INFLUENCE OF CHOPPER-HARVESTED GREEN CANE RESIDUE BLANKETS ON SUGARCANE PRODUCTION AND AGRICULTURAL RUNOFF

December 31, 2006

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FINAL REPORT

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BACKGROUND

This project was initiated in January 2002 to determine if the blanket of plant residues deposited on the soil surface after harvesting green sugarcane with a chopper harvester can serve as a barrier to soil, nutrient, and pesticide losses from sugarcane fields without reducing cane and sugar yields. Specifically, our objectives were to: 1) develop information regarding the factors which can influence yield losses in the subsequent ratoon crops where post-harvest crop residues are not removed, and 2) develop management strategies that reduce the negative impacts of the blanket of post-harvest crop residue on the yield of the subsequent ratoon crop. Research for the project was conducted in cooperator fields in the Bayou Lafourche sugarcane production area in the Barataria Terrebonne Estuary System (BTES) and in greenhouse facilities at the USDA-ARS's Sugarcane Research Laboratory in Houma and laboratory facilities at the USDA-ARS Ardoyne Research Farm in Schriever, LA. Aerial photographs of all field sites are included in Appendix 1. All experiments to be conducted in this study were completed and this report summarizes our findings and gives recommendations for proposed Best ManagementPractices (BMPs).

I. RESIDUE FACTORS INFLUENCING YIELD

A. Residue Effects on Soil Temperature and Soil Moisture

Two locations, one with a light and one with a heavy soil, were selected in 2004 and 2005 to determine the influence of post-harvest residues on soil temperature and soil moisture. Treatments consisting of: 1) complete residue removal by burning, 2) partial residue removal from the row top to wheel furrow by mechanical brushing, and 3) no residue removal, were applied to first-ratoon fields of LCP 85-384 sugarcane. Soil temperature was monitored from

January until June in both 2004 and 2005 and soil moisture was monitored from February to June in 2004 and from January to June in 2005 in the subsequent second-ratoon fields. Automated, programmable temperature sensors were utilized to continuously monitor soil temperature, with raw data saved on an hourly basis. Soil moisture levels were monitored using programmable data loggers and Watermark© soil moisture sensors. The soil moisture sensors measure soil resistivity and their output is inversely correlated to soil moisture with zero equated to saturation and 200 kPa to a dry soil.

Soil temperature data from all treatments exhibited typical diurnal fluctuations due to daily solar heating and night-time cooling. The extent of this variation was related to individual treatments. Typical results for soil temperature and soil moisture are seen in Figures 1 and 2, with complete monthly results for all field tests included in Appendixes 2 and 3. Averaged over both years and soil types, soil temperature in plots where the residue was not removed ranged from 6.3 to 32.0°C (19.2 average) and soil moisture from 0 to 61 kPa (13.1 average) (Table 1). In plots where residue was completely removed soil temperature ranged from 4.1 to 33.7°C (19.8 average) and soil moisture from 0 to 50.8 kPa (13.1 average). Finally, in plots where residue was

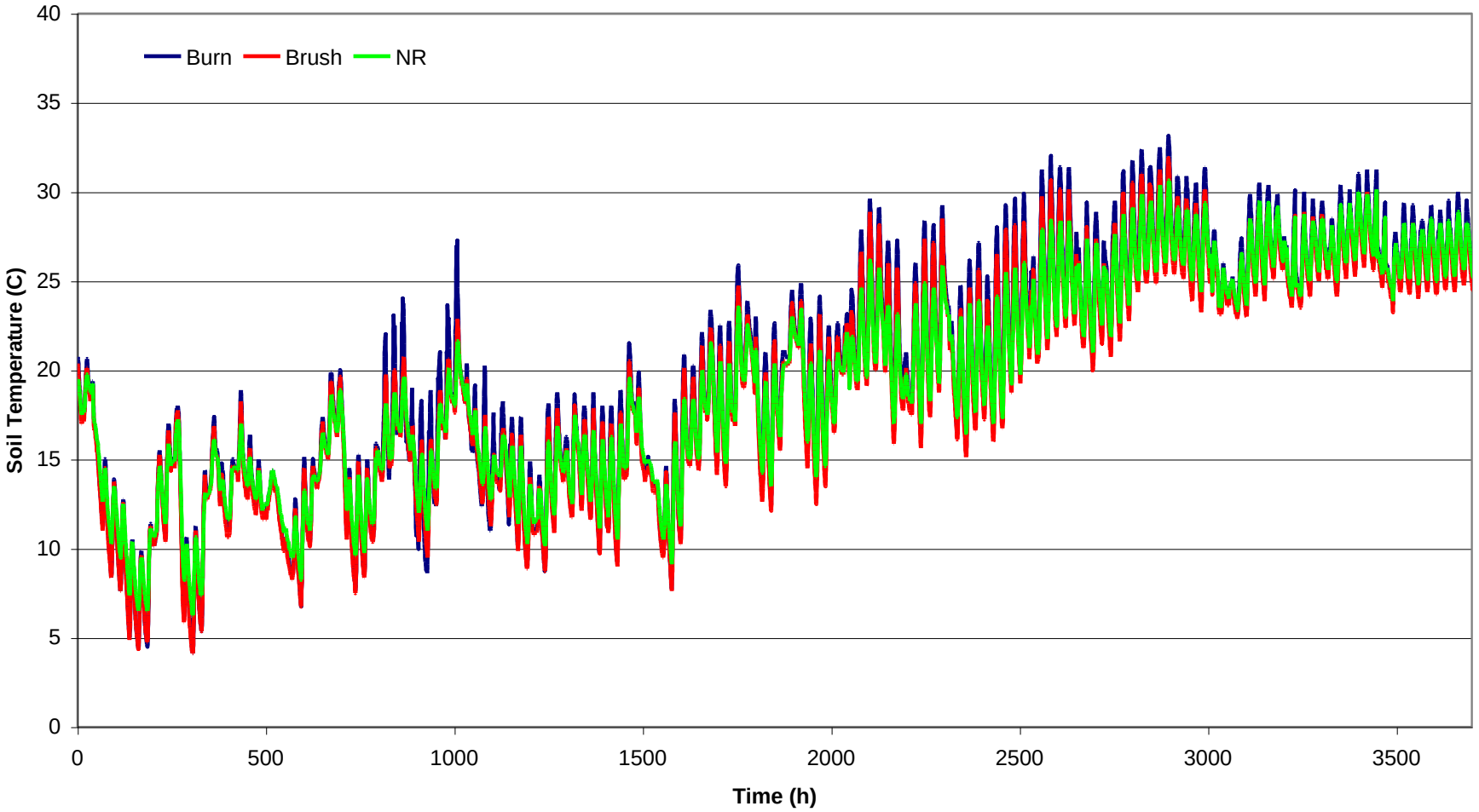

Figure 1. Soil temperature as influenced by residue cover on a light soil. Richard Farms, in Lafourche Parish, 2005.

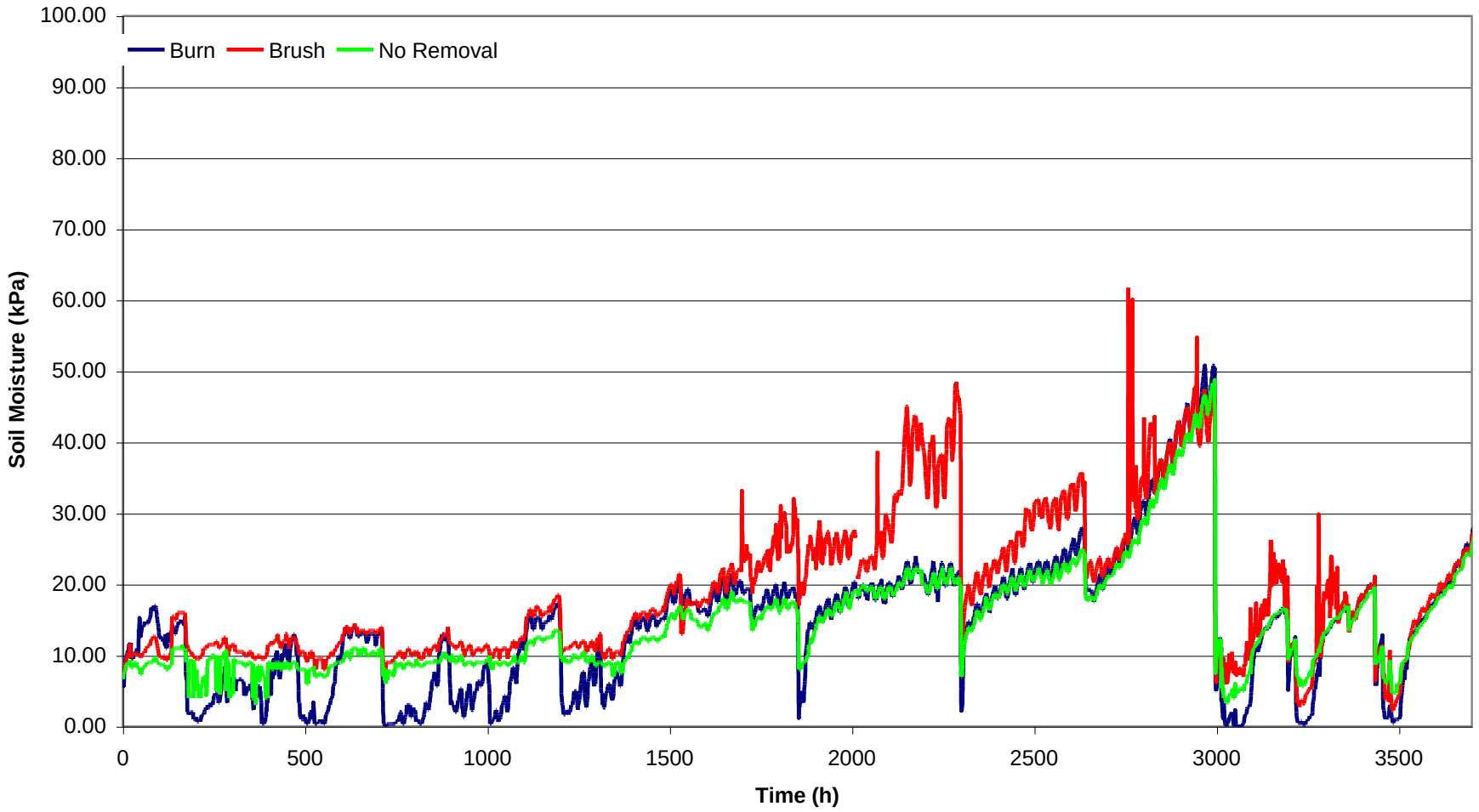

Figure 2. Soil moisture as influenced by residue cover on a light soil at Richard Farms in Lafourche Parish, 2005

Table 1. Effect of residue levels on soil temperature and soil moisture combined over soil types.

	Complete Removal		Partial Removal		No Removal	
	Soil Temp(C) †	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)
January	11.9	9.1	11.7	10.8	12.0	8.7
February	13.2	3.0	12.8	6.5	13.0	4.9
March	17.4	13.8	17.1	16.6	16.3	11.9
April	21.0	17.4	20.6	20.5	19.7	15.5
May	24.7	19.1	24.1	23.1	23.8	18.5
June	26.8	12.2	26.5	15.6	26.8	14.6
Average††	19.8	13.2	19.5	16.5	19.2	13.1
Minimum	4.1	0.0	3.7	0.0	6.3	0.0
Maximum	33.7	50.8	33.6	73.5	32.0	61.0
† Soil temperature and soil moisture levels. Averages of continuously recorded hourly readings. †† Seasonal, average, minimum and maximum temperatures.						

removed from the row top only soil temperature ranged from 3.7 to 33.6°C (19.5 average) and soil moisture from 0 to 73.5 kPa (16.5 average) (Table 1). Thus the overall effect of the residue was to keep the soil cooler by 0.6°C and wetter by 0.1 kPa. A more complete picture of the influence of the residue on soil temperature and moisture is seen if the data is evaluated on a monthly basis. In January and February, soil temperature and moisture was similar for the complete, partial and no removals treatments. In January the differences in temperature between treatments was 0.3°C (Table 1), with the no removal treatment having the warmest temperature (12.0°C). In February, the difference was 0.4°C and the complete removal treatment possessed the warmest temperature. Clearer differences were evident in March, April and May where the soil temperature was lower in the no removal treatment as compared to the complete removal treatment by 1.1, 1.3 and 0.9°C, respectively (Table 1). The soil moisture was higher in the no removal treatment in January, March, April and May and the complete removal treatment was wetter in January and June (Table 1).

In the 2004 light soil test, monthly soil temperature averages ranged from 6.0 to 29.8°C, 3.7 to 30.7°C and 7.5 to 29.5°C for the complete, partial and no removal treatments, respectively (Table 2). Soil temperature was lower in the no removal treatment in March and April, compared to the partial and complete removal treatments. Averaged over the entire

Table 2. Effect of residue levels on soil temperature and soil moisture on a light soil at Laurel Valley Plantation, in Lafourche Parish 2004.

	Complete Removal		Partial Removal		No Removal	
	Soil Temp(C) †	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)
January	10.3	-	11.5	-	10.9	-
February	11.1	0.33	12.3	1.4	11.7	0.2
March	18.2	21.8	18.9	25.4	17.1	16.8
April	20.3	15.5	20.7	17.0	19.4	15.4
May	23.5	16.0	23.7	19.7	23.7	15.4
June	25.9	14.0	26.1	14.9	26.7	15.5
Average††	17.3	13.9	18.0	16.1	17.0	13.0
Minimum	6.0	0.0	3.7	0.0	7.5	0.0
Maximum	29.8	47.5	30.7	53.0	29.5	46.0
† Soil temperature and soil moisture levels. Averages of continuously recorded hourly readings. †† Seasonal, average, minimum and maximum temperatures.						

measurement period, soil temperature was lowest in the no removal treatment (17.0°C), compared to the complete (17.3°C) and partial removal (18.0°C) treatments. Soil moisture ranged from 0 to 47.5-kPa, 0 to 53-kPa, and 0 to 46-kPa for the complete, partial and no removal treatments, respectively (Table 2). The soil moisture levels were higher in the no removal treatment (soil resistivity lower) in all months except June, compared to the partial and complete removal treatments. The season average soil moisture was also highest in the no removal treatment (13.0 kPa) compared to the complete (13.9 kPa) and partial removal (16.1 kPa) treatments (Table 2).

In the 2004 heavy soil test, soil temperature ranged from 5.7 to 30.8°C, 5.4 to 30.0°C, and 8.2 to 28.8°C for the complete, partial and no removal treatments, respectively (Table 3).

Soil temperatures were lower in the no removal treatment in both March and April, compared to the partial and complete removal treatments. The season average temperature was also lowest for the no removal treatment (19.2°C) as compared to the complete (19.5°C) and partial removal (19.6°C) treatments. Soil moisture varied from 0 to 37-kPa, 0 to 35- kPa, and 0 to 41-

Table 3. Effect of residue levels on levels soil temperature and soil moisture on a heavy soil at Gravois Farms, 2004.

	Complete Removal		Partial Removal		No Removal	
	Soil Temp(C) †	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)
January	10.9	-	10.9	-	11.0	-
February	11.4	0.44	11.4	1.7	11.4	0.3
March	18.2	13.2	18.2	14.4	17.0	9.8
April	20.2	13.8	20.5	14.2	19.5	11.0
May	23.6	15.7	24.0	12.3	23.7	14.1
June	26.4	10.7	26.7	8.2	26.9	10.0
Average††	19.5	11.1	19.6	10.4	19.2	9.3
Minimum	5.7	0.0	5.4	0.0	8.2	0.0
Maximum	30.8	37.0	30.0	35.0	28.8	41.0
† Soil temperature and soil moisture levels. Averages of continuously recorded hourly readings. †† Seasonal, average, minimum and maximum temperatures.						

kPa for the complete, partial and no removal treatments, respectively (Table 3). The soil moisture levels were higher in the no removal treatment in February, March and April as compared to the complete and partial treatments. The average soil moisture during the experiment was higher in the no removal treatment (9.3 kPa) compared to the partial (10.4 kPa) and complete removal (11.1 kPa) treatments (Table 3).

In the 2005 light soil test, soil temperature ranged from 4.1 to 33.1°C, 4.1 to 31.9°C, and 6.3 to 30.6°C for the complete, partial and no removal treatments, respectively (Table 4). Soil temperature was lower in the no removal treatment only in April and the average temperature during the experiment was lowest in the complete removal treatment (19.2°C) as compared to the no removal (19.5°C) and partial removal (19.9°C) treatments (Table 4). Soil moisture varied

from 0 to 21.5-kPa, 7.3 to 33.0-kPa, and 3.0 to 19.0-kPa for the complete, partial and no removal treatments, respectively (Table 4). The soil moisture levels were higher in the no removal treatment in January, April and May, as compared to the complete and partial removal

Table 4. Effect of residue levels on soil temperature and soil moisture on a light soil at Richard Farms, 2005.

	Complete Removal		Partial Removal		No Removal	
	Soil Temp(C) †	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)
January	12.1	12.9	12.4	11.5	12.7	9.1
February	14.4	5.4	14.8	11.0	14.7	8.5
March	15.6	10.0	16.1	13.4	15.8	10.8
April	20.9	18.2	21.8	27.5	20.7	17.5
May	24.5	25.2	25.4	29.0	24.5	24.2
June	26.2	13.0	26.8	15.3	26.7	14.0
Average††	19.2	14.5	19.9	19.0	19.5	14.8
Minimum	4.1	0.0	4.1	7.3	6.3	3.0
Maximum	33.1	21.5	31.9	33.0	30.6	19.0
† Soil temperature and soil moisture levels. Averages of continuously recorded hourly readings. †† Seasonal, average, minimum and maximum temperatures.						

treatments. The season averaged soil moisture was slightly higher in the complete removal treatments (14.5-kPA) as compared to the no removal (14.8-kPa) and partial removal (19.9-kPA) treatments, respectively (Table 4).

In the 2005 heavy soil test the soil temperatures ranged from 4.5 to 33.7°C, 4.6 to 33.6°C, and 7.1 to 32.0°C for the complete, partial, and no removal treatments, respectively (Table 5). Soil temperature was lower in the no removal treatment in all months except January. The season averaged soil temperature was also lowest for the no removal treatment (19.0°C), compared to the complete (19.9°C) and partial removal (20.0°C) treatments (Table 4). Soil moisture varied from 0.0 to 47.3-kPa, 1.5 to 73.5-kPa, and 1.0 to 61.0-kPa for the complete, partial and no removal treatments (Table 4). The soil moisture levels were higher in the no removal treatment only in April, as compared to the complete and partial removal treatments.

The season averaged soil moisture level was highest in the complete removal treatment (13.4-kPa), followed by the no removal (15.2-kPa) and partial removal (20.3-kPa) treatments (Table 5).

Taking the data as a whole several conclusions can be made. First, it is clear that the residue layer served as a temperature insulator preventing the soil from cooling as well as warming. This is most clearly seen by examining the total range in soil temperature for each

Table 5. Effect of residue levels on soil temperature and soil moisture on a heavy soil at Gravois Farms, 2005.

	Complete Removal		Partial Removal		No Removal	
	Soil Temp(C) †	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)	Soil Temp (C)	Soil Mois (kPa)
January	12.3	5.3	12.2	10.1	12.4	8.2
February	14.6	5.3	14.5	11.6	14.4	10.0
March	16.4	10.2	16.4	13.2	15.5	10.5
April	21.5	22.2	21.7	23.2	19.6	18.0
May	24.8	19.5	25.7	31.4	23.5	20.2
June	27.6	11.0	27.6	24.1	26.8	19.1
Average††	19.9	13.4	20.0	20.3	19.0	15.2
Minimum	4.5	0.0	4.6	1.5	7.1	1.0
Maximum	33.7	47.3	33.6	73.5	32.0	61.0
† Soil temperature and soil moisture levels. Averages of continuously recorded hourly readings. †† Seasonal, average, minimum and maximum temperatures.						

treatment. In the combined data set the range was 25.7°C, 29.6°C, and 29.9°C for the no removal, complete and partial removal treatments, respectively (Table 1). In all years and locations the no removal treatment had the smallest range in temperature, as compared to the complete and partial removal treatments (Tables 1-4). In addition, the no removal treatment resulted in the highest January temperatures in three out of four tests and the lowest March and April temperatures in three out of the four tests. Soil moisture levels were also increased by the presence of post-harvest residue. Soil moisture levels in April were higher in the no removal treatment in all four tests (Table 1-4). Finally, if the number of days in which the temperature

was greater or equal to 15.5°C (temperature required for sugarcane bud germination) is calculated for each treatment in the combined data set, several interesting trends are apparent. First, where the residue was not removed there were 10 and 17 fewer days above 15.5°C over the entire monitoring period than for the complete and partial removal treatments, respectively. Secondly, the biggest differences were seen in March and April, in which there were 3.7 and 6.8, fewer days above 15.5°C in the no removal compared to the complete removal treatment. These conditions could result in a significant delay in germination of the ratoon crop in the spring. This treatment also resulted in increased soil saturation. Both low soil temperature (Zhang et al., 2003) and high soil moisture can reduce plant growth (Glaz et al., 2002) and can also increase cane infection by facultative parasitic soil fungi (Samuels et al., 1952.) It has been previously reported that retention of post-harvest residue can accentuate problems of water-logging by decreasing the rate of soil drying after rainfall (Wood, 1991).

B. Allelopathic and Autotoxic Properties of Post-harvest Residue

Previous research indicated that post-harvest sugarcane residues can suppress both weed and crop development (Richard, 1999). It was hypothesized that residue suppression is due to the fact that the residue possess both allelopathic and autotoxic properties. Fresh post-harvest residue was collected from four fields of LCP 85-384 on the same day the sugarcane was harvested green with a chopper harvester. On the day following each collection, a cold-water procedure was used to extract putative allelochemicals using distilled water in a temperature-controlled water bath at 25 C with a 1:28 tissue to water weight ratio (Harper and Lynch, 1982). Temperature and residue concentrations were based on historical weather records during the months of residue decomposition in Louisiana (October-March). Final concentrations were 0,

0.1, 10, 25, and 100% of the original extract solution. Chemical analysis was conducted using gas chromatography and mass spectrometry.

To determine possible autotoxic and hormetic properties of the extract, soil bioassays were conducted using both light and heavy-textured soils. Soils were analyzed for chemical composition by A&L Laboratories (Memphis, TN) (Table 6). Pots, 15 cm in diameter, were filled with 2 kg soil. Single nodal pieces of sugarcane cv. LCP 85-384 were pre-germinated in distilled water-moistened tissue paper for 2 wk to break bud dormancy then planted in pots which were hand-watered daily at a rate of 150 ml of the extract solutions per pot. Leaf number and plant height were recorded every 2 wk for 8 wk. At the termination of the experiment, final height, leaf number, fresh weight, and dry weight were recorded. Plants were grown for 8 wk in a greenhouse under natural light with controlled relative humidity of 60-80% and temperature of 30/25 C (day/night). The experimental design was a randomized complete block with four replications for all treatments. The experiment was conducted twice using different residue and soil samples for the two trials.

Table 6. Chemical properties for the two soils used in the greenhouse experiments investigating the interaction of soil type with allelochemicals.

Soil classification	Commerce silt loam	Sharkey clay
PH	7.1	8.0
Phosphorus (mg/kg)	155 (very high)†	34 (optimum)
Potassium (mg/kg)	286 (very high)	101 (low)
Calcium (mg/kg)	4290 (optimum)	4063 (optimum)
Magnesium (mg/kg)	759 (very high)	249 (optimum)
Sulfur (mg/kg)	18 (medium)	16 (medium)
Cation exchange capacity (mol (+) /kg)	23.5	18.2
Organic matter (g/kg)	0.35	0.10
† Ratings based on soil recommendations for sugarcane production from A&L Laboratories, Memphis, TN.		

To identify a possible indicator species, the inhibitory activity of the various concentrations of the extract were determined by seed germination and radical growth bioassays on three test species: oat (*Avena nuda*) cv. Rodeo, common rye (*Secale cereale*), and tomato (*Lycopersicon esculentum*) cv. Celebrity and sugarcane cv. LCP 85-384. Fifty seeds of oat, rye, and tomato, and 10 nodal buds of sugarcane were germinated in 9.5 cm Petri dishes on Whatman no. 541 filter paper, with 5 ml of the various extract concentrations used to moisten the filter paper (Ahn and Chung, 2000; Ebana et al., 2001). Dishes were immediately sealed with parafilm® and incubated in the dark at a constant 26°C in an environmentally-controlled incubator. Three replications (dishes) were used for each plant species, and the experiment was conducted twice. Percent germination was recorded seven days after incubation with radicals protruding at least 1 mm through the seed coat considered germinated. Radical length was also recorded at this time using the same seedlings for oats, rye, and tomato. Percent sugarcane germination was recorded 14 d after incubation with buds protruding at least 1 cm from the stalk tissue considered germinated.

All data were analyzed using SAS with PROC MIXED (SAS Institute, 2001) with extract concentrations and soil type as fixed variables and trial and replication as random variables. Percentage data was transformed by the arc sine square root transformation. Differences between treatment least square means were compared using the pdiff option (Saxton, 1988) at the 0.05 probability level. Correlation analysis was made between the extract effects on sugarcane and the possible indicator species of rye, oat, and tomato. Data were also analyzed taking into account possible hormetic effects using methods described by Schabenberger et al. (1999) using the following equation:

$$E[Y|x] = \gamma + \frac{\alpha - \gamma}{1 + \omega \exp[\beta \ln(x/RD50)]}$$

where E[Y|x] represents the average response at x dosage, α and γ are the upper and lower asymptotes of the response, ω is the initial slope, β is the point of inflection of the curve , and RD50 is the effective dosage at which 50% of the total effect is demonstrated.

A Pseudo-r^2 value was calculated using methods described by Schabenberger et al. (1999) using the following equation:

$$\text{Pseudo-}r^2 = 1 - \text{SSRes}/\ \text{SStotal}_{(\text{corrected})}$$

Compounds identified by GC/MS from sugarcane extracts included: benzoic acid, decane, diacetyl glycol, methyl hexadecanoic acid, and phthalic acid ester. Of these compounds, benzoic acid and its derivatives have been shown to have allelopathic properties on several species including cotton (*Gossypium hirisutum* L.), wheat (*Triticum aestivum* L.) ryegrass (*Lolium* spp.), cucumber (*Cucumis sativa* L.), and radish (*Raphanus sativus*) (Inderjit and Bhowmik, 2004; Lodhi et al., 1987; Wu et al., 2002). Previous sugarcane research indicated that phenolics were involved in the phytotoxicity caused by sugarcane straw (Wang et al., 1967).

Generally, sugarcane development beyond germination was not effected by the extract, except for leaf development (Table 7). Leaf number was reduced by 0.5 leaves at 2 wk after treatment (WAT) by the 1.0 and 100% concentrations. At 4 WAT, the 1, 10, and 100% concentrations reduced leaf number relative to the water-only control. Other research showed that allelopathic activity from sugarcane leachates did not affect growth of weed seeds if sown 10 d after leachates was applied suggesting microbial degradation, chemical decomposition, and sorption (Sampietro et al., 2005). It was hypothesized that soil type would interact with the

Table 7. Comparisons of means for sugarcane growth as a function of increasing extract concentration from sugarcane post-harvest residue for two trials with four replications each averaged across both soil types.

	Weeks after planting								
	2	4	6	8	2	4	6	8	8
	Leaf number				Plant height				Plant dry weight
Concentration (%)	# per plant				cm				g
0	5.8ab†	7.1a	8.5a	9.4a	27.3a	28.3a	33.7a	46.2a	17.3a
0.1	5.8ab	6.7abc	8.1a	9.6a	27.7a	28.8a	30.6a	46.0a	17.1a
1.0	5.3c	6.3c	7.9a	8.9a	26.6a	27.0a	31.4a	44.5a	17.5a
10	5.4bc	6.4c	8.2a	9.5a	26.4a	28.6a	32.7a	45.7a	16.5a
25	5.9a	7.0ab	8.4a	9.6a	28.4a	28.8a	32.0a	47.5a	18.2a
100	5.3c	6.6bc	8.4a	9.4a	23.8a	28.1a	34.7a	46.7a	15.9a
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05.									

autotoxicity of the extract, but there was no significant soil type by concentration interaction in this experiment (data not shown).

Post-harvest residue extract significantly affected germination of oats and rye (Table 8). Oat germination was only affected by the two highest concentrations when compared to the water-only control, with a 17% reduction recorded for the 25 and 100% concentrations.

Table 8. Comparisons of means for oats, rye, tomato, and sugarcane germination and radical growth of oats, rye, and tomato as a function of increasing extract concentration from sugarcane post-harvest residue based on two trials with three replications each.

	Percent germination				Radical growth†		
	%				mm		
Concentration	oat	rye	tomato	sugarcane	oat	rye	tomato
0	74a‡	81a	84a	50bc	15a	29ab	12a
0.1	67ab	85a	86a	45bc	9b	31a	12a
1.0	68ab	78ab	88a	65ab	10b	28ab	12a
10	62ab	69bc	87a	95a	8b	27b	12a
25	57b	69bc	88a	30c	6b	27b	9a
100	57b	64c	90a	25c	6b	26b	10a

Rye seed germination was reduced only by the 10, 25, and 100% concentrations by 12, 12, and 17%, respectively. Radical growth of oats was reduced by all extract concentrations by 33 to 60% as compared to the control radicals. The 0.1% concentration increased rye radical growth by 2, 2, and 3 mm compared to the 10, 25, and 100% concentrations. Extracts, though, did not reduce rye radical growth compared to the control. In contrast to oat and rye, tomato seed germination and radical growth was not affected by extract treatment. Tomato growth may not have been affected because it is a dicot unlike rye and oats. Differential species-specificity has been reported with other allelochemicals (Batish et al., 2004).

Sugarcane bud germination was increased by 45% by the 10% extract concentration compared to the water-only control (Table 8). Statistical analysis for hormetic effects did reveal that the response curve for sugarcane germination was due to hormesis (r^2=0.82) (Figure 3). Oat, rye, and tomato did not exhibit hormesis based on nonconvergence to the log-logistic model (data not shown). Pearson correlation coefficients responses of sugarcane, rye, oats, and tomatoes to the extract were low. Oat, rye, and tomato had correlation coefficients of 0.26, 0.12, and 0.19, respectively; thus these would not appear to be good indicator species for sugarcane. A good indicator species shows correlation coefficients greater than 0.90 with the species under investigation (Ebana et al., 2001). One of the main reasons these species had poor correlation with the sugarcane response was because of the hormetic effects demonstrated only with sugarcane.

