Molecular Markers for Sources of Fugitive Dust in the San Joaquin Valley

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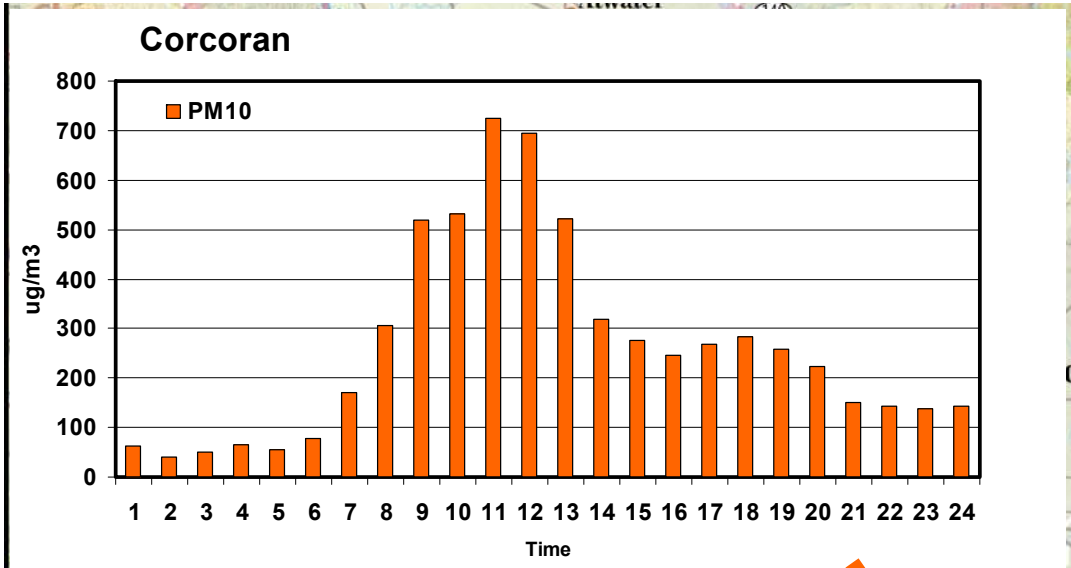
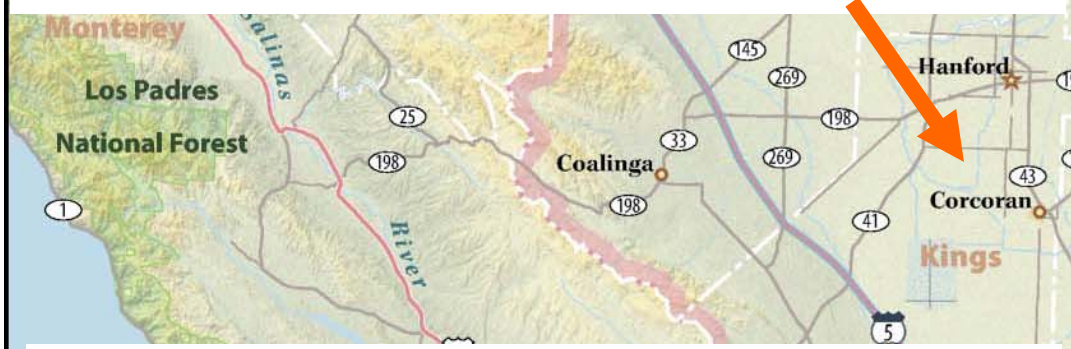
Estimates for Primary Emissions of PM for the San Joaquin Valley in Tons/Day, 2000

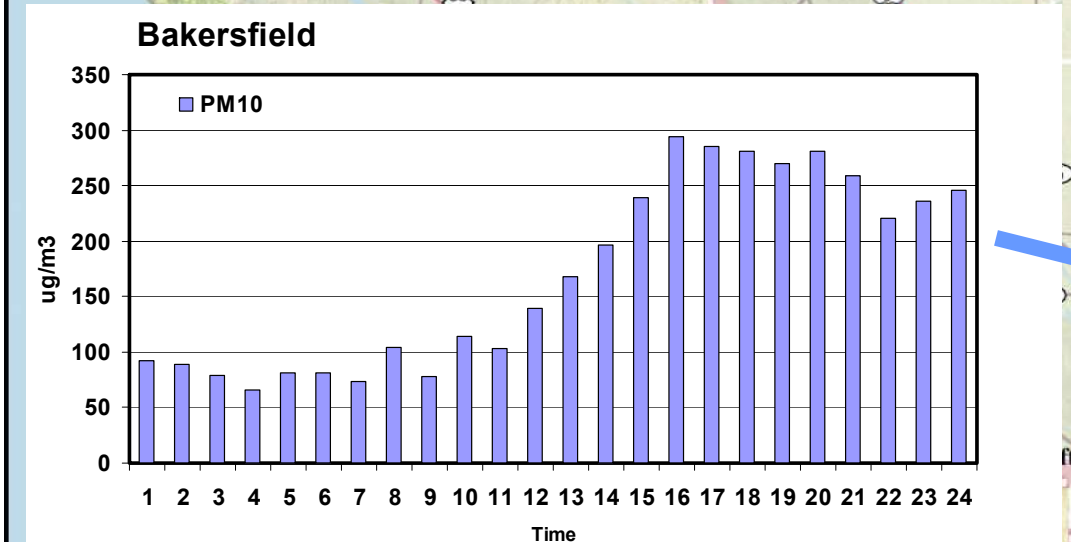
Source Category	PM10	PM2.5
Stationary Sources	42	32
Mobile Sources	16	15
Subtotal Stationary & Mobile Sources	58	47
Agricultural Waste Burning	42	41
Paved Road Dust	64	16
Construction & Demolition	24	4
Farming Operation	111	22
Windblown Dust	51	8
Subtotal Fugitive Dust Sources	292	91
Total	350	138

Natural Event Documentation
Corcoran, Oildale and Bakersfield, California
September 22, 2006

San Joaquin Valley Unified
Air Pollution Control District
April 20, 2007



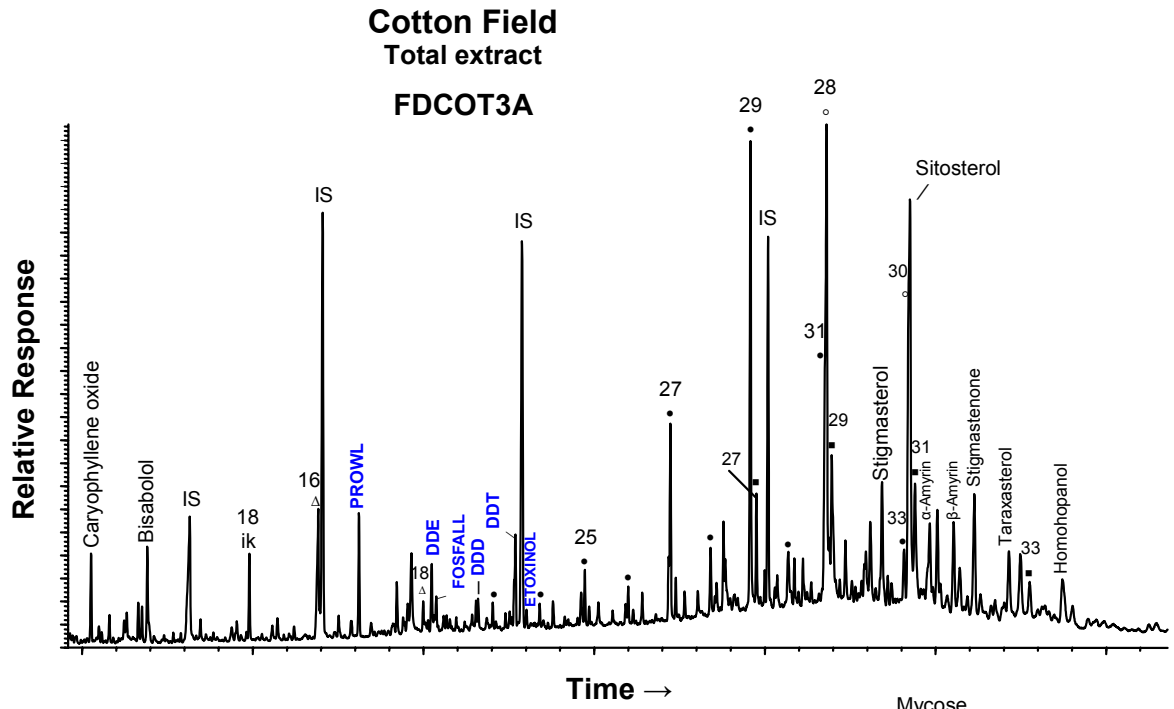


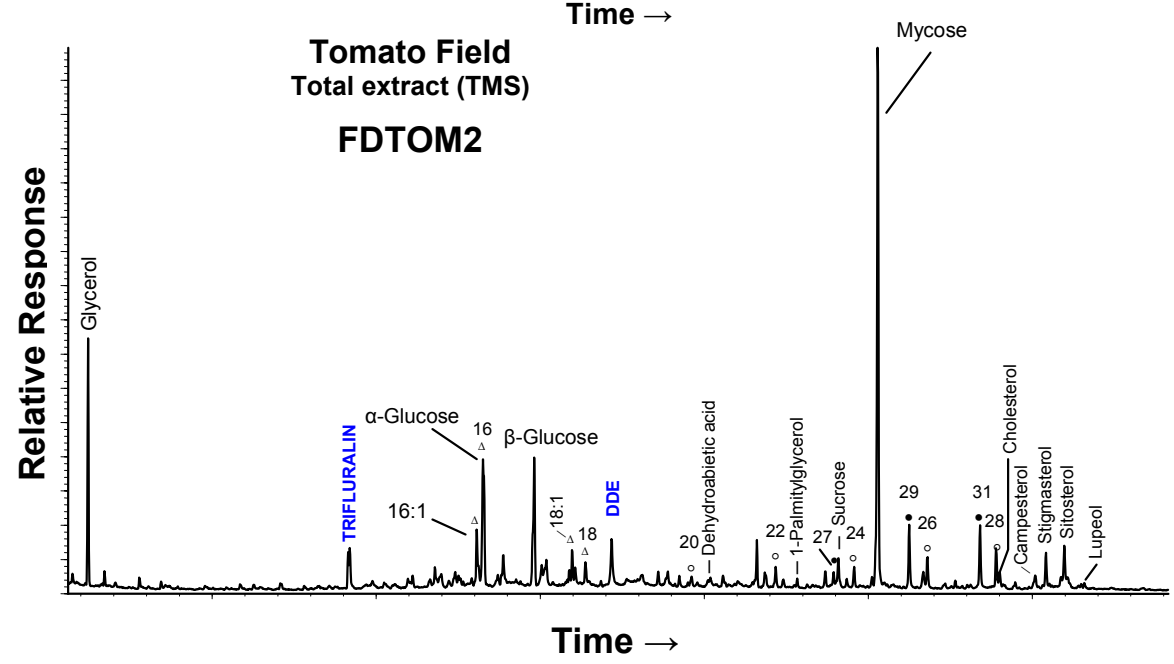


Problem:

Fugitive dust exposes humans to:

- "Natural dust"
- Pesticides
- Pharmaceuticals
- Microorganisms
  - San Joaquin Valley fever (Coccidioidomycosis)





Problem:

- **Fugitive dust exposes humans to:**
  - **Agricultural Waste Burning Products**
    - **e.g., Polycyclic Aromatic Hydrocarbons (PAHs)**

Average concentration of organic compounds in surface soils of crop fields (reported as $ng\,g^{-1}$)[a]

Compounds	Cotton fields (12)	Safflower fields (3)	Tomato fields (5)	Almond orchards (6)	Vineyards (3)	Compd ID[b]
PAHs						
Phenanthrene		3.2±3.4	0.6±0.1	3.4±1.7	12.3±19.6	a
Anthracene		0.7±0.7		4.4±2.2	1.9±2.8	a
4H-Cyclopentaphenanthrene					1.2±2.1	a
Fluoranthene		2.1±1.2	0.5±0.2	5.8±4.1	38.6±63.9	a
Pyrene		1.7±0.7	0.4±0.2	5.3±3.8	35.6±58.6	a
Benz[a]anthracene			0.2±0.2		13.8±22.6	a
Chrysene/triphenylene			0.3±0.3		26.2±42.7	a
Benzo[b]fluoranthene			0.5±0.2	4.2±3.0	35.5±58.6	a
Benzo[k]fluoranthene					12.7±21.0	a
Benzo[j]fluoranthene					2.1±3.3	a
Benzo[e]pyrene			0.3±0.2		21.5±34.9	a
Benzo[a]pyrene					21.0±34.6	a
Perylene					4.1±6.6	a
Indeno[123-cd]pyrene					29.4±48.8	a
Benzo[ghi]perylene					22.3±36.5	a
Dibenz[ah]anthracene					20.2±33.5	a
Coronene					6.4±10.0	a

What is the contribution of a given fugitive dust source to a particular site of interest?

Source Type 1

a_{11}
a_{21}
.
.
a_{n1}

Source Type 2

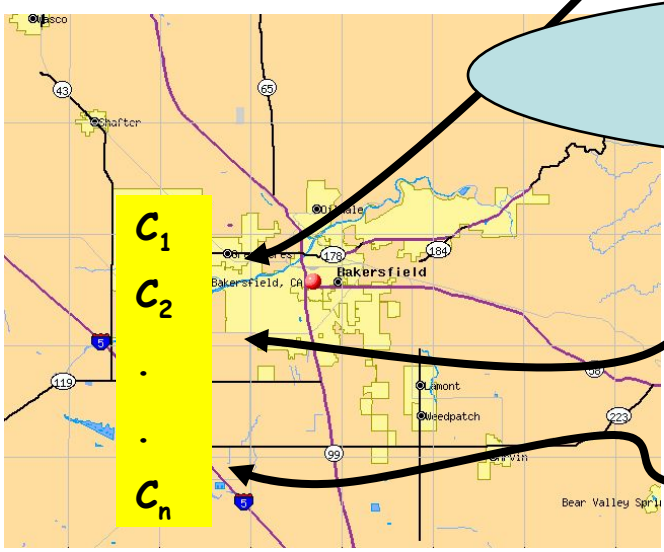
a_{12}
a_{22}
.
.
a_{n2}

. . . . . .

