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Executive Summary

Increasingly acid soils have been noted by agronomists and soil testing laboratories on soils of northern and central California. These soils tend to be moderately to highly weathered or poorly buffered and acidified through nitrogen fertilization. Water pH levels below 5.60 are sufficient to impact crop growth and quality, dependent on the crop. Current lime recommendations for California are based on calibration models developed in the eastern United States on soils of distinctly different parent material and growing conditions.

This project will develop lime requirement calibration models for California soils based on six standard laboratory test methods using 120 California soils selected from the San Joaquin Valley, North Coast and Sacramento Valleys of California. Soils will be selected from vineyards, tree crop, forage and row crop areas, where low pH values have been noted by commercial testing laboratories and agricultural consultants. Soils will be characterized for chemical and physical properties and the lime requirement assessed using greenhouse equilibration. All soil analysis will be conducted using California testing laboratories. Models developed will be validated using a second set of 20 soils in 2004.

Introduction

Increasingly acid soils have been noted on soils of northern and central California by field agronomists and soil testing laboratories. These soils tend to be moderate to highly weathered or poorly buffered and/or acidified through ammonium based nitrogen fertilizers. Acidity levels below a pH of 5.60 are sufficient to impact crop growth and quality, dependent on the crop species and cultivar. Current lime recommendations for California utilizing the SMP buffer method and are based on calibration models developed in the eastern United States on soils of distinctly different parent material, growing conditions and cropping systems.

In 2002 a project was initiated to evaluate lime requirement calibration models for California soils selected from the San Joaquin Valley, North Coast and Sacramento Valleys of California. Soils were selected from vineyards, tree crop, forage and row crop areas, where low pH values have been noted by commercial testing laboratories and agricultural consultants. Soils were characterized for chemical and physical properties and the lime requirement assessed using a 5-Day neutralization/ incubation tests and four buffer pH methods. An additional 21 soils were collected in 2004 on which to validate the lime recommendations developed on the initial set of 120 soils

Methods

Beginning in the spring of 2002 through 2003 one-hundred twenty-one soils were collected representing agricultural soils from 19 counties of central and northern California. At each site information was collected on the GPS location, soil series, (if known), method of irrigation, crop, moisture status, grower and farm. Sites included lettuce, lemon, heather, pistachio, watermelon, almond, tomato, onion, squash, potato, rice, grapes, peppers, pasture and corn crops (See Appendix A).

Soils were collected, air dried and pulverized to pass a 2.0 mm sieve. Soils were analyzed for: saturated paste moisture content; pH saturated paste method; saturated paste EC; pH (1:1) H_2O method; pH (1:1) 0.01 M $CaCl_2$ method; KCl extractable Al; ammonium acetate extractable K, Ca, Mg, and Na; Olsen extractable PO_4-P, DTPA extractable Zn, Mn, Fe and Cu; cation exchange capacity; soil organic matter and sand, silt and clay contents. Specific analyses were conducted in triplicate. Five reference soils from the North American Proficiency Testing (NAPT) program archives were included as quality assurance samples to authenticate the quality of the soil analyses. Soil lime methods based buffer pH included: SMP buffer pH (Sims 1995,); a modified SMP method (50% strength) Adams Evans buffer pH (Adams, 1984); Mehlich buffer pH (Mehlich, et al, 1976); and Woodruff Buffer pH (Sims, 1996). All soils were evaluated for exchangeable acidity based on a modified 5-Day incubation with calcium hydroxide (Adams, 1962). A proposed additional lime buffer capacity method was add to the project in 2003, based on a proposed University of Georgia direct calcium hydroxide addition and subsequent determination of pH as described by Liu et al (2005). In 2004 an additional 22 acid soils were collected from across California on which to validate the proposed lime recommendation model.

Results

In 2002 and 2003 a lab survey was conducted to evaluate the distribution of acid soils in California. A database obtained in 2003 from two California based soil testing laboratories[1] of 28,299 soil samples indicated that 20.2% of the soils analyzed by the saturated paste had a pH below 6.00 and 5.1% were below pH 5.00 . Although these results do not represent an equal distribution across the state, they are indicative of agricultural soils analyzed by the lab industry.

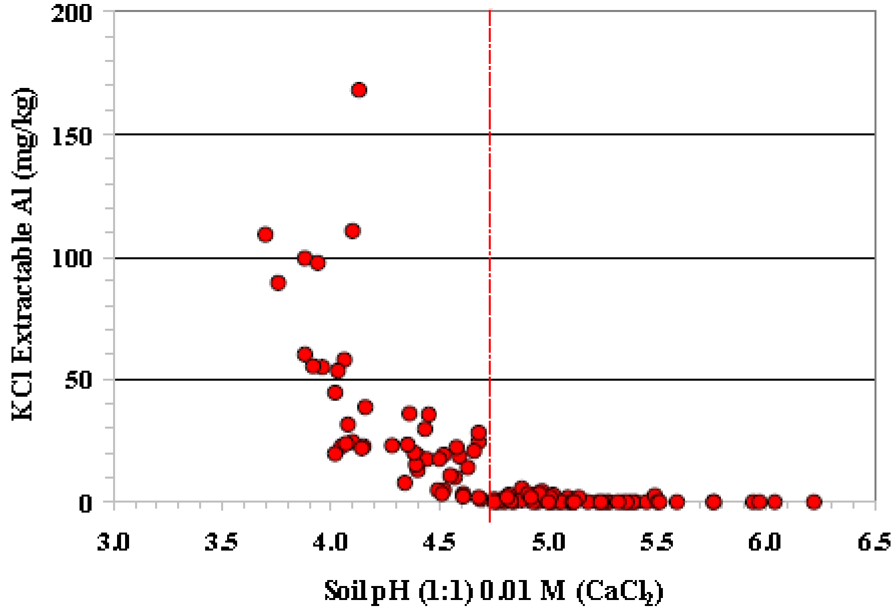
Of the 120 soils collected twenty-two had an initial soil pH (1:1) 0.01 M $CaCl_2$ method that exceeded 6.20, and thus deemed not appropriate for use in this study. Of the remaining ninety-eight soils, soil pH (1:1) 0.01 M $CaCl_2$ results indicated fourteen soils were less than 4.00, thirty-nine of the soils were between 4.50 to 5.00, forty-two had a pH in the range of 5.00 to 6.00 and three with a pH between 6.00 and 6.30 (see Table 1). Results for soil KCl extractable Al, an indicator of strongly acid soils, indicated five soils had Al values exceeding 100 mg kg^{-1}, twenty-six soils in the range of 20 - 100 mg/kg Al, thirty-seven soils with 1.0 - 20 mg kg^{-1} Al, and the remaining twenty had concentrations less than 1.00 gm kg^{-1} Al. Plotting pH (1:1) 0.01 M CaCl against Al content indicates that Al concentrations become significant (> 2.0 mg kg^{-1}) for soils with a pH 0.01 M $CaCl_2$ below 4.80 , Figure 1. For the saturated paste this is a pH of 5.10 and a pH (1:1) H_2O of 5.60. Extractable Al concentrations increased dramatically with decreasing pH.