In summary, sugarcane post-harvest residue showed allelopathic, autotoxic, and hormetic properties under controlled incubator and greenhouse environments. Benzoic acid was present in

the extracts. Due to the hormetic effects only on sugarcane germination, oat, rye, and tomato were not good indicator species for sugarcane.

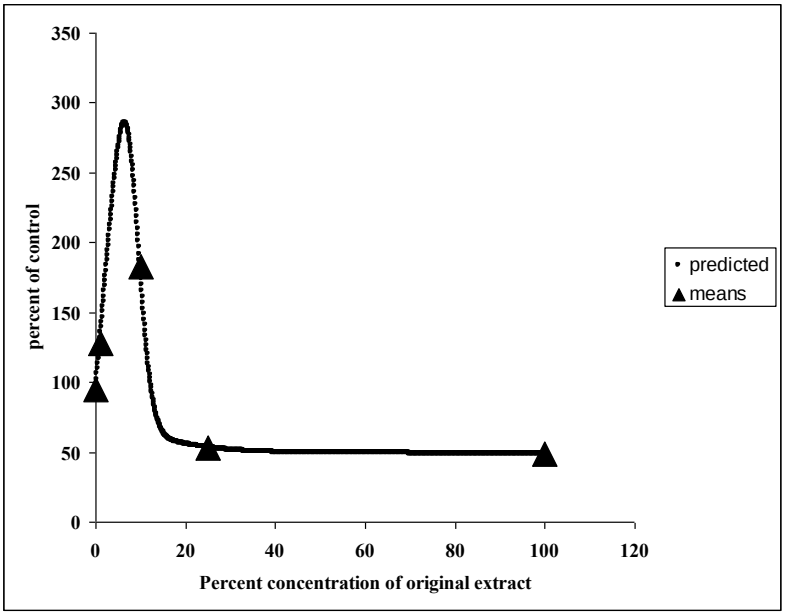

Figure 3. Hormetic response of sugarcane bud germination to various concentrations of post-harvest sugarcane residue extracts using the equation described by Schabenberger et al. (1999): $E[Y|x]= \gamma+ [\alpha-\gamma/ 1+ \omega \exp\{\beta\ln(x/RD50)\}]$. $E[Y|x]$ represents the average response at x dosage, α and γ are the upper and lower asymptotes of the response, ω is the initial slope, β is the point of inflection of the curve , and RD_{50} is the effective dosage at which 50% of the total effect is demonstrated. $F= 185.9$, $p< 0.0001$, $r^2= 0.84$, $\alpha= 225$, $\gamma= 25$, $\omega= 190$, $\beta= 16$, and $RD_{50} = 25$.

These results suggest that as the crop residue is decaying, benzoic acid would be released and carried into the soil during rainy periods where it would have an inhibitory effect on developing sugarcane shoots and roots. As the sugarcane yields increase, the amount of residue deposited on the soil would be expected to increase, hence the concentration of benzoic acid in the soil would also increase. The residue blanket would also serve to prevent the atmospheric

loss of the benzoic acid as well. With each successive harvest of the crop stubble buds that generate the subsequent ratoon crop generally move closer to the soil surface where the concentration of the benzoic acid in the soil solution would be the higher. Thus, the residue blanket would be generating more benzoic acid and keeping the soil wetter causing the benzoic acid to remain in the germination zone. Further studies are needed to establish the impact of benzoic acid in natural settings.

II. DEVELOPING BEST MANAGEMENT PRACTICES

A. Residue Removal Timing, Method and Soil Type Studies.

These studies were conducted to determine the influences of a chopper-harvester generated blanket of green cane residues on the yield of the following year's ratoon crop. Second, first, and plant-cane crops of LCP 85-384 growing on light and heavy textured soils were harvested in October, November, and December, 2003, respectively. Once harvested, treatments consisting of partial residue removal (remove residue from the row top by brushing to the wheel furrow) and complete removal by burning were imposed beginning immediately after harvest and continuing at monthly intervals until March, 2004. A no removal treatment was also included. The response of the subsequent crops to the various residue treatments was assessed by determining stalk counts and heights in August and cane yields following chopper harvest in 2004. TRS (Theoretical Recoverable Sugar) was assessed from a sub-sample of harvested billets from each plot. TRS is a parameter quantifying sugar concentration in harvested cane and is used to assess cane quality. Sugar yield (kg ha^{-1}) is then determined by multiplying cane yield (Mg ha^{-1}) by TRS (kg sugar Mg^{-1} cane). These tests were repeated in the 2004/5 growing season at new locations.

Third-ratoon studies

Statistical analysis was conducted using SAS PROC MIXED with year and replications as random variables and soil type, removal method, and removal timing as fixed variables. Statistical analysis revealed no interactions for third-ratoon yield data, so data was pooled across years, soil type, and/or removal timing and method in order to make stronger conclusions across multiple scenarios of cropping systems. Removal timing and method did not affect TRS in the third-ratoon crop which ranged from 107 to 111 kg/Mg (Table 9). Moreover, removal method had no effect on cane or sugar yield, which is contrary to previous work that reported that third-ratoon crops are the most sensitive to no removal of the residue (Viator et al., 2005).

Table 9. Effects of residue removal timing and method on third-ratoon TRS and cane and sugar yield.

Removal Month	TRS kg/Mg	Cane yield Mg/ha	Sugar yield kg/ha
October	107a†	41.9ab	4460ab
November	110a	40.7abc	4360abc
December	107a	41.5ab	4410ab
January	111a	43.0a	4680a
February	107a	39.6bc	4190bc
March	108a	37.4c	3960c
No removal	109a	38.8bc	4130bc
Method			
Complete removal	109a	39.7a	4250a
Partial removal	108a	41.7a	4450a
No removal	109a	38.8a	4130a

†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05

Removal timing did affect cane and sugar yield. Removal timings in February and March yielded similar to the no removal treatment; these treatments yielded an average of 4.4

Mg/ha and 580 kg/ha of cane and sugar, respectively, less than the January removal. October and December removals yielded 4.3 Mg/ha more cane and 470 kg/ha more sugar than the March removal. It appears that January is the preferred removal timing as the third-ratoon growing season begins. During this time the crop is dormant due to low temperatures. Cane and sugar yields were not improved by removal in February and March compared to the no removal treatment. These are all periods when the crop is emerging after winter dormancy, which appears to be sensitive physiological stages of growth.

Statistical analysis of growth data (Table 10) indicated a soil type by treatment interaction for stalk population but not for stalk height. Removal timing and method did not affect stalk population for the light soil studies; populations ranged from 114 000 to 123 000 stalks/ha. On the heavy soil, there were 11 000, 22 000, 16 000, and 15 000 fewer stalks/ha for

Table 10. Effects of residue removal timing and method on third-ratoon stalk population and height.

	Stalk population		Stalk height
Removal	Light soil	Heavy soil	
Month	Stalks/ha x 1000		cm
October	119a	102b	162a
November	121a	91c	160a
December	123a	105ab	161a
January	118a	113a	162a
February	116a	104ab	157b
March	118a	97bc	155b
No removal	114a	98bc	158b
Method			
Complete removal	119a	99a	159a
Partial removal	120a	106a	160a
No removal	114a	98a	158a

†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05

the October, November, March, and no removal treatments, respectively, compared to the January removal. Removal method did not affect stalk population on the heavy soil. Averaged across both soil types, removal method had no effect on stalk height. On the other hand, averaged across both soil types, stalk height was reduced by 4, 6, and 3 cm for the February, March, and no removal treatments, respectively, compared to the average height of the October, November, December, and January removals.

Second-ratoon studies

Second-ratoon data analysis revealed a significant soil by treatment interaction for yield data (Table 11) indicating that the treatments did not respond consistently across different soil types. Data analysis was conducted separately by soil type. Removal timing and method on heavy soil did not affect TRS (111 to 113 kg/Mg), cane yield (45.7 to 53.1 Mg/ha) or sugar yield (5100 to 5920 kg/ha) (Table 3).

Table 11. Effects of residue removal timing and method on second-ratoon TRS and cane and sugar yield.

	TRS		Cane yield		Sugar yield	
Removal	Light soil	Heavy soil	Light soil	Heavy soil	Light soil	Heavy soil
Month	kg/Mg		Mg/ha		kg/ha	
November	125a†	111a	57.2a	50.5a	7160a	5570a
December	125a	111a	57.8a	45.7a	7210a	5100a
January	122ab	112a	55.7a	50.5a	6760ab	5670a
February	116b	113a	55.1a	50.2a	6360b	5660a
March	119b	113a	57.6a	46.2a	6800ab	5200a
Control	117b	112a	54.2a	53.1a	6240b	5920a
Method						
Complete removal	121a	111a	57.5a	48.1a	6930a	5390a
Partial removal	122a	112a	55.8a	49.1a	6790a	5490a
No removal	117a	112a	54.2a	53.1a	6240a	5920a

†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05

On light soil, November and December removals had TRS levels of 125 kg/Mg compared to 116, 119, and 117 kg/Mg for the February, March, and no removal treatments, respectively. Cane yield on light soil was not affected by removal timing or method. Sugar yields, though, were 870 kg/ha lower for the February and no removal treatments when compared to the November and December removals. Removal method did not affect TRS, cane yield, or sugar yield on light soil. Stalk population and height had no interactions, so data was pooled across years and soil types (Table 12). Second-ratoon population and height were not affected by removal timing or method.

First-ratoon studies

A removal method by timing interaction for first-ratoon cane and sugar yield was obtained indicating that the removal method did not respond consistently across removal times or vice versa. Data analysis was conducted separately by removal timing and method (Table 13).

Table 12. Effects of residue removal timing and method on first and second-ratoon stalk population and height.

	Stalk population		Stalk height	
Removal	First-ratoon	Second-ratoon	First-ratoon	Second-ratoon
Month	Stalks/ ha x 1000		cm	
November	NA	130a	NA	176a
December	126a	127a	185a	172a
January	123a	127a	186a	173a
February	119c	128a	180b	174a
March	120bc	126a	180b	173a
Control	120bc	127a	181b	173a
Method				
Complete removal	118a	127a	183a	173a
Partial removal	122a	128a	182a	174a
No removal	120a	127a	181a	173a

†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05

TRS was not affected by removal time or method. The complete removal treatment in December produced 5.2 Mg/ha more cane than mechanical removal and 513 and 412 kg/ha more sugar than the partial and no removal treatments, respectively. On the other hand, the complete removal treatment in March reduced cane and sugar yields by 6.8 Mg/ha and 920 kg/ha relative to the no removal treatment. Cane and sugar yields were similar for the removal treatments at all other timings. Stalk population and height had no interactions, so data was pooled across years and soil types (Table 12). First-ratoon stalk populations and heights were not affected by removal method.

Table 13. Effects of residue removal timing and method on first-ratoon TRS and cane and sugar yield

	TRS			Cane yield			Sugar yield		
	Burn	Mech.	Cont.	Burn	Mech.	Cont.	Burn	Mech.	Cont.
Month		kg/Mg			Mg/ha			kg/ha	
Dec.	116Aa†	118Aa	114A	73.6Aa	68.4Ba	71.8A	8780Aa	8270Ba	8370Ba
Jan.	116Aa	114Aa	114A	74.0Aa	72.9Aa	71.8A	8840Aa	8480Aa	8370A
Feb.	110Aa	115Aa	114A	69.6Ab	69.2Aa	71.8A	7860Abc	8160Aa	8370A
Mar.	114Aa	112Aa	114A	65.0Bc	69.2ABa	71.8A	7450Bc	7960ABa	8370A
Cont.	114a	114a		71.8b	71.8a		8370b	8370a	

†Means within a column followed by the same lower case letter or in a row followed by the same upper case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05

In terms of removal timing, burning in December and January produced more cane (6.5 Mg/ha) and sugar (1150 kg/ha) than all removal timings and 2.0 Mg/ha and 448 kg/ha more than the no removal treatment (Table 13). Burning in March reduced cane yield by 6.5 Mg/ha relative to other timings and 2.0 Mg/ha relative to the no removal treatment. Moreover, burning in March reduced sugar yields by 1150 kg/ha compared to all other timings excluding February and 440 kg/ha relative to the no removal treatment. For the partial removal treatment, all parameters were similar for all timings and the no removal treatment. Removal methods analyzed by

removal date revealed that burning in December increased cane and sugar yields by 5.2 Mg/ha and 510 kg/ha compared to partial removal and 1.8 Mg/ha and 412 kg/ha compared to the no removal treatment. On the other hand, burning in March decreased cane and sugar yields by 6.8 Mg/ha and 920 kg/ha compared to the no removal treatment. Stalk populations for the November and December removals were 6 000 and 3 000 stalks/ha greater than the average of the February, March, and the no removal treatments (Table 12). Similarly, stalk height was 5 and 6 cm greater for the November and December removals compared to the average of the February, March, and no removal treatments.

To determine a general effect over all ratoon stages, data was combined for all ratoons for each soil type. All removals conducted during the pre-dormancy period (Oct-Dec) were pulled together and are labeled as harvest removal (Table 14). On light soil, removal timing affected all measured parameters. Removal during harvest increased TRS by 4 kg/Mg, cane yields by 2.7

Table 14. Effects of residue removal timing and method on all ratoon TRS and cane and sugar yield.

	TRS		Cane yield		Sugar yield	
Removal Month	Light soil	Heavy soil	Light soil	Heavy soil	Light soil	Heavy soil
	kg/Mg		Mg/ha		kg/ha	
Harvest	123a†	104a	56.7a	57.1ab	6980a	6180ab
January	120ab	107a	56.0ab	59.7a	6720ab	6550a
February	119b	102a	53.8bc	55.3bc	6390c	5830bc
March	119b	103a	53.2c	52.9c	6380c	5550c
Control	118b	104a	54.9bc	56.4bc	6480bc	6000bc
Method						
Complete removal	120b	108a	58.0a	58.7a	7000a	6500a
Partial removal	124a	108a	55.1a	57.1a	6860ab	6360a
No removal	118b	104a	54.9a	56.4a	6480b	6000b

†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05

Mg/ha, and sugar yields by 560 kg/ha compared to the average of the February, March, and the no removal treatments. Moreover, the January removal had an increase in both cane (2.8 Mg/ha) and sugar yields (340 kg/ha) compared to the average February and March removals. On heavy soil, only cane and sugar yields were affected by removal timing. The January removal increased cane and sugar yields by 4.8 Mg/ha and 750 kg/ha compared to the average of the February, March, and the no removal treatments. Moreover, the harvest removal had an increase in both cane (4.2 Mg/ha) and sugar (633 kg/ha) yields compared to the average of the February and March removals.

Residue removal method across ratoons revealed that on light soil TRS and sugar yields were affected by the degree of removal (Table 14). Partial removal increased TRS by 4 and 6 kg/Mg compared to the complete and no removal treatments. In terms of sugar yield, the complete and partial removal treatments had similar yields, but complete removal increased sugar yields by 520 kg/ha compared to the no removal treatment. On heavy soil, TRS and cane yields were similar for all removal methods, but the complete and partial removals increased sugar yields by 500 and 360 kg/ha, respectively, compared to the no removal treatment.

B. Chemical Adjuvant Studies

These tests were conducted to determine if residue decomposition could be accelerated by modifying its carbon to nitrogen ratio with chemical or biological adjuvants. Adjuvants were applied in the fall to recently harvested fields of first-ratoon of LCP 85-384. The second-ratoon crops were harvested in the fall of the following year. The adjuvants that were evaluated included: 1) 32% urea ammonium nitrate (UAN) solution (67 kg N/ha), 2) UAN (67 kg N/ha) +

Agrotain urease inhibitor with 7-day control, 3) UAN (67 kg N/ha) + Agrotain urease inhibitor with 14-day control, 4) Coron (67 kg N/ha), 5) Ammonium Thio-Sulfate (ATS) @130 L/ha, 6) N-Capture™ residue digester and 7) 1% molasses.

It was hypothesized that application of 67 kg N/ha of UAN would improve the C:N ratio in the soil so that native microorganisms could degrade the residues in a more timely fashion. Application of a urease inhibitor (Agrotain) with the UAN would slow the loss of nitrogen by leaching or volatilization by inhibiting the transformation of urea to ammonia. Coron is a commercially available controlled-release nitrogen source, which slowly releases ammonia and nitrate nitrogen over time, while maintaining the bulk of the applied fertilizer in an unavailable stabilized form. Ammonium thio-sulfate is a liquid nitrogen-sulfur fertilizer that has been reported to aid in the decomposition of post-harvest residues in small grains. N-Capture is a commercially available compost-fertilizer product that reportedly also aids in residue decomposition. Molasses is a by-product of sugar production that has also been reported to aid in decomposition of sugarcane residues. These treatments were compared to a no-removal, complete removal by burning, burn +UAN, and partial removal by brushing treatments. Residue levels were determined by collecting all residue in a 0.8-m^2 area of each treated plot, drying at 160°C and weighing the dried material.

In the 2003/4 growing season two residue x removal method x adjuvant application experiments were initiated on light and heavy soils in the BTES. The heavy soil test was inadvertently lost when the cooperating grower mistakenly burned the field. This test was repeated in the 2004/5 growing season to assure a complete and valid data set. The remaining light soil experiment was harvested in November, 2004. There was not a significant decrease in the amount of residue on the soil surface with any of the applied adjuvants as compared to the no

removal treatment (Table 15). This would indicate that none of the applied adjuvants increased the residue decomposition rate so as to significantly affect overall residue levels as the crop starts a new production cycle. Adjuvant application did not result in significant differences in gross cane yield or in theoretically recoverable sugar (TRS) levels (Table 15). Sugar yield was also unaffected by adjuvant addition, with the exception that application of Coron significantly

Table 15. Effect of chemical adjuvant addition on residue decomposition, gross cane and sugar yields on a light soil. Ellendale Plantation 2004.

Treatment	Mulch (Mg/ha)	Gross Cane (Mg/ha)	TRS (kg/Mg)	Sugar (kg/ha)
No Removal	11.4a†	73.5a	113.9a	9350ab
Complete Removal	1.13b	75.2a	98.8a	8310bc
Complete Removal + UAN	1.6b	74.9a	99.4a	8230bc
Partial Removal	5.2b	71.3a	115.0a	9130abc
UAN	11.0a	75.7a	99.6a	8430abc
UAN + AG 7day	11.6a	76.6a	111.4a	9450ab
UAN + AG 14 day	13.9a	70.8a	115.5a	9110abc
Coron	13.7a	71.3a	102.4a	7960c
ATS	11.6a	76.4a	113.8a	9720a
N-Capture	11.6a	73.3a	101.8a	8340bc
Molasses	14.1a	68.3a	118.1a	9000abc

†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05

decreased sugar yield as compared to the no removal treatment (Table 7). Stalk population was significantly greater where residue was removed either completely or partially as compared to the no removal treatment (Table 16). Stalks were also significantly taller were residue was completely removed and UAN was applied, as compared to the no removal treatment.

In the 2004/5 growing season three residue x removal method x adjuvant application experiments were initiated (two heavy soils and one light soil). These tests were harvested in November, 2005. Results from the light soil test at Ellendale Plantation confirmed the 2003/4

study, showing that adjuvant application did not result in a significant decrease in residue levels as compared to the no removal treatment (Table 17). Adjuvant application did not significantly

Table 16. Effect of chemical adjuvant addition on stalk population and height on a light soil. Ellendale Plantation.

	Stalk Population		Stalk Height	
	2004	2005	2004	2005
Treatment	No./ha x 1000		cm	
No Removal	161bc	136ab	197c	186ab
Complete Removal	173a†	134ab	202ab	166bc
Complete Removal + UAN	164abc	139ab	205a	180ab
Partial Removal	173a	142a	197bc	191a
UAN	164abc	120b	200abc	151c
UAN + AG 7 day	160bc	124ab	199abc	184ab
UAN + AG 14 day	164abc	131ab	199bc	191a
Coron	162abc	132ab	196c	178ab
ATS	157c	136ab	202ab	186ab
N-Capture	170ab	132ab	202ab	182ab
Molasses	159bc	132ab	200abc	176ab
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05				

increase gross cane yield, as compared to the no removal treatment. Application of UAN without a urease inhibitor significantly decreased gross cane yield, as compared to the no removal and partial removal treatments (Table 17). Gross cane yields were equivalent when a urease inhibitor was added to applied UAN (UAN+AG7 day, 14 day).

Adjuvant application did not result in a significant difference in TRS or sugar yield, as compared to the no removal treatment. Application of UAN without a urease inhibitor decreased sugar yields as compared to the no removal treatment (Table 17). There was not a significant difference in stalk numbers as a result of adjuvant addition (Table 16). There were significantly higher stalk numbers where the residue was partially removed, as compared to treatments where

UAN was applied without a urease inhibitor. Stalk height was also decreased by UAN application as compared to all other treatments (except complete removal) (Table 16).

Table 17. Effect of chemical adjuvant addition on residue decomposition, gross cane and sugar yields on a light soil. Ellendale Plantation, 2005.

Treatment	Mulch (Mg/ha)	Gross Cane (Mg/ha)	TRS (kg/Mg)	Sugar (kg/ha)
No Removal	13.6a	51.4a	111a	11480a
Complete Removal	0.5b†	45.0ab	115a	10370ab
Complete Removal + UAN	0.0b	46.8ab	111a	10390ab
Partial Removal	0.8b	51.6a	113a	11600a
UAN	13.0a	35.1b	112a	7820b
UAN + AG 7 day	13.8a	51.1a	115a	11700a
UAN + AG 14 day	14.6a	52.4a	112a	11750a
Coron	12.6a	42.9ab	115a	9830ab
ATS	14.8a	50.1ab	114a	11420a
N-Capture	14.6a	48.5ab	118a	11420a
Molasses	12.1a	39.7ab	117a	9240ab
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05				

Heavy soil adjuvant tests were conducted on Weimer Farms near Raceland, Louisiana. Two adjacent fields, with similar soil properties, were selected for these tests. Application of adjuvants did not decrease residue levels as compared to the no removal treatment at the first site (Table 18). Gross cane yield was not increased with adjuvant addition, as compared to the no removal treatment. In contrast, the complete removal plus UAN treatment significantly decreased yields (Table 18). The no removal treatment exhibited the highest TRS numerically and was significantly greater in 4 out of 10 cases. Sugar yield was largely unaffected by adjuvant addition, with the exception that yield was decreased in the complete removal treatment, as compared to the no removal treatment (Table 18). Adjuvant addition also did not affect stalk number or height (Table 19).

Similar residue decomposition results were obtained at the second site on Weimer farms. Mulch levels were not affected by adjuvant addition (Table 20), but were significantly lower where residue was mechanically removed or burned. In contrast to the first site, both gross cane and sugar yields were significantly greater where UAN was applied alone or with a 7-day urease inhibitor, as compared to the no removal treatment.

Table 18. Effect of chemical adjuvant addition on residue decomposition, gross cane and sugar yields on a heavy soil at Weimer Farms, Raceland, Louisiana, 2005A.

Treatment	Mulch (Mg/ha)	Gross Cane (Mg/ha)	TRS (kg/Mg)	Sugar (kg/ha)
No Removal	11.2ab	39.3ab	112.7a	4960ab
Complete Removal	0.1c†	34.4bc	103.2b	3980cd
Complete Removal + UAN	0.0c	30.7c	109.0ab	3740d
Partial Removal	0.4c	37.8ab	106.7ab	4520abc
UAN	11.1ab	39.5ab	102.1b	4490abc
UAN + AG 7 day	12.2ab	41.6a	106.3ab	4960ab
UAN + AG 14 day	10.0ab	38.8ab	103.8b	4520abc
Coron	9.8b	36.7ab	104.3b	4290bcd
ATS	11.1ab	42.0a	107.9ab	5070a
N-Capture	12.5a	37.8ab	107.5ab	4530abc
Molasses	10.6ab	40.6a	103.2b	4690ab

†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05

Adjuvant addition did not affect TRS levels as compared to the no removal treatment (Table 20). Stalk number were also not affected by adjuvant addition, compared to the no removal treatment. The no removal treatment also had the shortest stalks numerically at the second site, but this was only significantly different in plots where UAN was applied with a 7-day urease inhibitor (Table 19).

Table 19. Effect of chemical adjuvant addition on stalk population and height on a heavy soil at Weimer Farms, Raceland, Louisiana.

	Stalk Population		Stalk Height	
	2005 A	2005 B	2005 A	2005 B
Treatment	No./ha x 1000		cm	
No Removal	120ab	111a	167ab	146b
Complete Removal	120ab†	114a	158b	148ab
Complete Removal + UAN	110b	124a	156b	153ab
Partial Removal	117ab	120a	162ab	156ab
UAN	126a	124a	171a	158ab
UAN + AG 7 day	132a	128a	168ab	165a
UAN + AG 14 day	131a	122a	168ab	160ab
Coron	129a	124a	167ab	156ab
ATS	126a	120a	165ab	159ab
N-Capture	127a	121a	167ab	163ab
Molasses	128a	115a	168ab	155ab
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05				

Table 20. Effect of chemical adjuvant addition on residue decomposition, gross cane and sugar yields on a heavy soil at Weimer Farms, Raceland, Louisiana, 2005B.

Treatment	Mulch (Mg/ha)	Gross Cane (Mg/ha)	TRS (kg/Mg)	Sugar (kg/ha)
No Removal	7.3ab	30.8b	108.9ab	3730cd
Complete Removal	0.0c†	28.7b	109.9ab	3510d
Complete Removal + UAN	0.0c	29.8b	113.2a	3780bcd
Partial Removal	0.0c	31.0b	108.9ab	3780bcd
UAN	9.4a	39.1a	106.1ab	4660ab
UAN + AG 7 day	5.9b	39.1a	108.9ab	4780a
UAN + AG 14 day	10.0a	34.7ab	108.0ab	4190abcd
Coron	8.5ab	34.9ab	107.4ab	4210abcd
ATS	7.7ab	36.4ab	109.9ab	4470abc
N-Capture	7.3ab	36.4ab	105.8b	4290abcd
Molasses	9.8a	32.8ab	112.3ab	4070abcd
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05				

It is clear on examining the data from the four adjuvant tests that application of chemical-based adjuvants to post-harvest residues does not affect residue decomposition rate. In addition, yields were not consistently related to adjuvant addition. In previous work by the USDA-ARS-SRRC, Sugarcane Research Laboratory we have demonstrated that not removing post-harvest residues will decrease gross cane yield, TRS, sugar per acre, height and population compared to the traditional complete removal by burning treatment (Table 21). In addition, application of UAN at a rate of 60 lb N/A was found to increase gross cane yield sufficiently to circumvent the yield depressions caused by the residue (Table 22).

Table 21. Effect of residue retention on cane and sugar yield, height and population of third-ratoon LCP 85-384 on a heavy soil.

Mulch	Gross Cane	TRS	Sugar	Height	Pop
	Mg/ha	kg/Mg	kg/ha	cm	No/ha x 1000
NR	38.1b	90.4b	3450b	163.1b	152b
Burn	41.9a	94.7a	3970a	170.2a	160a
Brush	40.3ab	93.1a	3760a	167.5ab	160a
LSD (5%)	1.6	2.7	184.1	5.3	7

The beneficial effect of the UAN application does not appear to be related to the decomposition of the residue, but is apparently strictly a nitrogen response. The application of UAN at 120 lb N/A did not result in a significant increase in gross cane yield over the no removal treatment, but did increase plant height. This would indicate that adjusting the C:N ratio alone does not appear to be a viable option to increase residue decomposition. Laboratory studies of chemical adjuvants were not pursued, because of the failure of all adjuvants to work under field conditions. A different strategy, involving microbial adjuvants, was developed and studies were

conducted using USDA-ARS funds. These studies are promising and results are included in this report in the next section.

Table 22. Effect of nitrogen rate on cane and sugar yield, height and population of third-ratoon LCP 85-384 on a heavy soil.

Nitrogen	Gross Cane	TRS	Sugar	Height	Pop
	Mg/ha	kg/Mg	kg/has	cm	No/ha x 1000
0 lb N/A	39.0b	93.8	3660	164.0b	154
60 lb N/A	41.4a	92.0	3820	167.4ab	157
120 lb N/A	39.9ab	92.4	3700	169.4a	160
LSD (5%)	1.6	NS	NS	5.3	NS

C. Microbial Degradation of Post-Harvest Residues

A cooperative research project between ARS and Nicholls State University was initiated to isolate and characterize native bacteria and fungi that were capable of degrading post-harvest residues generated during the green-cane harvesting of sugarcane. This study began with the collection of soil samples from five locations: 1) a sugarcane field that had been conventionally managed where residue was burned, 2) a field where the residue had not been burned for 2 years, 3) a field where the residue had not been burned for 3 years, 4) a forest adjacent to a sugarcane field and, 5) an old established St. Augustine grass lawn. Soil microbes capable of degrading cellulose were then isolated from each sample using a selective media approach where cellulose provided the sole carbon source in the liquid media. A total of 9 bacterium and 7 fungi were isolated in this manner. The cellulose degrading ability of the microbes were evaluated in the lab through wet fermentation techniques, and two bacterial and two fungal isolates were selected for further study based on their ability to metabolize cellulose from 32 to 52% (Table 23). These isolates were identified with the cooperation of scientists and staff at the USDA-ARS, Southern Regional Research Center in New Orleans, LA.

Table 23. Cellulose metabolized in liquid fermentation study by microbe as estimated by the weight loss method.

Identified microbe	Source	%Weight loss†
Phanerochete Chrysosporium	Naquin woods	52
Cerioporiopsis sp.	Not burned 2 years	46
Cellulomonas Cellulovorans	Naquin woods	40
Corynebacterium Urealyticum	Field Burned	32

In the next stage of the study, dry fermentation techniques were utilized to determine the organisms' ability to degrade actual sugarcane post-harvest residues. In these experiments it was demonstrated that the most efficient degradation of these residues (19% of applied) occurred when all of the isolates were combined into a consortium (Table 24). The level was significantly greater than any of the individual species or the fungi or bacteria combined. Experiments also showed that the microbial consortium degraded dry sugarcane leaves to a significantly greater extent than green leaves with 22 and 14% of the leaves degraded for the dry and green leaves, respectively (Table 25).