Source Type n

a_{1m}
a_{2m}
.
.
a_{nm}

Atmospheric Chemistry f



C_1
C_2
.
.
C_n

Site of Interest

$$C_i = \sum_{j=1}^{m} f_{ij} a_{ij} s_j$$

Chemical Mass Balance (CMB) Modeling Approach

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ATMOSPHERIC ENVIRONMENT

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Soil sample collection and analysis for the Fugitive Dust Characterization Study

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Measurement of $PM_{2.5}$ emission potential from soil using the UC Davis resuspension test chamber

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Soil samples were analyzed for:

- **moisture content**
- **dry slit content**
- **N & C content**
- **PM10 index**
- **PM2.5 index**

Soil sample locations and classifications

Sample ID	Source	County	Latitude	Longitude	Soil classification
FDCOT1A	Cotton	Fresno	36°34′30″	120°05′12″	Chino fine sandy loam
FDCOT1B	Cotton	Fresno	36°34′41″	120°05′13″	Chino fine sandy loam
FDCOT1C	Cotton	Fresno	36°34′43″	120°05′09″	Chino fine sandy loam
FDCOT2A	Cotton	Fresno	36°15′28″	119°59′45″	Cerini clay loam
FDCOT2B	Cotton	Fresno	36°15′44″	119°59′47″	Cerini clay loam
FDCOT2C	Cotton	Fresno	36°15′45″	120°00′14″	Cerini clay loam
FDCOT3A	Cotton	Kern	35°12′27″	119°16′42″	Copus silty clay
FDCOT3B	Cotton	Kern	35°12′05″	119°17′14″	Copus silty clay
FDCOT3C	Cotton	Kern	35°12′08″	119°16′20″	Copus silty clay
FDCOT4A	Cotton	Kern	35°08′59″	119°01′22″	Lokern clay
FDCOT5A	Cotton	Kings	36°08′05″	119°58′56″	Westhaven loam
FDCOT6A	Cotton	Kings	35°57′42″	119°39′08″	Tulare clay
FDTOM1A	Tomato	Fresno	36°47′15″	120°26′18″	Panoche silty clay
FDTOM1B	Tomato	Fresno	36°47′17″	120°26′00″	Panoche silty clay
FDTOM1C	Tomato	Fresno	36°47′11″	120°25′48″	Panoche silty clay
FDTOM2A	Tomato	Fresno	36°18′19″	120°05′24″	CLAY
FDTOM3A	Tomato	Fresno	36°08′33″	120°07′10″	Sandy clay loam (UCD)
FDALM1A	Almonds	Kern	35°29′52″	119°09′31″	Driver coarse sandy loam
FDALM1B	Almonds	Kern	35°29′47″	119°09′31″	Driver coarse sandy loam
FDALM1C	Almonds	Kern	35°29′40″	119°09′12″	Driver coarse sandy loam
FDALM2	Almonds	Fresno	36°35′28″	120°03′50″	Loamy sand (UCD)
FDALM3	Almonds	Kern	35°39′27″	119°53′39″	Kimberlina fine sandy loam
FDALM4	Almonds	Merced	37°20′47″	120°43′25″	Dinuba sandy loam
FDGRA1	Grapes	Fresno	36°38′51″	119°49′05″	Hesperia fine sandy loam
FDGRA2	Grapes	Madera	36°53′03″	120°04′03″	Sandy loam (UCD)
FDGRA3	Grapes	Fresno	36°33′36″	119°39′49″	Hanford fine sandy loam
FDSAF1	Safflower	Kings	35°58′43″	119°39′41″	Tulare clay
FDSAF2	Safflower	Kern	35°11′37″	119°15′39″	Zalvidea sandy clay loam
FDSAF3	Safflower	Kern	35°09′09″	119°01′22″	Oldriver loam
FDCTD1	Dairy	Tulare	36°07′13″	119°31′13″	Organic
FDCTD2	Dairy	Fresno	36°30′54″	119°43′04″	Organic
FDCTF1	Feedlot	Kern	35°30′02″	119°06′30″	Organic
FDCTF2	Feedlot	Fresno	36°15′10″	120°15′53″	Organic
FDPVR1	Urban Paved Road	Kern	35°22′57″	119°02′47″	Paved road
FDPVR2	Urban Paved Road	Fresno	36°48′30″	119°51′38″	Paved road
FDPVR3	Rural Paved Road	Kern	35°36′07″	119°18′41″	Paved road
FDPVR4	Rural Paved Road	Tulare	36°09′00″	119°30′27″	Paved road
FDUPR1	Ag Unpaved Road	Fresno	36°34′45″	120°05′05″	Unpaved road
FDUPR2	Ag Unpaved Road	Kings	35°58′38″	119°39′41″	Unpaved road
FDUPR3	Ag Unpaved Road	Kern	35°12′08″	119°16′22″	Unpaved road
FDUPR4	Pub/Res Unpaved Road	Kings	36°05′51″	119°35′09″	Unpaved road
FDUPR5	Pub/Res Unpaved Road	Kern	35°36′52″	119°41′35″	Unpaved road
FDUPR6	Pub/Res Unpaved Road	Kings	36°00′34″	119°58′03″	Unpaved road
FDSTA1	Staging Area	Kings	36°08′02″	119°58′56″	Unpaved road
FDDIS1	Disturbed Land Salt Buildup	Kings	35°50′20″	119°39′44″	Disturbed land
FDDIS2	Disturbed Land Salt Buildup	Kern	35°09′05″	119°01′19″	Disturbed land
FDCON1	Construction/earthmoving	Fresno	36°43′32″	120°03′32″	Construction
FDCON2	Construction/earthmoving	Madera	36°56′27″	120°03′26″	Construction

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ATMOSPHERIC ENVIRONMENT

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Similarities and differences in PM_{10} chemical source profiles for geological dust from the San Joaquin Valley, Californi

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Composite geological profiles[a] (in percent of PM_{10} mass) from the San Joaquin Valley, California

	Paved road dust			Unpaved road dust			
Mnemonic[b]	FDPVRD1	FDPVRDR	PVRD	FDUPRDA	FDUPRDR	FDUPST1	UNPVRD
Source type	Urban	Rural	Composite	Agricultural	Residential	Staging area soil	Composite
County	Fresno	Kern /Tulare		Fresno/ Kings/ Kern	Kings /Kern	Kings	
Chloride (Cl^-)	0.0954±0.2220	0.11±0.1355	0.1027±0.1839	0.1326±0.1389	0.0546±0.1178	0.0861±0.0959	0.0911±0.1188
Nitrate (NO_3^-)	0±0.2204	0.0871±0.1321	0.0435±0.1817	1.0555±1.4987	0±0.117	0.1088±0.095	0.3881±0.8696
Phosphate (PO_4^{3-})	0±0.0000	0.0582±0.0823	0.0291±0.0582	0±0	0±0	0±0	0±0
Sulfate (SO_4^{2-})	0.3074±0.2290	0.25±0.1352	0.2787±0.1881	0.7321±0.3441	0.359±0.4148	0.3399±0.0988	0.477±0.3163
Ammonium (NH_4^+)	0.4272±0.2818	0.2193±0.1639	0.3233±0.2305	0.0955±0.0881	0.1309±0.1371	0.1341±0.1119	0.1202±0.1141
Soluble sodium (Na^+)	0.0869±0.0379	0.0708±0.032	0.0789±0.0351	0.3282±0.3398	0.0658±0.0328	0.1047±0.018	0.1662±0.1974
Soluble potassium (K^+)	0.148±0.0561	0.1538±0.1141	0.1509±0.0899	0.1269±0.0888	0.1143±0.0621	0.0442±0.0203	0.0951±0.0636
OC1	0.4671±0.3837	0.0821±0.172	0.2746±0.2973	0.0681±0.1047	0.1191±0.1744	0.2269±0.1602	0.138±0.1495
OC2	1.3117±0.5781	0.4559±0.2848	0.8838±0.6051	0.2681±0.1581	0.4015±0.2454	0.4822±0.2115	0.3839±0.2081
OC3	3.6049±1.5890	1.7359±0.8511	2.6704±1.3216	0.6862±0.4656	1.6049±0.7654	1.1725±0.6011	1.1545±0.6229
OC4	2.5477±0.7967	1.3664±0.3699	1.9571±0.8353	1.3796±1.123	1.9441±1.527	0.6208±0.2309	1.3148±1.1025
Pyrolyzed carbon (OP)	1.6007±0.6036	0.6175±0.5187	1.1091±0.6952	0.4561±0.4027	0.2895±0.2183	0±0.1709	0.2485±0.2823
Organic carbon (OC)	9.5322±2.5953	4.2578±1.0974	6.895±3.7295	2.8581±1.0813	4.359±2.1239	2.5024±0.7387	3.2399±1.4406
EC1	1.5795±0.5715	0.5767±0.3346	1.0781±0.7091	0.3495±0.2465	0.2745±0.1736	0.3746±0.1545	0.3329±0.1956
EC2	1.689±0.9471	0.3623±0.2817	1.0257±0.9381	0.2045±0.1553	0.1884±0.2142	0.3369±0.2249	0.2433±0.2005
EC3	0±0.0999	0±0.0597	0±0.0823	0±0.0338	0±0.053	0±0.0427	0±0.0439
Elemental carbon (EC)	1.6678±1.1784	0.3215±0.4597	0.9946±0.952	0.0979±0.2688	0.1734±0.3528	0.7115±0.3277	0.3276±0.3346
Total carbon (TC)	11.2±3.0696	4.5793±1.208	7.8896±4.6815	2.956±1.0999	4.5324±2.1121	3.2139±0.8245	3.5674±1.4549
Carbonate carbon (C in CO_3^{2-})	1.8728±0.6288	0.7473±0.5626	1.3101±0.5966	1.1985±0.2169	1.5919±0.4365	0.6949±0.2119	1.1618±0.3069
Sodium (Na)	0.1519±0.0502	0.1606±0.1057	0.1562±0.0828	0.3873±0.4129	0.15±0.1546	0.2124±0.0201	0.2499±0.2548
Magnesium (Mg)	0.7536±0.0427	0.8129±0.0597	0.7833±0.0519	0.6648±0.4256	0.8464±0.2224	1.2186±0.0201	0.9099±0.2823
Aluminum (Al)	7.9862±2.3696	12.0154±3.5443	10.0008±3.0147	9.0706±5.0928	10.811±3.2357	10.8431±3.1795	10.2416±3.9377
Silicon (Si)	23.4286±7.3732	32.904±10.3058	28.1663±8.9603	30.5722±13.5846	34.3955±10.9174	33.7781±10.5625	32.9153±11.7657
Phosphorus (P)	0.6382±0.2699	0.1372±0.0608	0.3877±0.3543	0.093±0.064	0.1262±0.0612	0.0359±0.0199	0.085±0.0524
Sulfur (S)	0.5001±0.1755	0.2031±0.0721	0.3516±0.21	0.4237±0.2257	0.1619±0.1067	0.3774±0.1305	0.321±0.1626
Chlorine (Cl)	0.2011±0.0650	0±0.0398	0.1006±0.1422	0.1687±0.2923	0±0.0707	0.1086±0.0333	0.0924±0.1747
Potassium (K)	2.7961±0.5479	2.8451±0.5498	2.8206±0.5488	2.8105±0.9518	2.6339±0.527	2.2158±0.4269	2.5534±0.6748
Calcium (Ca)	3.6212±0.5969	3.3487±1.554	3.485±1.1771	5.5414±2.9801	5.7244±4.0558	2.2566±0.3633	4.5075±2.9133
Titanium (Ti)	0.36±0.0478	0.5506±0.1261	0.4553±0.1348	0.4029±0.092	0.4549±0.0731	0.4649±0.0137	0.4409±0.0683
Vanadium (V)	0.0019±0.0310	0.0074±0.0217	0.0047±0.0267	0.0053±0.0676	0.0101±0.0538	0.0143±0.0182	0.0099±0.051
Chromium (Cr)	0.0009±0.0089	0.0008±0.0076	0.0008±0.0083	0.0006±0.0202	0.0028±0.0162	0.0093±0.0029	0.0042±0.0151
Manganese (Mn)	0.0752±0.0048	0.0766±0.0059	0.0759±0.0054	0.0969±0.0302	0.0861±0.0185	0.0751±0.0031	0.086±0.0205
Iron (Fe)	4.488±0.1665	5.9627±0.5818	5.2254±1.0428	5.2741±0.6007	5.1891±0.7571	6.0935±0.0686	5.5189±0.5594
Cobalt (Co)	0±0.0700	0.0044±0.093	0.0022±0.0823	0.001±0.0828	0±0.0816	0.0017±0.0948	0.0009±0.0866
Nickel (Ni)	0.0026±0.0020	0±0.0022	0.0013±0.0021	0.002±0.0055	0.0053±0.0043	0.0124±0.0009	0.0066±0.0053
Copper (Cu)	0.0252±0.0025	0.0084±0.003	0.0168±0.0119	0.0153±0.0072	0.0163±0.0113	0.0065±0.0006	0.0127±0.0078
Zinc (Zn)	0.1119±0.0047	0.0812±0.0658	0.0965±0.0467	0.039±0.0212	0.0358±0.0095	0.0208±0.0006	0.0319±0.0134
Gallium (Ga)	0.0011±0.0025	0.0018±0.0006	0.0014±0.0018	0±0.0047	0.001±0.0036	0±0.0007	0.0003±0.0035
Arsenic (As)	0.0021±0.0037	0.0011±0.0011	0.0016±0.0027	0.0021±0.0049	0.0009±0.0053	0.0012±0.0006	0.0014±0.0042
Selenium (Se)	0.0002±0.0013	0.0003±0.0005	0.0002±0.001	0.0004±0.0026	0.0003±0.002	0.0003±0.0004	0.0003±0.0019
Bromine (Br)	0.0025±0.0010	0.0008±0.0003	0.0016±0.0012	0.0015±0.0026	0.002±0.0015	0.0015±0.0003	0.0017±0.0017
Rubidium (Rb)	0.0107±0.0010	0.0171±0.0012	0.0139±0.0046	0.0156±0.0031	0.0125±0.0033	0.01±0.0003	0.0127±0.0028
Strontium (Sr)	0.0309±0.0015	0.0301±0.0017	0.0305±0.0016	0.0523±0.0109	0.0323±0.006	0.0254±0.0004	0.0367±0.014
Yttrium (Y)	0.0016±0.0012	0.0034±0.0007	0.0025±0.0013	0.0029±0.0029	0.0032±0.0019	0.003±0.0004	0.003±0.002
Zirconium (Zr)	0.0186±0.0016	0.0105±0.0033	0.0146±0.0057	0.0122±0.003	0.0111±0.0023	0.0144±0.0005	0.0126±0.0022
Molybdenum (Mo)	0.0007±0.0035	0±0.0011	0.0004±0.0026	0±0.0066	0.002±0.0051	0±0.001	0.0007±0.0048
Palladium (Pd)	0±0.0213	0.0001±0.007	0±0.0159	0±0.04	0.0014±0.0311	0±0.0063	0.0005±0.0295
Silver (Ag)	0±0.0249	0±0.0081	0±0.0185	0±0.0469	0±0.0367	0±0.0073	0±0.0346
Cadmium (Cd)	0±0.0263	0±0.0087	0±0.0196	0.0014±0.0494	0.0011±0.0387	0±0.0077	0.0008±0.0365
Indium (In)	0±0.0296	0.0004±0.0096	0.0002±0.022	0±0.056	0±0.0435	0±0.0087	0±0.0413
Tin (Sn)	0.0159±0.0374	0±0.012	0.008±0.0278	0.0074±0.0703	0.0078±0.0548	0.0015±0.0108	0.0056±0.0518
Antimony (Sb)	0.0215±0.0433	0.0018±0.0139	0.0116±0.0321	0.0076±0.082	0.0086±0.0637	0.001±0.0125	0.0057±0.0604
Barium (Ba)	0.1627±0.1055	0.0803±0.0318	0.1215±0.0779	0.0903±0.2757	0.0491±0.2126	0.0703±0.0283	0.0699±0.2017
Lanthanum (La)	0±0.2058	0.0221±0.0642	0.0111±0.1524	0.0948±0.3919	0.0675±0.3052	0±0.0576	0.0541±0.2887
Gold (Au)	0±0.0058	0.0006±0.0034	0.0003±0.0048	0.0019±0.0086	0.0003±0.0068	0±0.0014	0.0007±0.0064
Mercury (Hg)	0.0006±0.0030	0.0009±0.0009	0.0008±0.0022	0.0014±0.0057	0.0014±0.0044	0±0.0009	0.0009±0.0042
Thallium (Tl)	0±0.0030	0.0005±0.001	0.0003±0.0022	0.0003±0.0055	0.0005±0.0043	0±0.0009	0.0003±0.0041
Lead (Pb)	0.0161±0.0031	0.0057±0.0028	0.0109±0.0074	0.0058±0.0073	0.0203±0.0133	0.0043±0.0008	0.0101±0.0088
Uranium (U)	0.0009±0.0032	0.0013±0.0018	0.0011±0.0026	0.0017±0.0055	0.0028±0.0046	0±0.0015	0.0015±0.0042

Soil samples were analyzed for:

- **Ions**
- **OC & EC**
- **Elements**

Success of Source-Receptor Modeling:

Depends on distinguishable differences in the chemical composition of emission profiles as well as the chemical stability of the compounds of interest.