Table 1. Soil physio-chemical properties used in the California liming project.

Soil Property	Unit	Range	Median
Saturated Paste Moisture	%	19.8 - 69.3	32.9
EC (sp)	dS m^{-1}	0.13 - 6.74	0.61
pH (Saturated Paste)		4.00 - 6.57	5.36
pH (1:1) H_2O		4.21 - 6.80	5.50
pH (1:1) $CaCl_2$		3.62 - 6.23	4.80
KCl Extr. Al	mg kg^{-1}	0.0 - 515	2.90
SOM	%	0.18 - 6.04	2.04
CEC	cmol kg^{-1}	1.02 - 38.3	9.3
Exch. Acidity (Mehlich)	cmol kg^{-1}	0.57 - 6.86	1.86
Clay	%	4.0 - 61.0	19.6
$CaCO_3$ Lime Req (5-Day Incub)	lbs ac^{-1}	210 - 10,590	1380

[1] Based on Soil samples analyzed by: Dellavalle Laboratories, Fresno, CA; and Sunland Laboratories, Rancho Cordova, CA

Figure 1. Relationship of soil pH (1:1) 0.01 M $CaCl_2$ and KCl extractable Al for ninety- eight soils collected from central and northern California.



Soil saturated paste moisture content ranged from 19.8 - 69.3% indicating the soils evaluated ranged from loamy sand to clay in texture. Sixty-nine of the soils had a saturated paste method EC, based on the of less than 1.00 dS m^{-1}. Twenty-one percent of the soils collected contained less than 100 mg kg^{-1} extractable K, 35% in the range of 100 - 150 mg kg^{-1} and the remainder more than 150 mg $kg^{-1}$of K.

Fifty percent of the soils collected contained less than 800 mg kg^{-1} Ca and 177 mg kg^{-1} for Mg. A majority of the soils had Olsen extractable PO_4-P values less than 25.0 mg kg. Results for sand analysis indicate these soils were dominated by coarse textured materials with fifty-percent of the soils having more than 47% sand by weight. Soil organic matter ranged from 0.18 - 6.04 % (w/w) with a median of 2.04%. Cation exchanged capacity (CEC) indicated that fifty percent of the soils were below 6.3 cmol kg^{-1}. 5-Day lime incubation values ranged from 210 to 10,590 lbs ac^{-1} with a median of 1380 lbs ac^{-1} $CaCO_3$. A 5-Day Incubation was chosen over the that of a 3-Day as used by Adams, 1962 since 30% of the soils evaluated required additional time to fully equilibrate. Thirty soils had a 5-Day incubation lime rate of less than 1000 lbs ac^{-1}, fifty-one in a range of 1000 - 4000, lbs ac^{-1} and seventeen with a rate exceeding 4000 lbs ac^{-1} .

Correlation results indicate a strong relationship between saturated paste moisture content and CEC and clay content, and negative relationship between sand and all the buffer pH methods (Table 2). pH by the (1:1) 0.01 M $CaCl_2$ method had the highest correlation with KCl Al content, whereas KCl extractable Al was had a strong inverse correlation with all the buffer pH methods, the strongest noted for Mehlich buffer pH. Aside from the other buffer methods the Mehlich buffer had a strong inverse correlation with both saturated paste moisture, KCl extractable Al and clay content of the ninety-eight soils evaluated.

Table 2. Correlation matrix of soil properties and buffer pH methods.

	SP	pH Sp	pH (1:1)s	KCl Al	CEC	Sand	Clay	SMP	Adam Evan	Wd.	Mehl
SP	1.00	0.12	0.08	0.22	0.69	-0.80	0.90	-0.67	-0.75	-0.57	-0.65
pH Sp		1.00	0.93	-0.47	0.17	-0.15	0.11	0.34	0.15	0.41	0.40
pH (1:1)s			1.00	-0.52	0.19	-0.12	0.09	0.42	0.23	0.52	0.48
KCl - AL				1.00	0.00	-0.01	0.10	-0.58	-0.40	-0.56	-0.62
CEC					1.00	-0.62	0.72	-0.37	-0.47	-0.37	-0.45
Sand						1.00	-0.91	0.59	0.72	0.49	0.59
Clay							1.00	-0.64	-0.77	-0.55	-0.64
SMP								1.00	0.93	0.95	0.95
Ad. E..									1.00	0.88	0.89
Woodruf										1.00	0.92
Mehlich											1.00

Using the Mehlich method the amount of exchangeable acidity (AC) was estimated from the equation (EQ1) developed by Mehlich (1984):

EQ1 $$AC = [6.60 - \text{Mehlich buffer pH}] \times 4 \text{ cmol kg}^{-1}$$

A plot of AC with clay content is shown in Figure 2. As clay content increased for these ninety-eight soils the amount of exchangeable acidity (AC) generally increased. Clay was positively correlated with AC, whereas sand content was negatively correlated.

A plot of pH (1:1) 0.01 M $CaCl_2$ and AC is shown in Figure 3. As pH decreased there was a corresponding increase in AC. Although the data shows a weak relationship ($R^2 = 0.206$), there is a unique area plot of the data points forming defined boundaries for AC as a function of pH (1:1) 0.01 M $CaCl_2$. Thus at a pH of 6.00 the AC range is limited to 0.5 - 1.5 cmol kg^{-1} ; while at pH of 5.00 the AC range is 0.5 - 4.5 cmol kg^{-1}; and at a pH of 4.00 AC ranges from 0.5 - 7.0 cmol kg^{-1}. The increasing range in AC as a function of pH is associated with clay content and the amount of exchange Al. This relationship was noted for all three soil pH methods evaluated but was the strongest for the pH (1:1) 0.01 M $CaCl_2$ method.

Figure 2. Relationship of clay content and Mehlich buffer exchangeable acidity (AC).