Table 24. Cellulose metabolized in solid state fermentation incubations by individual microbes and consortiums.

Consortium	% Cellulose weight loss after 28 days
Control	1.8e†
Phanerocchete	7.4bc
Cerioporiopsis	6.1cd
Cellulomonas	4.8cde
Corynebacterium	2.1de
Phanerochete + Cerioporiopsis (Fungi)	10.4b
Cellulomonas + Corynebacterium (Bacteria)	7.3bc
All microbes combined	18.7a
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05	

In a similar dry fermentation experiment it was also demonstrated that sterilizing the residues prior to incubation with the consortium did not significantly affect degradation as compared to the non-sterile control (Table 25).

Table 25. Effect of sterilization and leaf age on cellulose metabolized by microbial consortium.

Condition	% Cellulose weight lose after 28 days
Non sterile leaf with all microbes	21.6a†
Sterile leaf with all microbes	19.2a
Green leaf with all microbes	13.6b
Dry leaf with all microbes	22.1a
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05	

A dry fermentation experiment was also performed in which the carbon to nitrogen ratio (C:N) of the residue was adjusted to 10, 20, 30, 40 and 50:1. An inverse, although not statistically significant, relation was documented between the C:N ratio and the total residue degraded, with 19, 22, 25, 26 and 28% degraded with C:N ratios of 50, 40, 30, 20 and 10 to 1, respectively (Table 26).

Table 26. Effect of C:N Ratio and cellulose metabolized by microbial consortium.

C:N ratio	% Cellulose weight loss after 28 days†
50:1	19.2c†
40:1	22.0bc
30:1	24.8ab
20:1	26.4ab
10:1	27.6a
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05	

Due to the positive results achieved in the laboratory fermentation experiments a greenhouse study was initiated to determine the extent of residue decomposition that would

occur under non-sterile, ambient temperature conditions. The results of this study showed that over a six-month time frame, a statistically greater degree of degradation occurred when all isolates were combined compared to bacterial or fungal isolates alone (Table 27).

Table 27. Cellulose metabolized by bacterial and fungal isolates and combined consortium in non-sterile, green house study.

Treatment	% Cellulose weight loss after 28 days
Control	0.9d†
Bacteria	7.6c
Fungi	11.4b
Bacteria + Fungi	24.6a
†Means within a column followed by the same lower case letter are not statistically different using the F probability values and the PROC MIXED macro as described by Saxton (1998) at alpha= 0.05	

Finally, a field experiment was initiated in the fall of 2003 to determine if the fungal and bacterial isolates could survive in competition with native microorganisms, and still accelerate the decomposition of post-harvest residues. Preliminary results from the 2003/2004 growing season did not show an accelerated breakdown of post-harvest residues; however, populations of both the bacterial and fungal inoculants steadily increased at each sampling date (Table 28). This would indicate that the isolates were successful in competing with indigenous microorganisms and becoming established in the field environment.

Table 28. Influence of microbial adjuvants on soil properties and microbial levels in Ardoyne field study, 2003-2004.

	PH	TOC	Bacteria	Fungi	NO_3	NO_2	NH_3	P
	December, 2003							
Control	6.5	4.1	27000	209	1.5	0.5	0.5	0.2
Bacteria	6.0	3.2	22500	118	1.8	0.2	0.5	0.2
Fungi	5.3	4.4	31210	212	2.1	1.2	2.0	0.4
Both	4.9	4.2	29700	125	3.0	2	2.0	0.2
	January, 2004							
Control	6.3	4.1	26420	198	1.3	0.2	0.6	0.2
Bacteria	6.0	3.4	303500	139	1.6	0	0.3	0.2
Fungi	5.3	4.5	266000	567	2.1	0.1	0.9	0.3
Both	5.0	4.2	352000	754	3.0	0	1.3	0.2
	February, 2004							
Control	6.1	4.1	25400	123	1.1	0.3	0.7	0.2
Bacteria	6.1	3.7	456000	176	1.0	0	0.1	0.2
Fungi	5.6	4.6	301900	887	1.3	0	0.3	0.2
Both	5.2	4.4	298700	957	2.1	0	0.4	0.2
	March, 2004							
Control	6.1	4.2	29800	154	1.1	0.4	0.6	0.2
Bacteria	6.3	4.0	789400	201	0.9	0	0.1	0.1
Fungi	5.8	4.6	405200	990	1.1	0	0.1	0.2
Both	5.4	4.9	398600	998	1.3	0	0.2	0.2
	April, 2004							
Control	6.1	3.2	21300	166	1.1	0.5	0.4	0.2
Bacteria	6.4	4.0	885000	223	0.7	0	0.0	0.1
Fungi	6.0	4.7	505000	996	0.5	0	0.0	0.1
Both	5.7	5.0	401500	1035	0.9	0	0.0	0.0

III. CONCLUSIONS AND RECOMMENDATIONS

As previously stated, the goal of this project was develop methods that will allow the blanket of plant residues deposited on the soil surface after harvesting green cane with a chopper harvester to minimize soil, nutrient, and pesticide losses from sugarcane fields without reducing the cane and sugar yields of the subsequent ratoon crop. However to determine if this was a feasible approach for Louisiana producers, it was necessary to determine why retention of post-harvest residues had an adverse affect on subsequent sugarcane yields. To accomplish this task we proposed two objectives. First, it was necessary to develop information regarding the factors which can influence yield losses in the ratoon crops where post-harvest crop residues are not removed. Secondly, management strategies had to be developed that would reduce the potential negative impact of the blanket of crop residue on the yield of the subsequent ratoon crop. The results from our studies have accomplished both of these objectives.

Retention of post-harvest residues was found to decrease soil temperature in the months of March and April and increase soil moisture in April in all studies. These conditions would clearly delay the emergence of the ratoon crop and would contribute to the observed yield depressions. Louisiana sugarcane producers already have the shortest growing season of any sugarcane production region in the world. Further shortening of this season due to a delay in spring emergence would directly affect subsequent cane and sugar yields. Aqueous extracts of post-harvest residues were also found to exhibit allelopathic and autotoxic properties. Sugarcane leaf development was significantly decreased with extract addition and sugarcane germination was numerically decreased. The residue extract also decreased the germination and growth of oats and rye, but did not have any effects on tomatoes. The combined effects of decreased soil temperature, increased soil moisture and autotoxic residue characteristics would clearly have an

influence of germination and growth of ratoon sugarcane crops and could quite possibly account for the observed decrease in crop yield.

Results of method and time of residue removal studies suggest several approaches to minimize yield losses associated with residue retention. First, if residue is to be removed either by burning or by mechanical means, this should be accomplished immediately after harvest or while the cane is still dormant (i.e. January). Delaying removal until February or March will decrease cane and sugar yields by slowing the warming and drying of the soil and accentuating the release of additional toxic substances at a critical time of crop establishment. Secondly, if the producer wishes to avoid the potential negative impacts of burning the residue, it may be removed mechanically from the row top provided that it is removed in the suggested time frame after harvest or when cane is still dormant. Retention of residue in the wheel furrows has been demonstrated to decrease pesticide and nutrient run-off (Selim et al., 2003). However, research is still needed to develop or modify current cultivating practices to handle the additional residue deposited in the wheel furrow.

Studies conducted to evaluate the potential use of chemical adjuvants as tools to manage post-harvest residues did not show an advantage to any of the materials studies. Residue decomposition rates were not accelerated and yields were in general, not affected. This is most likely the result of the short time in which decomposition must occur (December-January) and the cool, wet conditions that are present at this time. Encouraging results were obtained in laboratory, greenhouse and field studies that evaluated biological adjuvants. A microbial consortium consisting of two bacteria and two fungi was effective at degrading post-harvest residues in the laboratory and greenhouse and was found to survive under field conditions. Future studies will involve formulation of the organisms to maximize their effectiveness under

field conditions. If these experiments are successful, growers would utilize this technology to inoculate their sugarcane fields a single time to establish the microbial consortium. The organisms would then be available to begin degrading the residues immediately after harvest in the fall well before the start of the subsequent ratoon crop's growing season. Success in this line of research will allow sugarcane growers to utilize the blanket of post-harvest residues generated during the chopper harvesting of green cane to minimize the potential impact of soil, nutrient and pesticide losses from sugarcane fields in the fragile Barataria-Terrebonne National Estuary without significantly impacting crop yields.

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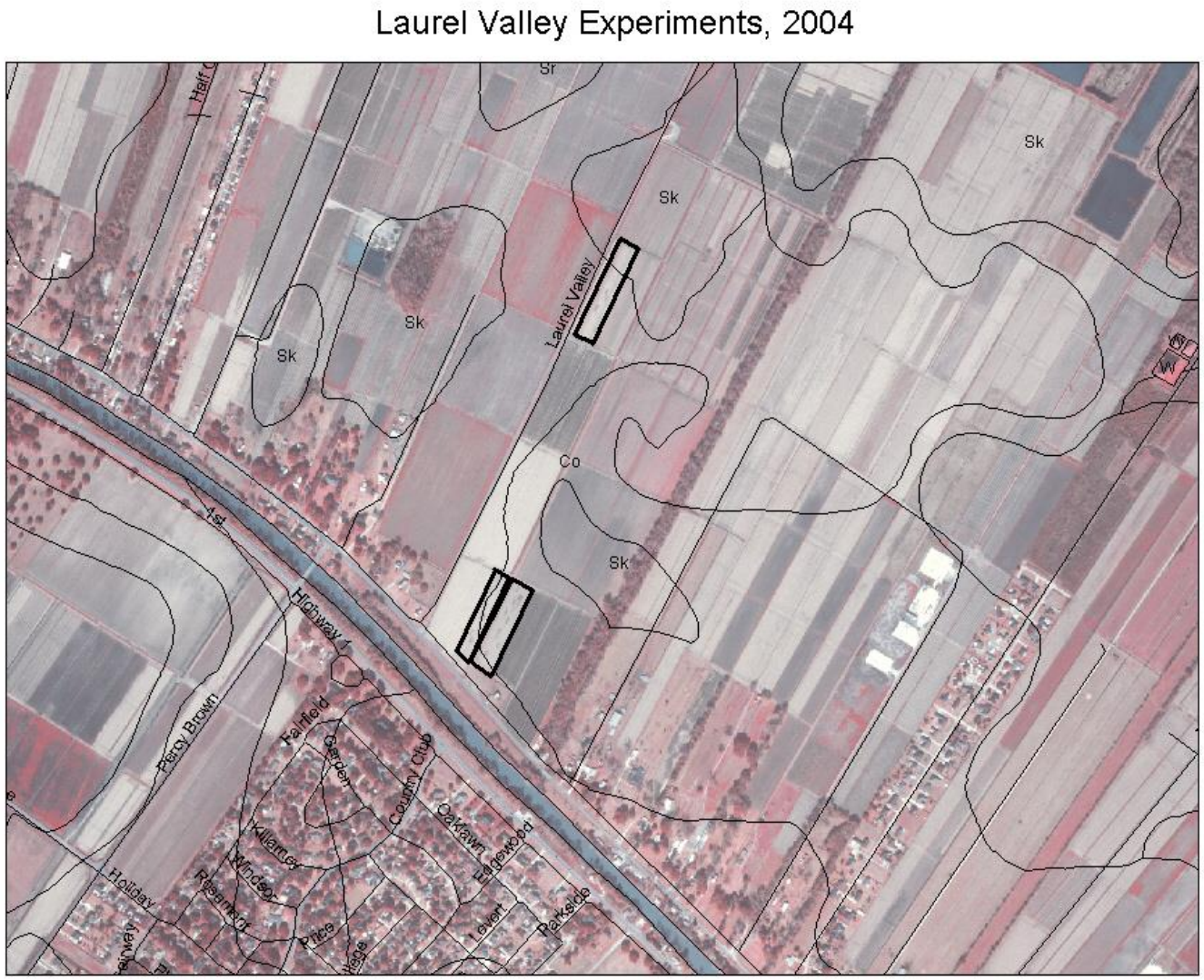
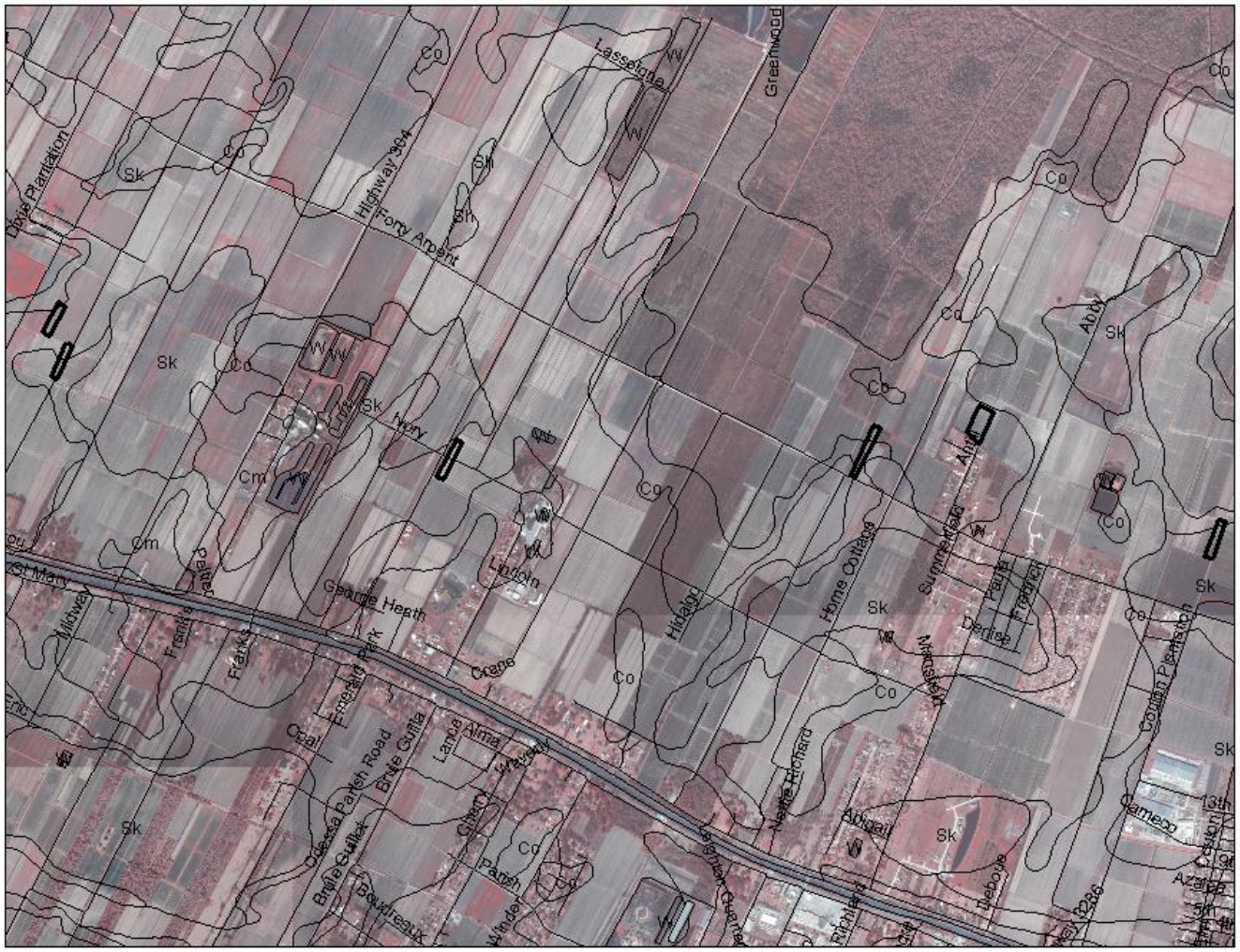
Appendix 1. Experiment locations.



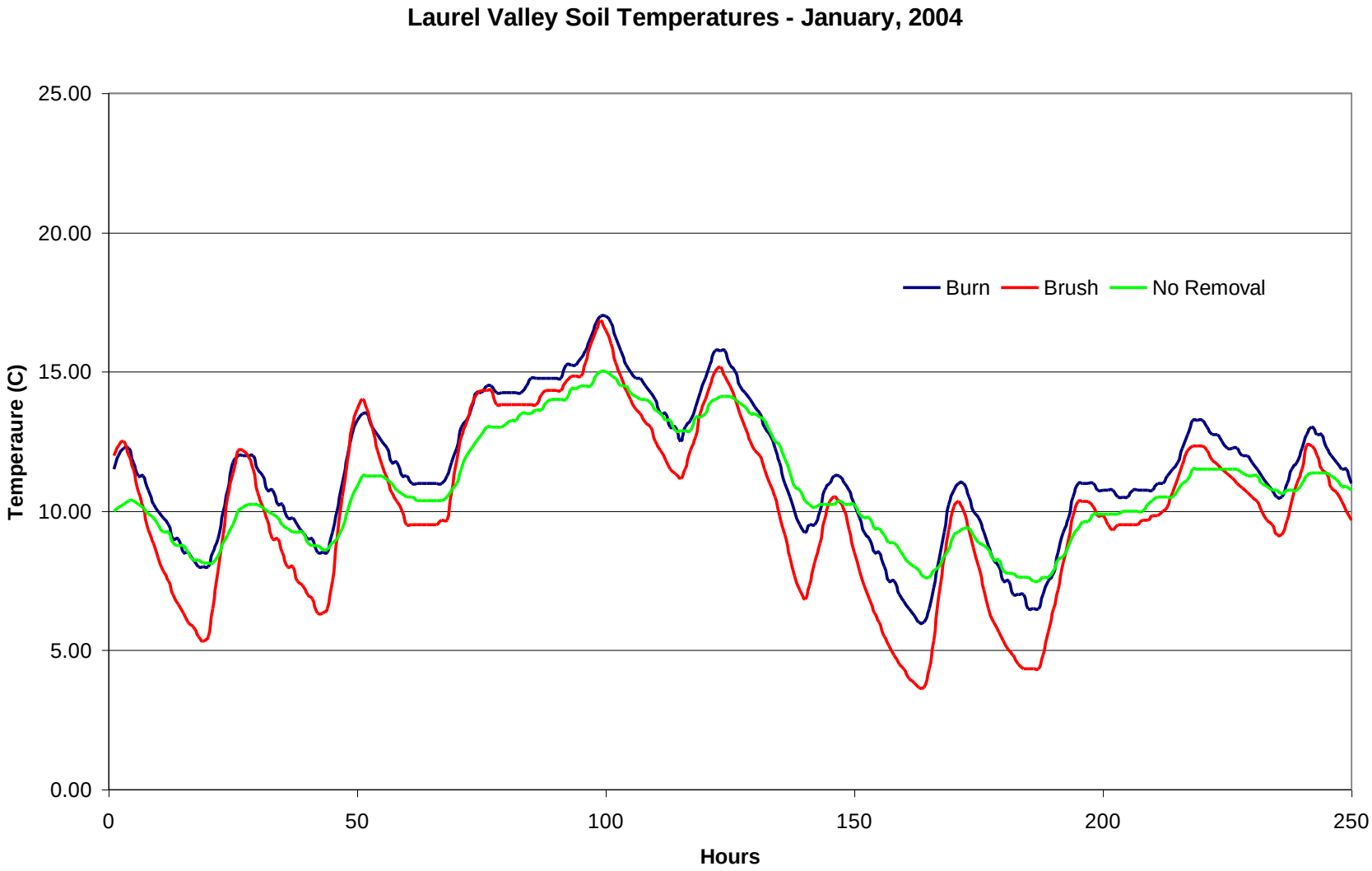
Gravois Farms Experiments, 2004 & 2005

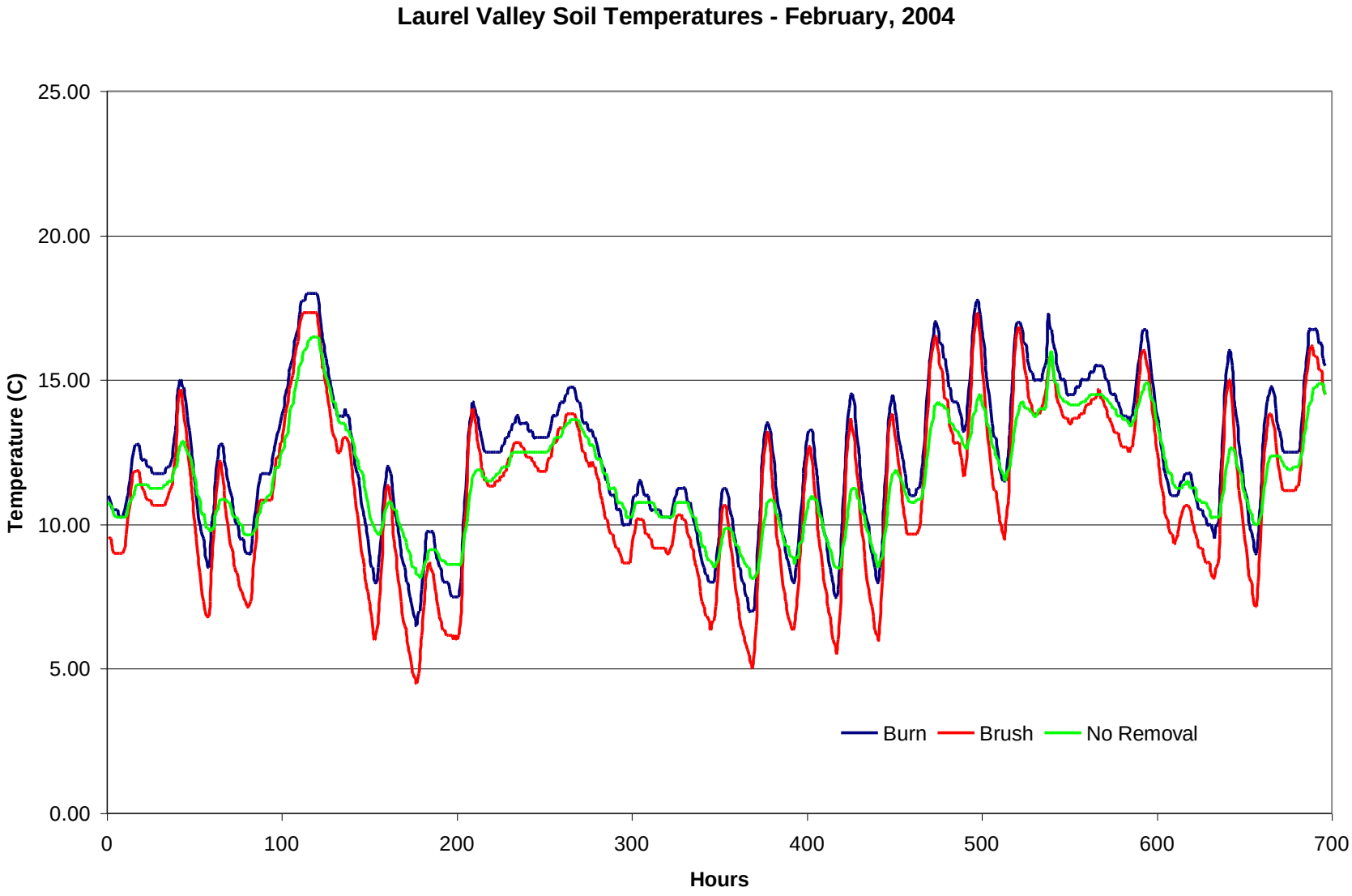


Richard and Weimer Farms Experiments, 2005

Ellendale Plantation Experiments, 2004-2005

Appendix 2. Soil temperature data from all years and locations.