- **Elements** – often, abundance is similar in emissions from different sources
- **Organic Compounds** – large number of compounds, but some are not very stable

Requirements for Organic Marker Compounds

- Stable or at least quasi-stable under atmospheric conditions
- Present in detectable amounts in the source emissions and atmosphere

Three workable arrangements:

1) Specific organic marker for each individual source
2) Compound assemblage with individual compounds not source specific, but with a distinct – source specific – concentration pattern
3) Compound assemblage released from several sources with the same concentration pattern but where one source type dominates the overall emissions

Organic Marker Compounds for Fugitive Dust from Feedlots and Dairy Farms

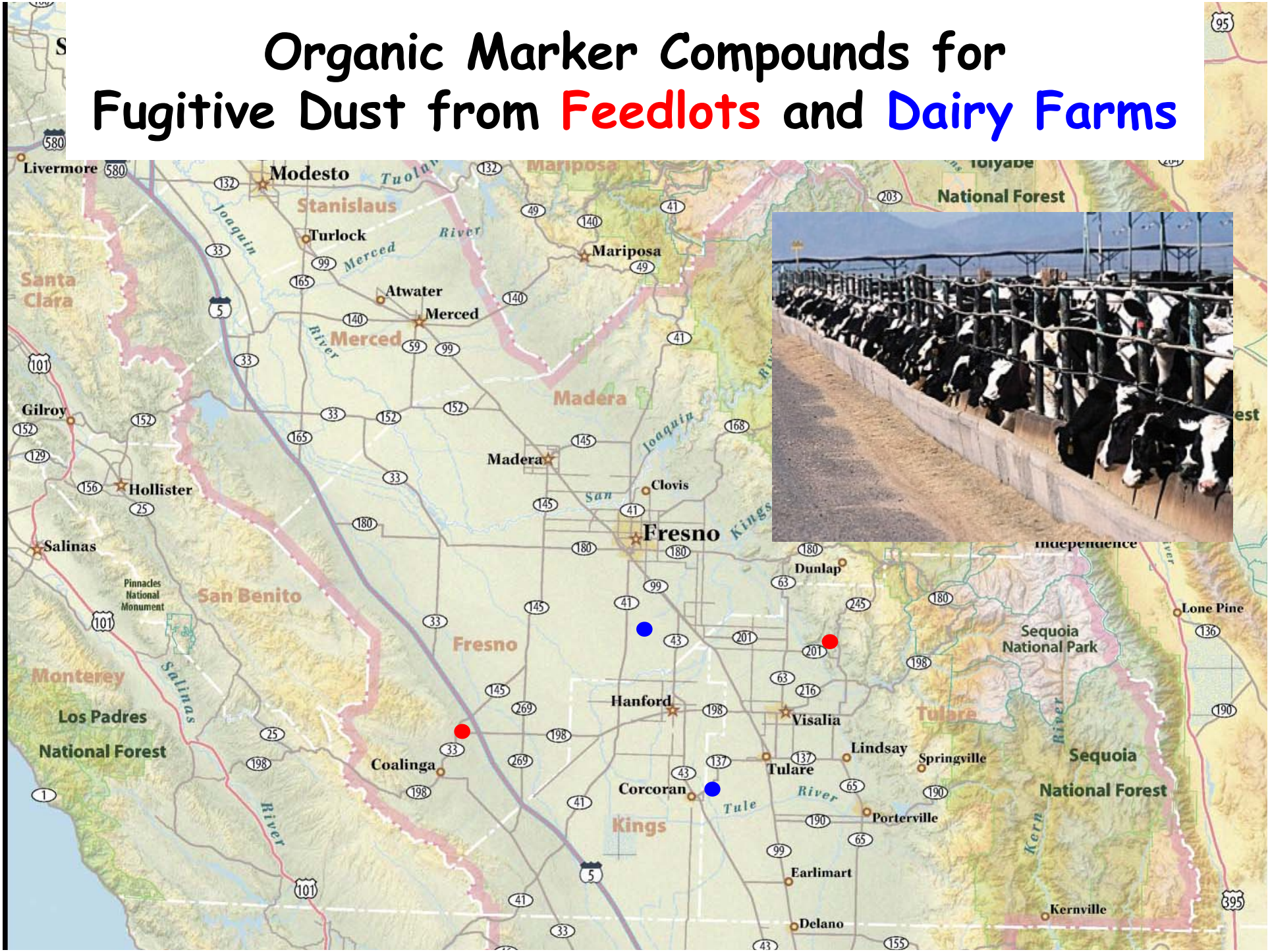
Cattle Population in the San Joaquin Valley

- Dairy Cattle ~ 2,000,000
- Range Cattle ~ 400,000
- Feedlot Cattle ~ 300,000

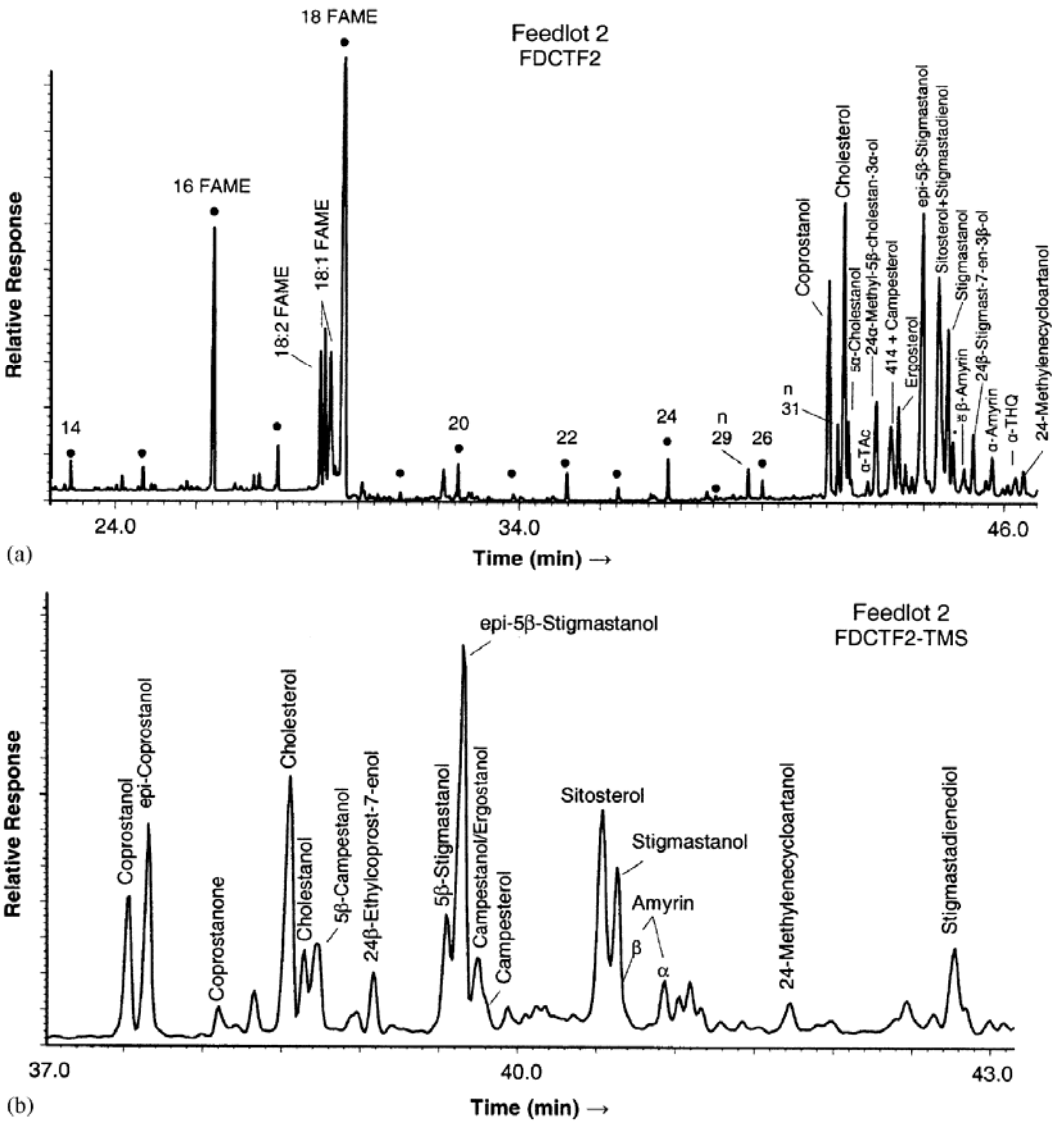
Dust Emissions depend on:

- Size of herd
- Type – dairy farms vs. feedlot
- Daily temp. & rainfall
- Lot design, manure management
- Activity pattern of cattle

Organic Marker Compounds for Fugitive Dust from Feedlots and Dairy Farms



Organic Marker Compounds for Fugitive Dust from Feedlots and Dairy Farms



Searching for unique markers, investigated:

- Food
- Food additives
- Metabolic conversion products

Cattle Fodder

Feedstuffs:

- forages (fresh, hay, silage)
- processed grains (corn, wheat, oats, barley, distiller's dried grain, canola, cottonseed, sunflower, beet pulp, almond hulls, etc.)
- feed supplements (minerals, vitamins, fats)
- pharmaceuticals

Major Organics in Feedstuffs:

- biopolymers
- lipids
- phytosterols
- vitamins
- others

Major Organics in Feedstuffs:

- Biopolymers
- Lipids
- Phytosterols
- Vitamins
- Others

n-Alkanoic Acids

n-Alkenoic Acids

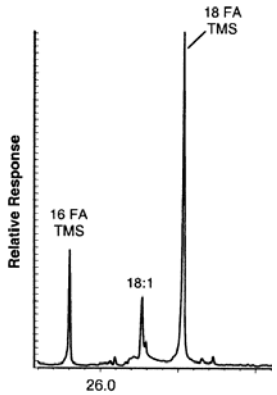
Undigested Fodder

$$\frac{\text{Stearic Acid (C18)}}{\text{Palmitic Acid (C16)}} = 0.2 \text{ to } 0.5$$

$$\frac{\sum \text{Unsaturated C18-Acids (Oleic Acid, Linoleic Acid, Linolenic Acid)}}{\text{Stearic Acid (C18)}} = 10 \text{ to } 20$$

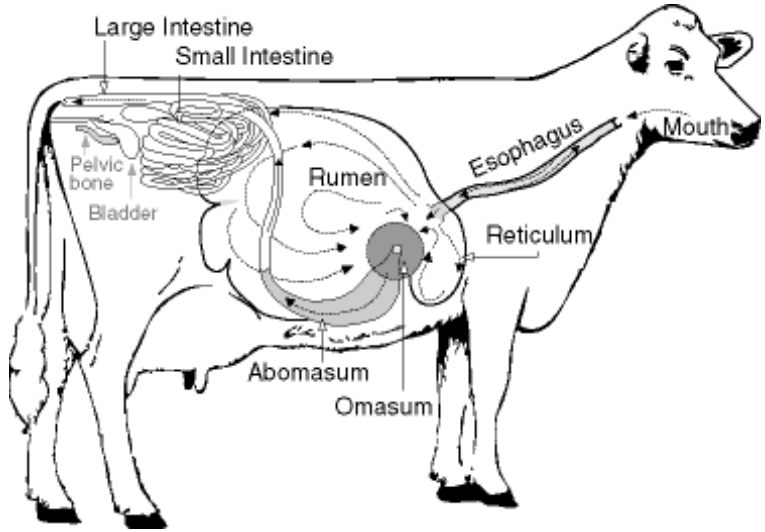
$$\frac{\sum \text{Unsaturated C18-Acids}}{\text{Palmitoleic Acid (C16:1)}} = 5 \text{ to } 10$$

Surface Soil



$$\frac{\text{Stearic Acid (C18)}}{\text{Palmitic Acid (C16)}} = 2 \text{ to } 4$$

Ruminant Digestion
(enzymatic lipolysis of triglycerides & hydrogenation)



Any Interference with other Sources of Fugitive Dust?