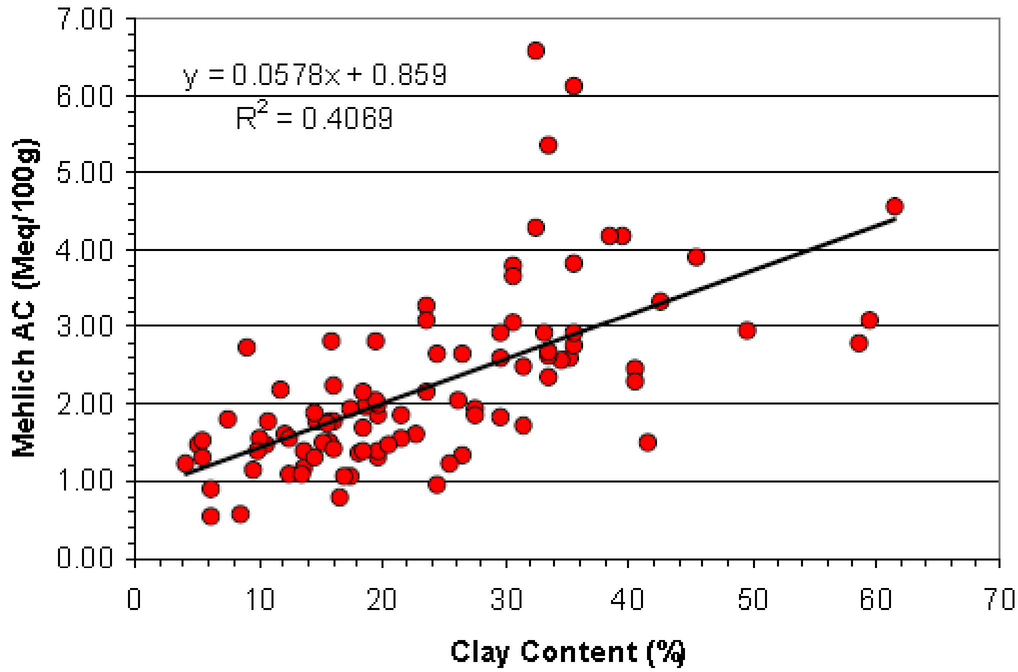
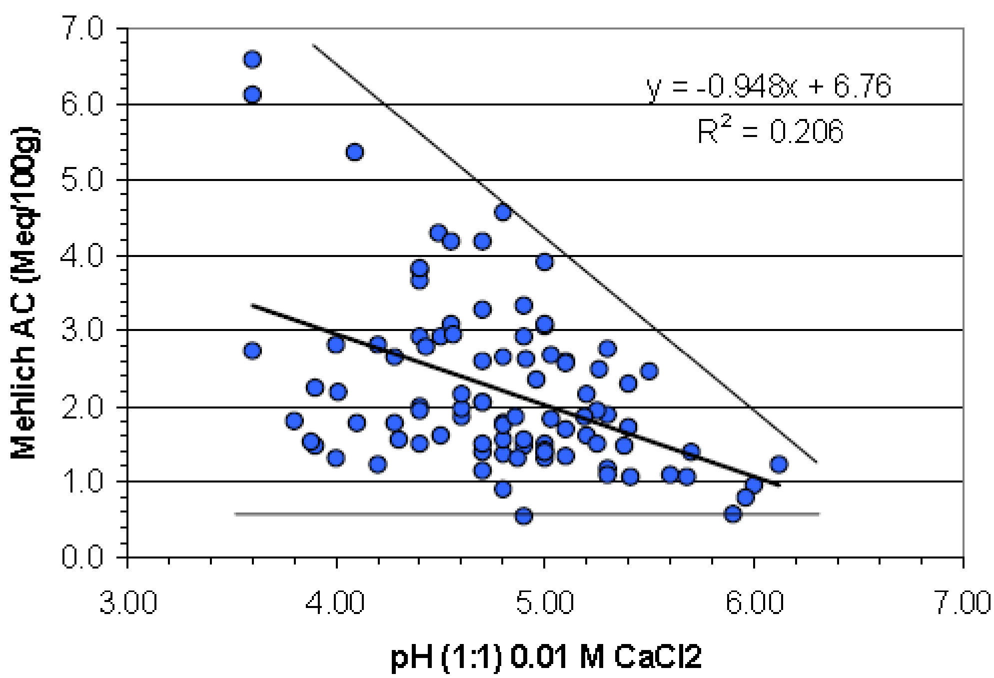


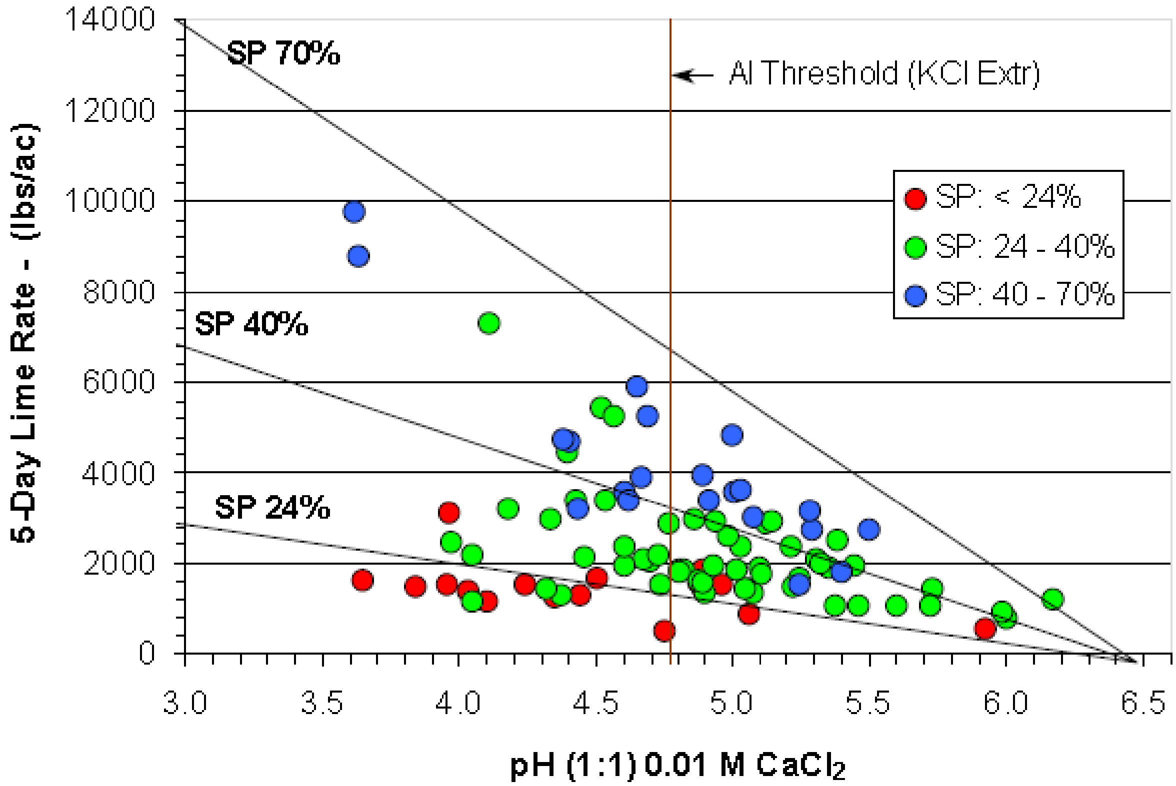
Figure 3. Relationship of pH (1:1) 0.01 M $CaCl_2$ and Mehlich buffer exchangeable acidity
(AC).