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Temperature (C)
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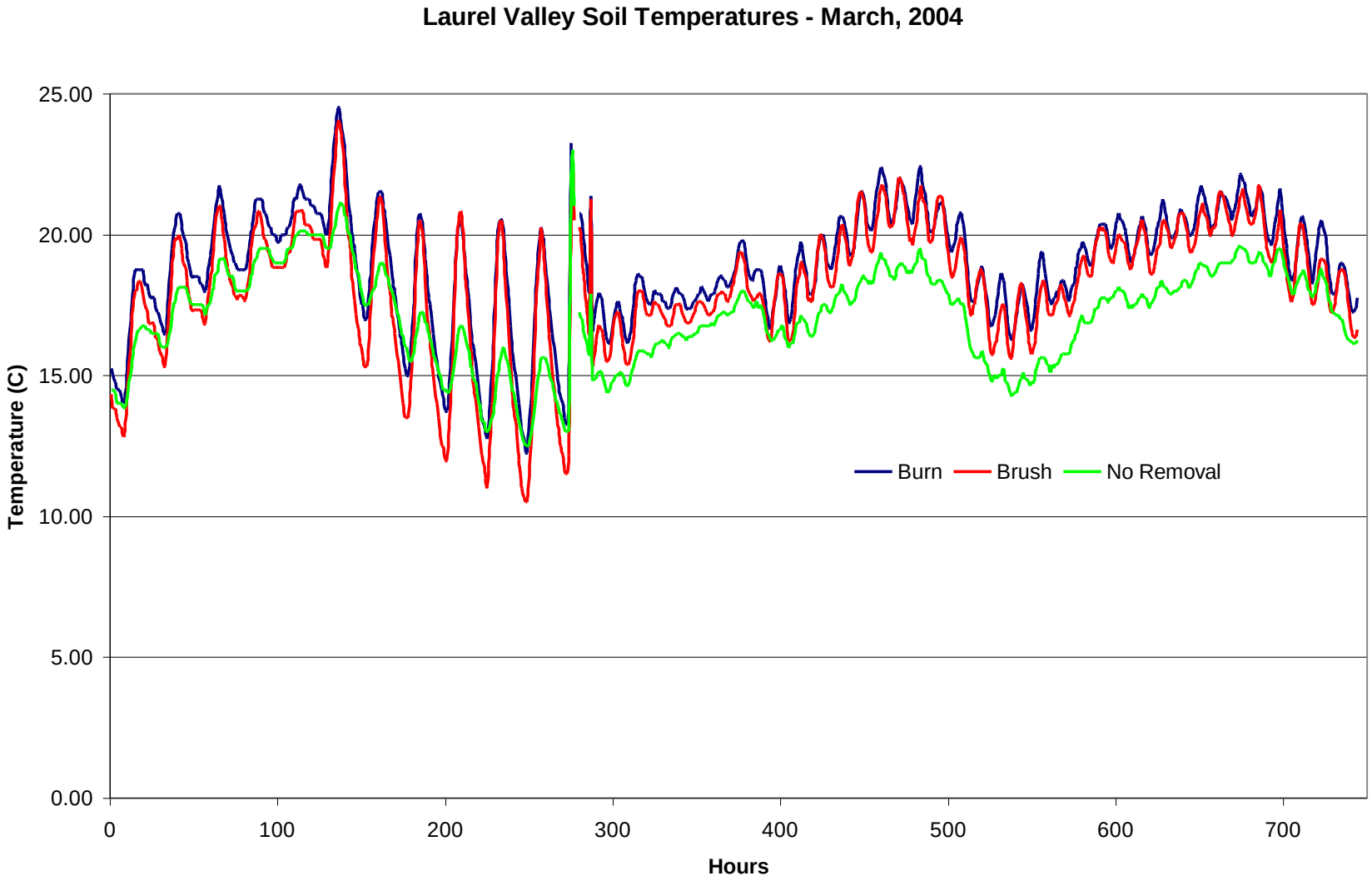
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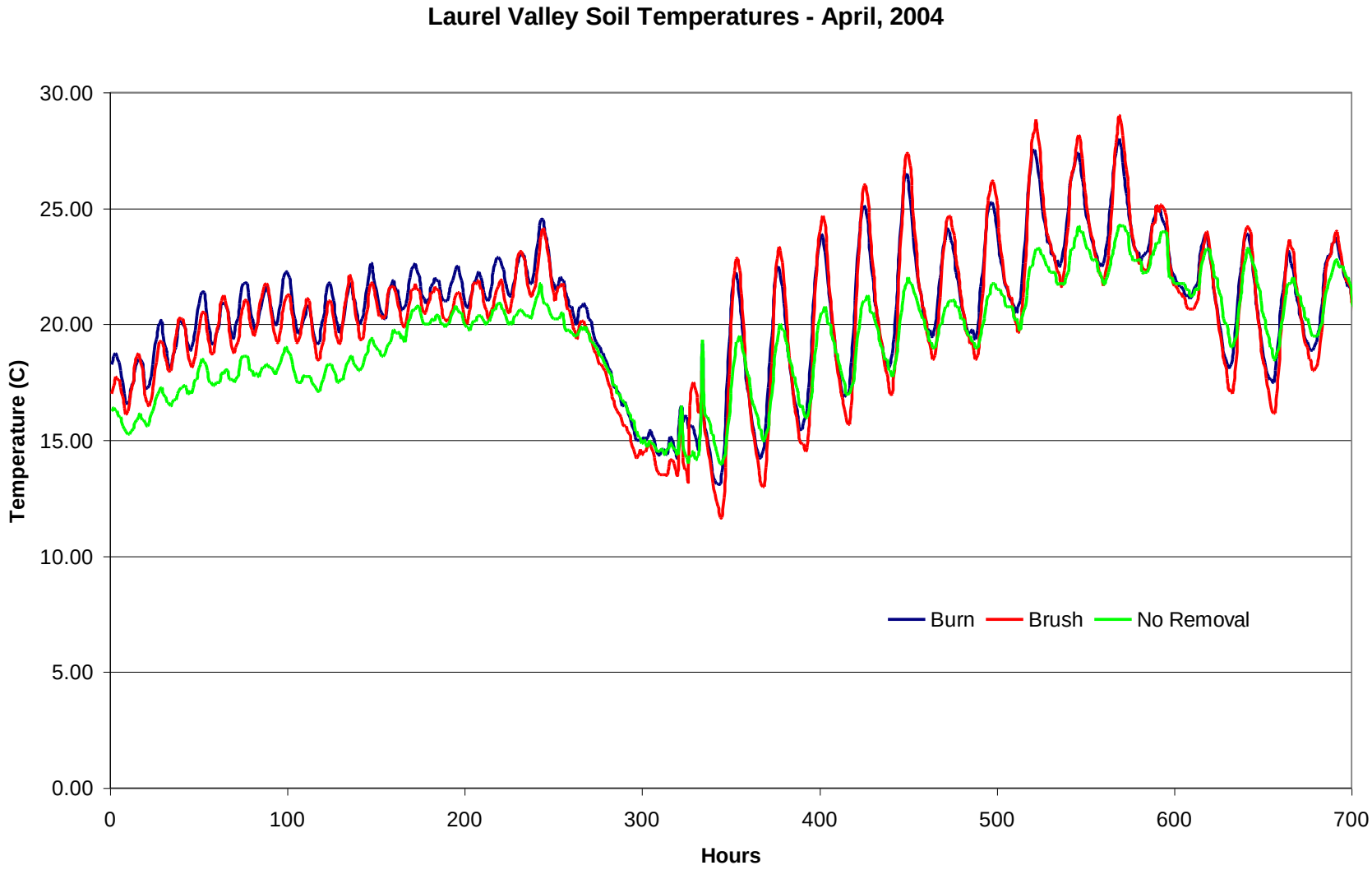
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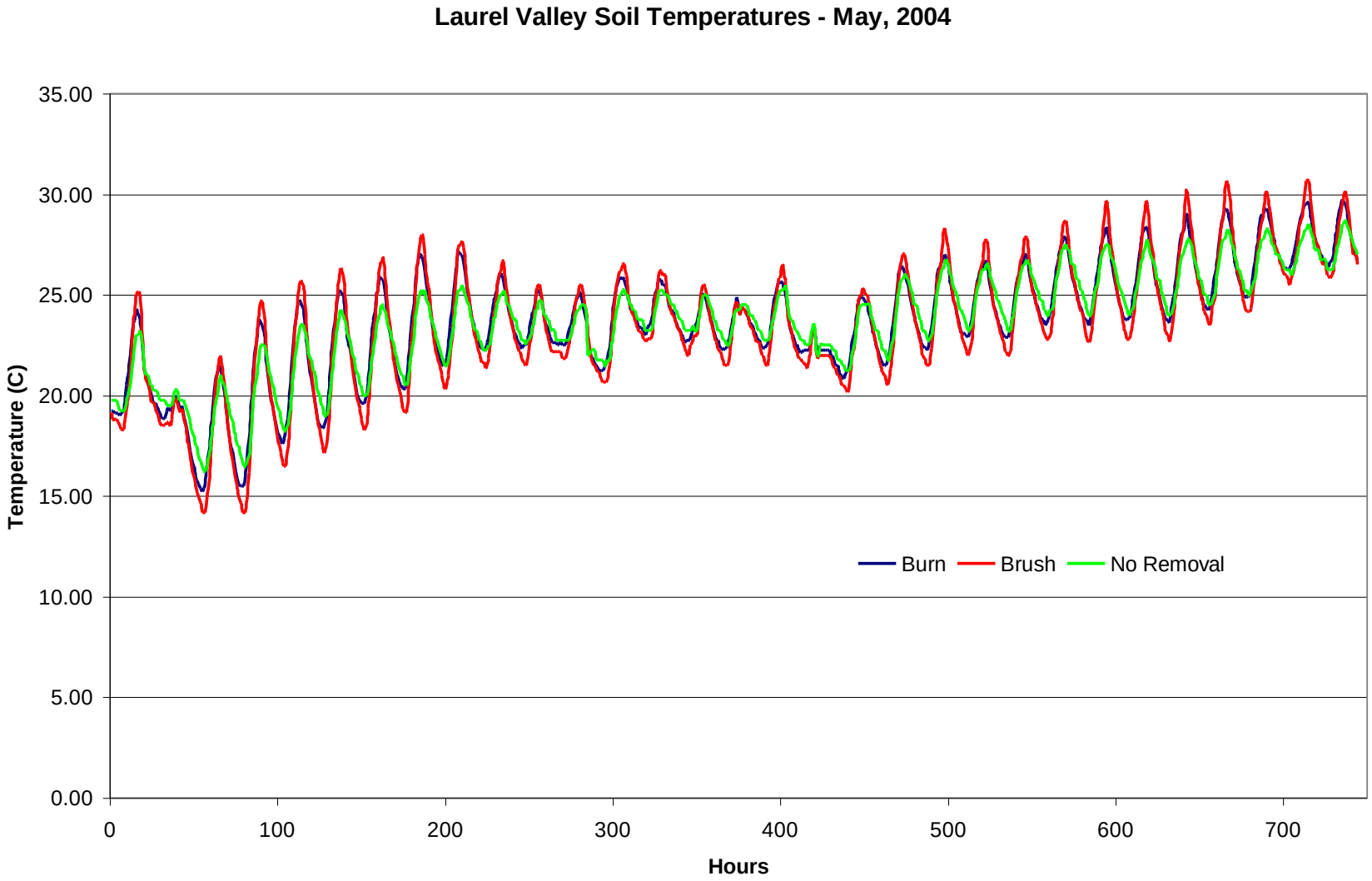
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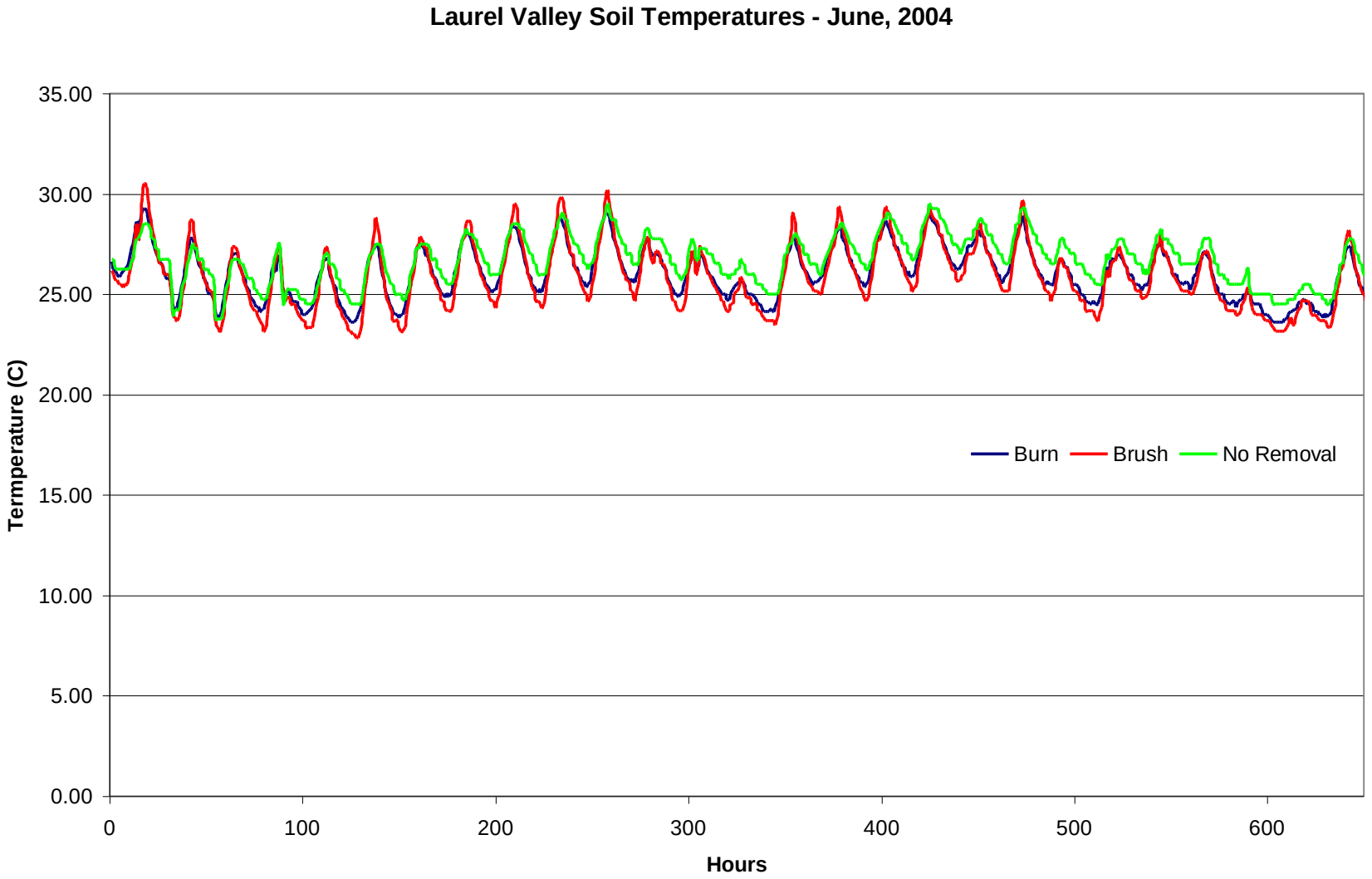
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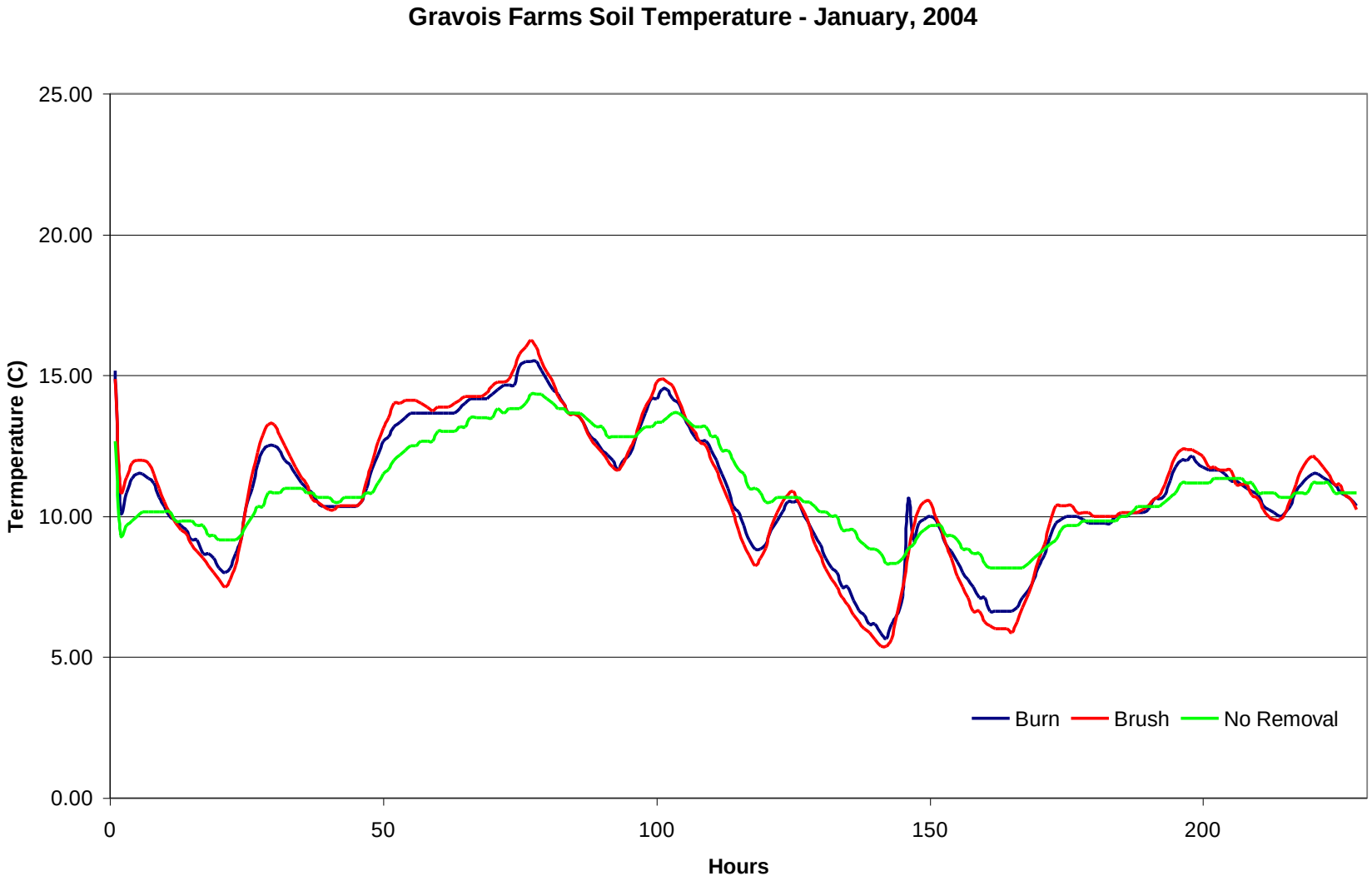
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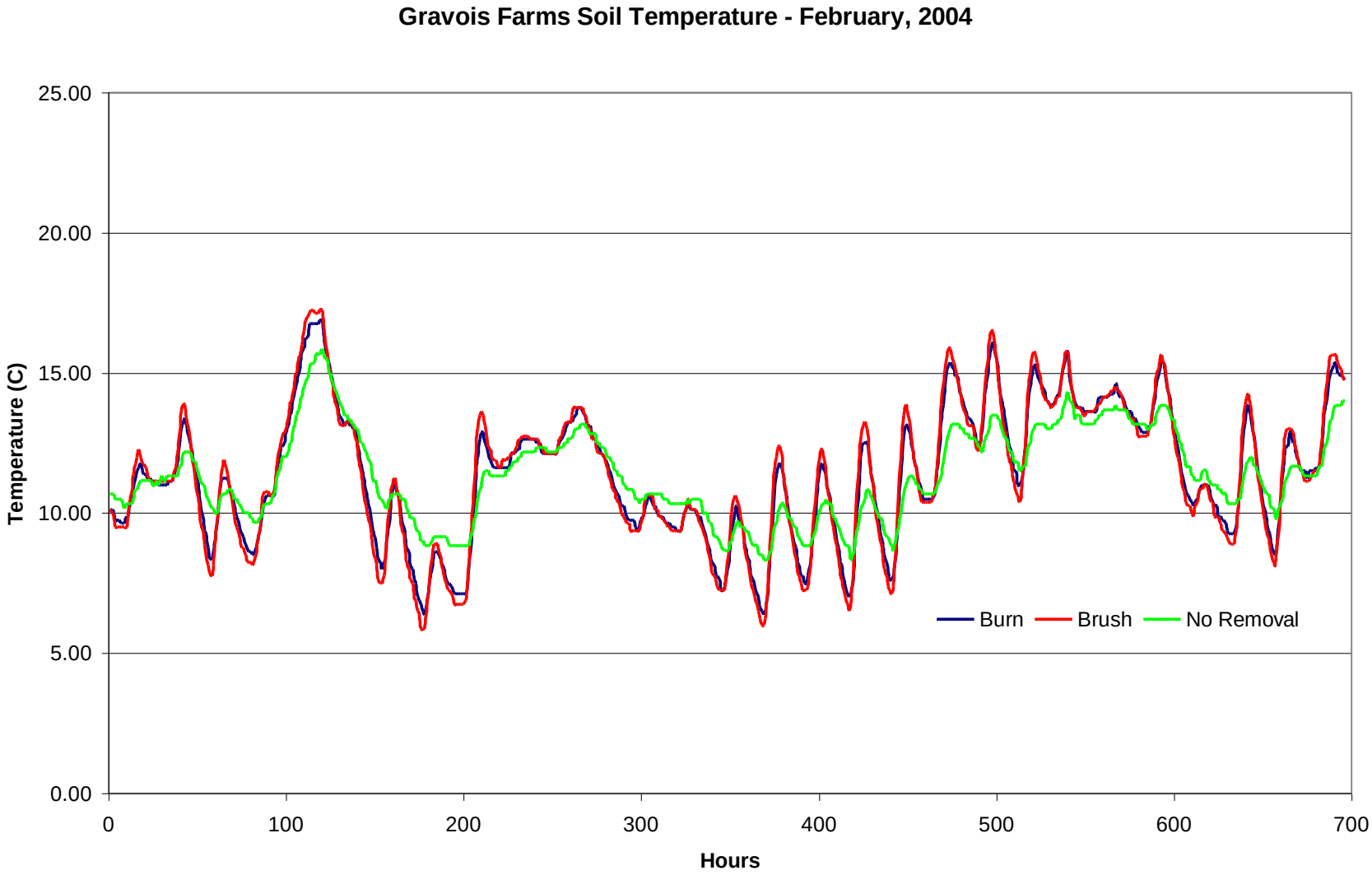
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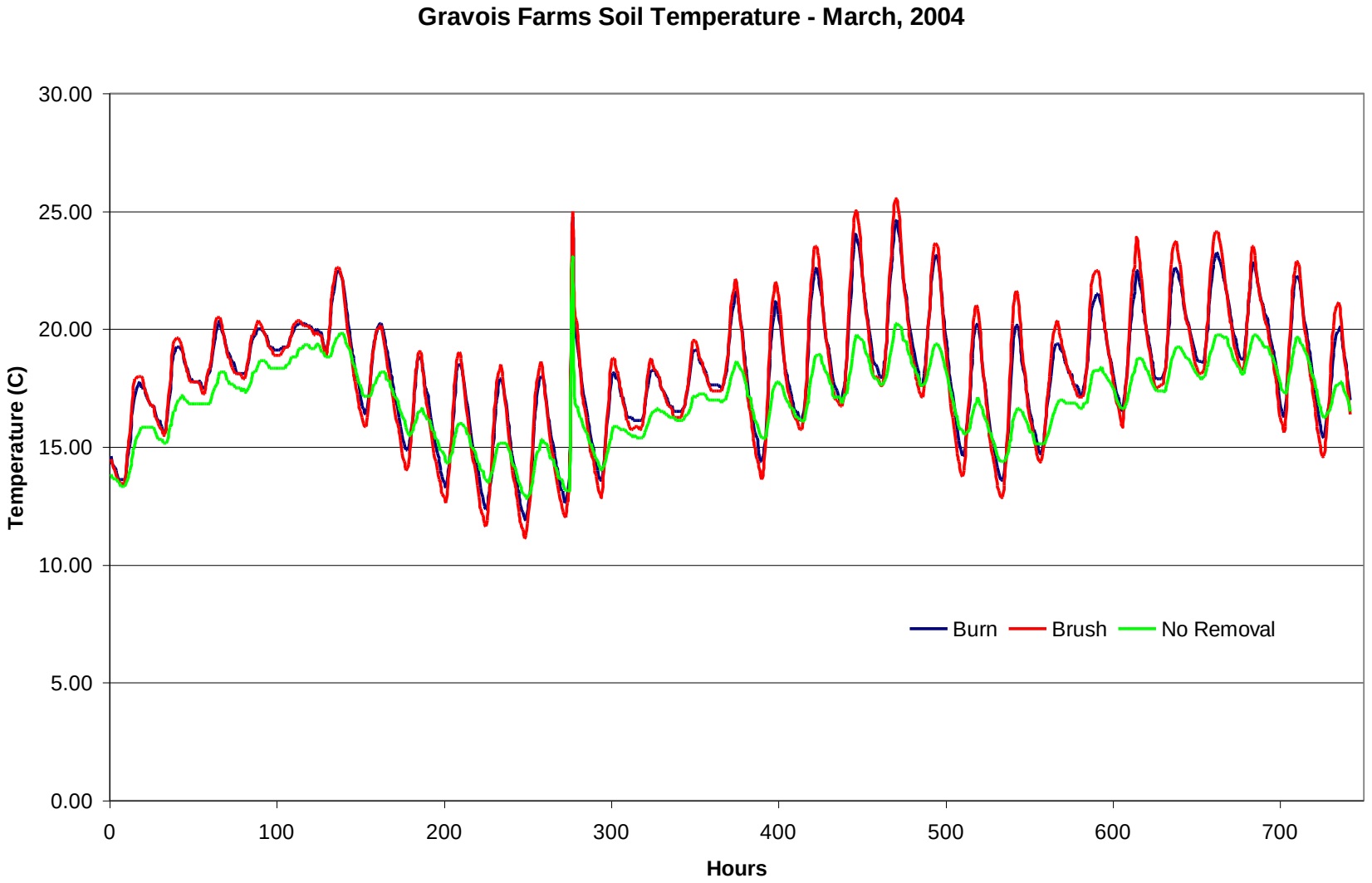
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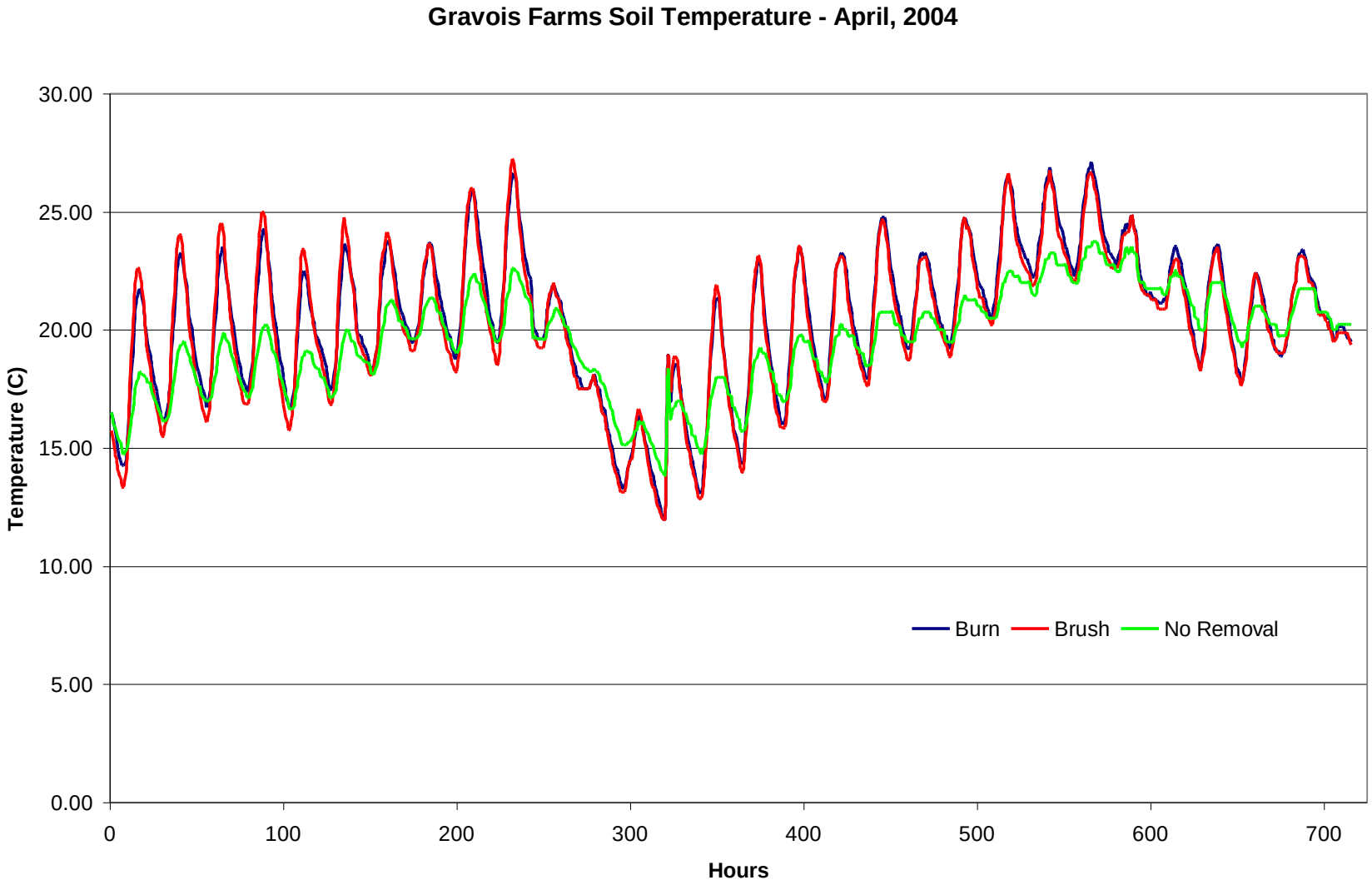