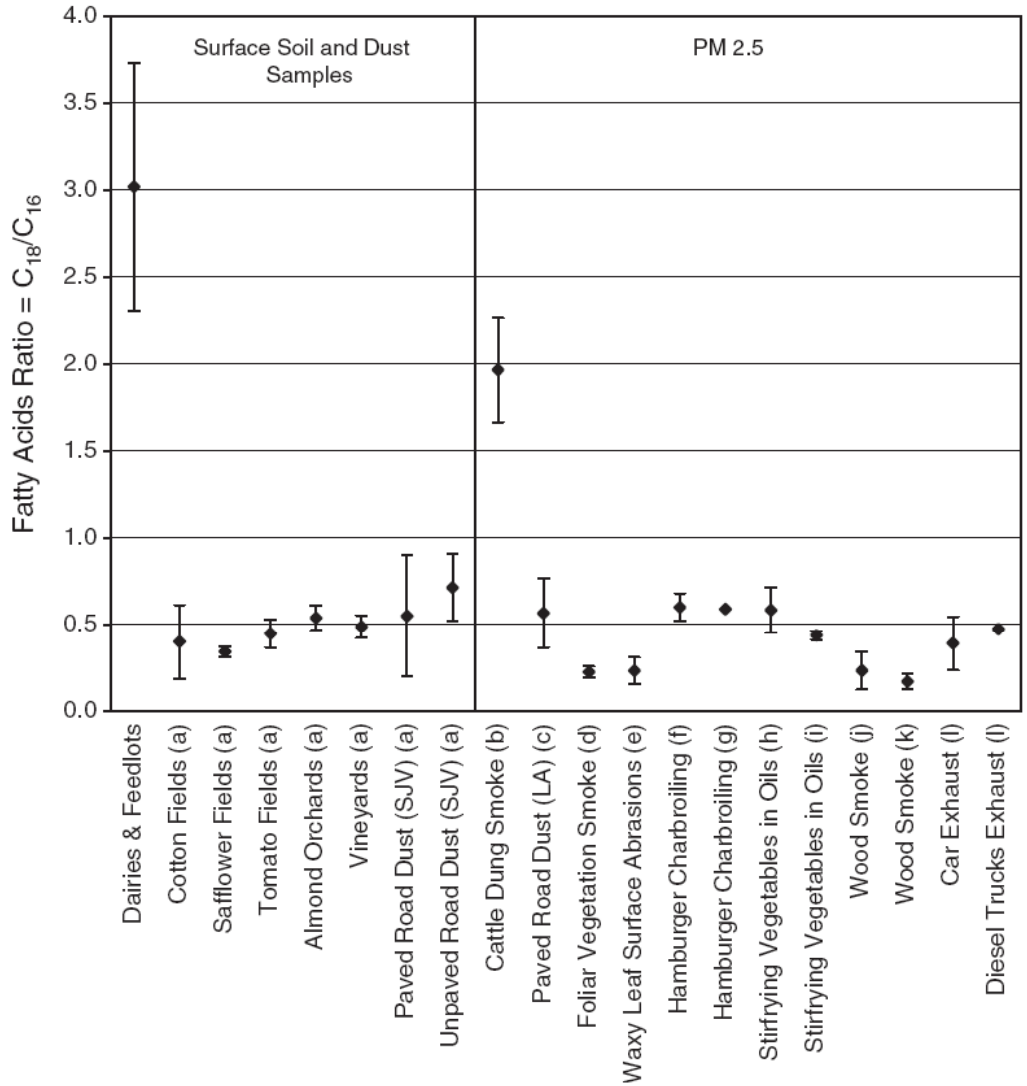


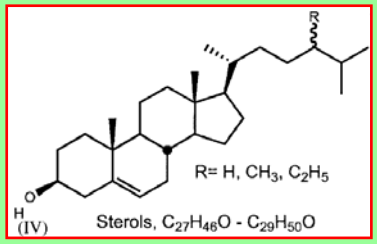
Fig. 5. Fatty acid ratio = C_{18}/C_{16} in surface soils of open lot dairies and beef cattle feedlots, agricultural fields, dust from paved and unpaved roads, and in PM2.5 of many urban and rural sources. (a) Rogge et al. (2006); (b) Sheesley et al. (2003); (c) Rogge et al. (1993b); (d) Hays et al. (2002); (e) Rogge et al. (1993c); (f) Rogge et al. (1991); (g) Schauer et al. (1999), (h) Rogge (1999); (i) Schauer et al. (2002); (j) Rogge et al. (1998); (k) Schauer et al. (2001); (m) Rogge et al. (1993a).

Major Organics in Feedstuffs:

- Biopolymers
- Lipids
- Phytosterols
- Vitamins
- Others

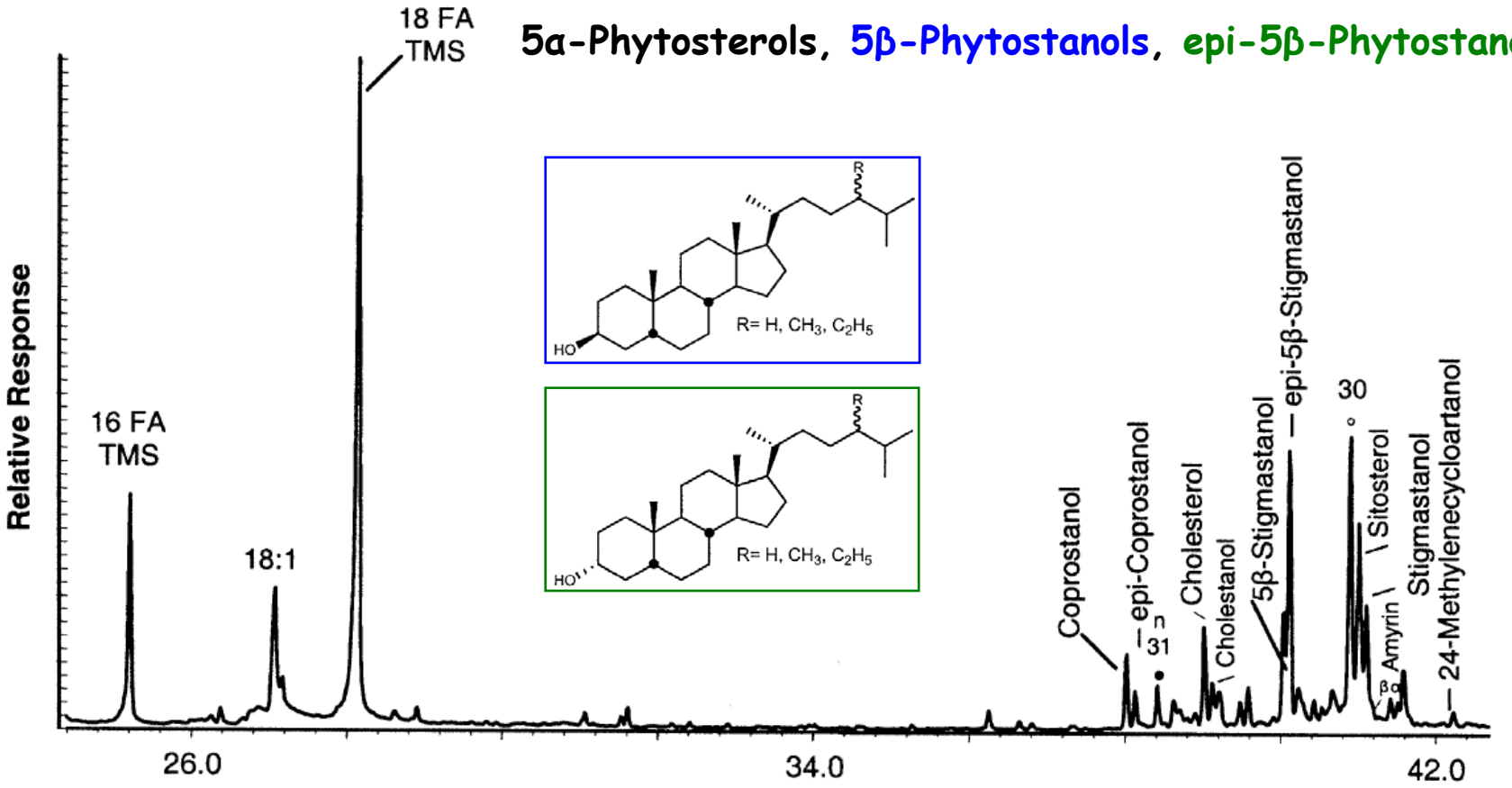
- Sitosterol
- Stigmasterol
- Campesterol
- Brassicasterol

Undigested Fodder

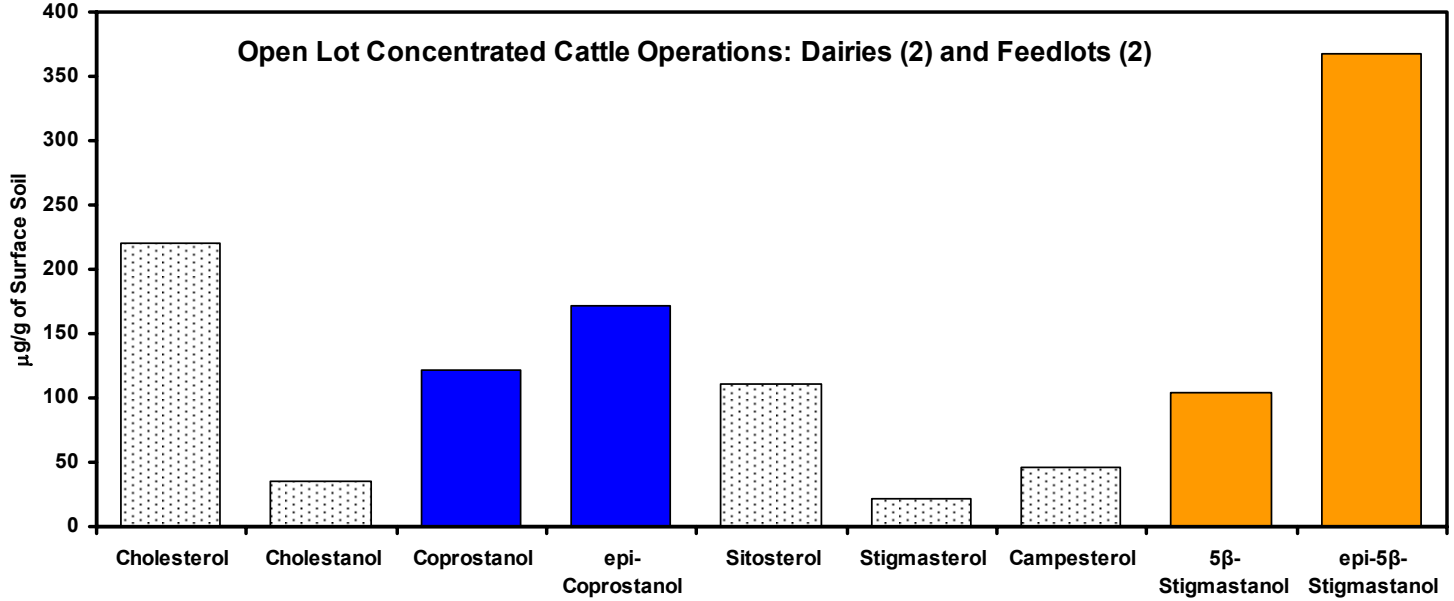


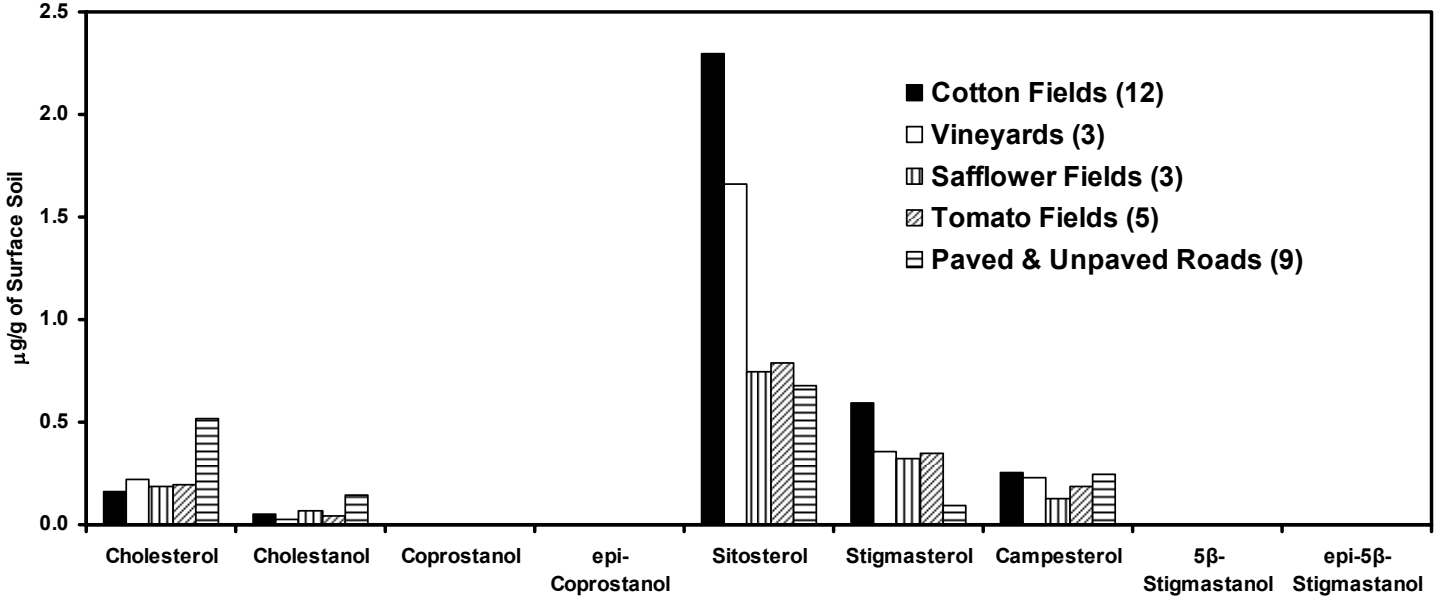
Digestion (Biohydrogenated by gut microflora)

5α-Phytosterols, 5β-Phytostanols, epi-5β-Phytostanols



Any Interference with other Sources of Fugitive Dust?





Major Organics in Feedstuffs:

- Biopolymers
- Lipids
- Phytosterols
- Vitamins
- Others

Tocopherols

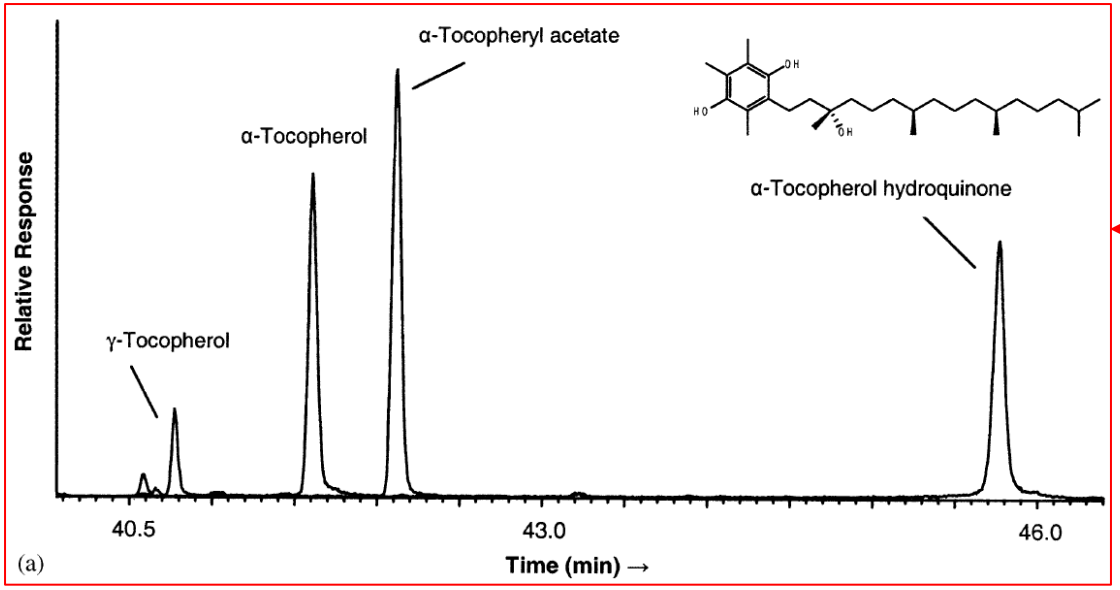
- α-Tocopherol (Vitamin E)
- γ-Tocopherol (")