A plot of 5-day lime incubation rate ($CaCO_3$ lbs ac^{-1}) with pH (1:1) 0.01 M $CaCl_2$ indicates another unique area plot, Figure 4. Shown in the figure is salt pH 4.80 where
Al concentrations exceeded 1.00 mg kg^{-1}. A plot of isolines of saturated paste moisture on this figure indicates that "general" ranges of 5-day incubation lime rates can be further separated for a given pH by the saturated paste moisture content. As an example a soil with 24% saturated paste moisture and a salt pH of 5.00 would have a lime application rate of 1400 lbs ac^{-1}, while a soil with an identical pH and 40% saturated paste moisture content would have a lime application rate of 3000 lbs ac^{-1}. These isolines for separating 5-day incubation lime rates are only approximate as some soils, (as indicated in the legend) fall outside the isolines demarcating their boundaries. Nonetheless, eighty-one of the ninety-eight soils fall with in the boundary areas, indicating that saturated paste moisture can be used as a co-variable in estimating lime requirement as determined by a 5-Day incubation.

This use of soil saturated paste moisture content in conjunction with pH is similar to a model used by the University of Illinois in 1950s using soil texture classification and soil pH to estimate lime recommendations (citation).

Figure 4. Relationship of pH (1:1) 0.01 M CaCl2 and 5-Day incubation lime rate, ninety-eight California soils.



Buffer Evaluation

Results for the SMP buffer method ranged from pH 5.45 to 7.45, with a median of 6.89. Based on reported SMP lime recommendation (Sims, 1996), the threshold SMP buffer pH for which no lime is required was 6.95. Using this recommendation model for SMP estimating lime, 46% of the California soils evaluated had no lime requirement. The 5- Day lime incubation rate on these same soils ranged from 125 - 1380 lbs ac^{-1}, with an median of 860 lbs ac^{-1} $CaCO_3$. Generally these soils were poorly buffered and had less than 20 mg kg^{-1} of extractable Al.

Estimated lime rates by the Woodruff method (based on recommendations of Sims, 1996) indicate rates ranged from 733 to 13,500 lbs ac^{-1} $CaCO_3$, with a median of 4,600 lbs ac^{-1}. Estimated lime rates for the Mehlich method (based on lime recommendations of Mehlich, 1984) ranged from 250 -10,500 lbs ac^{-1}, with a median of 3,800 lbs ac^{-1} $CaCO_3$. No lime rate was determined for the Adams Evans buffer method.

Regression of the lime requirement form the 5-Day lime incubation on SMP buffer pH indicated it described more than 87% of the variability (Figure 5a). There was a sigmoidal tendency in the distribution in the data for the SMP method, with values below the linear estimate for with SMP buffer pH of 6.30 to 7.10 and higher than the estimate for soils less than pH 6.30. The Adams Evans buffer pH method (Figure 5c) had the poorest correlation with 5-Day incubation method, whereas the Woodruff buffer (Figure 5b) approached that of the SMP method. There was a sigmoidal tendency in the distribution of the Woodruff buffer pH data, similar to that of the SMP method. A regression of the Mehlich buffer pH method (Figure 5d) and 5-Day Lime incubation indicated very good agreement, predicting 87% of the 5-Day incubation, equal to that of SMP buffer.

Results of the University of Georgia Lime Buffer Capacity method (LBC) of Liu et al (2005), indicates lime rates for the ninety-eight California soils ranged from 250 to 8460 lbs ac^{-1}, with a median of 1,910 lbs ac^{-1} $CaCO_3$. Generally there was good agreement between the LBC lime recommendations with that of the 5-Day incubation (Figure 6).

A regression of the soils data indicates that the LBC lime rate described 83% of the variability of the 5-Day Incubation method, with a slope coefficient of 1.04. There was generally very good agreement for soils with lime rates less than 4,000 lbs ac^{-1} $CaCO_3$,
however there was significant dispersion for soils with lime rates exceeding this rate. This dispersion was attributed to soils of fine texture (SP > 50%) and ones soils with greater than 200 mg kg^{-1} KCl extractable Al. The LBC method is based on a 30 minute equilibration of calcium hydroxide and it is likely that for very acid, fine textured soils that there was insufficient time to complete neutralization of the acidity.

Figure 5. Regression of 5-Day Lime incubation versus four buffers for ninety-eight California soils.

