
SD	flaxseed	9,000
SD	hay; alfalfa	2,500,000
SD	hay; all	4,300,000
SD	hay; all other	1,800,000
SD	oats	360,000
SD	proso millet	122,451
SD	rye	36,000
SD	seeds; alfalfa	12,136
SD	seeds; other	12,900
SD	sorghum	145,000
SD	soybeans	2,670,000
SD	sunflower	690,000
SD	wheat; all	3,854,000
SD	wheat; durum	24,000

State	Commodity	Acres Harvested
SD	wheat; other spring	2,250,000
SD	wheat; winter all	1,580,000
UT	apples	2,386
UT	barley	100,000
UT	beans; all dry edible	5,201
UT	cherries	1,941
UT	corn; for grain	20,000
UT	corn; for silage	40,000
UT	fruits and vegetables; other	6,695
UT	hay; alfalfa	545,000
UT	hay; all	705,000
UT	hay; all other	160,000
UT	oats	9,000
UT	peaches	1,298
UT	potatoes	3,247
UT	seeds; alfalfa	3,393
UT	seeds; other	3,739
UT	wheat; all	185,000
UT	wheat; other spring	25,000
UT	wheat; winter all	160,000
WA	apples	154,930
WA	asparagus	23,000
WA	barley	440,000
WA	beans; all dry edible	35,000
WA	blueberries	1,311
WA	canola	12,686
WA	cherries	17,700
WA	corn; for grain	120,000
WA	corn; for silage	50,000
WA	fruits and vegetables; other	189,269
WA	grapes	35,265
WA	hay; alfalfa	490,000
WA	hay; all	800,000
WA	hay; all other	310,000
WA	hops	30,621
WA	oats	14,000
WA	peaches	2,200
WA	pears	23,555
WA	peas; dry edible	126,975
WA	plums and prunes	571
WA	potatoes	161,000
WA	seeds; alfalfa	13,197

State	Commodity	Acres Harvested
WA	seeds; KBG	45,103
WA	seeds; other	13,693
WA	sugarbeets	13,000
WA	wheat; all	2,745,000
WA	wheat; other spring	395,000
WA	wheat; winter all	2,350,000
WY	barley	120,000
WY	beans; all dry edible	31,000
WY	corn; for grain	50,000
WY	corn; for silage	33,000
WY	hay; alfalfa	620,000
WY	hay; all	1,220,000
WY	hay; all other	600,000
WY	oats	32,000
WY	potatoes	704
WY	seeds; alfalfa	3,927
WY	seeds; other	766
WY	sugarbeets	56,800
WY	wheat; all	236,000
WY	wheat; other spring	26,000
WY	wheat; winter all	210,000

APPENDIX B

ADDITIONAL CROP PRODUCTION MAPS

(Additional crop production maps showing community-level production will be included in the Task 1 final report.)