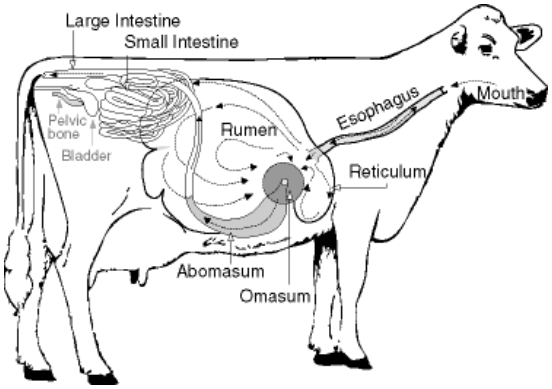
Undigested Fodder

Food Processing (Substantial loss in Vitamins)

Digestion (Bio-conversion by gut microflora)

α-Tocopheryl acetate → Processed Fodder / Vitamin Additions





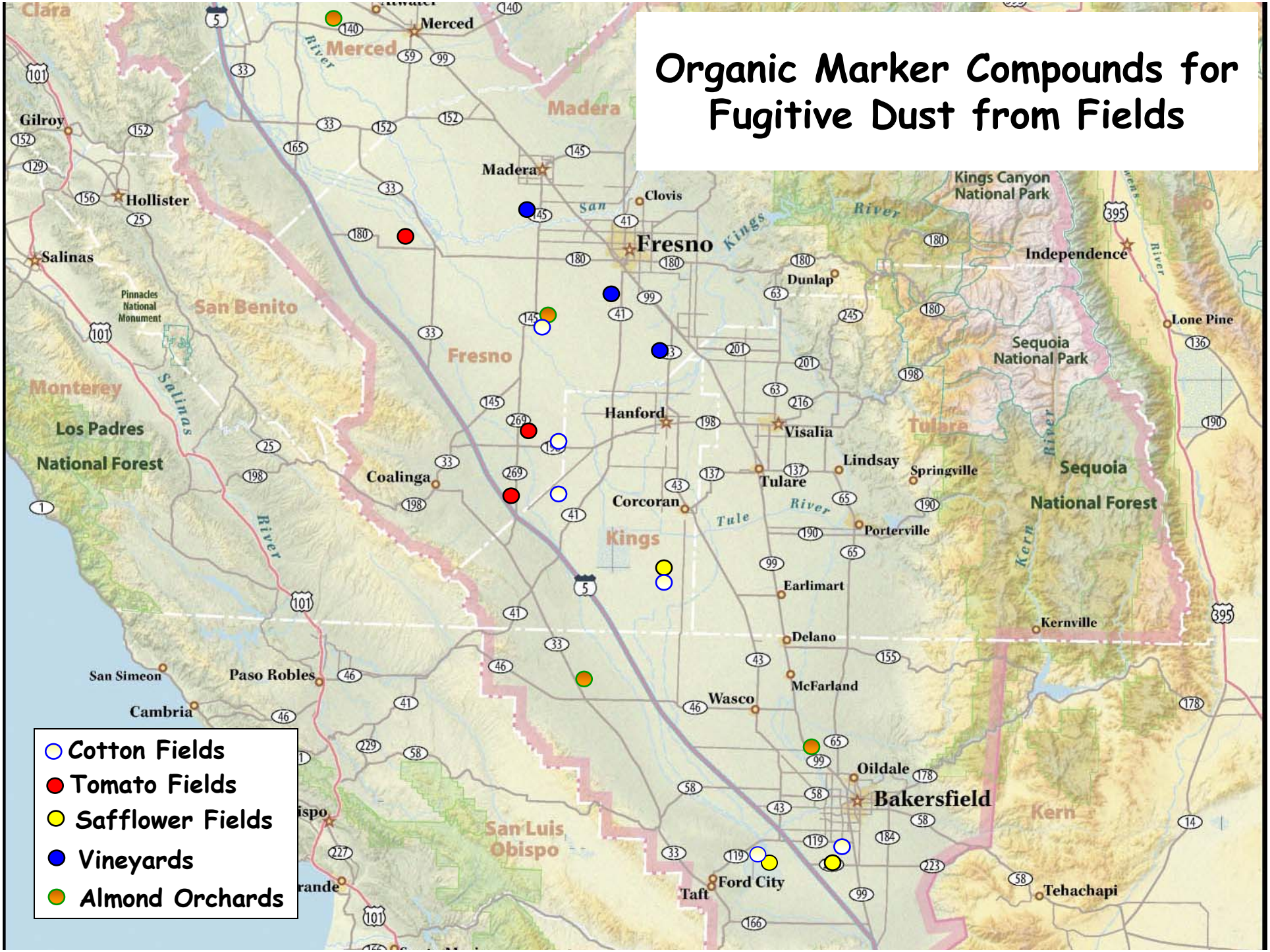
Fugitive Dust from Agricultural Fields

Tub-grinding rice st

Major Crops in the San Joaquin Valley

Type	Acreage	SJV Rank in US	US Rank in World
Cotton	800,000 – 900,000	2	2
Safflower	100,000 – 150,000	2	1
Tomato	300,000 - 350,000		
Almonds	500,000 – 600,000	1	1
Grapes & Resins	800,000 – 900,000		

Organic Marker Compounds for Fugitive Dust from Fields



Organic Marker Compounds for Fugitive Dust from Agricultural Crop Fields

Investigated Biogenic Compounds: Alkanes, Alkanoic Acids, Alkenoic Acids, Alkanols, Alkanals, Alkan-2-ones, Triterpenoids, Isoprenoids, Steroids, Saccharides

Others: Pesticides: DDT, DDD, DDE, Fosfall, Chloropyrifos, Prowl, Etoxinol, Trifluralin

Incomplete Combustion Products: Polycyclic Aromatic Hydrocarbons (PAHs)

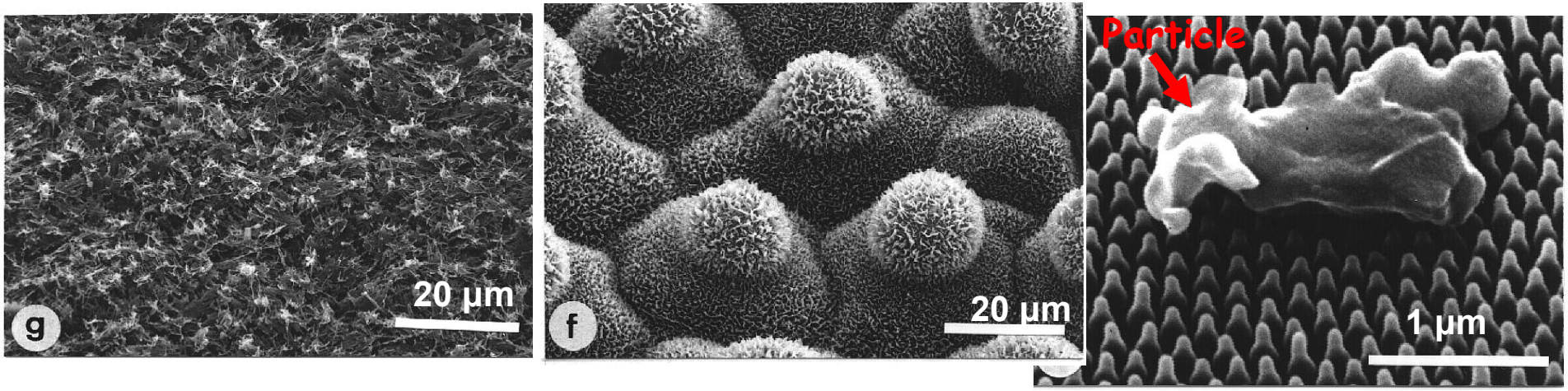
Table 2. Average concentrations of organic compounds in surface soils of crop fileds (reported as ng g^{-1})[a]