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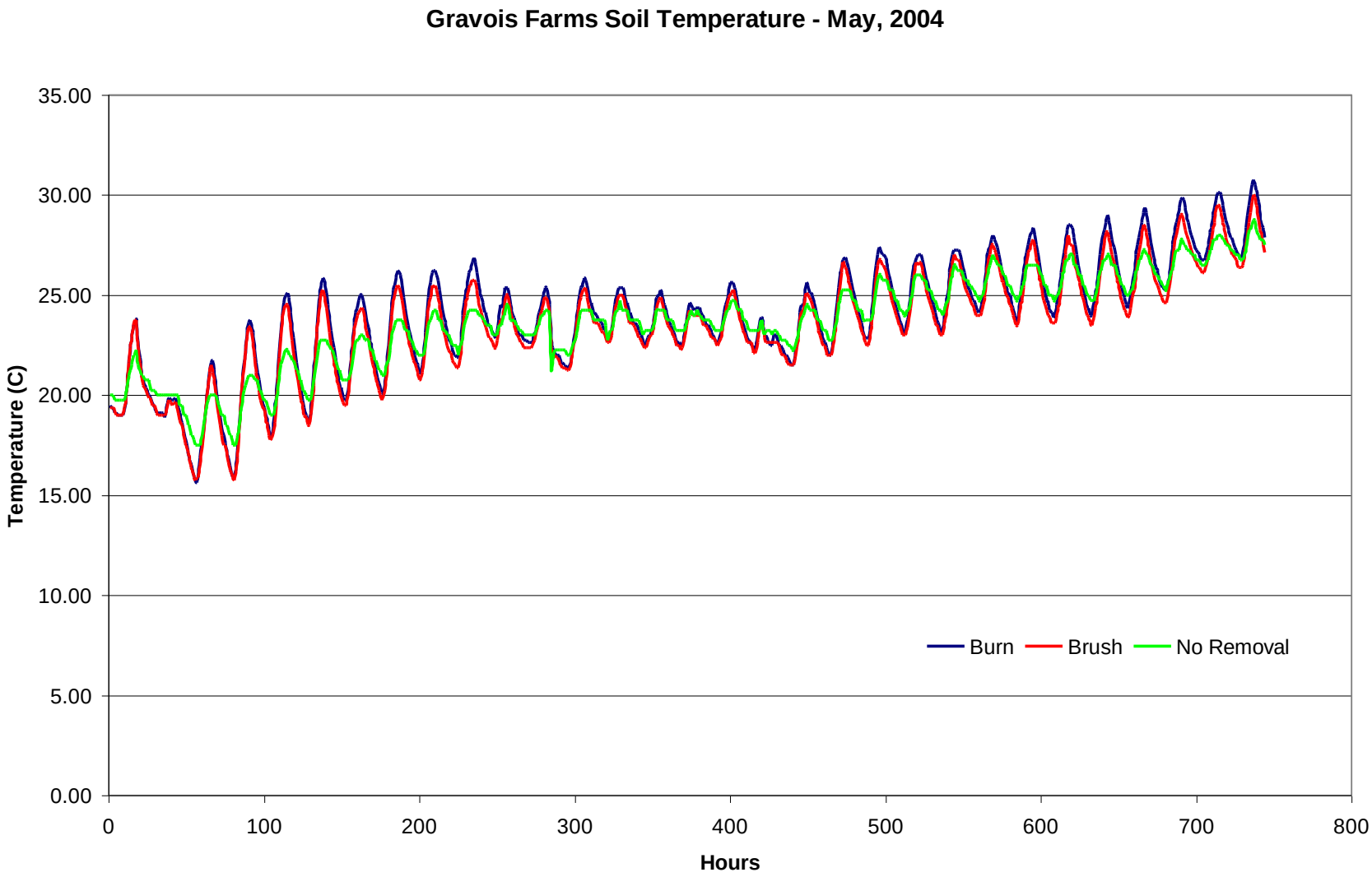
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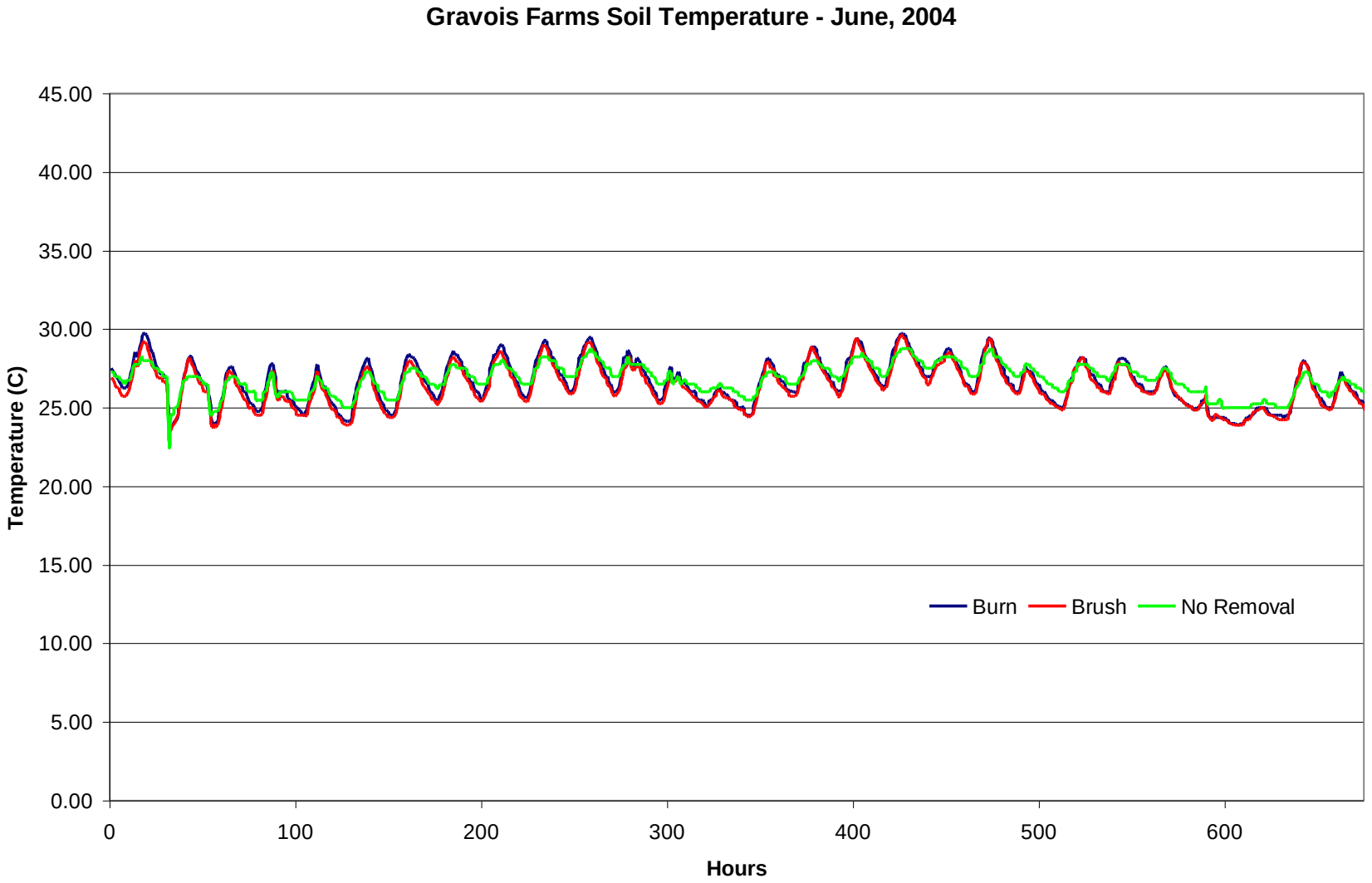
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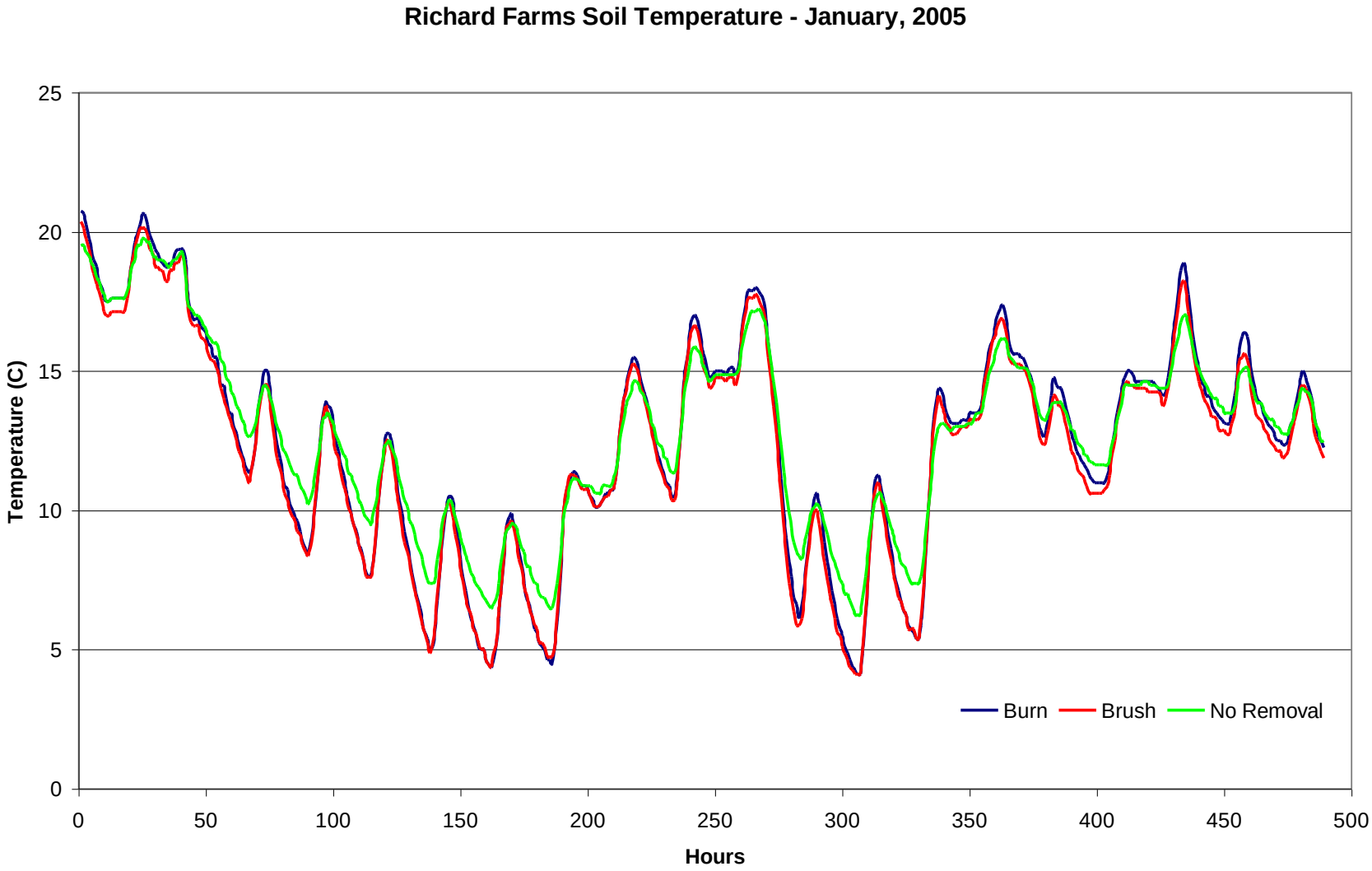
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Temperature (C)
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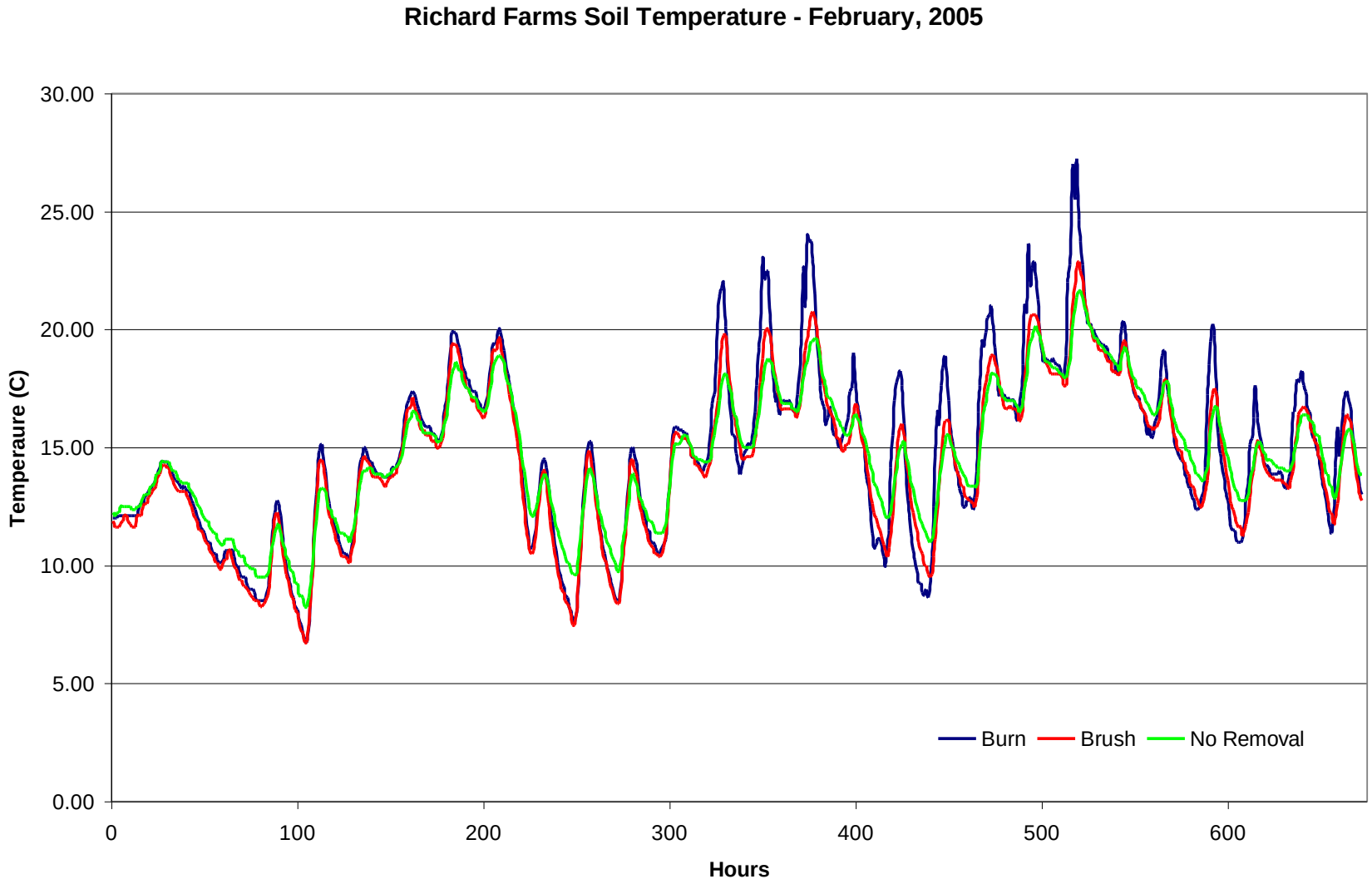
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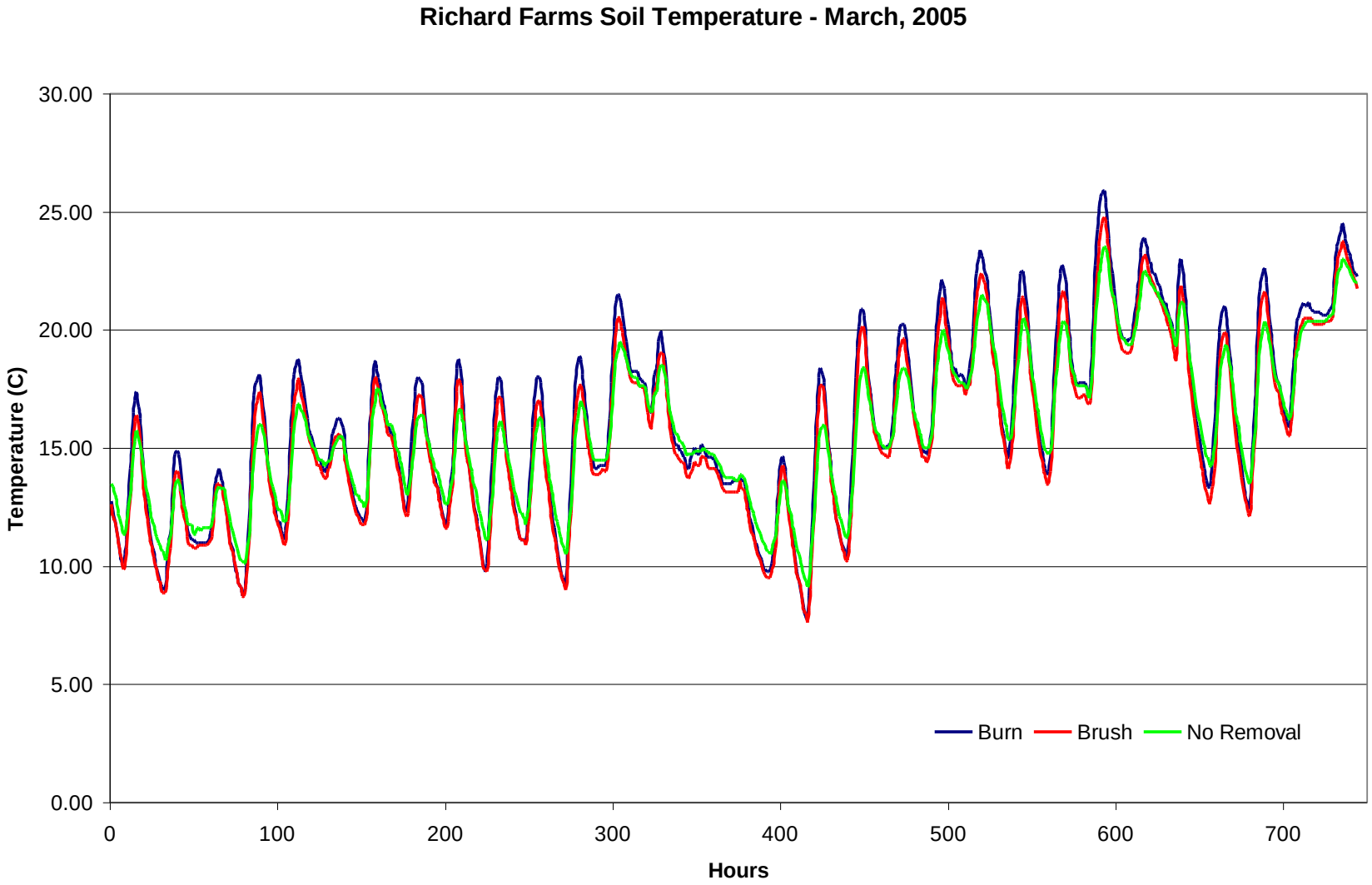
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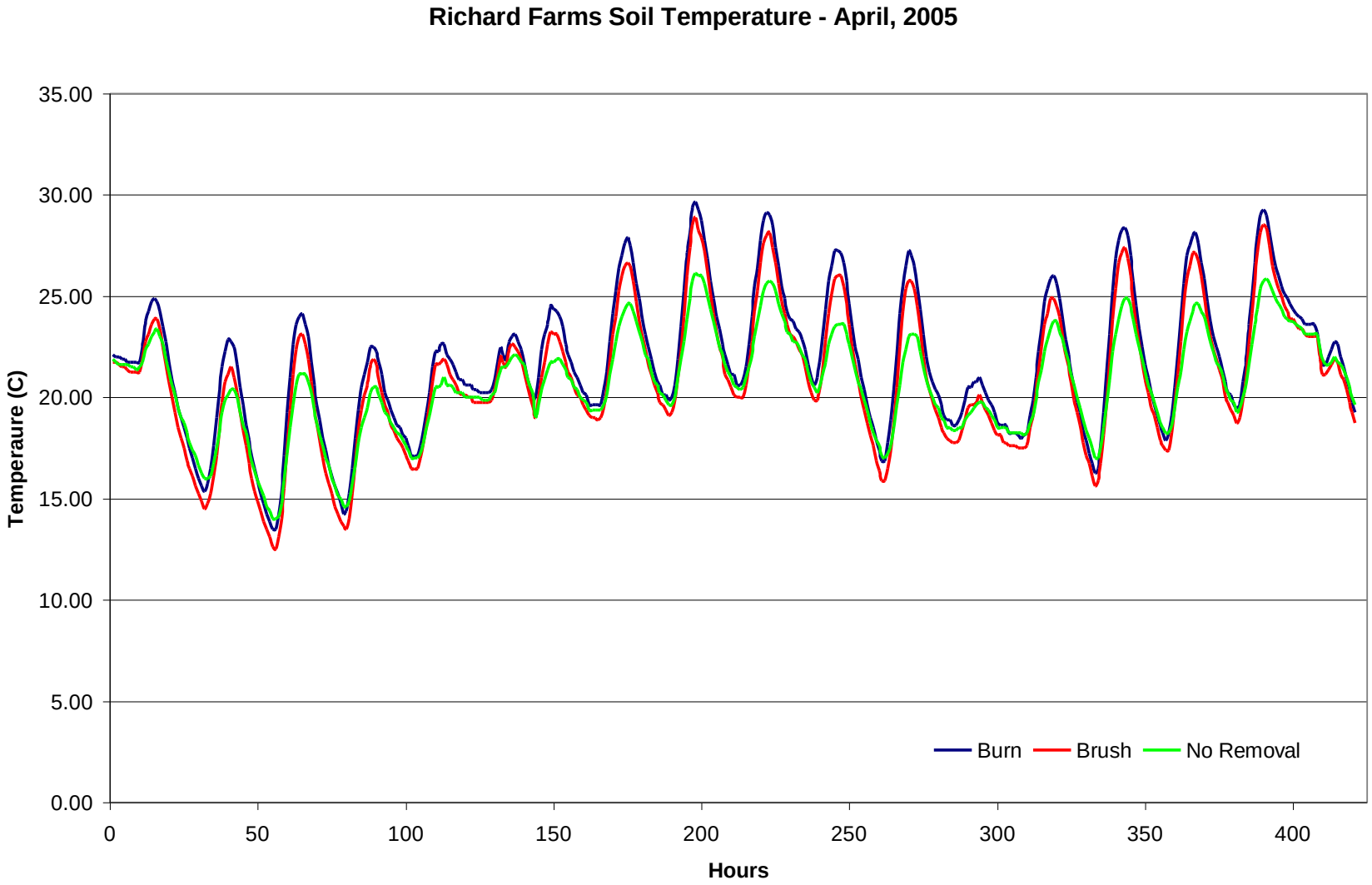
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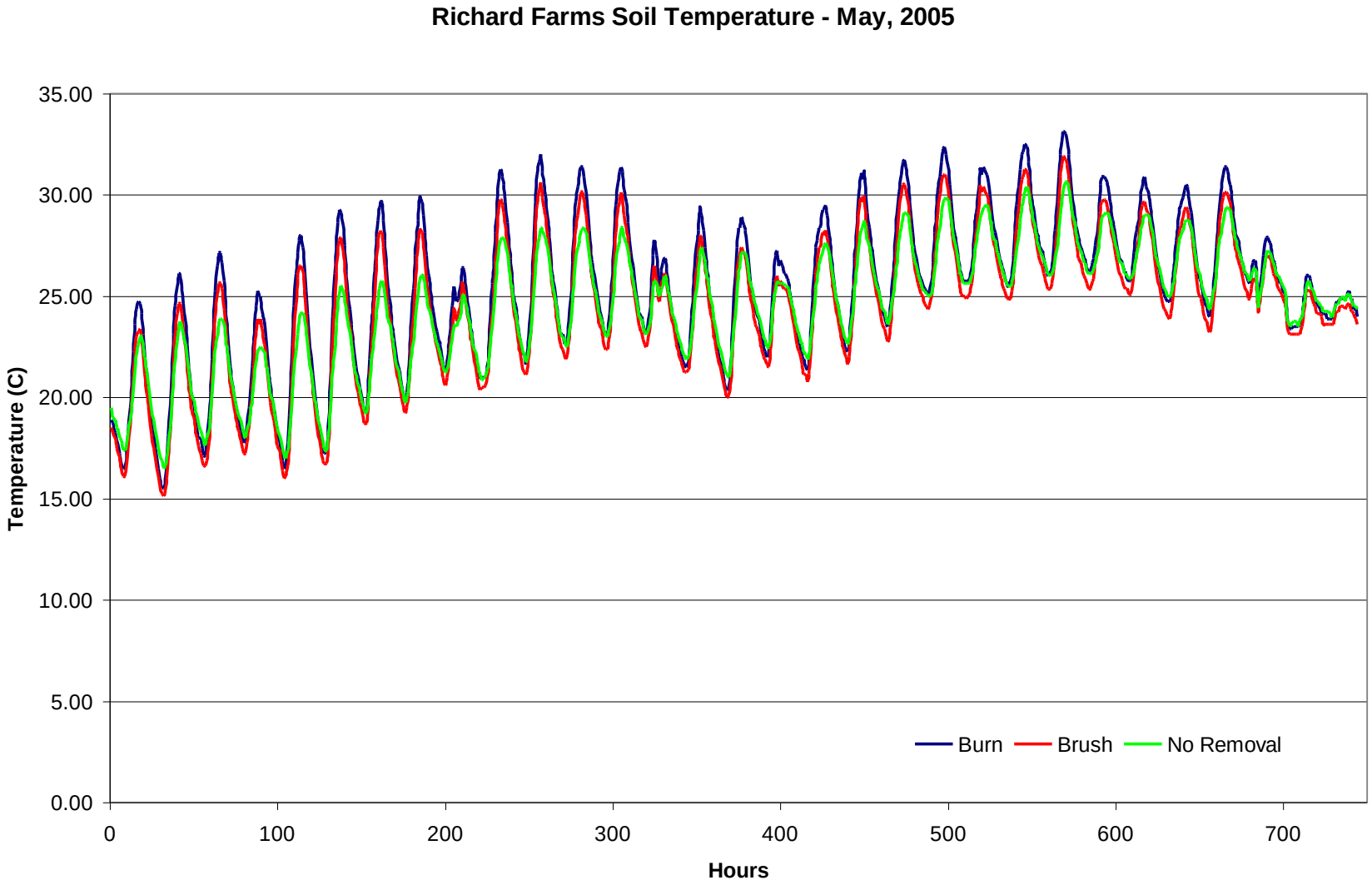
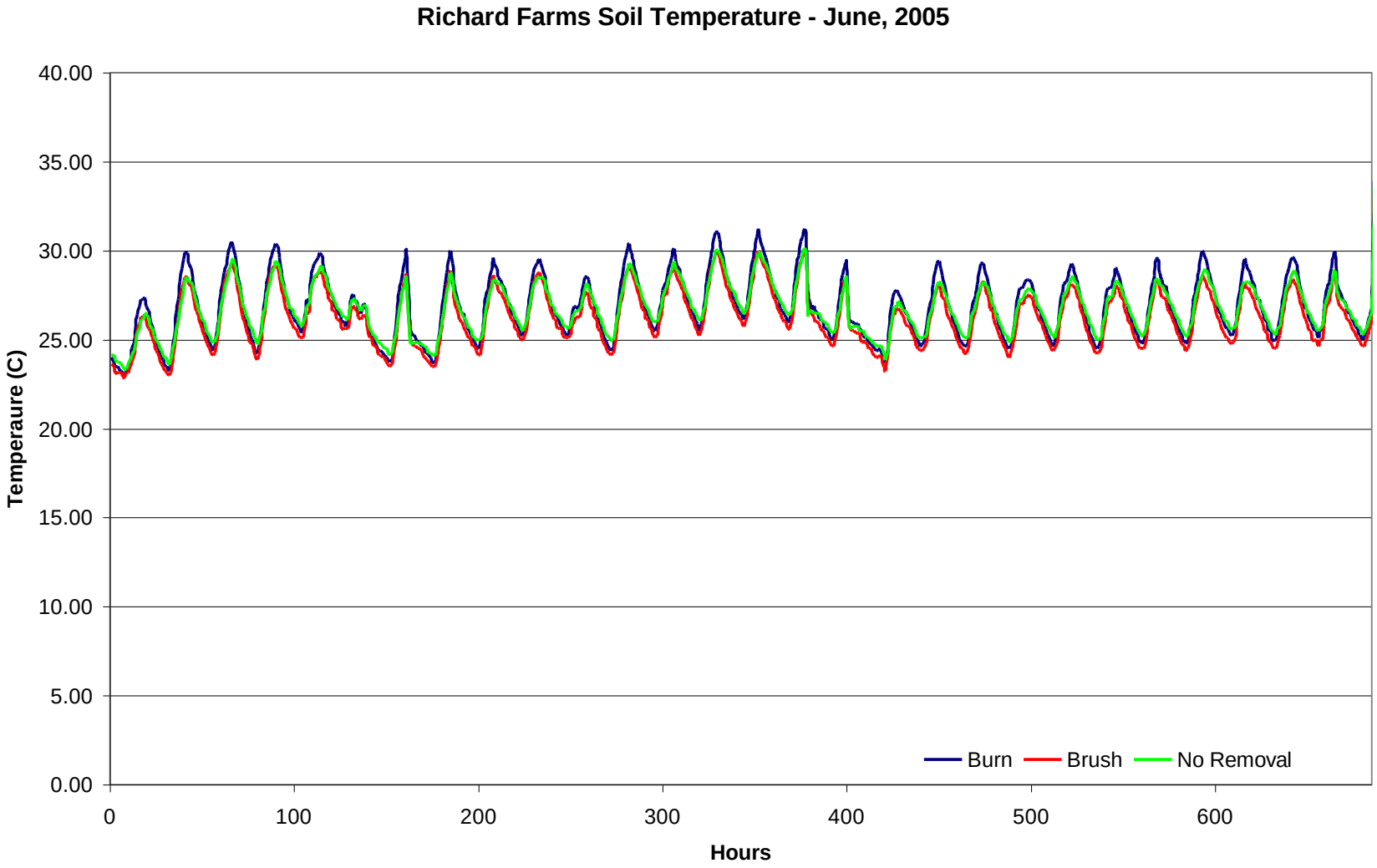
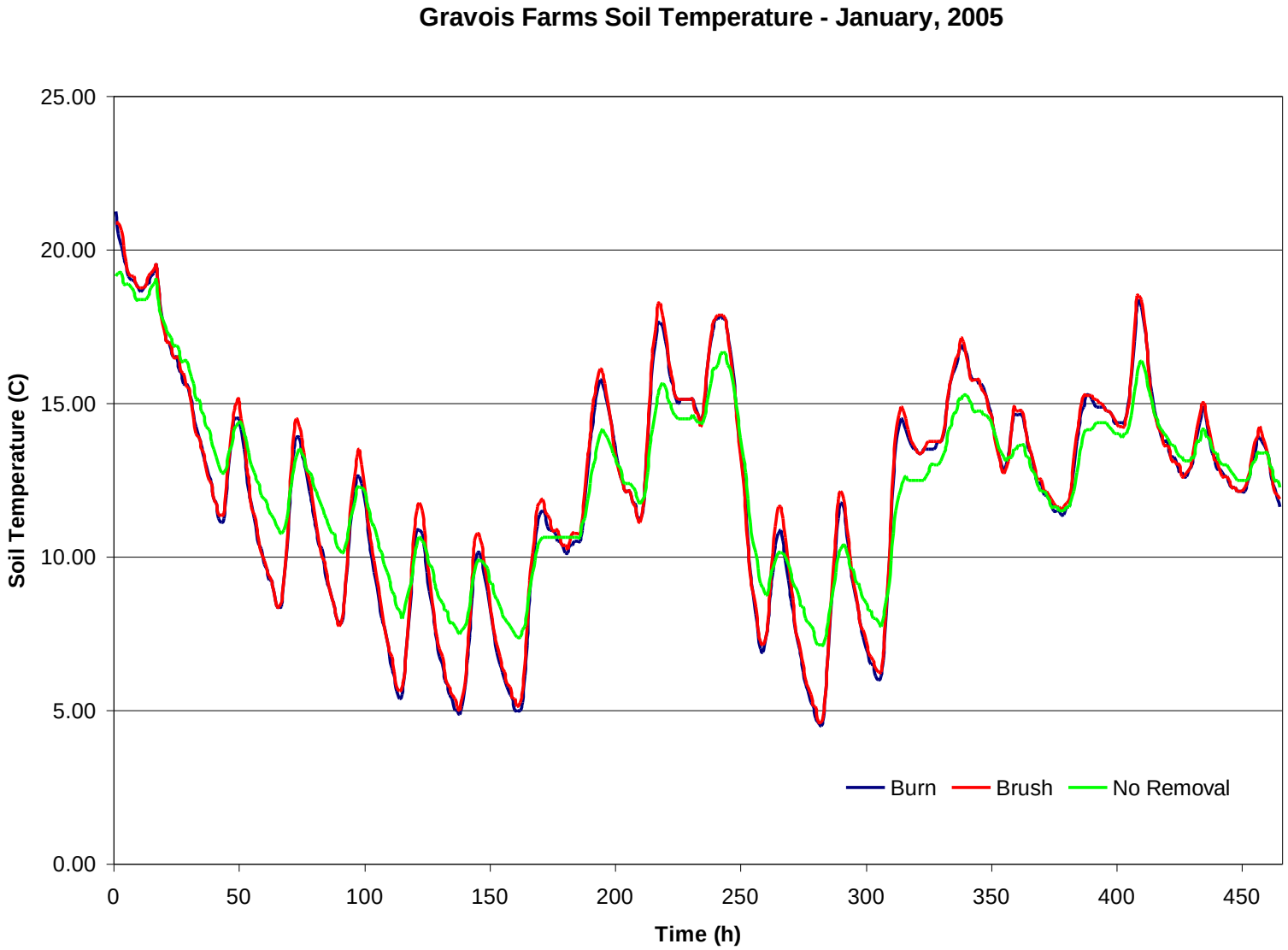
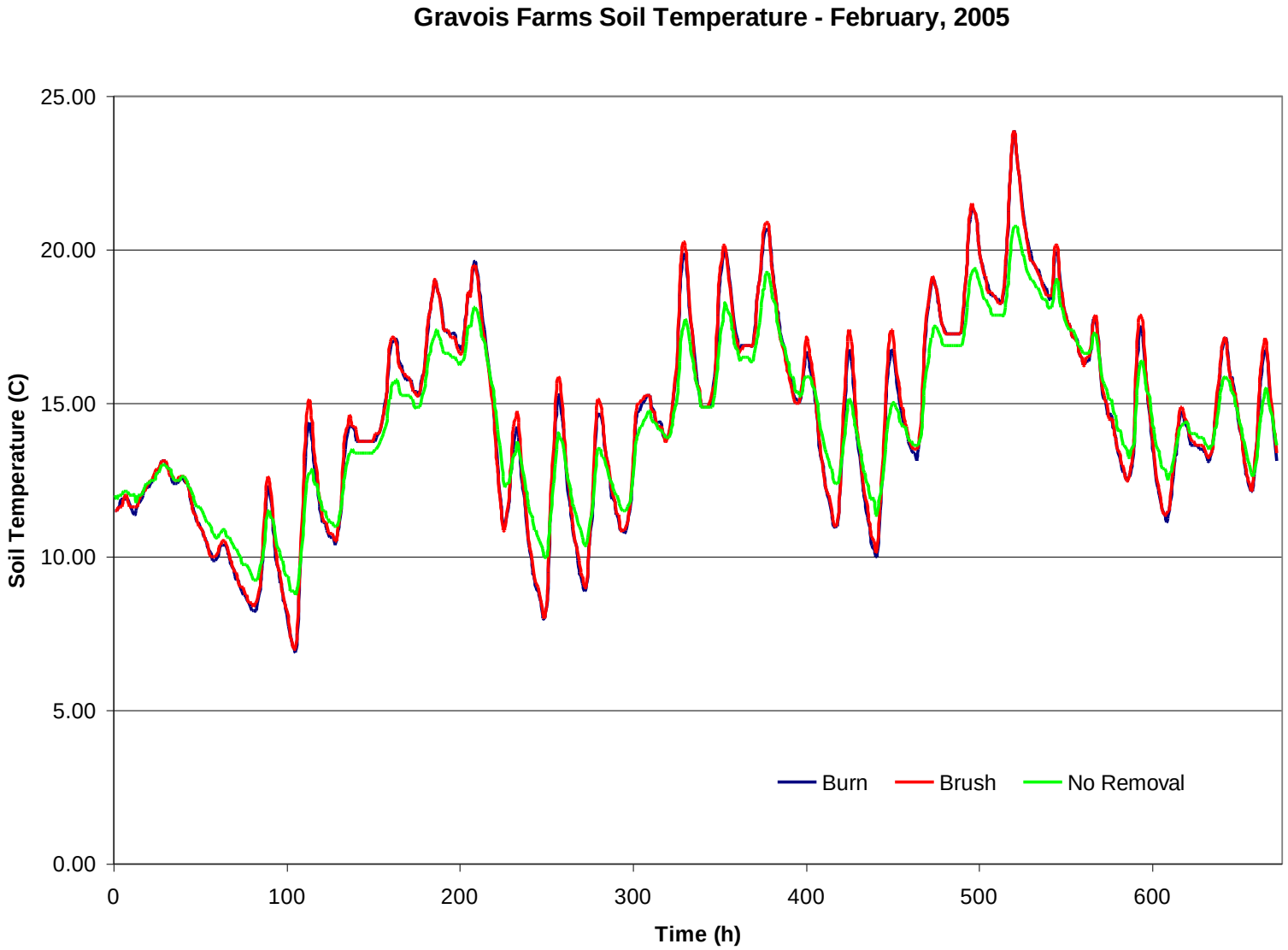
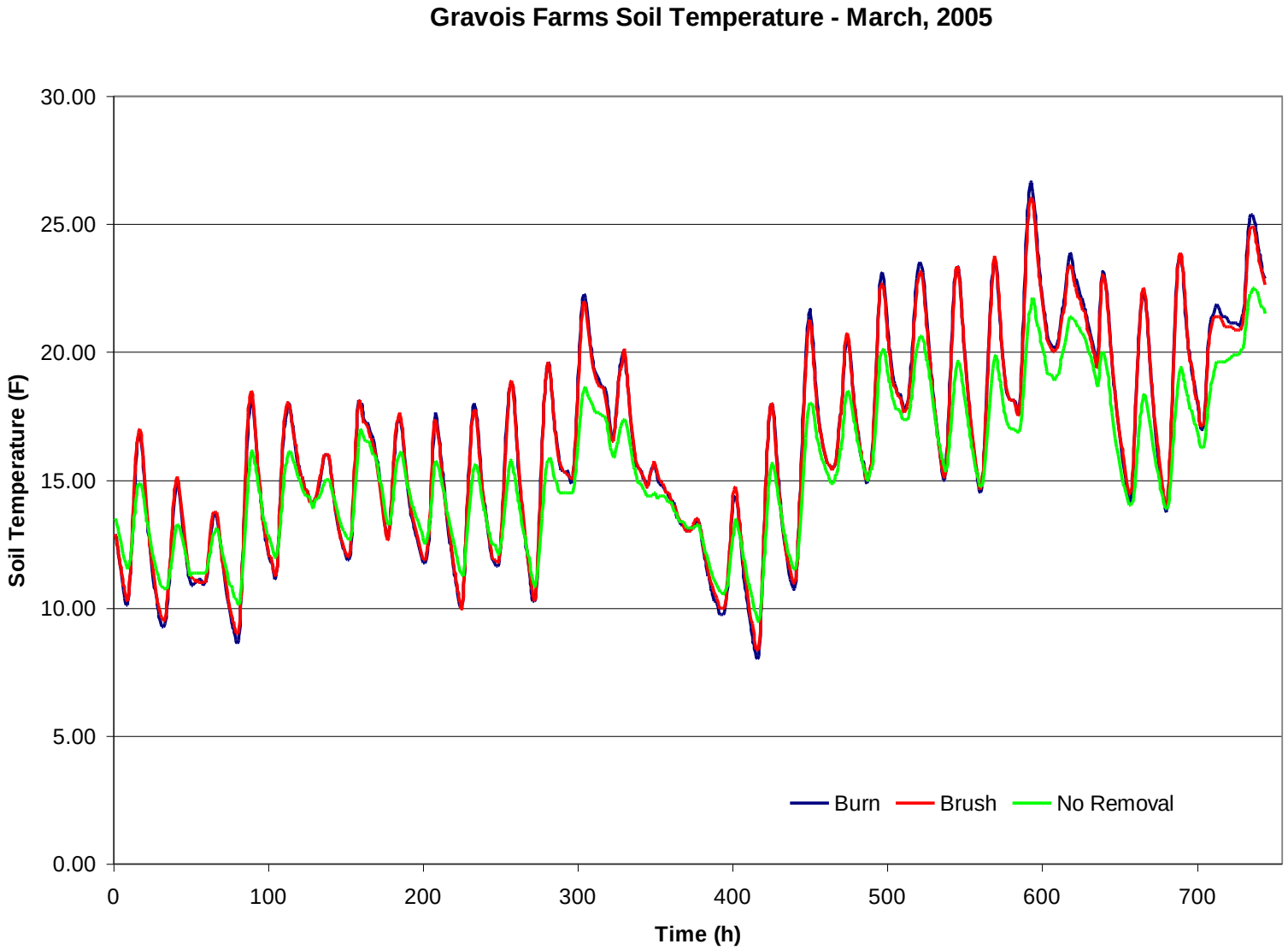
Brush
No Removal