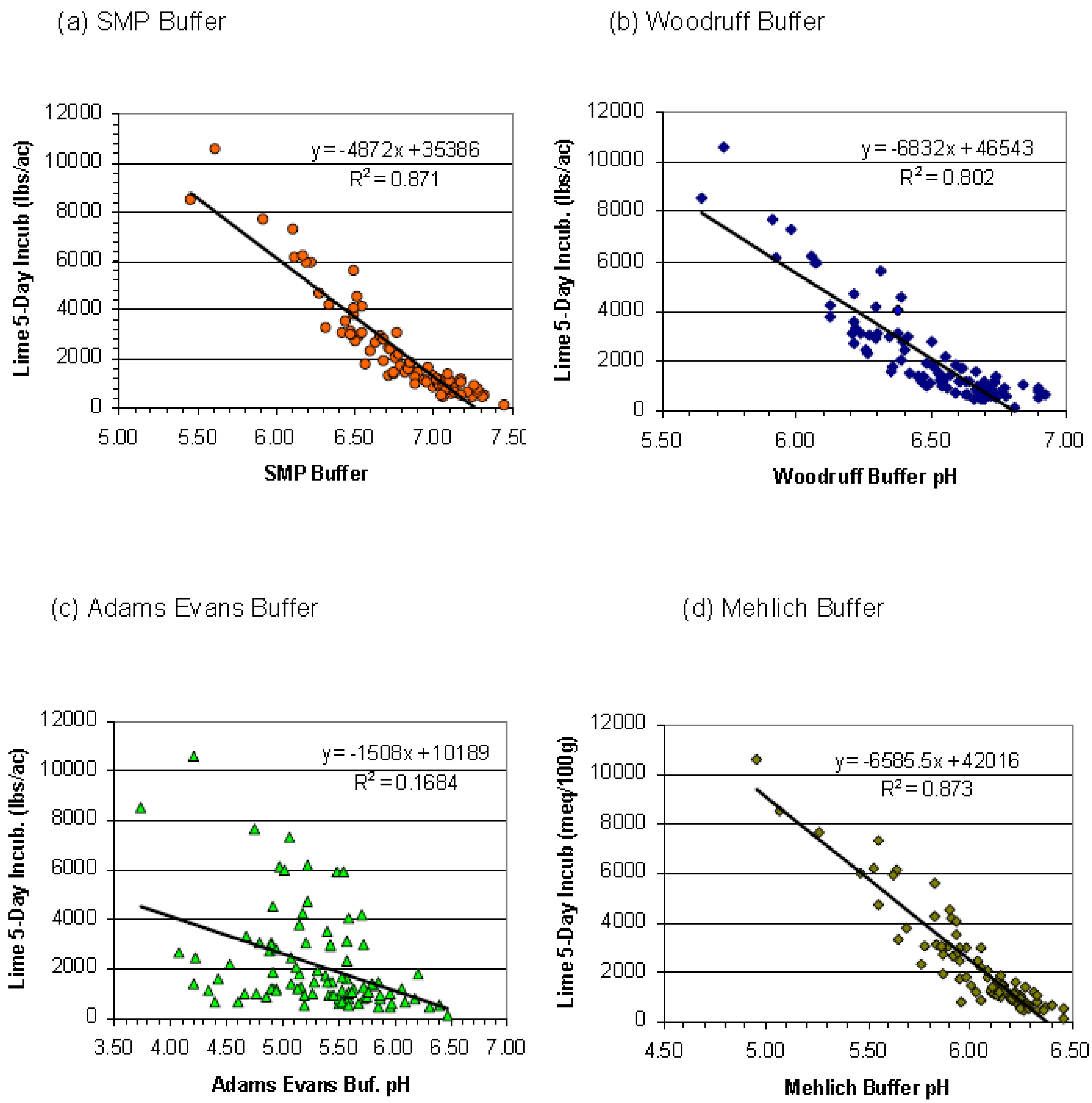
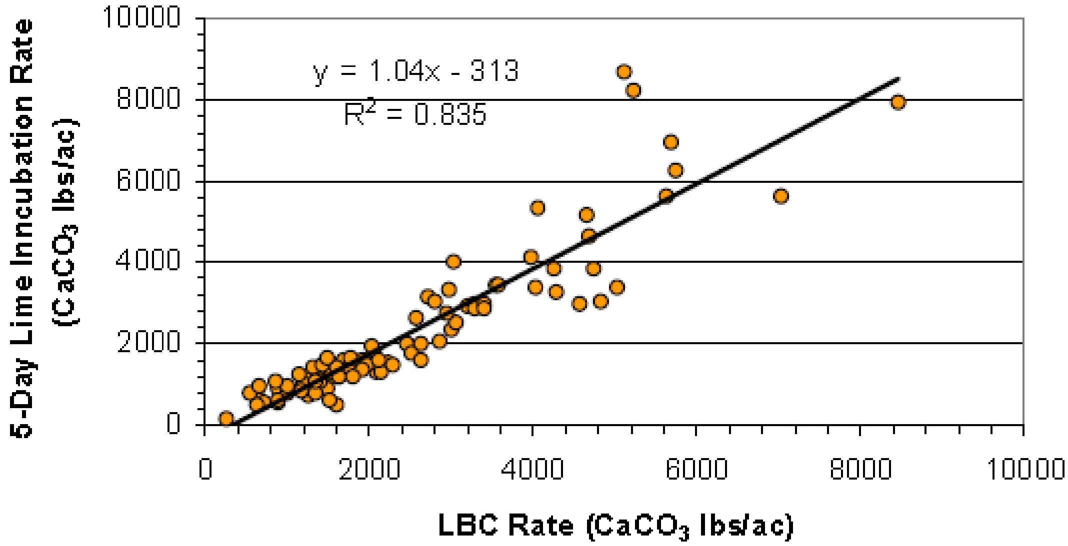


Figure 6. Comparison of 5-Day Lime incubation and LBC lime rate, for ninety-eight California soils.



Multi linear regression models of chemical properties were developed, exclusive of buffer pH methods, to further evaluate 5-Day incubation lime rates of the ninety-eight soils being evaluated. Forward regression models of 5-Day Incubation Lime rate as the dependent variable indicates that a three component model of pH (1:1) 0.01 M $CaCl_2$, saturated paste moisture content, and KCl extractable Al explained 74.7% of the variation in 5-Day Lime Incubation rate (See Table 3). This model is in good agreement with the results noted in Figure 4 indicating that saturated paste moisture content is an integral component in estimating soil lime requirement.Both Saturated paste moisture and KCl Al had positive coefficients, while pH (1:1) 0.01 M $CaCl_2$ had a negative coefficient.

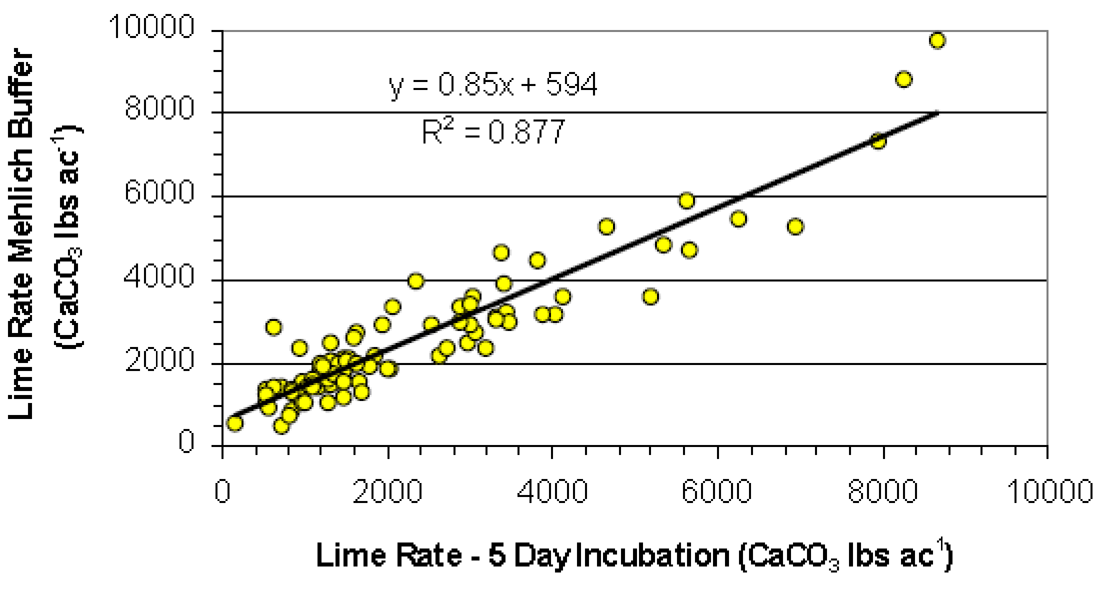
Table 3. Multi linear regression model for tons of 5-Day lime incubation rate.

Component	Coefficient	Std Error	p-Level
Intercept	3962	1122	0.00065
Saturated Paste	112	9.9	0.000000
pH (1:1) 0.01 M$CaCl_2$	-1203	232	0.000002
Al (KCl Extractable)	9.0	1.9	0.000009

Additional multi linear models for 5-Day lime incubation were evaluated that were inclusive of buffer pH methods. A forward regression model of 5-Day incubation lime rate as the dependent variable indicates that a three component model of Mehlich Buffer pH, exchangeable K and silt content explained 90% of the variation in 5-Day Lime Incubation rate. This model is only slightly better than that obtained by using the Mehlich buffer alone of 87% (See Figure 5d).