Compounds	Cotton Fields (12)	Safflower Fields (3)	Tomato Fields (5)	Almonds Orchards (6)	Vineyards (3)	Compd ID[b]
***n*-Alkanes**						
n-Tetradecane	3.1 ± 0.9	3.5 ± 3.1	2.3 ± 0.3	7.0 ± 8.4	2.6 ± 1.5	a
n-Pentadecane	6.2 ± 2.4	8.4 ± 2.4	4.3 ± 0.8	58.7 ± 29.5	4.0 ± 1.0	a
n-Hexadecane	5.1 ± 1.9	11.7 ± 6.2	4.4 ± 0.6	10.3 ± 3.4	3.9 ± 0.5	a
n-Heptadecane	11.5 ± 4.5	25.8 ± 24.7	5.0 ± 2.7	80.4 ± 40.5	10.7 ± 7.3	a
n-Octadecane	5.8 ± 1.9	26.0 ± 30.6	4.6 ± 1.3	17.1 ± 5.6	4.5 ± 1.0	a
n-Nonadecane	7.9 ± 3.5	26.1 ± 24.5	5.3 ± 1.4	19.7 ± 23.5	5.1 ± 3.1	a
n-Eicosane	10.3 ± 4.8	29.8 ± 30.1	6.6 ± 2.1	22.7 ± 15.2	7.5 ± 1.7	a
n-Heneicosane	7.6 ± 8.3		4.2 ± 3.9		2.9 ± 2.7	a
n-Docosane	14.4 ± 9.5	17.1 ± 10.2	6.4 ± 1.8	43.8 ± 24.9	9.1 ± 2.9	a
n-Tricosane	36.2 ± 28.4	57.4 ± 11.6	14.5 ± 1.8	197 ± 167	19.0 ± 7.3	a
n-Tetracosane	19.8 ± 16.2	25.4 ± 12.4	6.1 ± 2.7	63.7 ± 53.2	12.6 ± 6.5	a
n-Pentacosane	77.0 ± 54.7	78.4 ± 19.5	39.5 ± 8.7	703 ± 541	66.8 ± 32.4	a
n-Hexacosane	35.8 ± 31.4	39.3 ± 16.2	10.6 ± 3.7	174 ± 99.0	25.2 ± 22.1	a
n-Heptacosane	299 ± 192	386 ± 161	178 ± 40.5	2,723 ± 1,841	138 ± 83.9	a
n-Octacosane	67.7 ± 43.9	68.3 ± 22.1	28.5 ± 6.6	692 ± 446	36.5 ± 35.8	a
n-Nonacosane	657 ± 305	705 ± 332	545 ± 119	21,066 ± 11,626	416 ± 267	a
n-Triacontane	65.2 ± 26.7	47.2 ± 24.2	80.2 ± 20.6	1,023 ± 618	32.4 ± 19.6	a
n-Hentriacontane	705 ± 241	477 ± 276	1,823 ± 383	19,190 ± 10,811	329 ± 138	a
n-Dotriacontane	44.8 ± 11.7	26.3 ± 14.5	217 ± 45.9	566 ± 321	20.2 ± 7.6	a
n-Tritriacontane	140 ± 46.3	78.9 ± 34.2	648 ± 73.7	3,954 ± 2,812	130 ± 52.6	a
n-Tetratriacone			12.7 ± 1.0	198 ± 96	5.3 ± 5.8	a
n-Pentatriacontane	7.4 ± 5.4		23.7 ± 7.9	1,908 ± 1,787	29.9 ± 21.2	a
Range of CPI (C_{22}-C_{33})[c]	3.9 - 13.0	4.7 - 10.6	8.7 - 9.7	17.7 - 20.2	5.9 - 15.8	
***n*-Alkanoic acids**						
n-Nonanoic acid	98.7 ± 173.5	111 ± 36.7	11.4 ± 67.1	208 ± 162	204 ± 119	a
n-Decanoic acid	17.6 ± 22.3	62.3 ± 46.7	34.0 ± 12.5	60.2 ± 35.2	38.9 ± 16.2	a
n-Undecanoic acid	2.6 ± 2.9	43.8 ± 49.4	11.3 ± 6.3	24.4 ± 13.7	7.3 ± 2.4	a
n-Dodecanoic acid	38.8 ± 49.8	126 ± 135	55.3 ± 28.4	102 ± 35.0	49.0 ± 27.1	a
n-Tridecanoic acid	6.0 ± 4.2	62.9 ± 56.9	14.8 ± 3.4	48.9 ± 28.7	13.6 ± 5.1	a
n-Tetradecanoic acid	152 ± 151	207 ± 111	110 ± 36.8	329 ± 160	153 ± 55.9	a
n-Pentadecanoic acid	53.5 ± 56.9	98.8 ± 71.8	46.9 ± 15.0	171 ± 97.1	74.4 ± 19.5	a
n-Hexadecanoic acid	1,1334 ± 631	1,148 ± 304	811 ± 180	5,737 ± 3,013	875 ± 461	a
n-Heptadecanoic acid	51.7 ± 29.4	86.3 ± 58.4	34.5 ± 6.4	319 ± 201	36.9 ± 7.6	a
n-Octadecanoic acid	423 ± 476	392 ± 102	356 ± 69.7	3,063 ± 1,405	434 ± 248	a
n-Nonadecanoic acid	12.4 ± 14.5	47.6 ± 38.1	10.8 ± 1.1	143 ± 95.8	8.8 ± 0.7	a
n-Eicosanoic acid	79.8 ± 64.7	180 ± 34.0	168 ± 73.7	1,487 ± 876	60.1 ± 24.1	a
n-Heneicosanoic acid	64.9 ± 72.3	99.5 ± 61.6	27.4 ± 2.2	382 ± 217	27.8 ± 13.0	
n-Docosanoic acid	281 ± 257	366 ± 164	175 ± 28.6	2,066 ± 1,108	184 ± 98.3	a
n-Tricosanoic acid	251 ± 258	282 ± 190	90.9 ± 2.5	689 ± 386	145 ± 98.9	a
n-Tetracosanic acid	577 ± 565	865 ± 763	270 ± 23.1	3,474 ± 2,208	393 ± 200	a
n-Pentacosanic acid	307 ± 377	434 ± 450	71.8 ± 14.9	641 ± 413	119 ± 52.6	a
n-Hexacosanic acid	868 ± 1,077	1,427 ± 1,576	223 ± 53.8	3,843 ± 3,001	429 ± 185	a
n-Heptacosanic acid	452 ± 624	689 ± 793	63.1 ± 28.1	690 ± 407	130 ± 55.0	a
n-Octacosanoic acid	1,960 ± 2,403	3,753 ± 3,843	455 ± 149	5,980 ± 3,382	801 ± 332	a
n-Nonacosanoic acid	465 ± 551	584 ± 486	91.5 ± 35.9	1,753 ± 828	275 ± 141	a
n-Triacontanoic acid	1,511 ± 1,397	2,297 ± 1,754	489 ± 114	10,055 ± 4,583	1,395 ± 691	a
n-Hentriacontanoic acid	294 ± 306	296 ± 219	76.7 ± 15.0	915 ± 474	208 ± 79.8	a
n-Dotriacontanoic acid	797 ± 643	853 ± 548	397 ± 120	4,214 ± 2,128	913 ± 351	a
n-Tritriacontanoic acid	117 ± 124	116 ± 97.0	48.4 ± 17.6	225 ± 101	60.6 ± 17.0	
n-Tetratriacontanic acid	236 ± 216	204 ± 122	114 ± 24.8	674 ± 367	184 ± 28.8	a
n-Pentatriacontanoic acid	25.5 ± 46.7	10.5 ± 18.2			11.9 ± 1.4	a
n-Hexatriacontanoic acid	64.9 ± 78.3	40.6 ± 20.8			36.4 ± 10.7	a
CPI (C_{24}-C_{34})[c]	2.8 - 4.2	3.7 - 4.4	4.1 - 4.5	5.3 - 6.0	4.0 - 4.7	
***n*-Alkenoic acids**						
n-Octadecenoic acid	896.6 ± 671.8	512 ± 203	433 ± 53.3	4,242 ± 2,900	651 ± 692	a
n-Octadecadienoic acid	889.8 ± 1,386	141 ± 8.1	143 ± 50.2	1,873 ± 869	142 ± 154	a
***n*-Alkanols**						
n-Hexadecanol	37.0 ± 29.6	97.3 ± 98.7	11.4 ± 16.1			a
n-Octadecanol	9.0 ± 6.4	96.4 ± 34.4	3.1 ± 5.3	109 ± 99		b
n-Eicosanol	17.3 ± 16.3	134 ± 44.1	60 ± 104	668 ± 583	7.5 ± 13.0	b
n-Docosanol	93.3 ± 43.4	808 ± 792	186 ± 170	1,042 ± 664	50.6 ± 28.0	a
n-Tricosanol	42.4 ± 48.1	47.4 ± 21.9	4.0 ± 6.9	182 ± 364	5.4 ± 6.1	b
n-Tetracosanol	193 ± 179	975 ± 1,001	168 ± 149	6,906 ± 7,862	114 ± 52	b
n-Pentacosanol				581 ± 1,163		b
n-Hexacosanol	382 ± 318	2,148 ± 1,630	353 ± 106	4,501 ± 4,419	881 ± 454	b
n-Heptacosanol	29.3 ± 36.1		15.2 ± 21.5	267 ± 535	24.3 ± 42.0	b
n-Octacosanol	2,564 ± 2078	3,609 ± 1,820	1,664 ± 375	2,710 ± 2,153	1,427 ± 535	b
n-Nonacosanol	359 ± 423	280 ± 140	83.5 ± 68.9	909 ± 762	49.1 ± 56.1	b
n-Triacontanol	2,158 ± 1,697	3,898 ± 1,654	1,685 ± 1,455		932 ± 466	b
n-Hentriacontanol	315 ± 402					b
n-Dotriacontanol	967 ± 782	755 ± 394	359 ± 413		534 ± 152	b
CPI (C_{22}-C_{32})[c]	6.4 - 48.6	13.8 - 34.8	18.7 - 43.0	4.9 - 9.8	25.3 - 54.9	
***n*-Alkanals**						
n-Nonanal	6.5 ± 1.8	34.2 ± 22.4	7.0 ± 3.9	181 ± 226	14.8 ± 0.9	b
n-Decanal	3.3 ± 4.0	22.7 ± 12.0	4.2 ± 2.5	37.1 ± 45.5	7.5 ± 2.1	a
n-Dodecanal		21.7 ± 3.8	3.6 ± 4.9		1.6 ± 1.4	b
n-Tridecanal		37.3 ± 12.8	4.3 ± 3.9	32.5 ± 24.4	2.2 ± 2.1	a
n-Tetradecanal	3.9 ± 8.1	135 ± 63	6.2 ± 6.2	53.4 ± 34.4	5.6 ± 2.1	a
n-Pentadecanal	14.2 ± 10.0	53.7 ± 31.5	6.8 ± 3.3	129 ± 107	5.5 ± 1.7	b
n-Hexadecanal	20.7 ± 21.1	59.8 ± 43.8	14.2 ± 14.1	90.1 ± 52.6	6.0 ± 1.9	b
n-Heptadecanal	17.7 ± 21.7	47.4 ± 28.6	6.8 ± 3.5	58.9 ± 38.0	5.4 ± 2.1	b
n-Octadecanal	33.3 ± 29.9	50.2 ± 20.9	12.1 ± 7.8	82.7 ± 47.6	6.4 ± 2.7	b
n-Nonadecanal	22.1 ± 26.1	56.4 ± 43.7	5.6 ± 5.4	7.9 ± 15.7	2.3 ± 2.3	b
n-Eicosanal	37.1 ± 45.5	83.2 ± 69.5	12.9 ± 4.3	104 ± 83	7.2 ± 3.5	b
n-Heneicosanal	45.2 ± 61.6	95.4 ± 67.9	15.4 ± 4.2		1.7 ± 2.9	b
n-Docosanal	87 ± 100	146 ± 103	31.3 ± 9.7	264 ± 208	31.3 ± 18.3	b
n-Tricosanal	88 ± 114	155 ± 121	22.4 ± 6.7	156 ± 160	22.3 ± 11.4	b
n-Tetracosanal	134 ± 162	224 ± 168	46.3 ± 3.2	622 ± 603	69.4 ± 38.6	b
n-Pentacosanal	120 ± 161	186 ± 137	23.2 ± 14.0	241 ± 237	46.8 ± 26.5	b
n-Hexacosanal	251 ± 249	290 ± 173	88.2 ± 29.5	1,296 ± 1,042	340 ± 246	b
n-Heptacosanal	149 ± 193	168 ± 102	42.5 ± 27.1	384 ± 232	70.2 ± 45.0	b
n-Octacosanal	465 ± 357	339 ± 106	346 ± 122	2,773 ± 1,997	793 ± 812	b
n-Nonacosanal	139 ± 106	137 ± 59	83.0 ± 34.9	684 ± 424	154 ± 132	b
n-Triacontanal	371 ± 238	228 ± 40	370 ± 324		1,184 ± 1,485	b
n-Hentriacontanal	53.4 ± 32.6				79.6 ± 89.6	b
n-Dotriatacontanal	453 ± 154	156 ± 29	220 ± 121		786 ± 976	b
CPI (C_{22}-C_{32})[c]	2.1 - 6.8	1.5 - 2.7	4.7 - 6.5	2.6 - 4.4	4.8 - 10.9	b
***n*-Alkan-2-ones**						
n-Decan-2-one		5.7 ± 4.1	0.5 ± 0.9	5.2 ± 10.4		
n-Undecan-2-one		4.2 ± 2.5	1.1 ± 0.7	3.8 ± 4.6		b
n-Dodecan-2-one	0.6 ± 0.5	5.8 ± 1.5	0.8 ± 0.7	1.1 ± 1.9	0.1 ± 0.2	a
n-Tridecan-2-one	3.5 ± 1.8	14.0 ± 5.1	3.4 ± 1.8	6.6 ± 8.2	0.9 ± 0.5	a
n-Tetradecan-2-one	0.7 ± 0.8	14.2 ± 13.8	0.4 ± 0.7	0.7 ± 1.5	0.3 ± 0.3	a
n-Pentadecan-2-one	1.2 ± 1.0	16.8 ± 10.5	0.9 ± 0.1	6.8 ± 5.6	0.3 ± 0.3	a
n-Hexadecan-2-one	1.3 ± 0.8	17.9 ± 21.9	0.9 ± 0.5	2.8 ± 5.7	0.3 ± 0.5	b
n-Heptadecan-2-one	2.4 ± 2.3	21.2 ± 25.8	1.8 ± 0.5	10.8 ± 8.2	0.4 ± 0.7	b
n-Octadecan-2-one	1.8 ± 2.1	20.9 ± 25.2	1.0 ± 0.9	2.4 ± 4.8		b
n-Nonadecan-2-one	3.9 ± 3.3	20.1 ± 23.5	1.2 ± 0.2	1.3 ± 2.5	0.4 ± 0.7	b
n-Eicosan-2-one	6.0 ± 5.3	22.8 ± 26.6	1.4 ± 0.4			b
n-Heneicosan-2-one	5.8 ± 5.4	21.5 ± 23.0	1.4 ± 0.8	6.6 ± 9.3	0.2 ± 0.4	b
n-Docosan-2-one	7.3 ± 7.0	21.9 ± 22.4	1.4 ± 1.0	6.0 ± 8.3	1.0 ± 0.5	b
n-Tricosan-2-one	17.4 ± 16.7	31.4 ± 24.6	2.5 ± 1.5	15.9 ± 16.7	3.5 ± 1.7	b
n- Tetracosan-2-one	13.0 ± 16.3	30.3 ± 28.1	2.3 ± 1.6	13.9 ± 9.8	2.1 ± 0.8	b
n-Pentacosan-2-one	36.4 ± 46.5	55.1 ± 44.7	5.6 ± 2.5	69.2 ± 79.6	7.5 ± 3.7	b
n-Hexacosan-2-one	31.2 ± 44.2	49.8 ± 45.4	3.9 ± 2.2	25.7 ± 21.1	4.8 ± 2.6	b
n-Heptacosan-2-one	103 ± 141	139 ± 110	12.5 ± 6.9	231 ± 289	20.0 ± 10.7	b
n-Octacosan-2-one	48.4 ± 69.5	61.5 ± 50.3	6.4 ± 3.6	49.4 ± 42.8	10.1 ± 4.9	b
n-Nonacosan-2-one	144 ± 179	167 ± 101	40.8 ± 19.3	504 ± 406	53.0 ± 30.4	b
n-Triacontan-2-one	44.0 ± 61.7	49.3 ± 30.7	10.7 ± 4.1	90.8 ± 62.7	16.7 ± 8.4	b
n-Hentriacontan-2-one	115 ± 117	121 ± 22	75.1 ± 41.1	743 ± 490	83.7 ± 45.7	b
n-Dotriacontan-2-one	29.4 ± 41.3	32.5 ± 22.4	10.9 ± 3.3	66.1 ± 42.6	14.4 ± 6.7	b
n-Tritriacontan-2-one	80.2 ± 88.8	60.9 ± 12.1	76.2 ± 27.3	323 ± 249	50.9 ± 20.8	b
n-Tetracontan-2-one	10.6 ± 11.8	12.7 ± 8.2	9.7 ± 1.5	11.1 ± 22.2	11.0 ± 7.6	b
n- Pentacontan-2-one	16.7 ± 19.5	12.7 ± 1.9	18.6 ± 3.9	78.6 ± 49.0	12.3 ± 5.8	b
CPI (C_{23}-C_{33})[c]	2.5 - 5.3	1.9 - 3.4	4.6 - 5.5	6.4 - 8.3	3.8 - 3.9	
PAHs						
Phenanthrene		3.2 ± 3.4	0.6 ± 0.1	3.4 ± 1.7	12.3 ± 19.6	a
Anthracene		0.7 ± 0.7		4.4 ± 2.2	1.9 ± 2.8	a
4H-Cyclopentaphenanthrene					1.2 ± 2.1	a
Fluoranthene		2.1 ± 1.2	0.5 ± 0.2	5.8 ± 4.1	38.6 ± 63.9	a
Pyrene		1.7 ± 0.7	0.4 ± 0.2	5.3 ± 3.8	35.6 ± 58.6	a
Benz[a]anthracene			0.2 ± 0.2		13.8 ± 22.6	a
Chrysene/Triphenylene			0.3 ± 0.3		26.2 ± 42.7	a
Benzo[b]fluoranthene			0.5 ± 0.2	4.2 ± 3.0	35.5 ± 58.6	a
Benzo[k]fluoranthene					12.7 ± 21.0	a
Benzo[j]fluoranthene					2.1 ± 3.3	a
Benzo[e]pyrene			0.3 ± 0.2		21.5 ± 34.9	a
Benzo[a]pyrene					21.0 ± 34.6	a
Perylene					4.1 ± 6.6	a
Indeno[123-cd]pyrene					29.4 ± 48.8	a
Benzo[ghi]perylene					22.3 ± 36.5	a
Dibenzo[ah]anthracene					20.2 ± 33.5	a
Coronene					6.4 ± 10.0	a
Triterpenoids						
24-Methylenecycloartanol	39.9 ± 13.4		26.0 ± 5.0	1,539 ± 658	24.4 ± 15.7	b
Cycloartenol			105 ± 41	592 ± 626		a
Ursolic acid				21,067 ± 17,031		b
α-Amyrin	183 ± 135	356 ± 453	50.7 ± 22.2	927 ± 870	53.1 ± 32.9	a
β-Amyrin	121 ± 83	1,833 ± 2,528	61.0 ± 7.8	692 ± 986	29.8 ± 18.2	a
Oleanolic acid				11,451 ± 9,169		b
Ursonic acid				1,770 ± 1,854		b
Oleananonic acid				1,735 ± 1,573		b
Betulinic acid				9,280 ± 7,974		b
Betulin				469 ± 349		b
Taraxasterol	113 ± 112	3,501 ± 3,718				b
3α-Lupeol		1,175 ± 799		143 ± 285		b
Steroids						
Cholesterol	145 ± 157	712 ± 473	194 ± 16.3	3,057 ± 3,213	217 ± 146	a
Cholestanol	43.7 ± 55.1	68.1 ± 45.9	40.3 ± 11.3	414 ± 392	28.9 ± 26.8	a
Cholest-4-en-3-one		26.5 ± 28.2	38.3 ± 25.2	199 ± 224		b
Sitosterol	2,792 ± 1,551	3,449 ± 3,197	712 ± 157	46,950 ± 16,358	1,775 ± 1,236	a
5-α-Stigmastan-3-one	155 ± 116	109 ± 38	87.6 ± 28.5	2,505 ± 1,189	253 ± 168	b
24S-Stigmast-7-en-3-ol	79.2 ± 71.5	50.0 ± 29.1	22.0 ± 15.0	1,117 ± 1,159	39.4 ± 46.0	b
Stigmasterol	675 ± 373	1,688 ± 1,589	425 ± 102	2,671 ± 1,613	386 ± 233	a
Stigmast-4-en-3-one	821 ± 554	205 ± 12	220 ± 76	21,333 ± 15,252	467 ± 364	b
24S-Ethyl-3α,5β-cyclocholest-22(E)-en-6-one	118 ± 80	55.5 ± 10.4	96.6 ± 44.2		59.8 ± 39.9	b
Stigmasta-3,5-dien-7-one	55.0 ± 42.4	30.4 ± 10.6	20.6 ± 7.9	3,085 ± 2,726	48.1 ± 36.7	b
Campesterol	321 ± 190	513 ± 664	206 ± 35.5	2,877 ± 1,602	225 ± 170	a
γ-Ergosterol	70.2 ± 53.2	24.7 ± 3.8	28.3 ± 5.1	1,117 ± 565	61.1 ± 58.3	b
Ergostanol	45.9 ± 31.0	44.2 ± 27.7	27.2 ± 5.7	520 ± 680	32.9 ± 27.8	b
Ergosterol	40.6 ± 21.6			651 ± 405	9.9 ± 17.2	a
Brassicasterol	5.3 ± 9.2			142 ± 44	5.7 ± 9.9	b
Isoprenoids						
Phytol	622 ± 443	76.2 ± 65.8	422 ± 179	5,964 ± 6,045	42.7 ± 41.0	a
Phytone	43.3 ± 32.6	70.8 ± 26.2	58.6 ± 15.2	426 ± 394	16.3 ± 9.4	b
Squalene	303 ± 226	89.3 ± 89.7	30.1 ± 26.1	282 ± 209	247 ± 352	a
α-Tocopherol	250 ± 210	19.7 ± 5.3	94.8 ± 80.6	7,227 ± 4,567	177 ± 178	a
γ-Tocopherol	22.8 ± 19.0	1.7 ± 0.6	8.6 ± 7.3	667 ± 408	17.9 ± 20.2	b
Saccharides						
α- + β-Glucose	584 ± 653	998 ± 1,013	595 ± 177	2,256 ± 2,707	142 ± 181	a
Sucrose	393 ± 648	1,311 ± 659	437 ± 201	1,848 ± 1,368	481 ± 406	a
Mycose	2,765 ± 2,258	5,903 ± 148	5,072 ± 2,429	30,206 ± 12,057	4,279 ± 4,589	a
Sorbitol				3,361 ± 2,745		a
Inositol		323 ± 411				a
Glycerol	105 ± 152	175 ± 153	261 ± 48	3,405 ± 366	115 ± 138	
Levoglucosan		66.2 ± 77.2				a
Pesticides						
DDT	348 ± 492	215 ± 201				b
DDD	103 ± 146	97.5 ± 10.6				b
DDE	540 ± 387		618 ± 797		396 ± 267	b
Fosfall	663 ± 1,279		89 ± 138		58 ± 101	b
Chloropyrifos				1,398 ± 1,112		b
Prowl	537 ± 759	63.3 ± 36.6				b
Etoxinol	54.7 ± 77.3					b
Trifluralin			23.4 ± 40.5			b