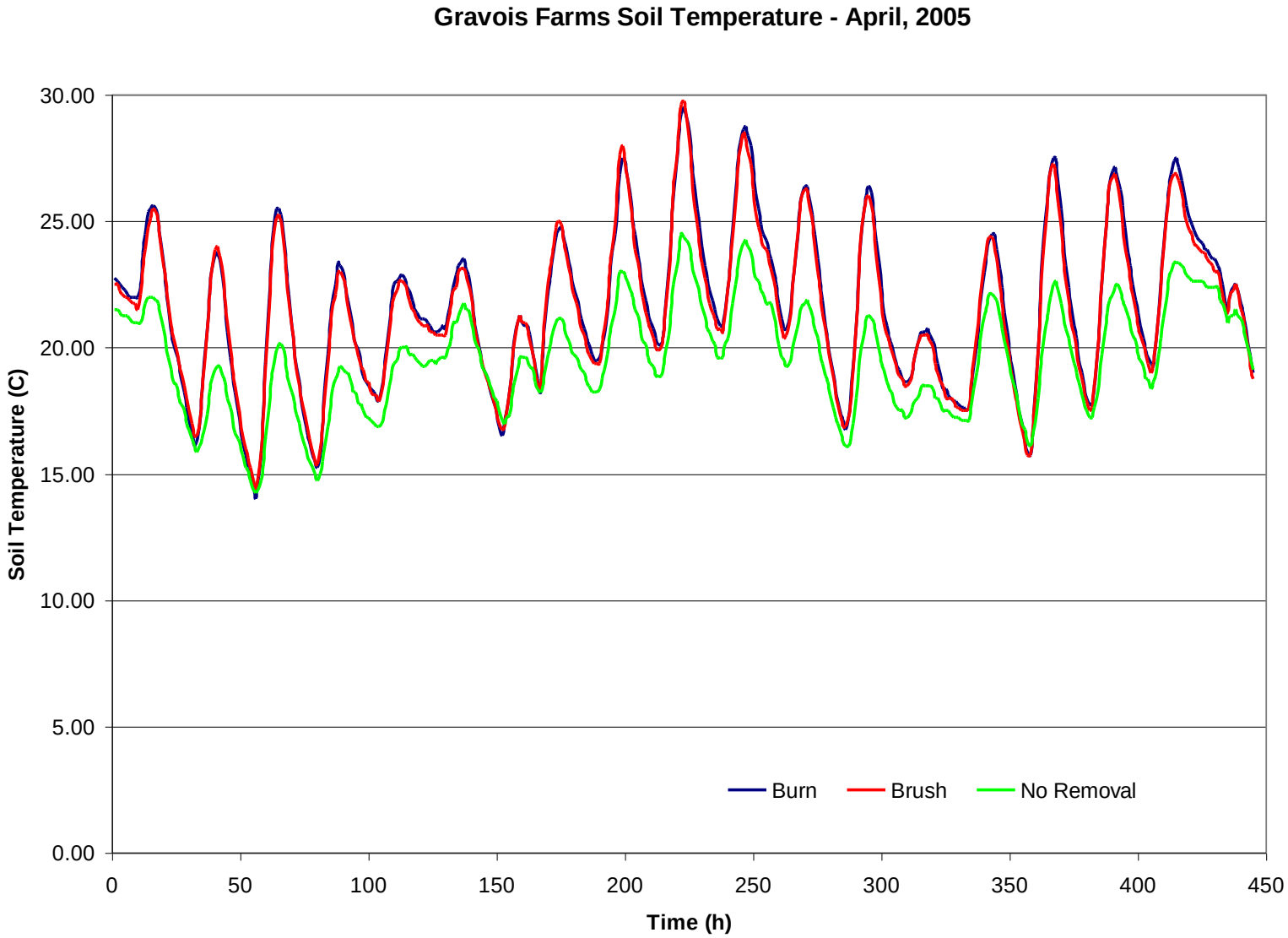

Richard Farms Soil Temperature - May, 2005
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Temperature (C)
0
100
200
300
400
500
600
700
Hours
Burn
Brush
No Removal

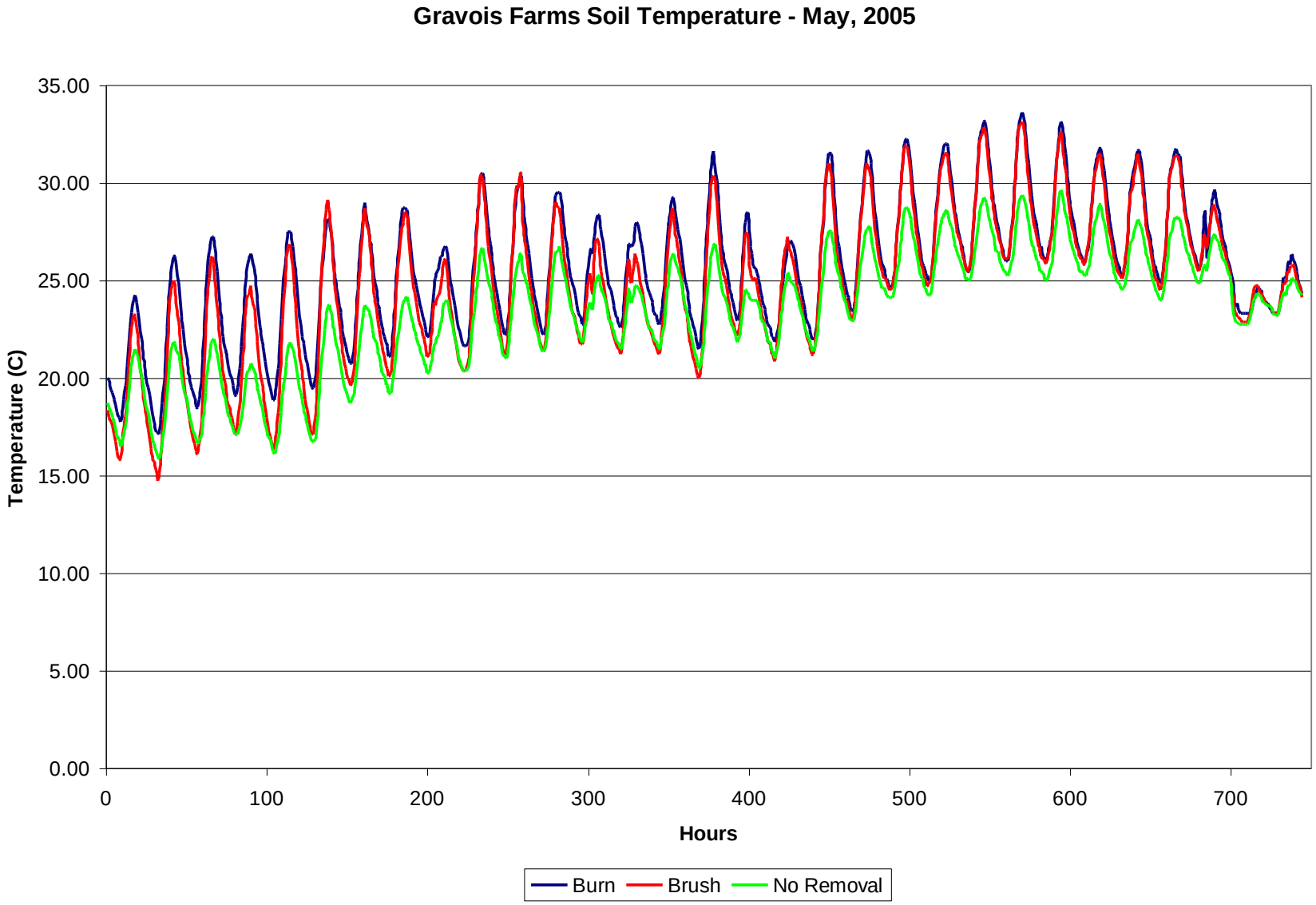

Richard Farms Soil Temperature - June, 2005
Temperaure (C)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
Hours
Burn
Brush
No Removal

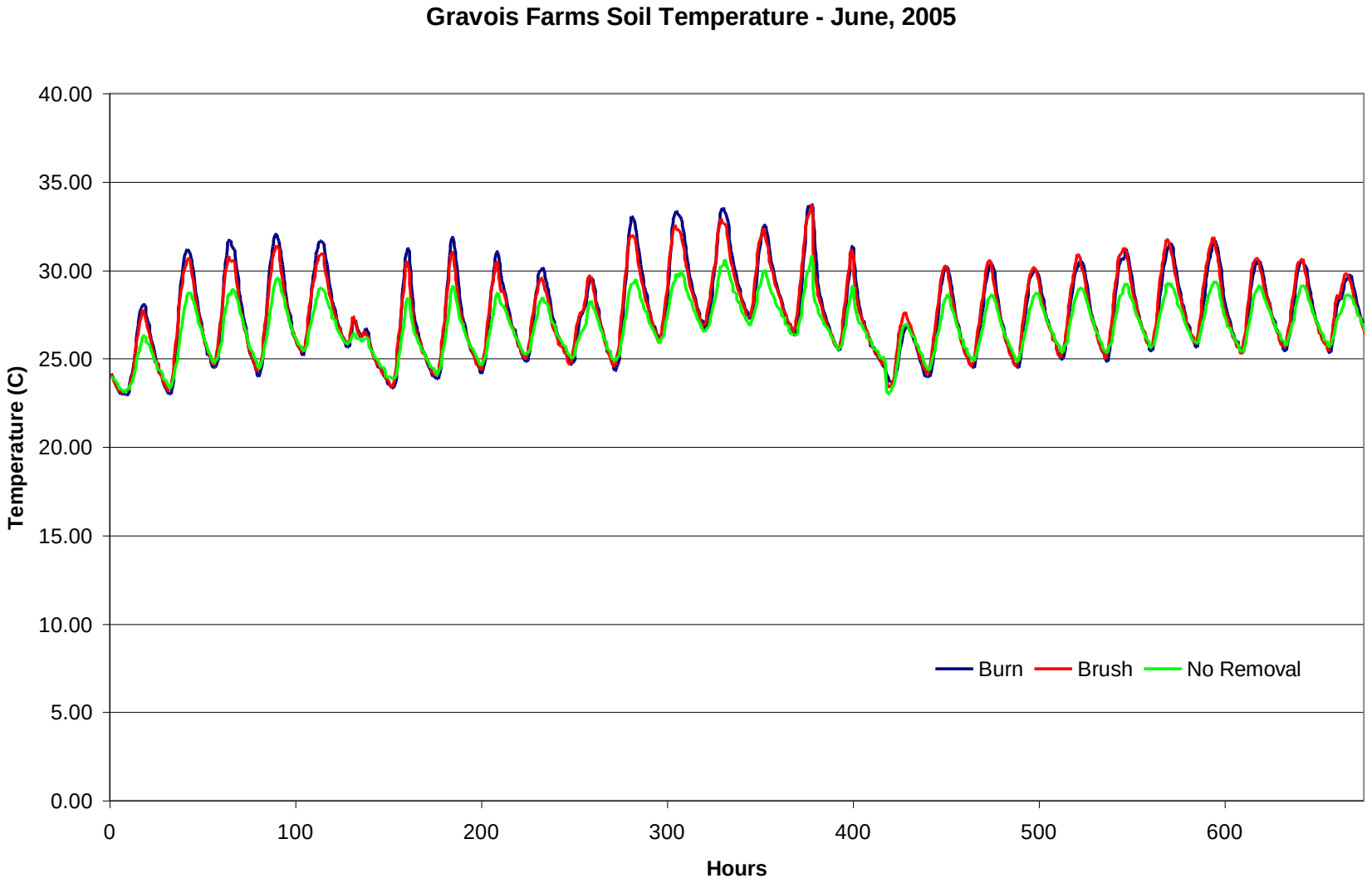

Gravois Farms Soil Temperature - January, 2005
25.00
20.00
15.00
10.00
5.00
0.00
Soil Temperature (C)
0
50
100
150
200
250
300
350
400
450
Time (h)
Burn
Brush
No Removal


Gravois Farms Soil Temperature - February, 2005
25.00
20.00
15.00
10.00
5.00
0.00
Soil Temperature (C)
0
100
200
300
400
500
600
Time (h)
Burn
Brush
No Removal

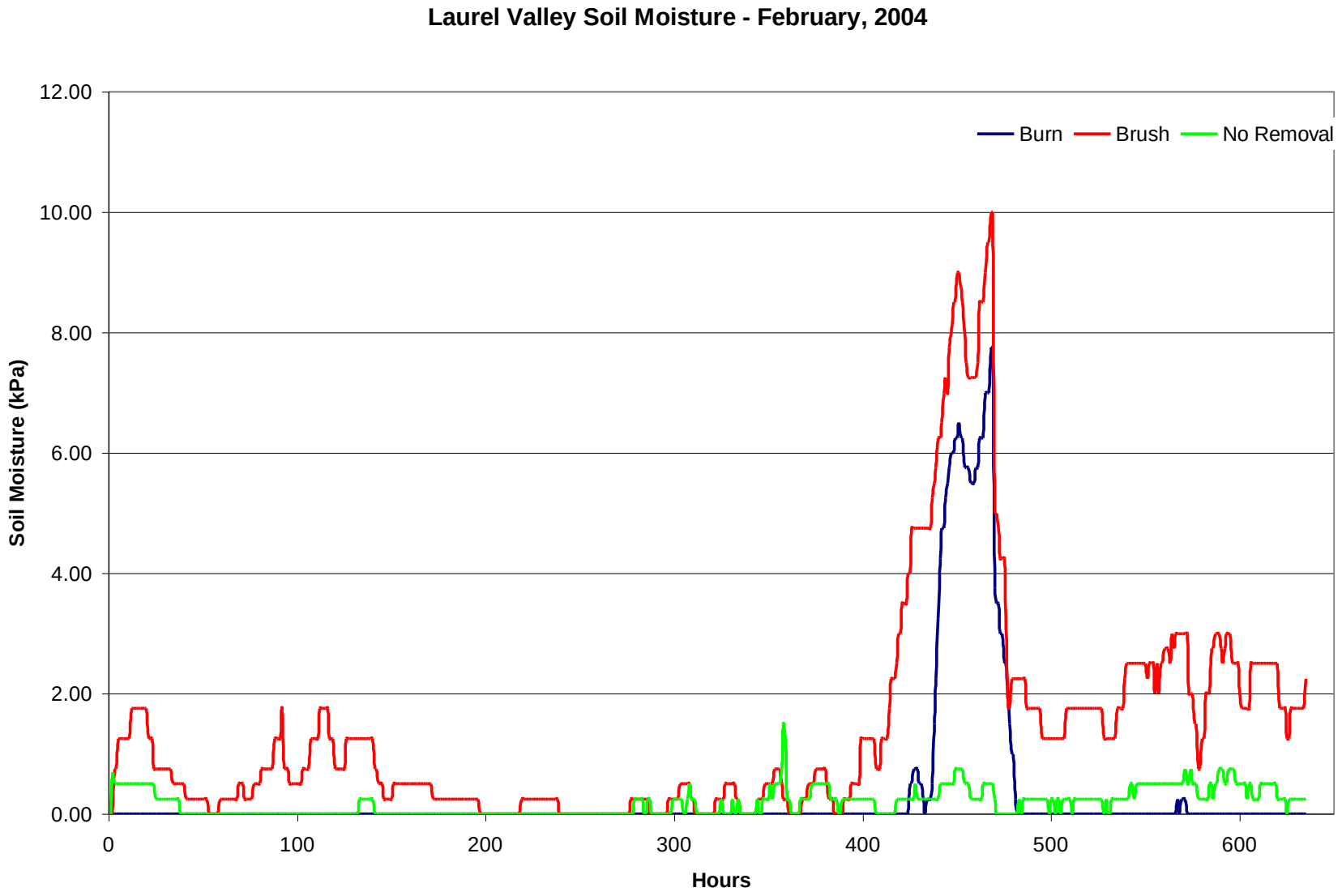

Gravois Farms Soil Temperature - March, 2005
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Soil Temperature (F)
0
100
200
300
400
500
600
700
Time (h)
Burn
Brush
No Removal

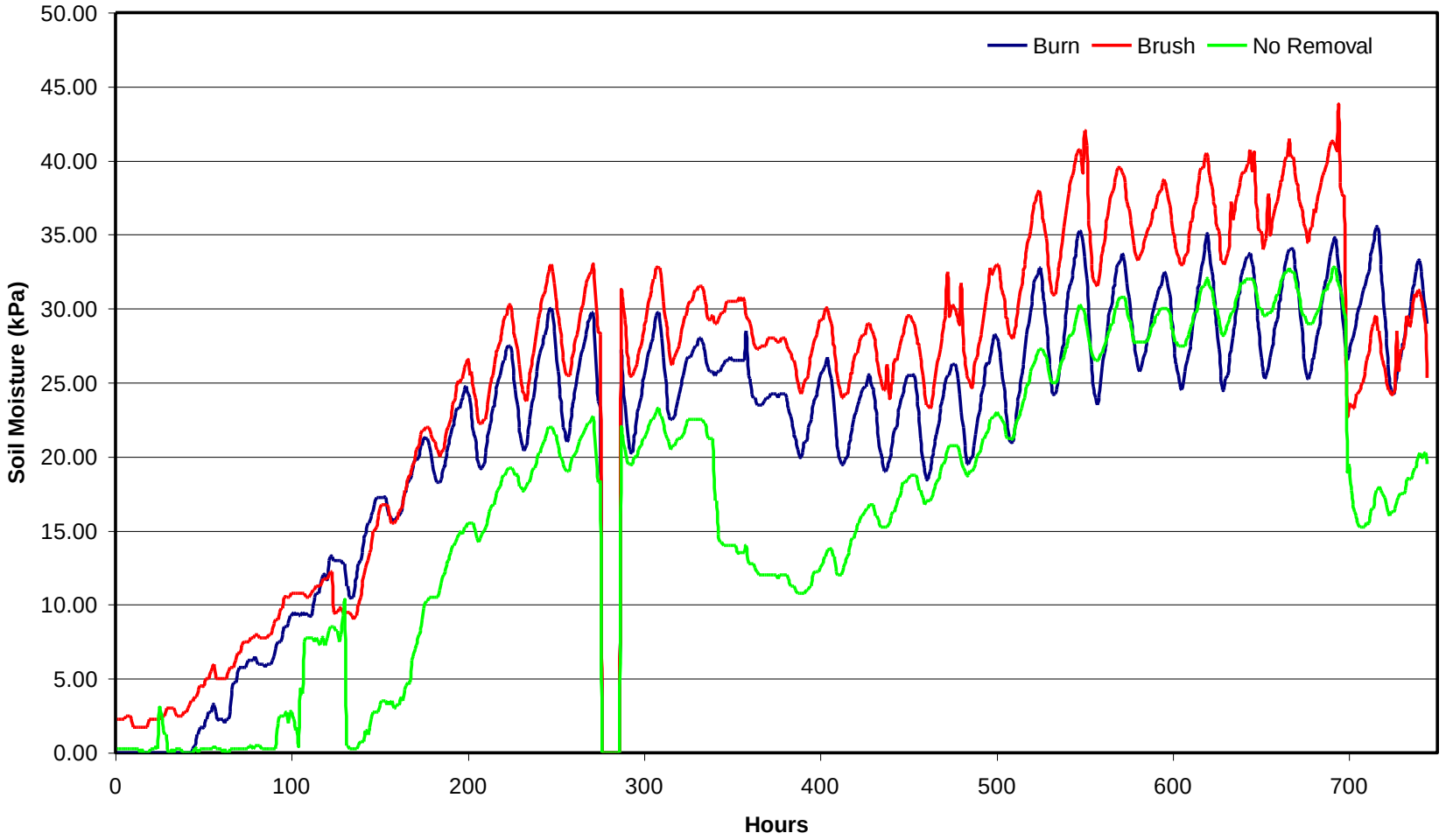

Gravois Farms Soil Temperature - April, 2005
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Soil Temperature (C)
0
50
100
150
200
250
300
350
400
450
Time (h)
Burn
Brush
No Removal

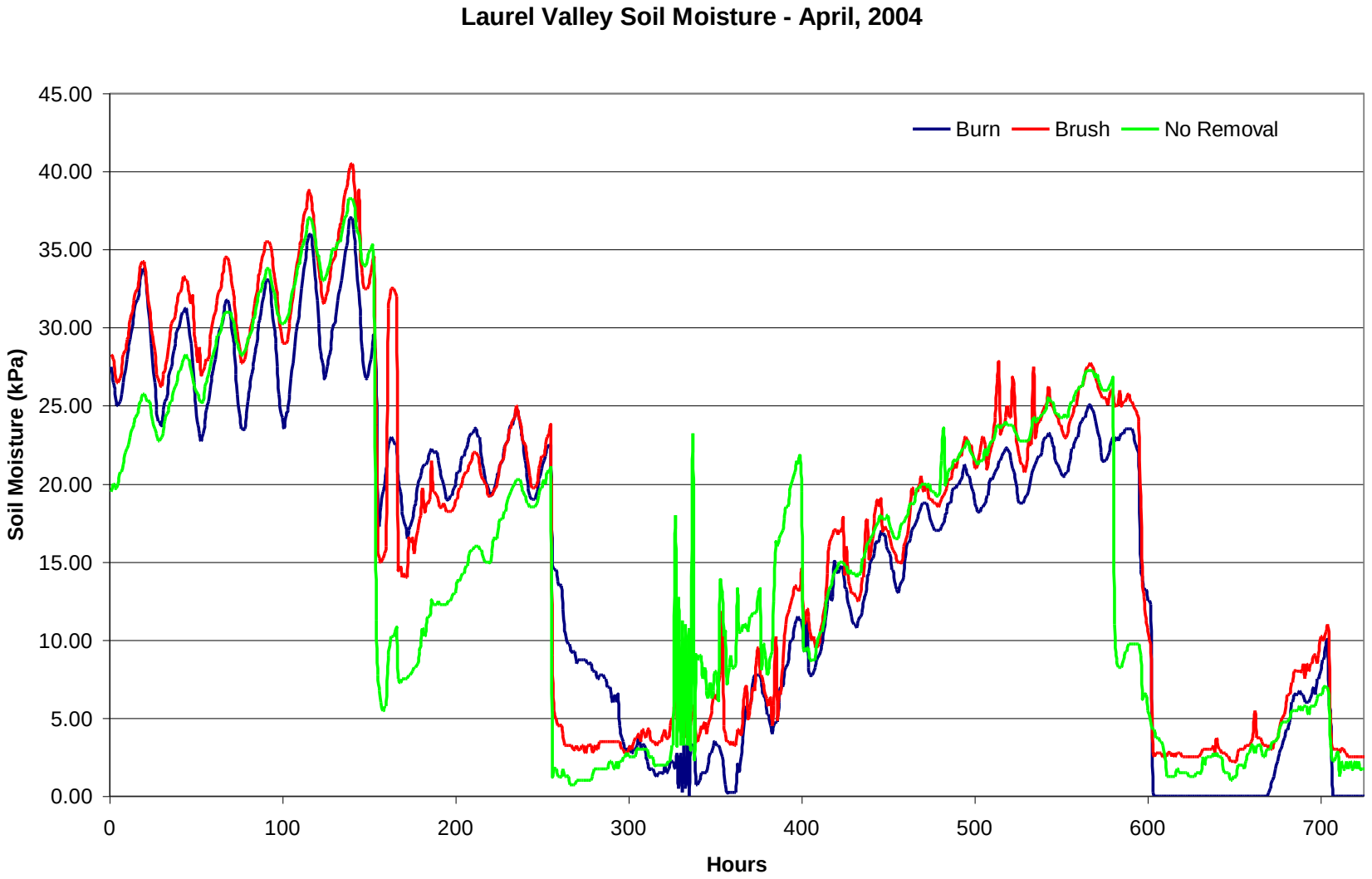

Gravois Farms Soil Temperature - May, 2005
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Temperature (C)
0
100
200
300
400
500
600
700
Hours
Burn
Brush
No Removal