Using the lime recommendation developed by Mehlich (1976) based on the Mehlich buffer pH method a comparison was made with the 5-Day lime incubation rate (See Figure 7). Results indicate the Mehlich lime rate is 85% of the 5-Day lime incubation rate accounting for 87% of the variability. As the 5-Day Incubation study is based on equilibrium to pH 7.00 using a 1:1 H_2O method and the Mehlich buffer is based on pH depression from 6.60, the slope differential of 85% between the methods is reasonable. In addition as the lime rate error for Mehlich buffer method is 240 lbs ac^{-1} and that for the 5-Day incubation is 160 lbs ac-1 CaCO3, the differences noted in the plot for specific soils is not as great as it appears in Figure 7.

Figure 7. Comparison of Mehlich buffer lime recommendation and 5 Day Lime Incubation rate for ninety-eight California soils.



Validation Soils

During 2003 and 2004 an additional twenty-two soils were collected from the San Joaquin Valley, North Coast and Sacramento Valleys of California for validating the principle models developed in phase I of the project. Soils were collected by field agronomists from vineyards, forests and row crop areas. Soil properties are listed in Table 4. Generally the validation soils were slightly more acidic than the initial ninety- eight soils collected in 2001. Soil pH (1:1) 0.01 M $CaCl_2$ ranged from 3.19 to 5.75 with a median 4.42. Eight of the soils were below pH (1:1) 0.01 M $CaCl_2$ 4.00 and five soils above 5.00. Soil saturated paste moisture and CEC were identical to the original ninety- eight soil database. Results for soil KCl extractable Al indicated five soils had Al values exceeding 100 mg kg^{-1}, eight soils in the range of 20 - 100 mg/kg Al, eight soils with 1.0 - 20 mg kg^{-1} Al. Mehlich buffer pH values ranged from 4.17 - 6.30 with a median of 5.14. Exchangeable Acidity as calculated from the Mehlich Buffer, ranged from 9.72 to 1.2 cmol kg^{-1}.

5-Day lime incubation lime rates ranged from 480 to 26,600 lbs ac^{-1} with a median of 1940 lbs ac^{-1} $CaCO_3$. Soil CA-320 with a lime rate of 26,600 lbs ac^{-1} was removed from the data set, as it exceeded the original data set range by 2.5X.

Table 4. Soil physio-chemical properties of twenty-two validation soils in the California liming project.

Soil Property	Unit	Range	Median
Saturated Paste Moisture	%	19.9 - 68.2	35.7
EC (sp)	dS m^{-1}	0.18 - 1.06	0.38
pH (Saturated Paste)		3.74 - 6.31	4.76
pH (1:1) H_2O		3.86 - 6.58	4.96
pH (1:1) $CaCl_2$		3.18 - 5.75	4.42
Mehlich Buffer pH		4.00 - 6.20	5.58
KCl Extr. Al	mg kg^{-1}	1.0 - 503	50.5
SOM	%	0.22 - 9.92	1.36
CEC	cmol kg^{-1}	1.74 - 29.5	7.3
Exch. Acidity (Mehlich)	cmol kg^{-1}	1.42 - 10.4	4.1
$CaCO_3$ Lime Req (5-Day Incub)	lbs ac^{-1}	486 - 26,630	1940

Figure 8. Comparison of Mehlich buffer lime recommendation and 5 Day Lime Incubation rate for one hundred twenty California soils.

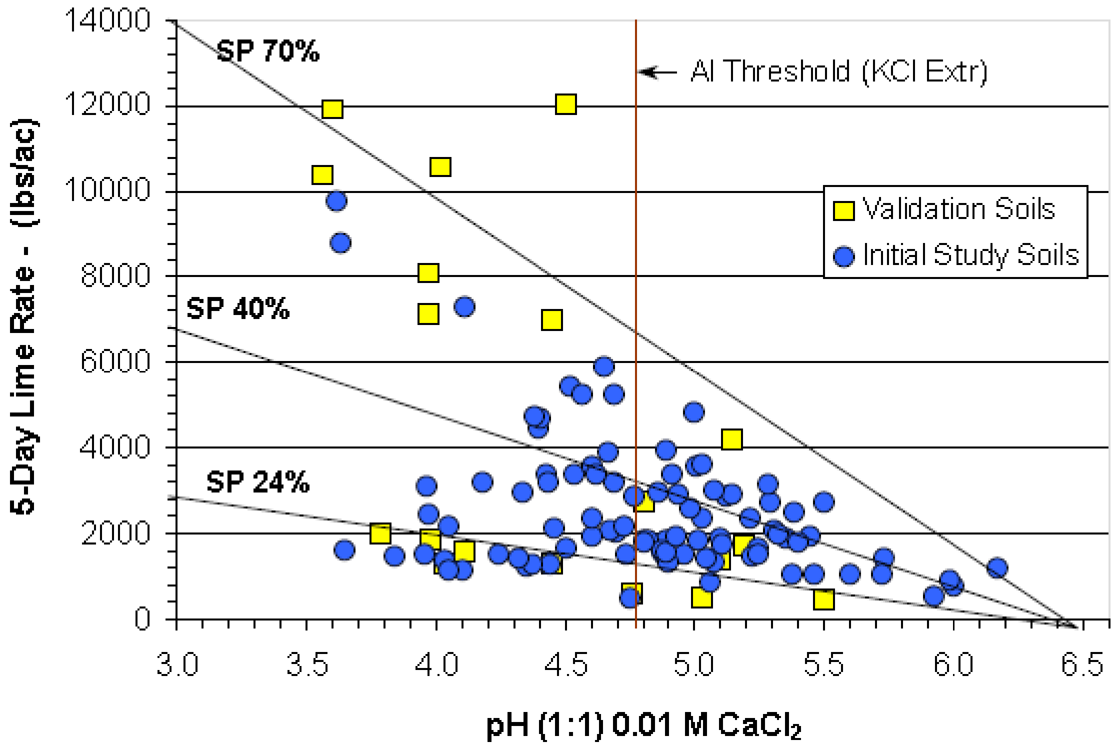
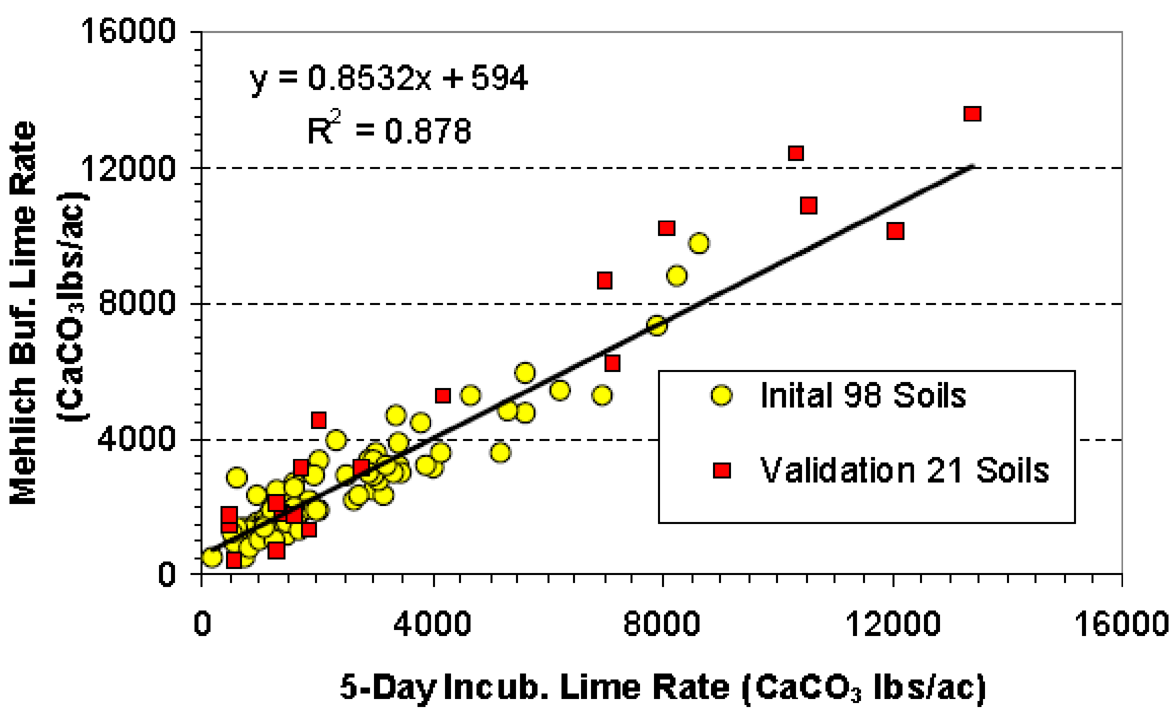