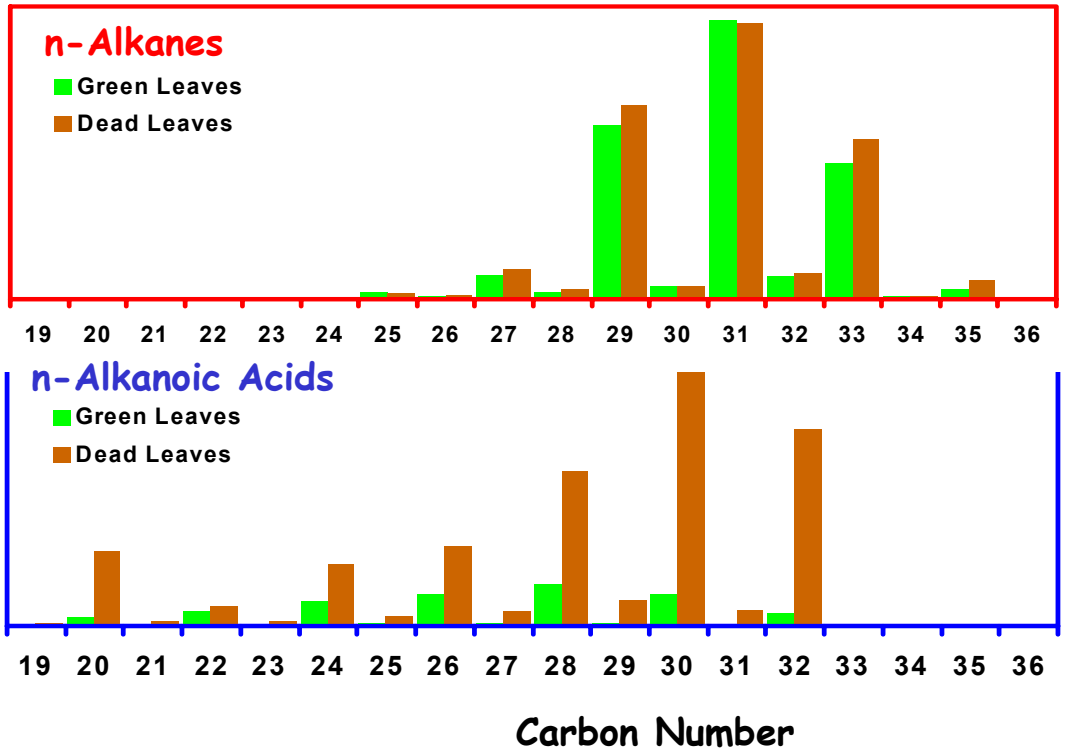
[a] Surface soil samples were collected after the growing season of 1997.

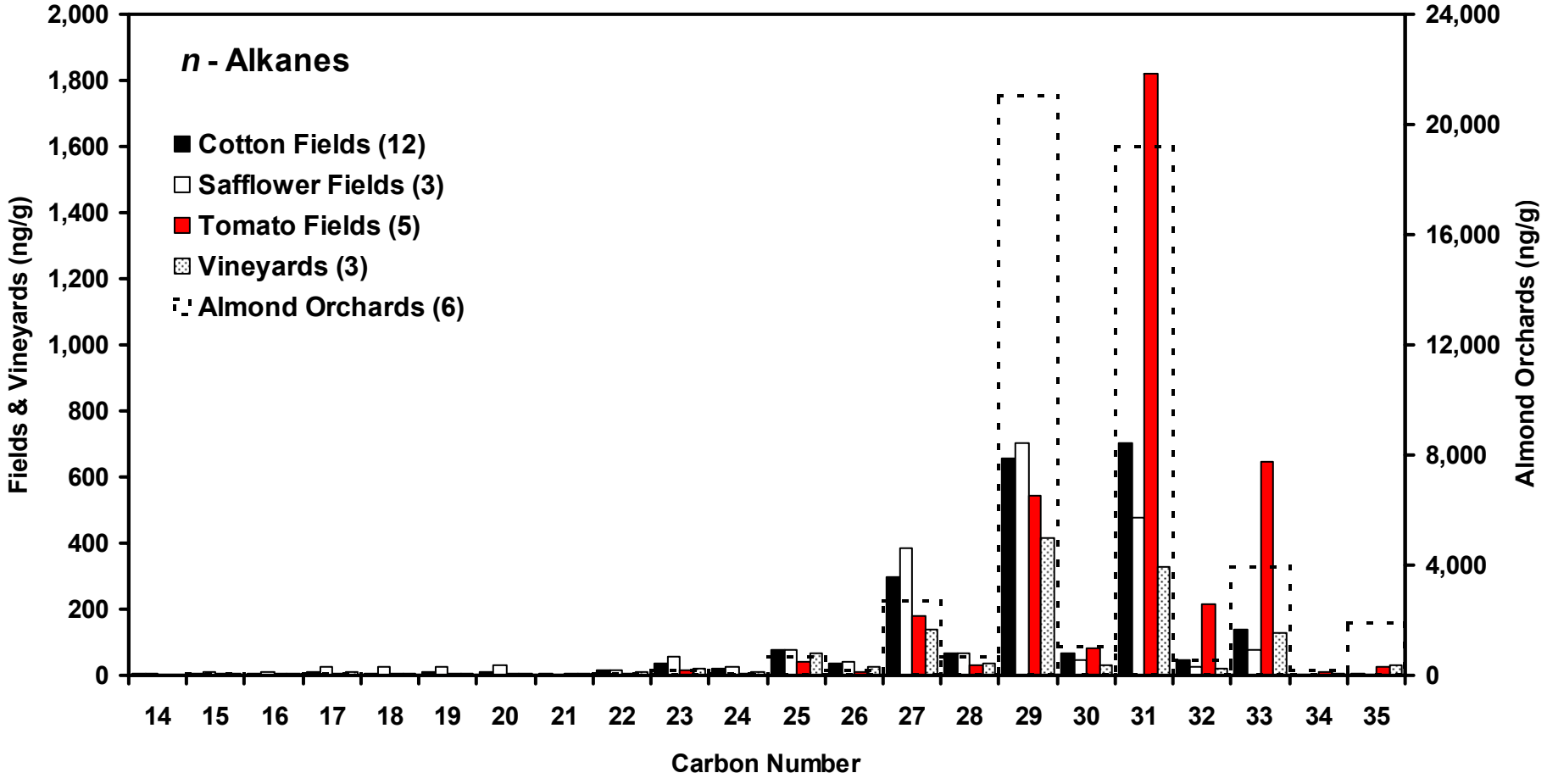
[b] Compound identification: a, authentic standard verification and quantification; b, MS-spectrum verification and quantified using authentic standard with similar structure, polarity, and volatility.

[c] CPI: *n*-alkanes = ΣC_{23}-C_{33}/ΣC_{22}-C_{32}; *n*-alkanoic acids = ΣC_{24}-C_{34}/ΣC_{23}-C_{33}; *n*-alkanols and *n*-alkanals = ΣC_{22}-C_{32}/ΣC_{21}-C_{31}; *n*-alkanones = ΣC_{23}-C_{30}/ΣC_{22}-C_{29}



Particulate (PM2.5) Leaves Surface Abrasion Products




n - Alkanes
Cotton Fields (12)
Safflower Fields (3)
Tomato Fields (5)
Vineyards (3)
Almond Orchards (6)
Fields & Vineyards (ng/g)
Almond Orchards (ng/g)
Carbon Number
0
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
0
4,000
8,000
12,000
16,000
20,000
24,000
14
15
16
17
18
19
20
21
22
23
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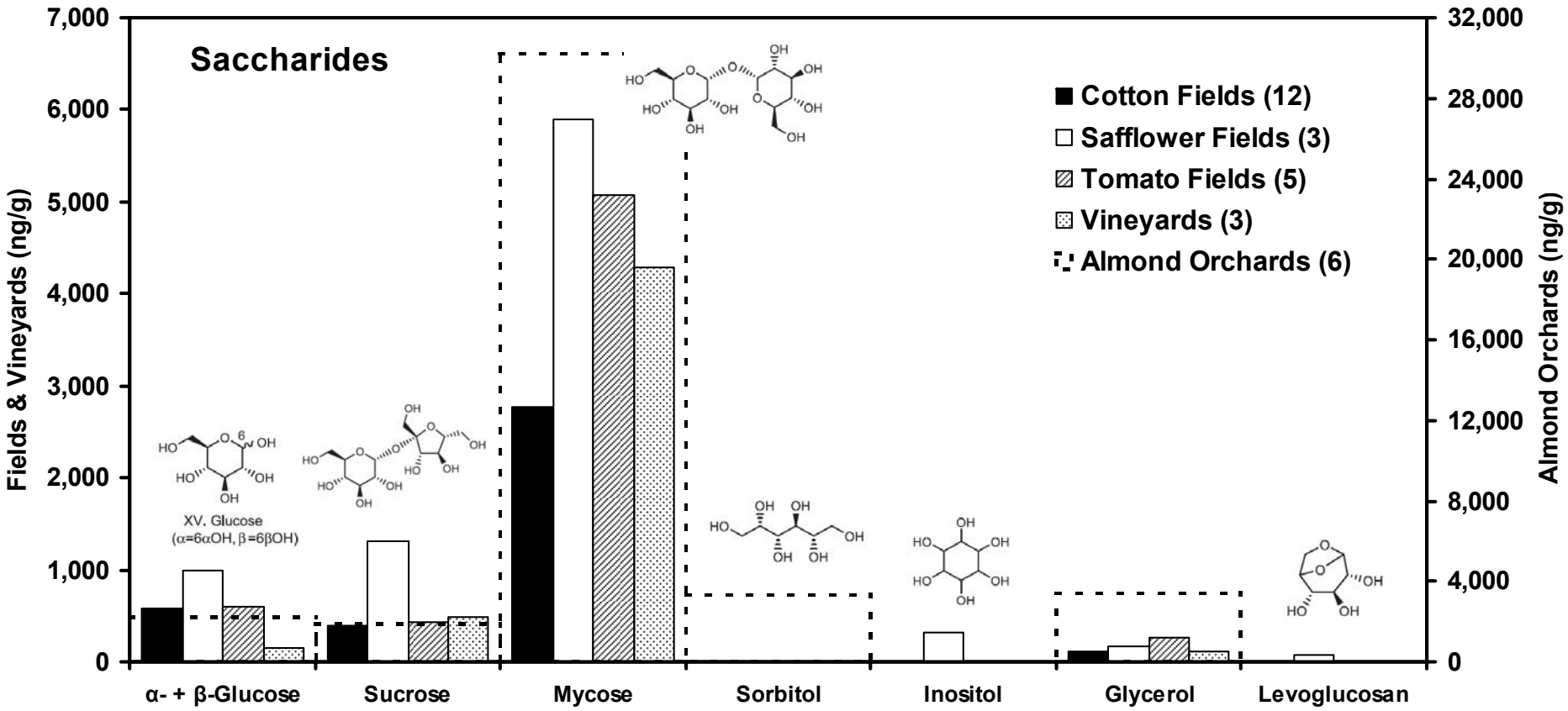
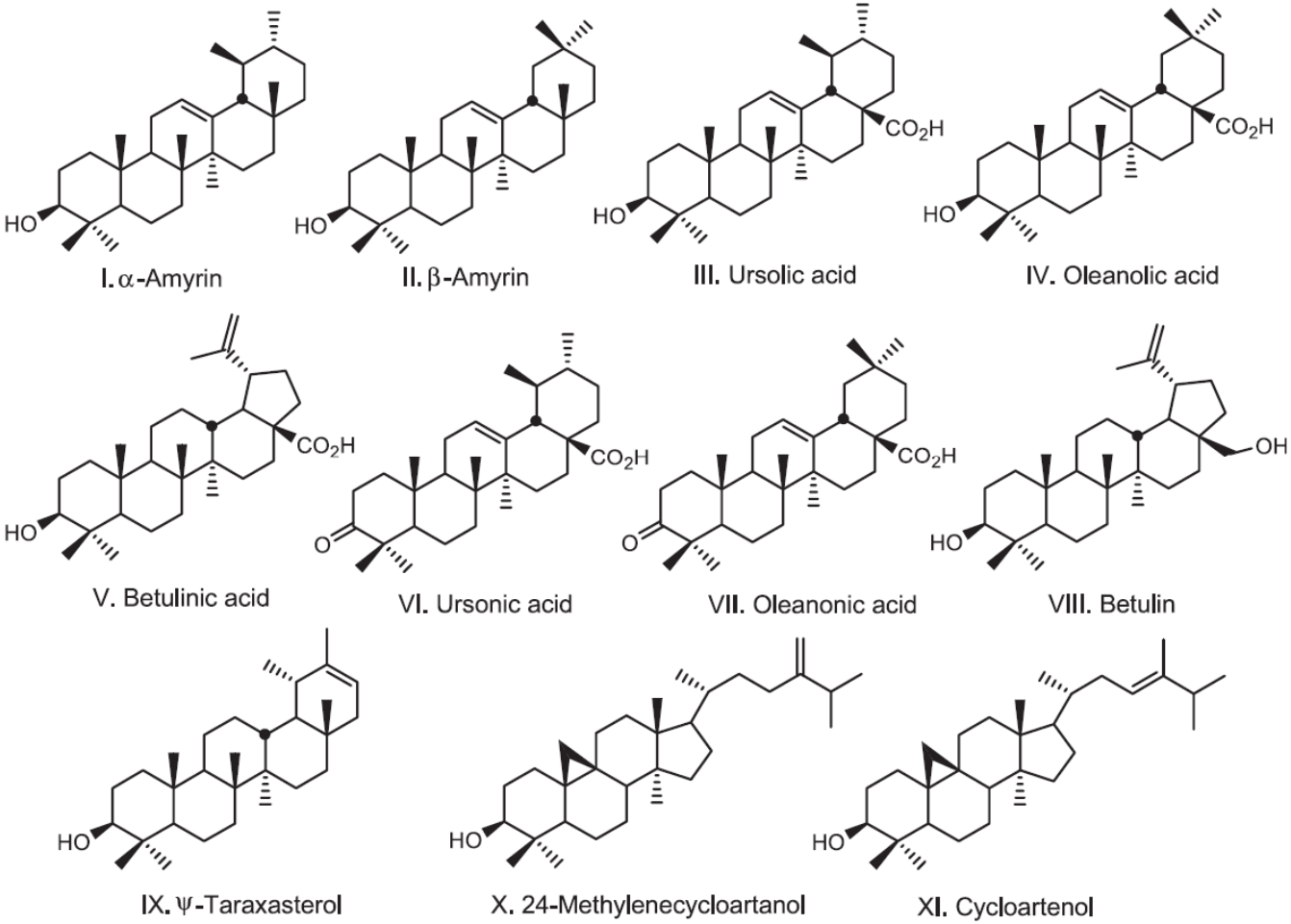
Generic Markers for Fugitive Dust from Cultivated & Active Land: α- and β-Glucose, Sucrose, and Mycose (Trehalose)