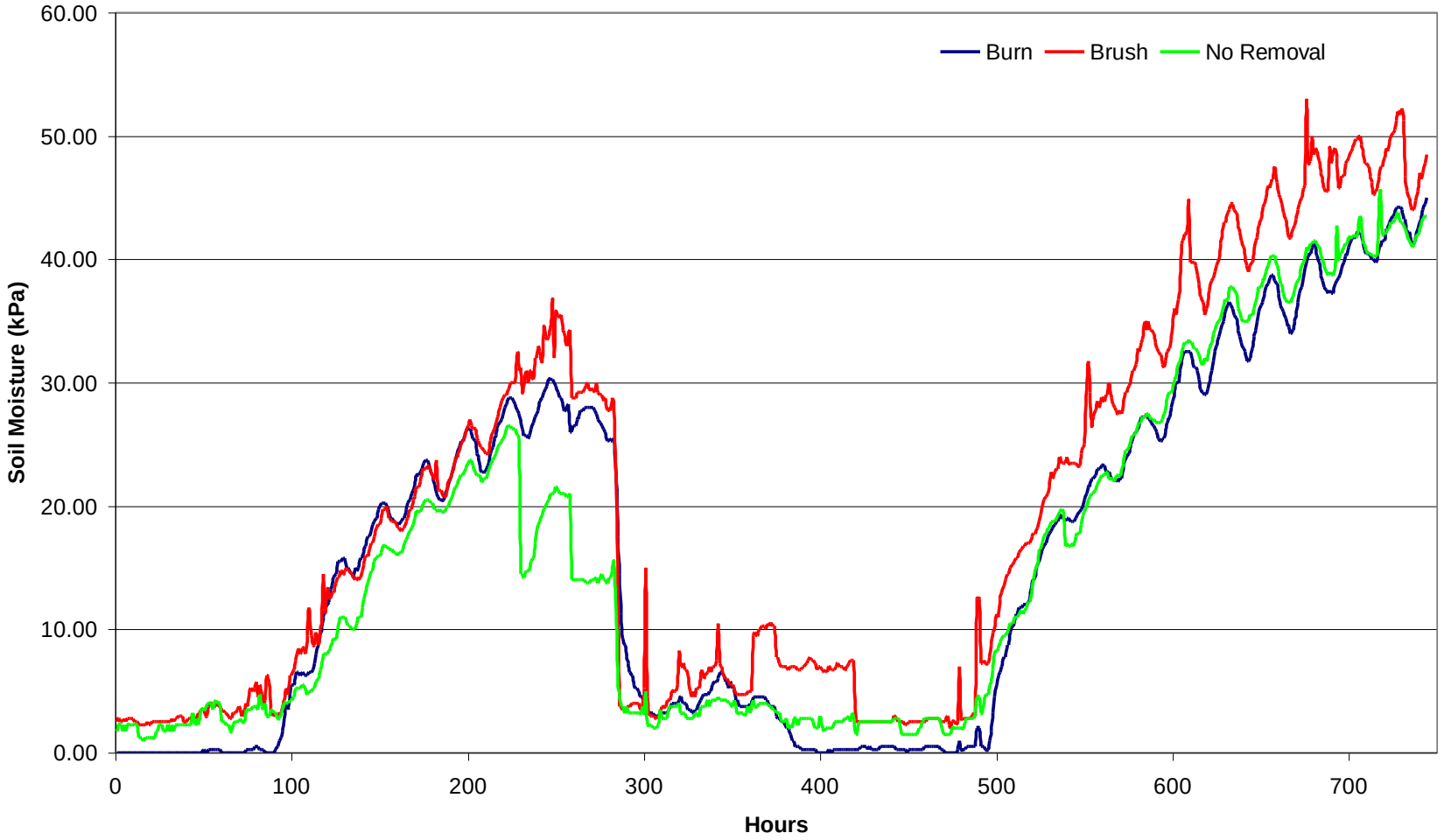

Gravois Farms Soil Temperature - June, 2005
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Temperature (C)
0
100
200
300
400
500
600
Hours
Burn
Brush
No Removal

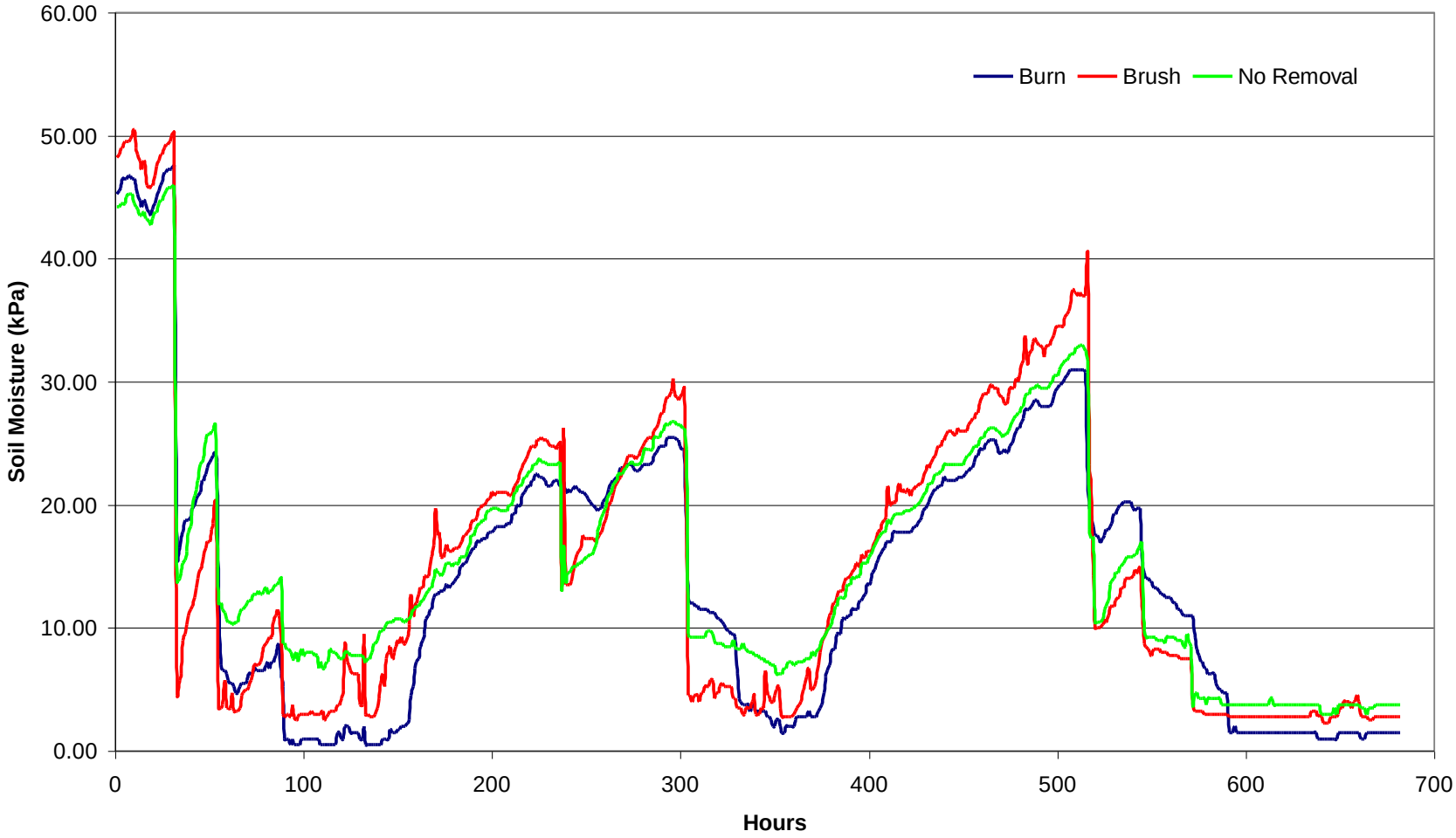
Appendix 3. Soil moisture data from all years and locations.

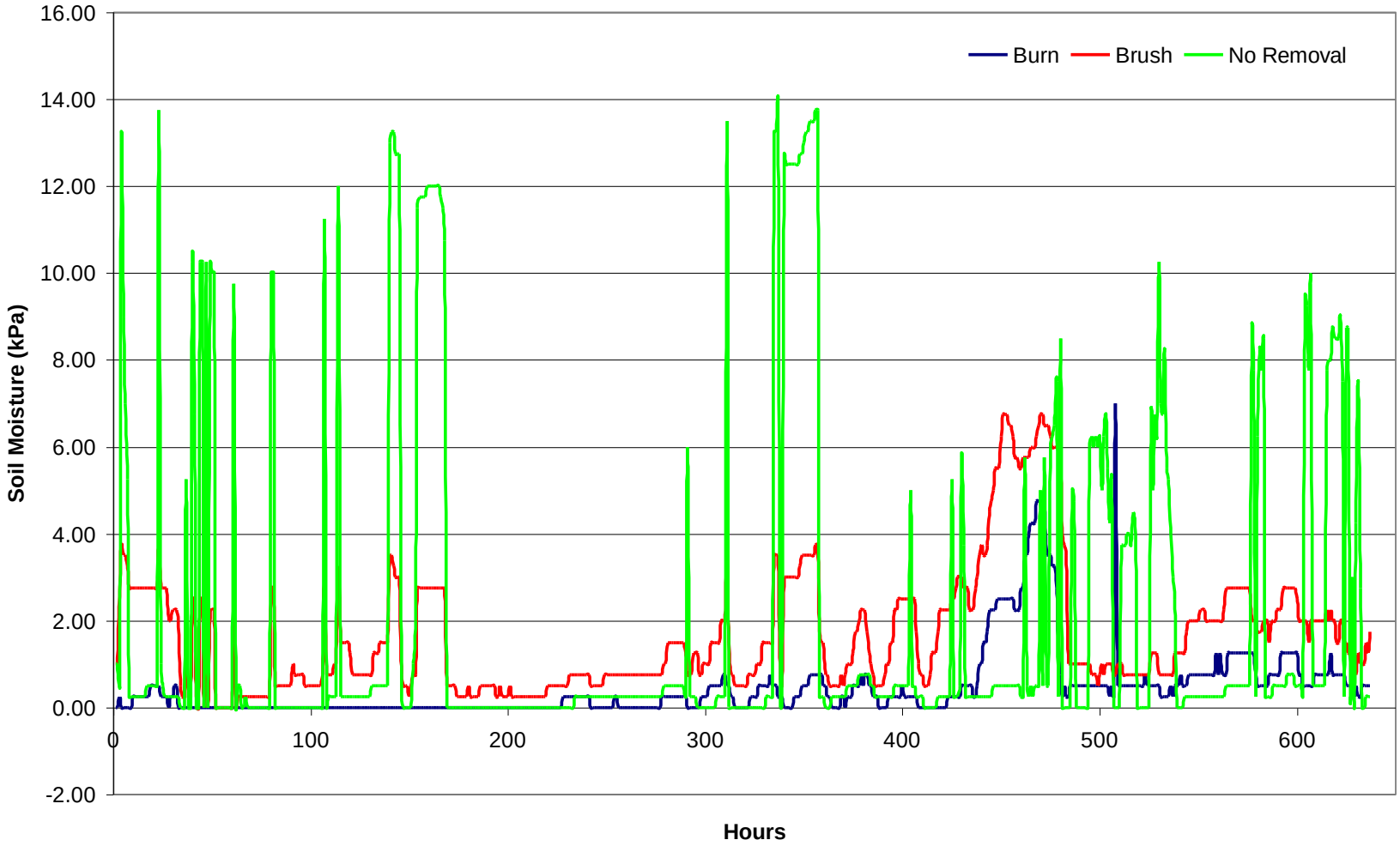


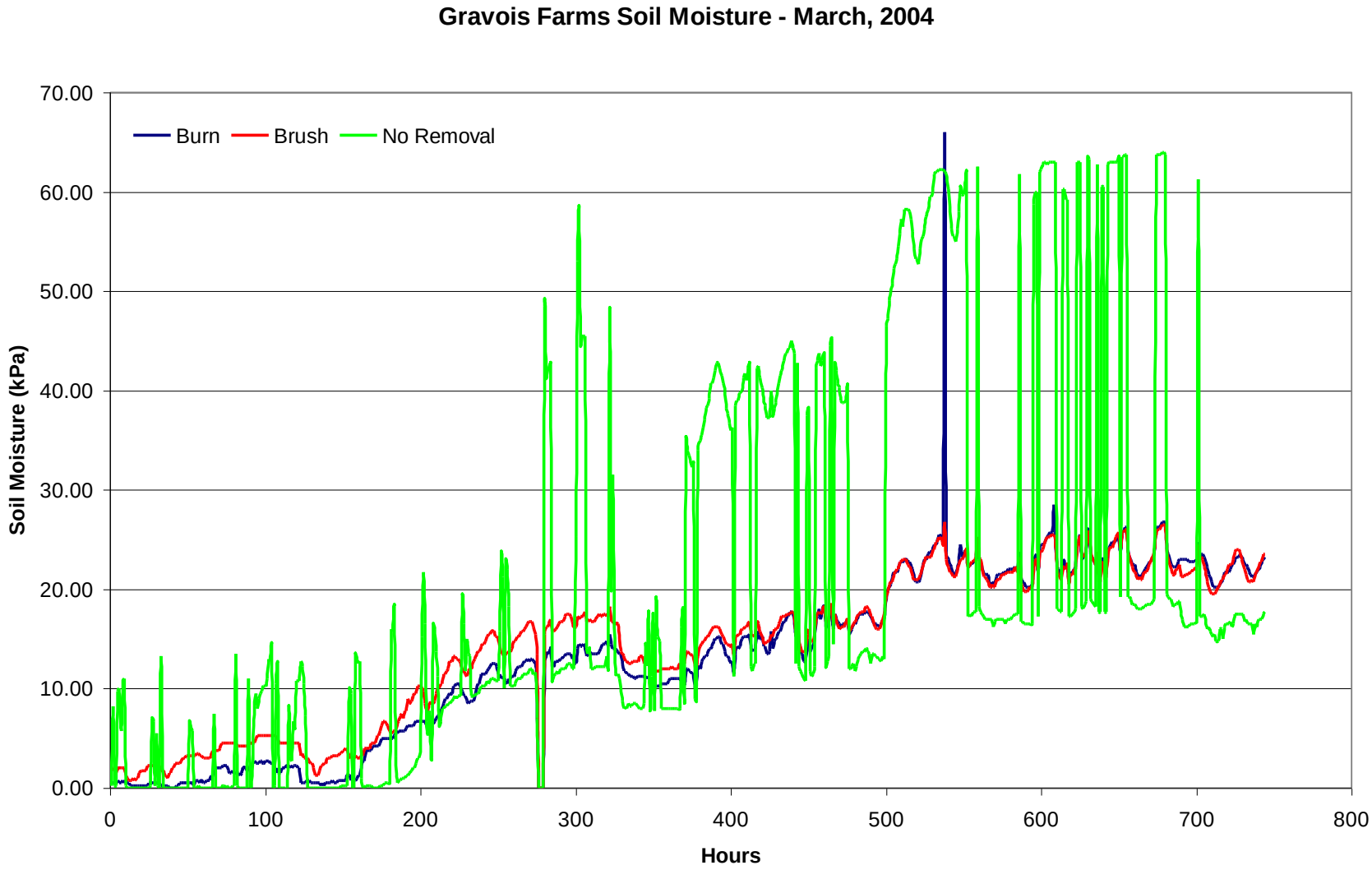

Laurel Valley Soil Moisture - March, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
Hours

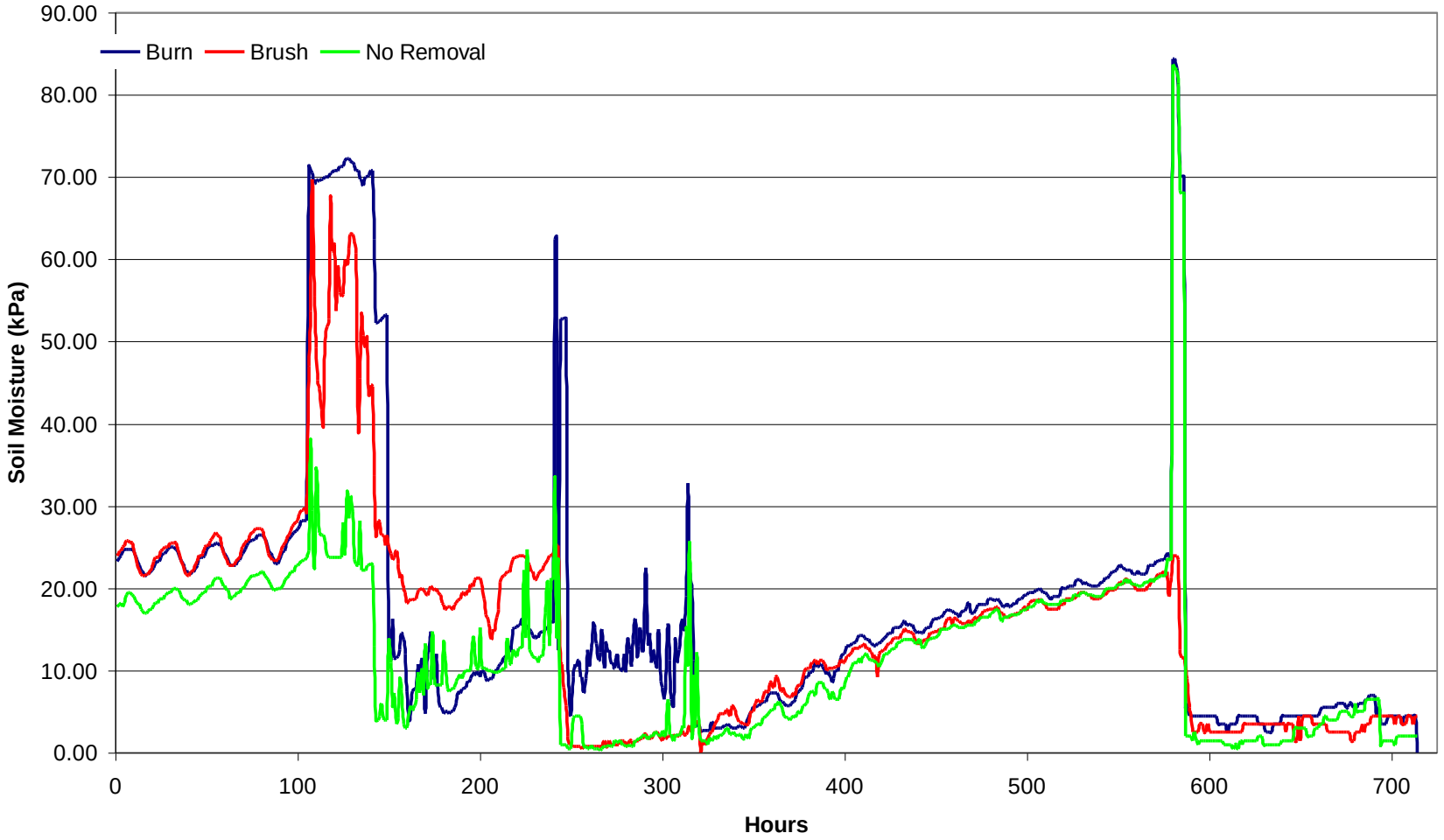

Laurel Valley Soil Moisture - April, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
Hours

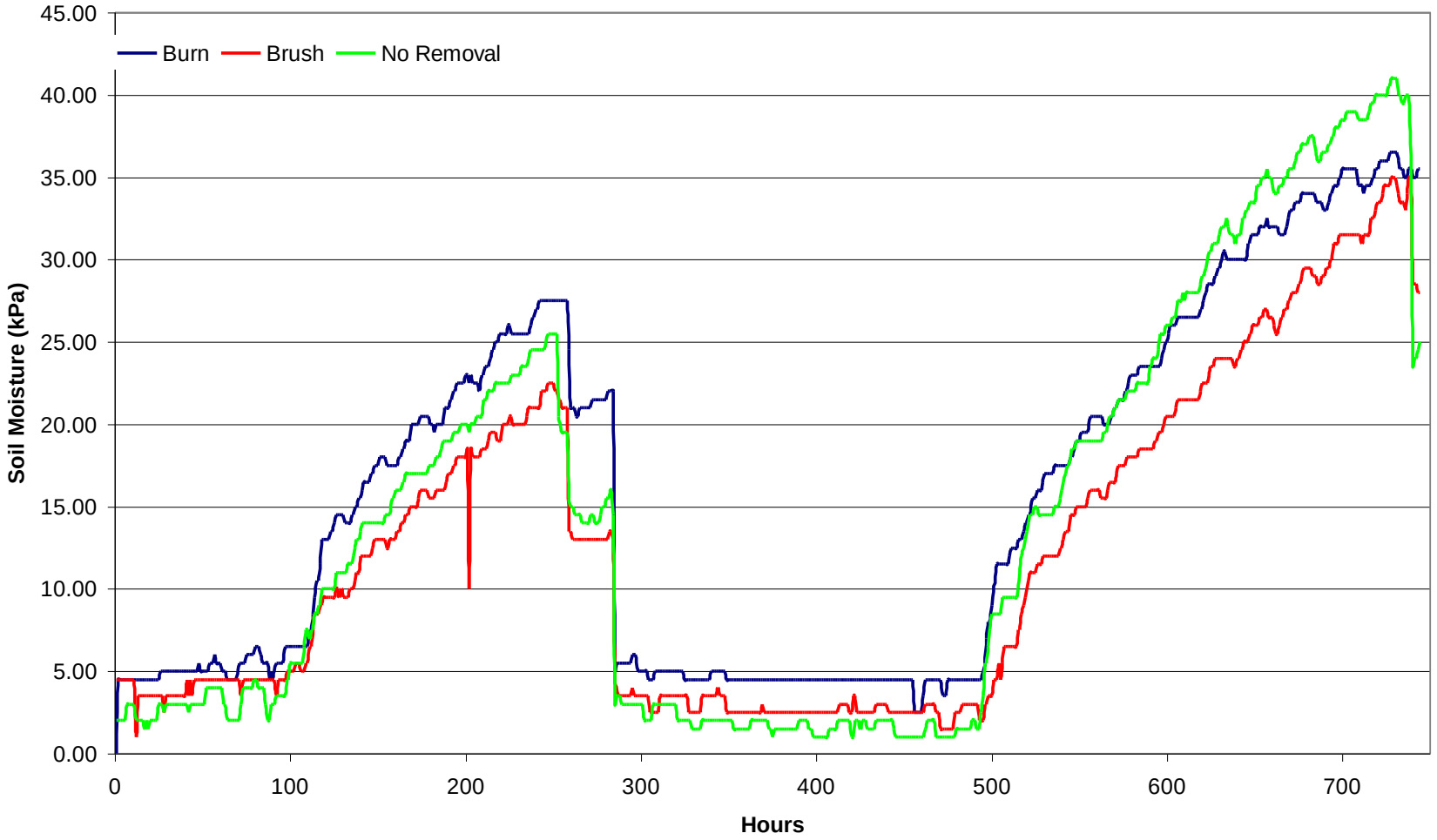

Laurel Valley Soil Moisture - May, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
Hours

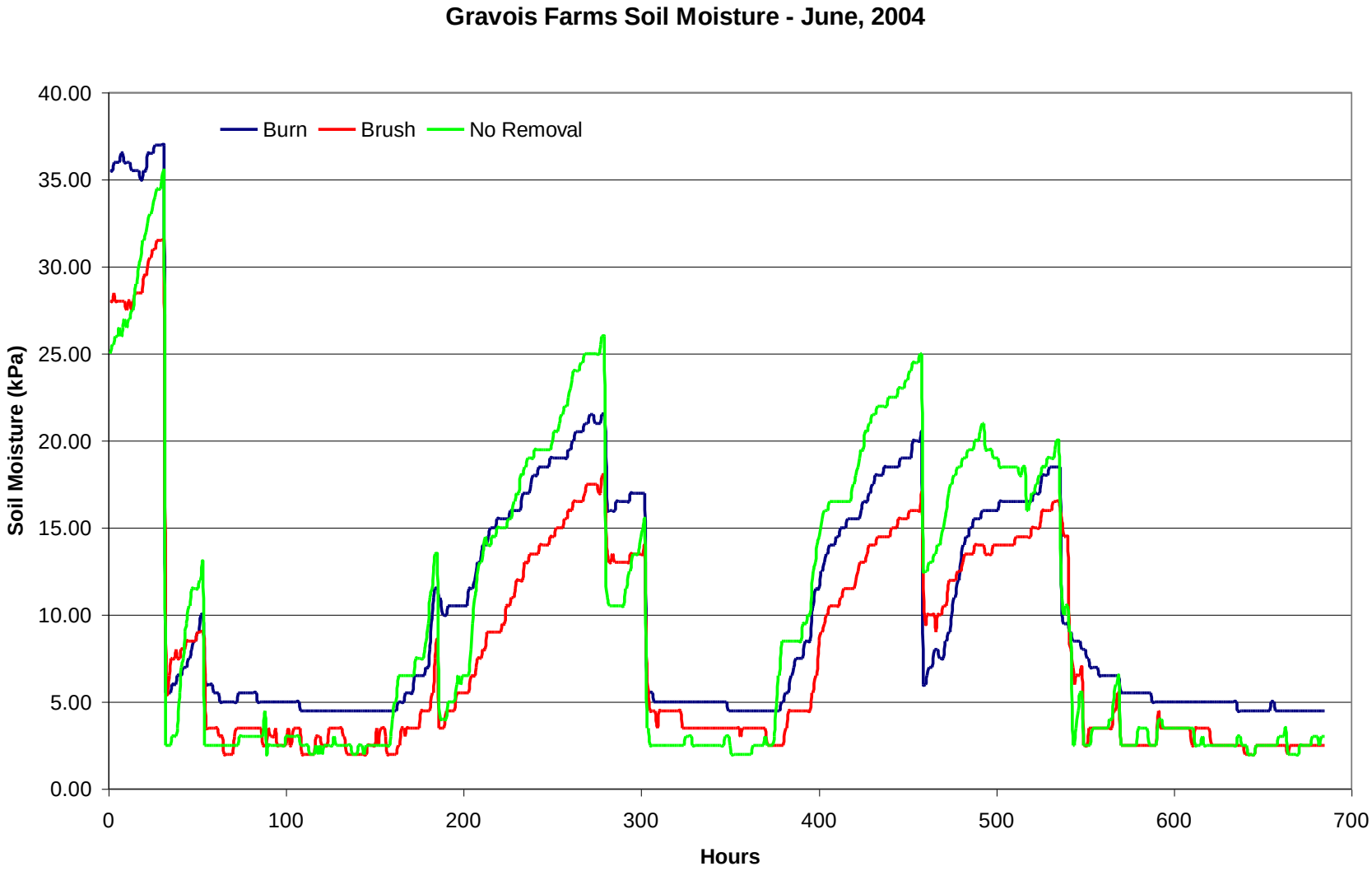

Laurel Valley Soil Moisture - June, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
Hours

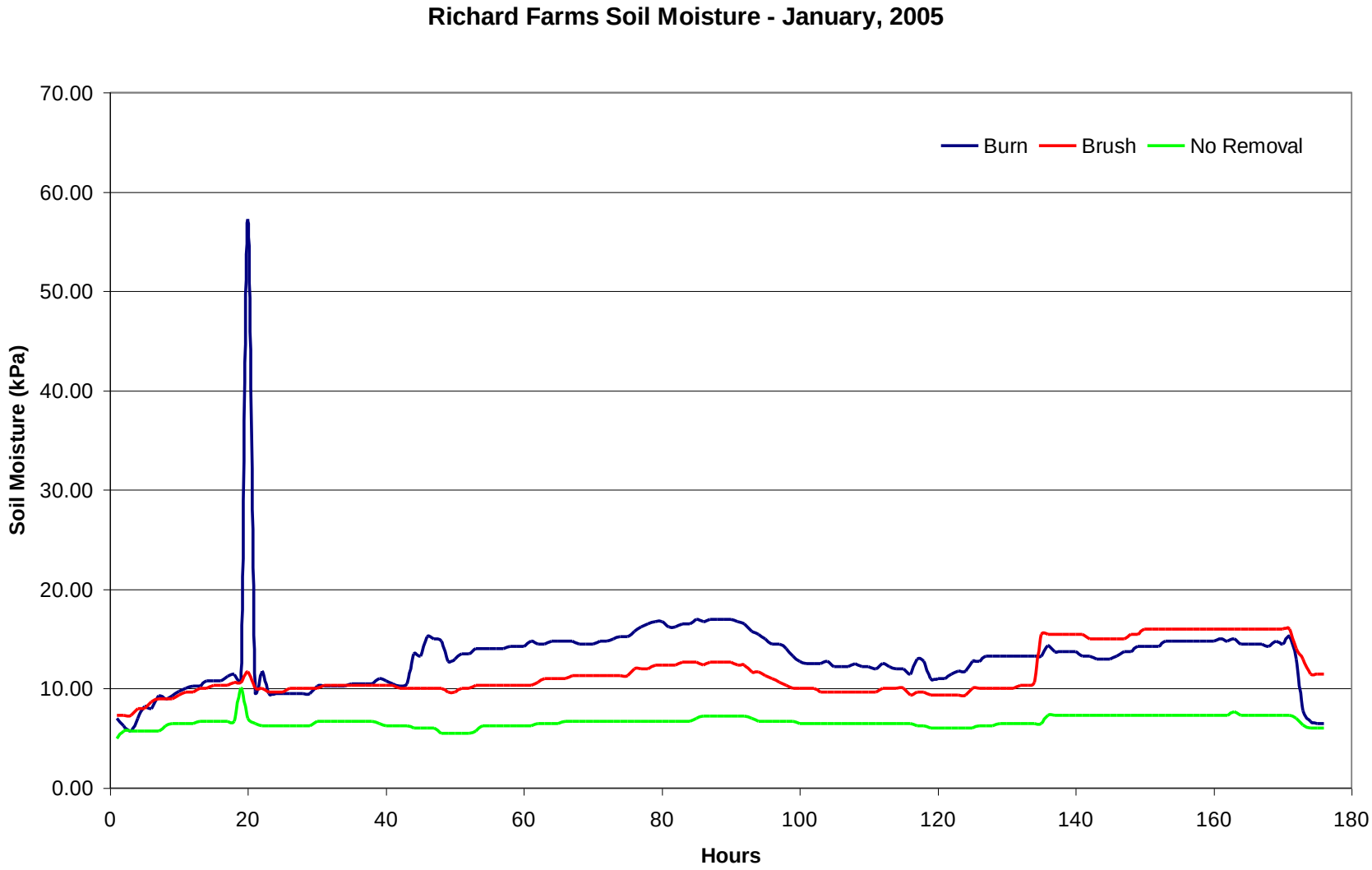

Gravois Farms Soil Moisture - February, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
0
100
200
300
400
500
600
Hours