Figure 7. Comparison of Mehlich buffer lime recommendation and 5 Day Lime Incubation rate for one hundred twenty California soils.



SUMMARY AND CONCLUSIONS

Two models were selected for predicting lime requirements for California soils. The first is based on soil pH (1:1) 0.01 M $CaCl_2$ and saturated paste moisture (application rate based on 5-Day incubation lime rate). The pH method is easily implemented and soil saturated paste is a routine analysis conducted in California agricultural testing laboratories. Table 5 depicts the estimated lime rate based on the 119 soil evaluated. Lime rates listed are based on neutralization of soil acidity to a pH of 7.00 to a depth of 6 inches and are rounded to the nearest 250 lbs ac^{-1} of 100% $CaCO_3$. The actual lime application rate will require adjustment as typical agricultural lime ranges from 60 - 80 Calcium Carbonate Equivalent (CCE). It is suggested that for soils testing below a pH (1:1) 0.01 M $CaCl_2$ of 4.80, be also analyzed for KCl extractable aluminum as additional lime maybe needed to neutralize the added acidity. The lime rate determined using the following equation:

EQ2: $\text{Lime Rate lbs ac}^{-1} = 3960 + 112\,(SP) - 1203\,(pH) - 9.0\,(Al)$

where SP is the saturated moisture percentage in percent, pH is pH (1:1) 0.01 M $CaCl_2$, and Al is KCl extractable Al in mg kg^{-1}. For every 100 mg kg^{-1} of extractable Aluminum
an additional 900 mg kg^{-1} $CaCO_3$ is required..

The 2nd model recommended for estimating lime rate for California soils is based on the Mehlich buffer pH method. This model explained 87% of the variability in 5-Day incubation results. It has the advantage that only one additional soil test is needed and provides for the estimate of exchangeable acidity. The equation for acidity and determining lime application rate from the Mehlich buffer are as follows:

EQ3: $AC = (6.60 - \text{Mehlich Buf pH}) \times 4$

EQ3: $\text{Lime Rate lbs ac}^{-1} = ((0.10 \times (AC^2)) + AC) \times (2000 \times 0.446)$

A comparison of the estimated lime rate for the 5-Day Incubation and the two models is shown in Table 6. In general there is very good agreement between the two models and the 5-Day Incubuation. The relative difference between the two models for a majority of the soils is generally within the lime rate error of estimation, which for these methods is approximately 240 lbs ac^{-1} of 100% $CaCO_3$.
Soils with high KCl extractable Aluminum (Al > 100 mg kg^{-1}) were the exception with the Mehlich buffer indicating a much higher lime rate, similar to the amount listed for the 5-Day incubation method.

Table 5. Recommended lime rates for California soils, based on pH (1:1) 0.01 M CaCl2 and saturated paste moisture.

Soil pH (1:1) 0.01 M $CaCl_2$	Lime Rate[1] $CaCO_3$ lbs ac^{-1}					
	Soil Saturated Paste Moisture Content (%)					
	< 20	20 - 30	30 - 40	40 - 50	50 - 60	60 - 70
6.40	-	-	-	-	-	500
6.20	-	-	500	750	1000	1250
6.00	-	500	750	1250	1500	2000
5.80	500	750	1250	1750	2000	2500
5.60	500	1000	1500	2000	2750	3250
5.40	750	1250	1750	2500	3250	4000
5.20	1000	1250	2250	3000	4000	4750
5.00	1000	1500	2500	3500	4500	5500
4.80	1250	1750	2750	4000	5000	6250
4.60	1250	2000	3250	4500	5750	7000
4.40	1500	2250	3500	5000	6500	7750
4.20	1500	2500	3750	5500	7000	8500
4.00	1750	2500	4000	6000	7500	9250
3.80	1750	2750	4500	6500	8250	10000
3.40	2000	3000	4750	6750	8750	10500
3.20	2150	3250	5150	7250	9500	11500

[1] Lime rate based on 100% $CaCO_3$

applied to neutralize acidity to pH 7.00 to a soil depth of 6 inches. Minimum Lime application rate 500 lbs ac^{-1} .

Table 6. Comparison of lime rates, 5-Day Incubation, Model pH-SP and Mehlich buffer.

Soil ID	pH (1:1) 0.01 M $CaCl_2$	Sat. Paste (%)	KCl AL mg kg $^{-1}$	5-Day Incub. lbs ac^{-1}	Model 1 lbs ac^{-1}	(Mehlich Buf) lbs ac^{-1}
CA-100	5.35	25.4	0.0	900	1250	1180
CA-108	4.46	26.2	5.2	1500	2000	2140
CA-131	3.65	20.4	115	3200	2750	3120
CA-162	5.29	47.1	0.0	5200	3000	4030
CA-184	4.43	64.6	28	3900	6250	3200
CA-305 [1]	4.90	22.9	1.3	1300	1500	1760
CA-308	4.80	48.3	149	7000	4000	6240

[1] Soils CA-305 and 308 were collected as validation soils.