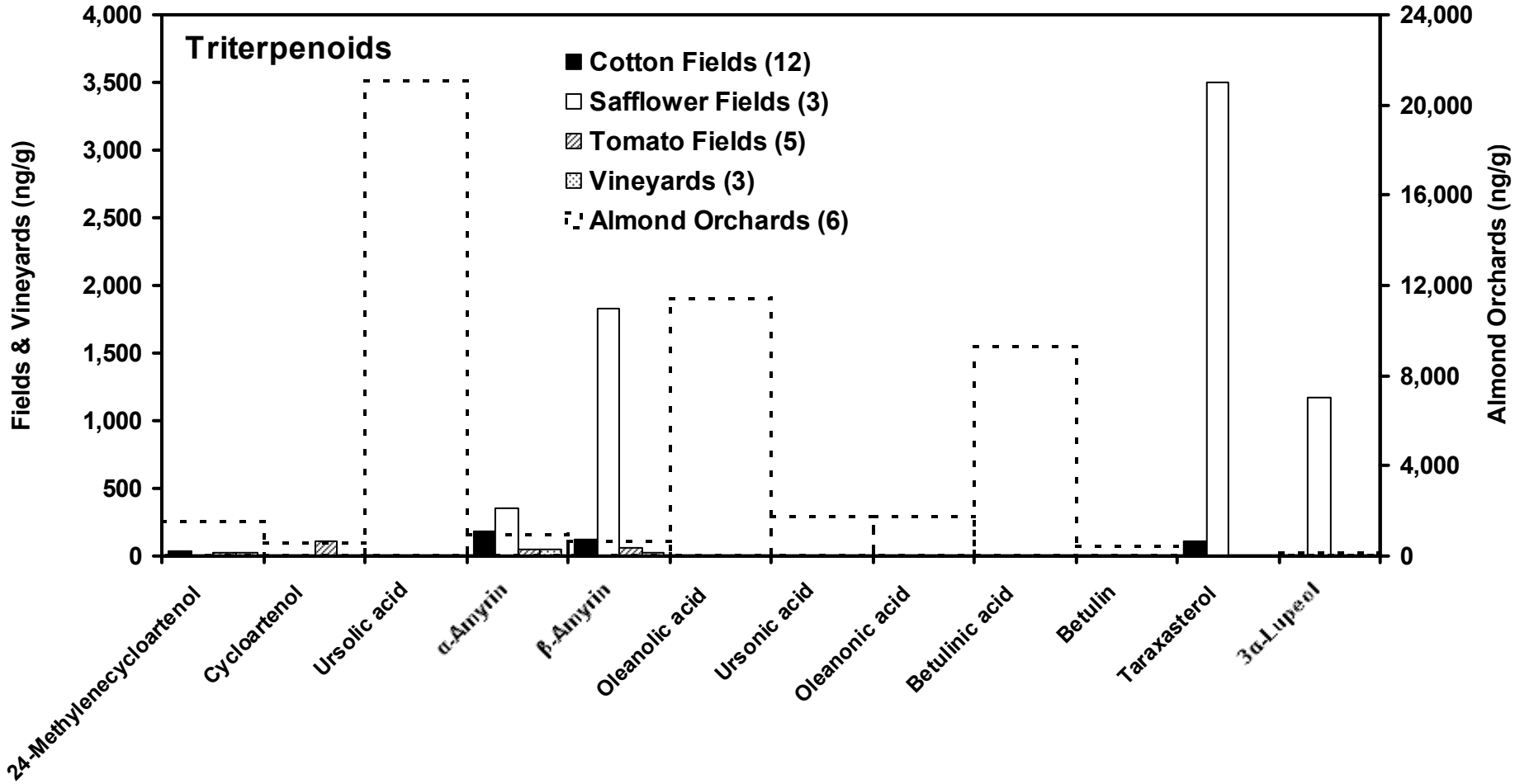


Triterpenoids

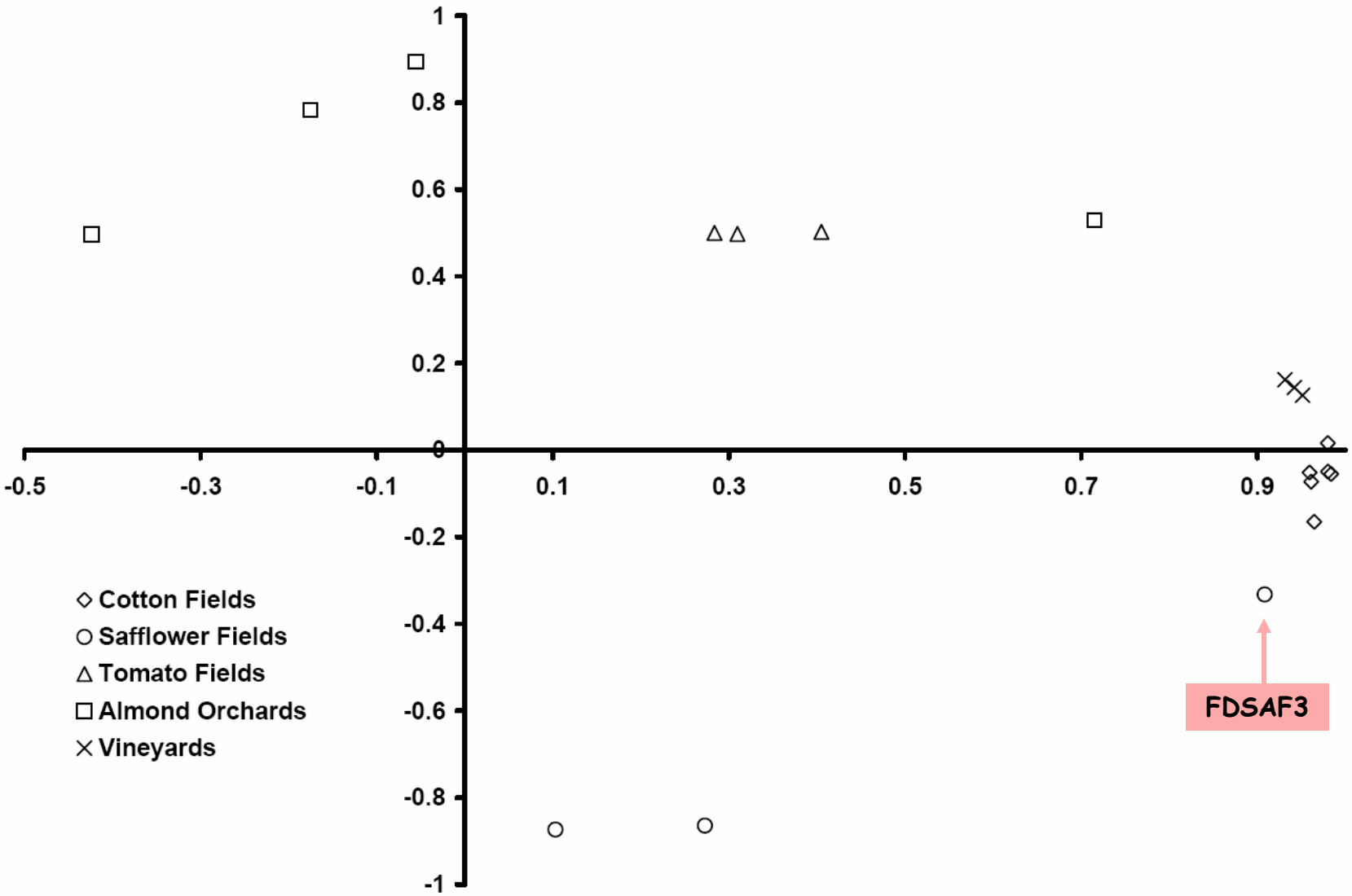
Chemo-systematic markers that are used to differentiate even closely related plants.



Triterpenoids



Principal Component Analysis with Varimax Rotation for Triterpenoids



Summary of crop rotations and soil classifications for the agricultural fields with C_{max} for their aliphatic lipids

Sample ID	Crop rotation history					Soil classification	C_{max} for aliphatic lipids with carbon number >C20				
	1993	1994	1995	1996	1997		Plant surface waxes				
							Alkanes	Alkanoic acids	Alkanols	Alkanals	Alkan-2-ones
FDCOT1A	Almonds	Almonds	Almonds	Almonds	Cotton	Chino fine sandy loan	31	30	30	30	31
FDCOT1B	Almonds	Almonds	Almonds	Almonds	Cotton	Chino fine sandy loan	31	30	30	28	31
FDCOT1C	Almonds	Almonds	Almonds	Almonds	Cotton	Chino fine sandy loan	31	30	30	28	31
FDCOT2A	Acala cotton	Pima cotton	Pima cotton	Fallow	Pima cotton	Cerini clay loam	31	30	28	28	31
FDCOT2B	Acala cotton	Pima cotton	Pima cotton	Fallow	Pima cotton	Cerini clay loam	31	30	28	28	31
FDCOT2C	Acala cotton	Pima cotton	Pima cotton	Fallow	Pima cotton	Cerini clay loam	31	30	28	28	31
FDCOT3A	Cotton	Safflower	Cotton	Wheat	Cotton	Copus silty clay	29	28	28	28	29
FDCOT3B	Cotton	Safflower	Cotton	Wheat	Cotton	Copus silty clay	29	28	28	28	29
FDCOT3C	Cotton	Safflower	Cotton	Wheat	Cotton	Copus silty clay	29	28	28	28	29
FDCOT4A	Cotton	Cotton	Safflower	Cotton	Cotton	Lokern clay	31	30	28	30	29
FDCOT5A	Garlic	Cotton	Garbanzo	Cotton	Cotton	Westhaven loam	29	30	28	28	31
FDCOT6A	n.k.	n.k.	n.k.	n.k.	Cotton	Tulare clay	29	28	30	28	29
FDSAF1	n.k.	n.k.	n.k.	n.k.	Safflower	Tulare clay	29	28	30	26	29
FDSAF2	Safflower	Cotton	Cotton	Safflower	Safflower	Zalvidea sancy clay loam	29	28	30	28	29
						Oldriver loam	29	30	30	28	31
FDTOM1A	Upland cotton	Upland cotton	Pima cotton	Pima cotton	Tomatoes	Panachoe silty clay	31	28	30	30	31
FDTOM1B	Upland cotton	Upland cotton	Pima cotton	Pima cotton	Tomatoes	Panachoe silty clay	31	30	30	30	31
FDTOM1C	Upland cotton	Upland cotton	Pima cotton	Pima cotton	Tomatoes	Panachoe silty clay	31	30	30	30	31
FDTOM2A	n.k.	n.k.	n.k.	n.k.	Tomatoes	Clay	31	30	28	28	33
FDTOM3A	n.k.	n.k.	n.k.	n.k.	Tomatoes	Sandy clay loam (UCD)	31	28	28	28	33
FDALM1A	Almonds	Almonds	Almonds	Almonds	Almonds	Driver coarse sandy loam	29	30	24	28	31
FDALM1B	Almonds	Almonds	Almonds	Almonds	Almonds	Driver coarse sandy loam	29	30	24	28	31
FDALM1C	Almonds	Almonds	Almonds	Almonds	Almonds	Driver coarse sandy loam	29	30	24	28	31
FDALM2	Almonds	Almonds	Almonds	Almonds	Almonds	Loamy sand (UCD)	29	30	24	28	31
FDALM3	Almonds	Almonds	Almonds	Almonds	Almonds	Kimberlina fine sandy loam	29	30	24	28	31
FDALM4	Almonds	Almonds	Almonds	Almonds	Almonds	Dinuba sandy loam	29	30	24	28	31
FDGRA1	Grapes	Grapes	Grapes	Grapes	Grapes	Hesperia fine sandy loam	29	30	28	30	31
FDGRA2	Grapes	Grapes	Grapes	Grapes	Grapes	Sandy loam (UCD)	29	30	28	30	31
FDGRA1	Grapes	Grapes	Grapes	Grapes	Grapes	Handford fine sandy loam	29	30	28	30	31

Conclusions:

Potential Organic Markers for Particulate Matter from Concentrated Cattle Operations

- C18/C16 – Fatty acid ratio
- α-Tocopheryl acetate
- 5β-Stigmastanol & epi-5β-Stigmastanol

Conclusions:

Potential Organic Markers for Particulate Matter from Crop Fields

- Generic Markers: Sugars
- Triterpenoids

Conclusions:

Verification of Proposed Marker Compounds

Conduct study downwind from fugitive dust sources and at selected sites at urban areas:

1. Generate source profiles for PM10 & PM2.5
2. Contributions of individual fugitive dust source types to selected receptor site

Conclusions: Major Organic Source Markers for PM

Source Markers	Major Source Type	Associated Sources
Odd-Carbon n-Alkanes (>C_{25}) Even-Carbon n-Alkanoic Acids (>C_{23})	Leaf Surface Waxes	Burning of Vegetative Detritus, Soil Dust, Vegetarian Cooking
Even-Carbon n-Alkanes	Plastic Waste Burning	
Cholesterol	Meat Cooking	Food Processing Industry
5β-, epi-5β-Stigmastanol, CF18/CF16, Vitamin E acetate	Dairy Farms & Feedlots	
Levoglucosan	Biomass Burning (Cellulose)	Wildfires Forest Fires Agricultural Waste Burning
Resin Acids	Soft Wood Burning	
Syringyl Derivatives	Hard Wood Lignin	
Saccharides: Mycose, Sucrose, α-, β-Glucose	Fugitive Dust from Cultivated Land	
Triterpenoids	Crop Fields	
Iso-, Anteiso-Alkanes (>C_{26})	Cigarette Smoke	
Hopanes & Steranes	Vehicular Emission	Heavy Oil Burning
Benzothiazole	Tire Wear	

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Organic marker compounds for surface soil and fugitive dust from open lot dairies and cattle feedlots

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Organic marker compounds in surface soils of crop fields from the San Joaquin Valley fugitive dust characterization study

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