Results of the California pH - Lime project were presented at the 9th International Symposium on Soil and Plant Analysis held in Cancun Mexico January 30 - February 5, 2005 and at a laboratory workshop in Salinas, California on March 16, 2005, which was attended by 18 laboratory personnel. A paper will be submitted to Communications In Soil and Plant Analysis for publication in 2006. Results will be presented as an invited paper at the American Society of Agronomy meetings November 6-9, 2005 in Salt Lake City, UT.

A laboratory Fact sheet on the two models for estimating lime application is being prepared and will be reviewed by soil Extension personnel of the University California, prior to disbursement to commercial laboratories serving the California.

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Appendix A. California liming study soil collection information.

SOIL ID	DATE COLLECTED	MOISTURE STATUS	IRRIGATION METHOD	CROP	GPS LAT	GPS LON	LOG#	PH 1
CA-100	2/13/02	MOIST	BURIED DRIP	LETTUCE	36.7276	-119.87150	221014-5	5.50
CA-101	3/21/03	MOIST	MICROSPRINKLERS	ALMOND	37.2477	-120.38430		4.95
CA-102	3/27/03	DRY	MICROSPRINKLERS	ALMOND	35.9602	-119.10992		4.90
CA-103	3/27/03	MOIST	MICROSPRINKLERS	ALMOND	37.1073	-120.17420		5.50
CA-104	2/12/02	MOIST	FURROW	TOMATO	37.3174	-120.36247	2110338-1	5.70
CA-105	2/15/02	MOIST	FLOOD	ALMOND	36.8803	-119.98967	222098-2	4.90
CA-106	4/1/02	DRY	FURROW	SQUASH	36.7418	-119.87140	223084-1	5.40
CA-107	4/30/02	DRY ON TOP,	DRIP	GRAPES			223076-1	5.50
CA-108	4/30/02	MOSTLY DRY	DRIP	GRAPES			223241-1	5.00
CA-109	5/2/02	MOIST	DRIP	GRAPES			222171-2	5.10
CA-110	4/30/02	MOIST	DRIP	GRAPES			223240-1	4.80
CA-111	5/3/02	DRY	DRIP	GRAPES			223068-1	5.30
CA-112	5/1/02	MOIST	DRIP	GRAPES			222170-1	5.70
CA-113	5/2/02	DRY	FLOOD	GRAPES			2111296-3	4.50
CA-114	5/1/02	DRY ON TOP,	DRIP	GRAPES			222169-1	5.30
CA-115	3/27/03	MOIST	MICROSPRINKLERS	ALMOND	37.1103	-120.16971		5.60
CA-116	4/30/02	MOIST	DRIP	GRAPES			223239-1	5.50
CA-117	5/17/02	MOIST	DRIP	PISTACHIOS	37.1059	-120.04292	219439-3	4.20
CA-118								
CA-119	5/22/02	MOSTLY DRY	FLOOD	ALMOND	37.3337	-120.38023	224069-3	5.40
CA-120	5/23/02	MOSTLY DRY	FLOOD	ALMOND	37.6395	-120.81118	211016-2	4.80
CA-121								
CA-122	5/23/02	MOIST	FLOOD	ALMOND	37.5860	-121.02564	2161483-1	5.50
CA-123								
CA-124	5/28/02	MOIST	FURROW	CORN	37.3347	-120.30857	9301-13	5.20
CA-125								
CA-126	11/13/02	MOIST	BURIED DRIP	PEPPERS	36.7390	-119.87203	223084	5.41
CA-127	11/12/02	DRY	SOLID SET	WATERMELON	33.8283	-117.16500	223080	4.85
CA-128	1/21/03	MOIST	MICROSPRINKLERS	ALMOND	37.7920	-120.87499	2210044	4.77
CA-129	1/21/03	MOIST	MICROSPRINKLERS	ALMOND	37.7905	-120.92930	2210044	4.68
CA-130	1/21/03	MOIST	MICROSPRINKLERS	ALMOND	37.7948	-120.94177		
CA-131	1/21/03	MOIST	FLOOD	ALMOND	37.7871	-121.00690		
CA-132	1/21/03	MOIST	FLOOD	ALMOND	37.7837	-121.00376		
CA-133	1/21/03	MOIST	FLOOD	ALMOND	37.7877	-121.00011		
CA-134	1/21/03	MOIST	FLOOD	ALMOND	37.7717	-120.98300		
CA-135	1/21/03	MOIST	SPRINKLERS	ALMOND	37.7756	-120.98243		
CA-136	1/21/03	MOIST	MICROSPRINKLERS	ALMOND	37.7734	-120.95726		
CA-137	1/21/03	MOIST	MICROSPRINKLERS	ALMOND	37.7702	-120.96171		
CA-138	1/4/03	MOIST	FLOOD	VEGETABLES	36.7356	-119.87309		
CA-139	1/4/03	MOIST	FLOOD	ONIONS	36.7357	-119.85795		
CA-140	1/22/03			GRAPES	38.9217	-122.77342		
CA-141	1/22/03			GRAPES	38.7362	-122.43540		
CA-142	1/22/03			GRAPES	38.3111	-122.37505		
CA-143	1/22/03			GRAPES	38.4403	-122.85728		
CA-144	1/22/03			GRAPES	38.3567	-122.44812		
CA-145	1/22/03			GRAPES	38.5895	-122.55650		
CA-146	1/22/03			GRAPES	38.4357	-122.29079		
CA-147	1/22/03			GRAPES	38.5869	-122.57143		
CA-148	1/22/03			GRAPES	38.3705	-122.27951		
CA-149	1/22/03			GRAPES	38.5303	-120.80812		
CA-150	1/25/03		MICROSPRINKLERS	CHERRIES	37.3917	-121.13700		
CA-151	1/25/03		FLOOD	ALFALFA	38.2182	-120.07706		
CA-152	1/25/03		FLOOD	PASTURE	38.1624	-121.11407		
CA-153	1/25/03		FLOOD	RICE	38.2845	-121.11136		
CA-154	1/25/03		FLOOD	RICE	38.2845	-121.11136		
CA-155	1/25/03		FLOOD	RICE	38.4828	-121.10695		
CA-156	1/25/03		FLOOD	RICE	38.2845	-121.11136		
CA-157	1/25/03		MICROSPRINKLERS	LEMONS	36.2677	-121.26760		
CA-158	1/25/03		SOLID SET	HEATHER	36.5159	-121.46143		
CA-159	1/25/03							
CA-160	1/25/03		SPRINKLERS	POTATOES	35.1744	-118.50038		
CA-161	1/25/03		FURROW	TOMATOES	35.1379	-119.07135		

[1] Soil materials stored at Precision Agri-Lab, Madera, CA.