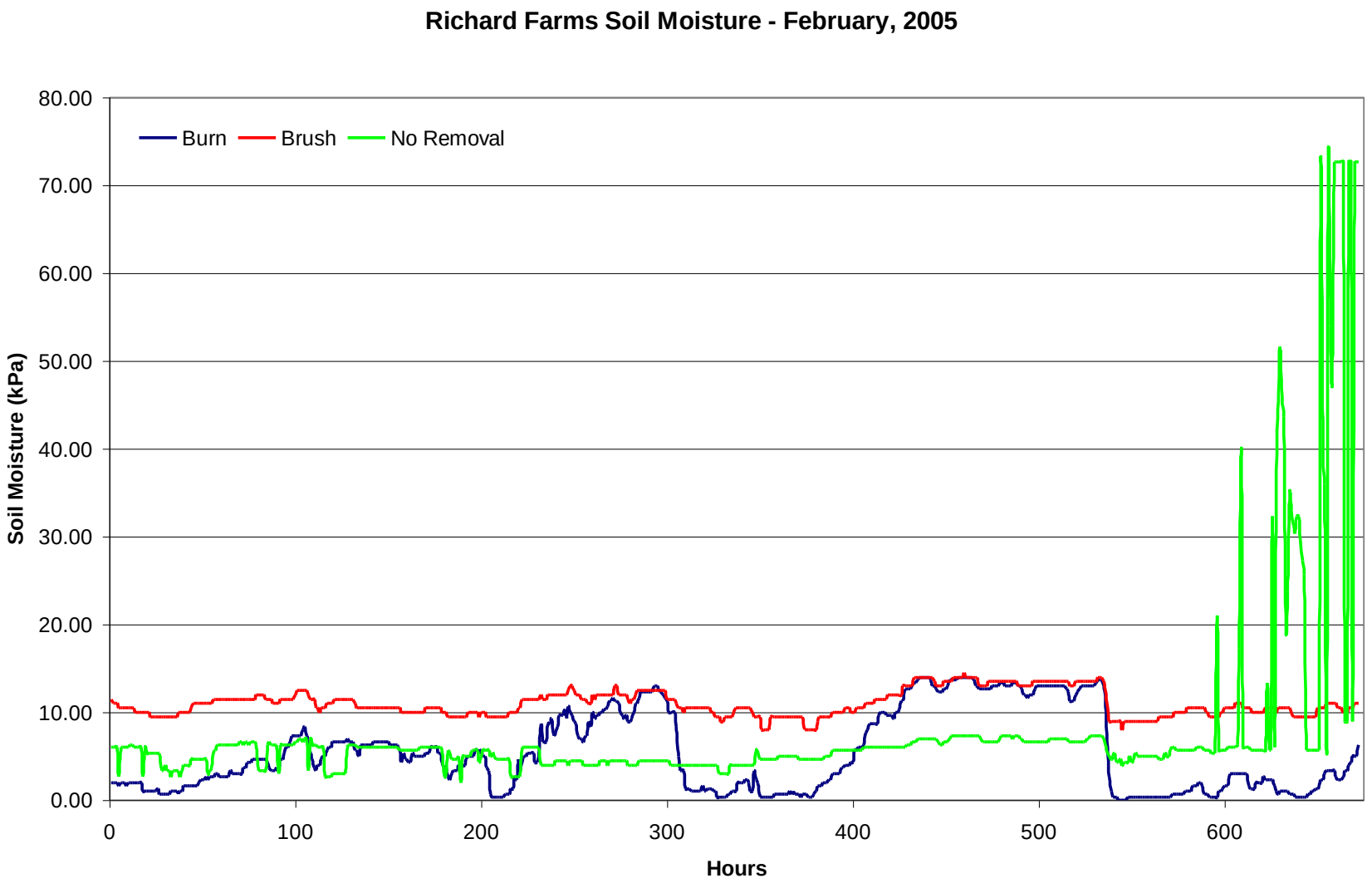

Gravois Farms Soil Moisture - March, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
800
Hours

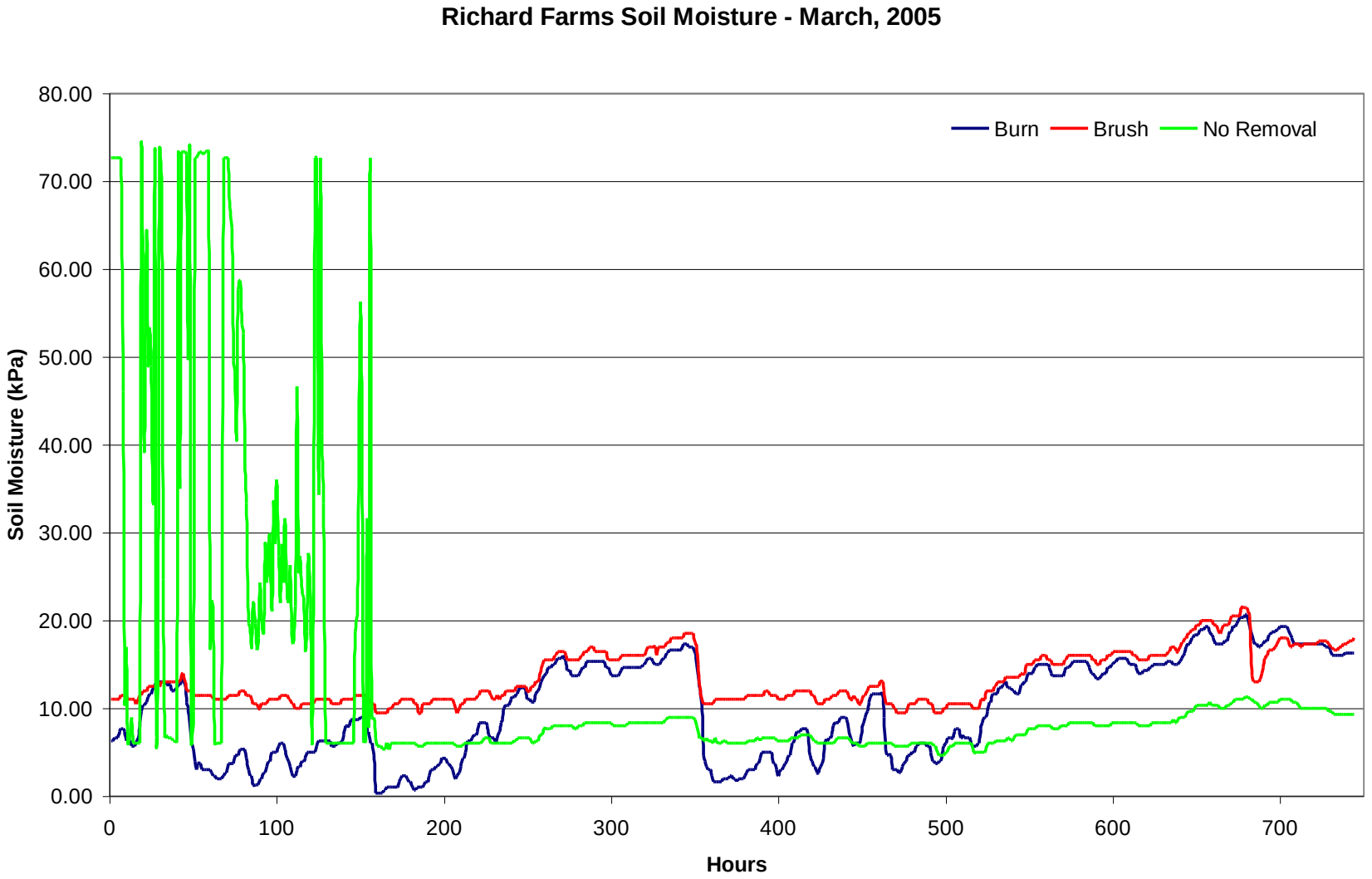

Gravois Farms Soil Moisture - April, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
Hours

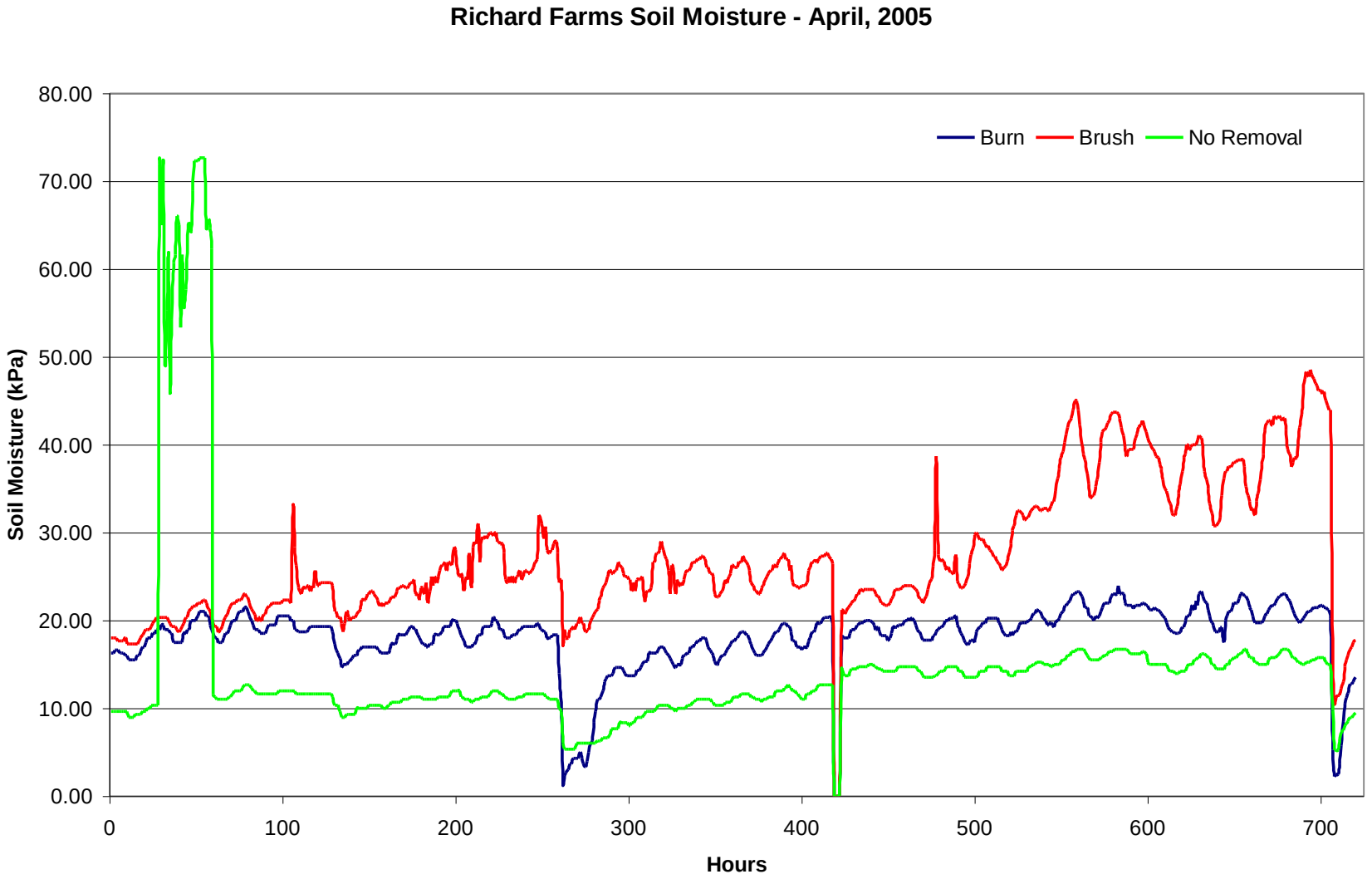

Gravois Farms Soil Moisture - May, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
Hours

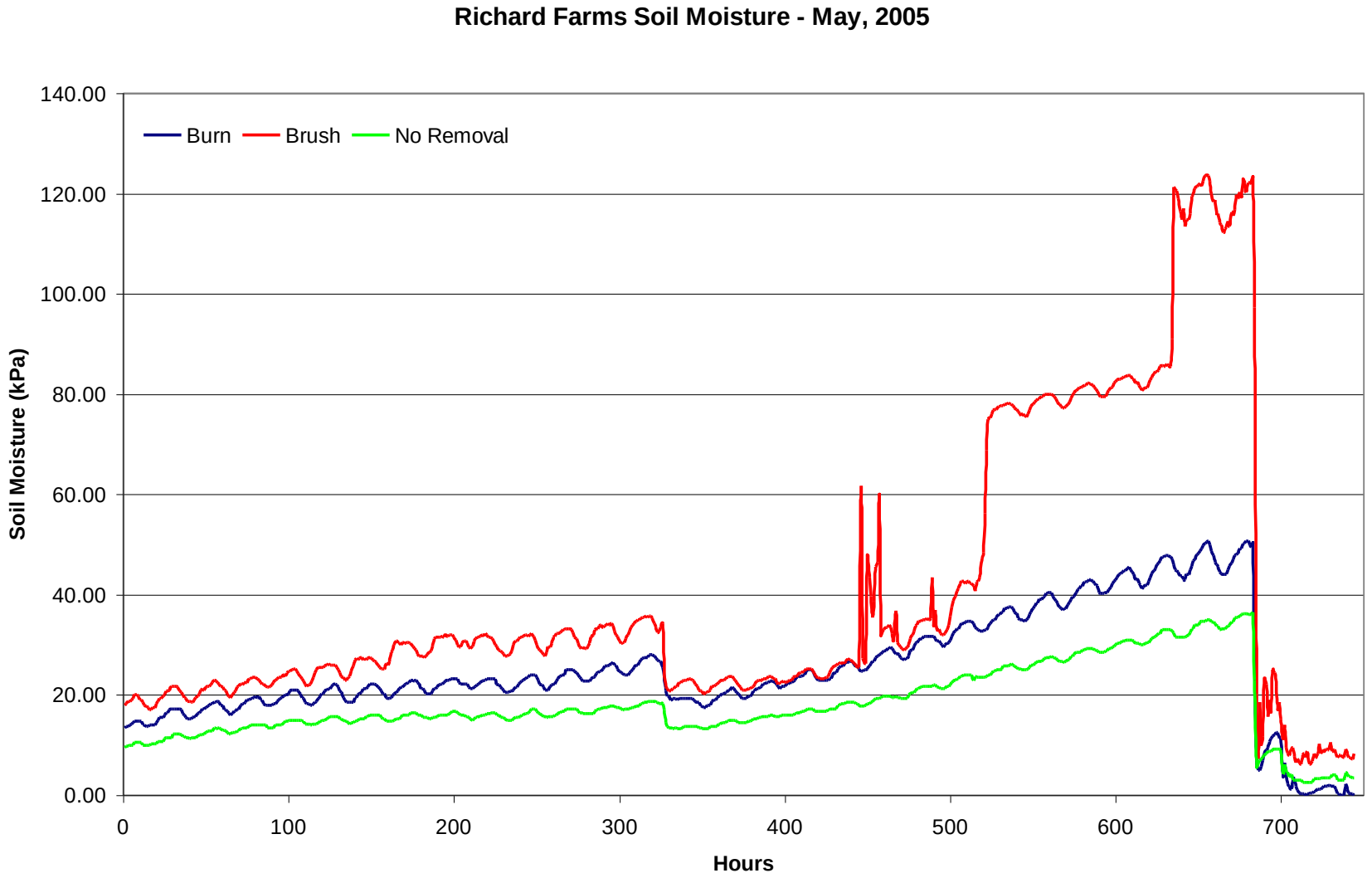

Gravois Farms Soil Moisture - June, 2004
Burn
Brush
No Removal
Soil Moisture (kPa)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
Hours

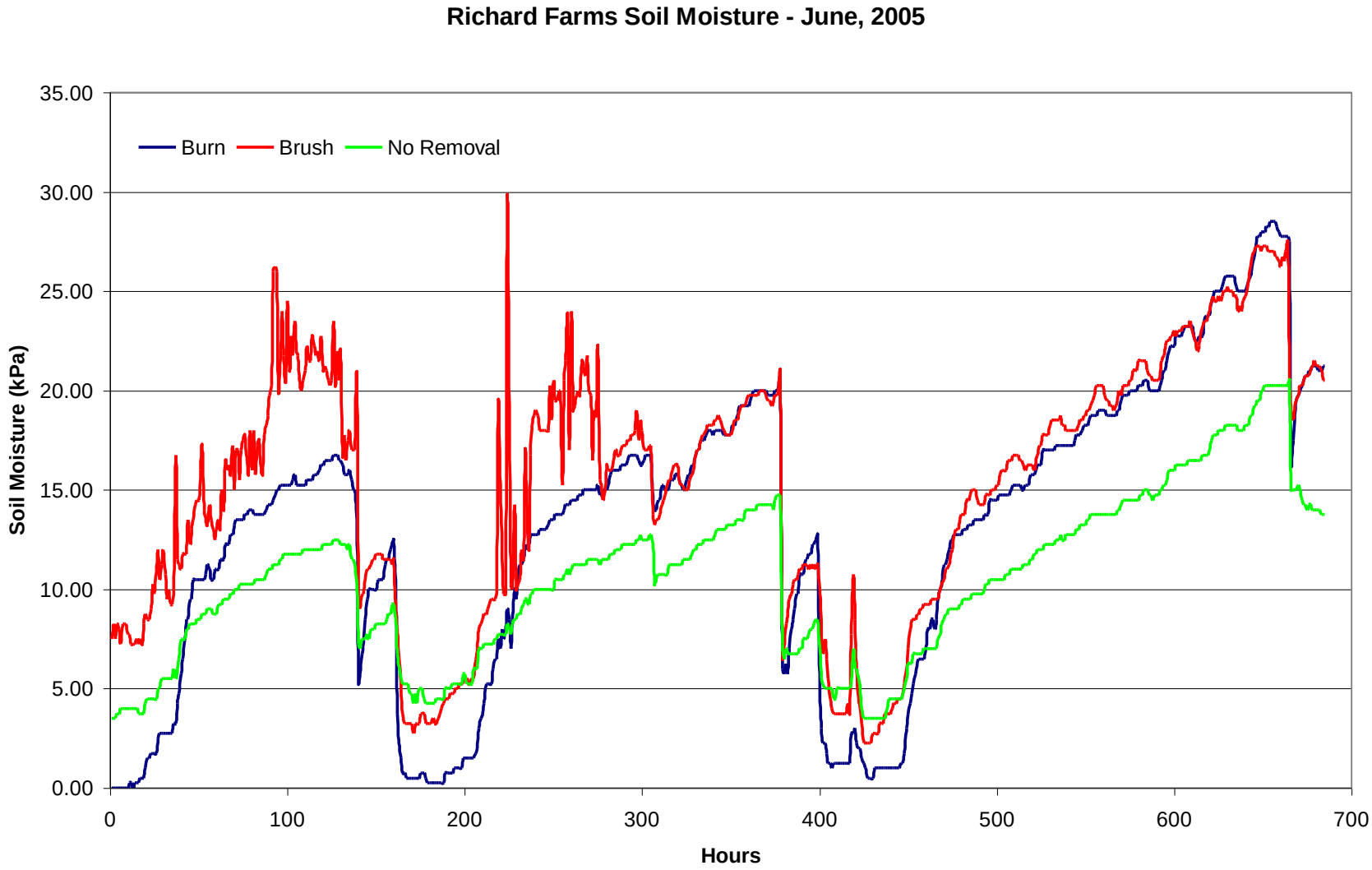

Richard Farms Soil Moisture - January, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
20
40
60
80
100
120
140
160
180
Hours

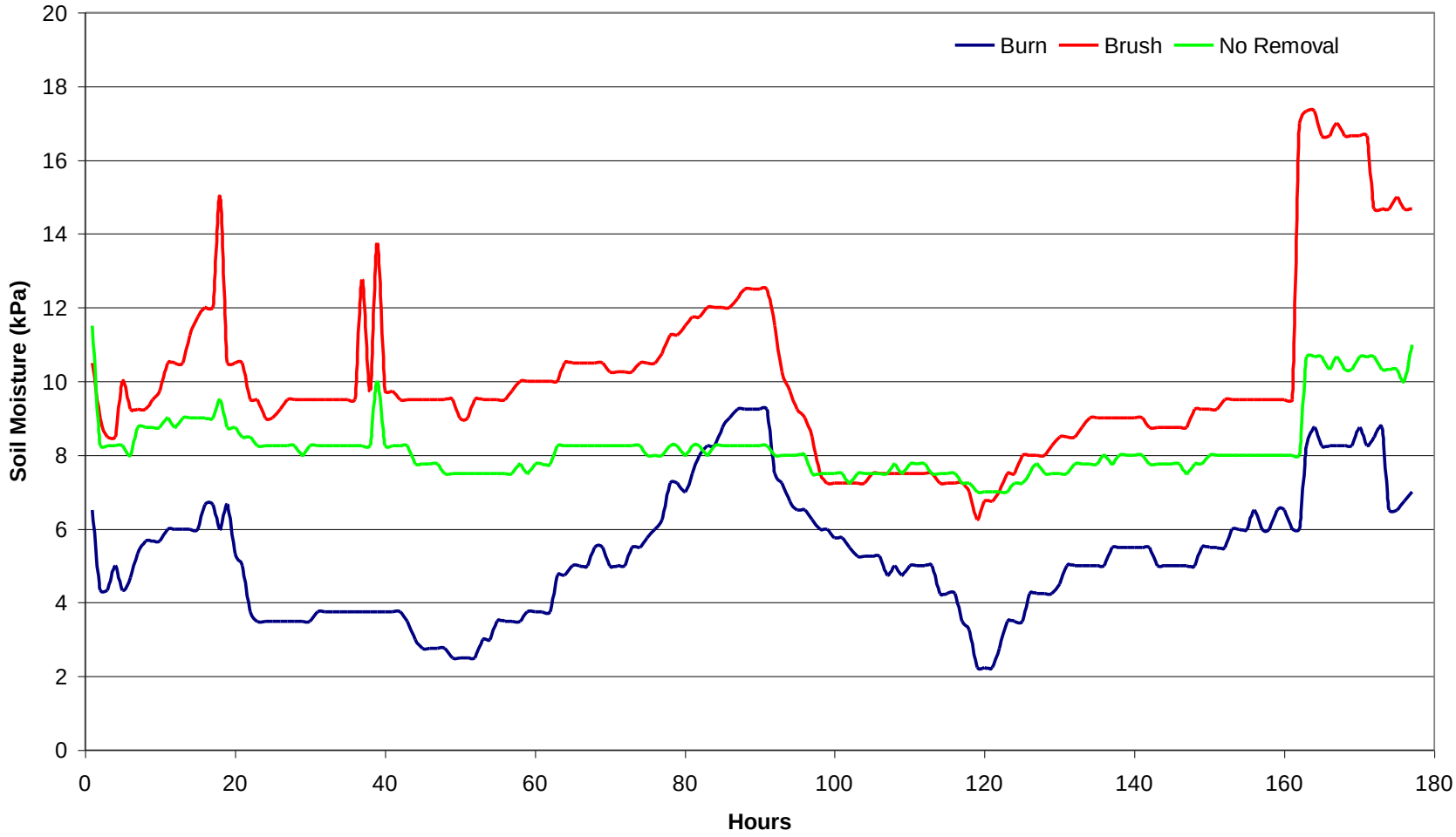

Richard Farms Soil Moisture - February, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
Hours

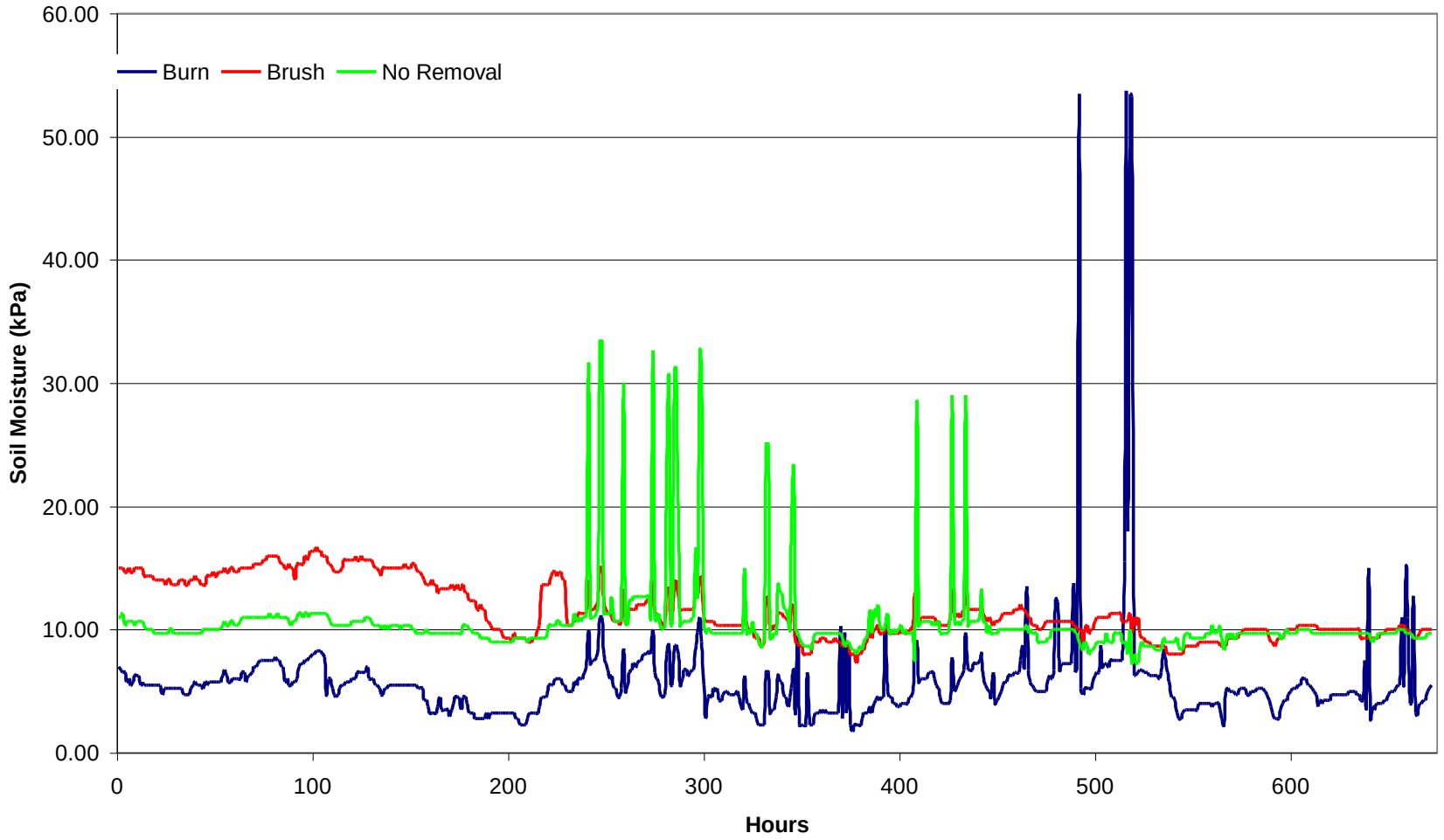

Richard Farms Soil Moisture - March, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
Hours

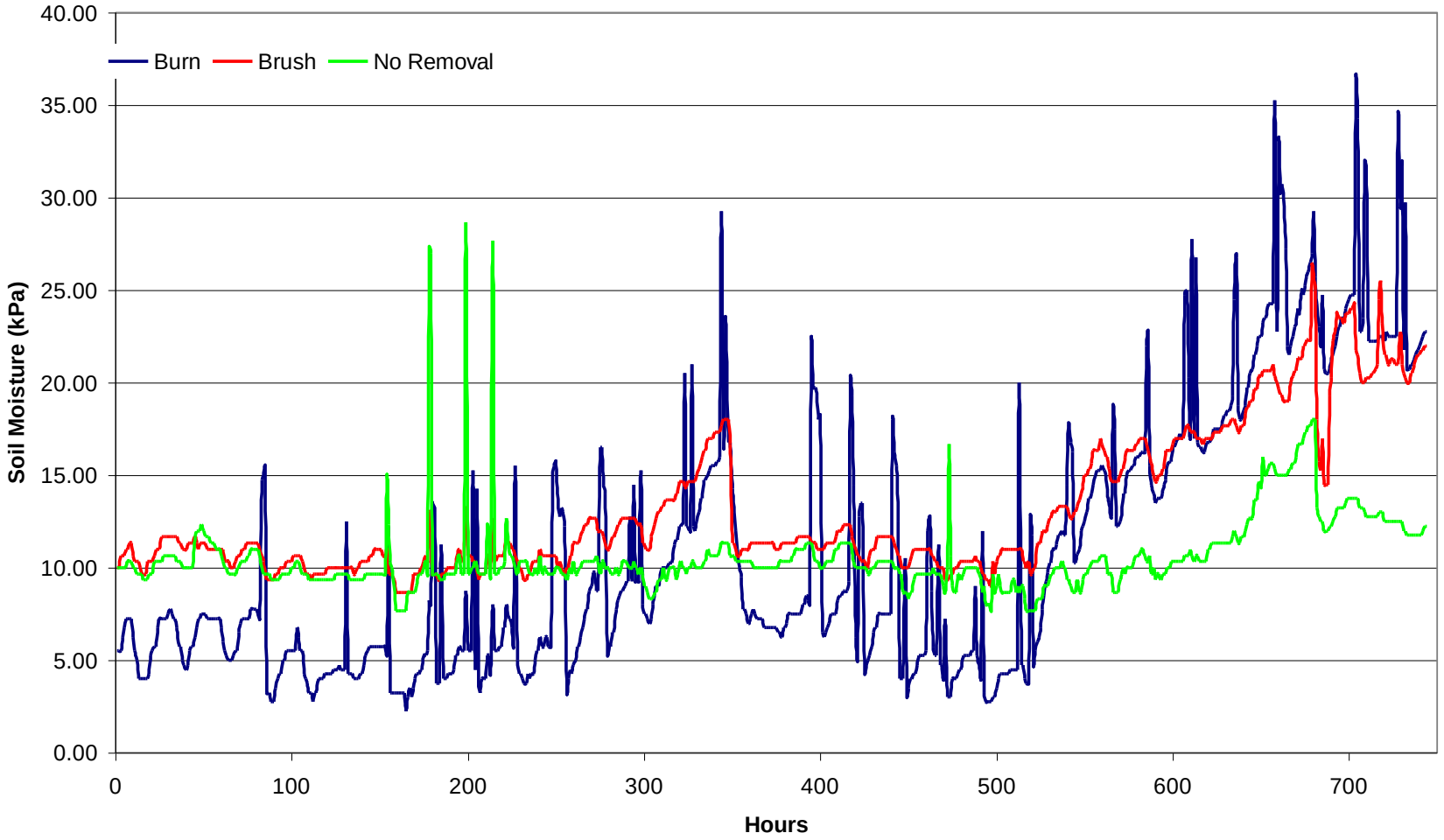

Richard Farms Soil Moisture - April, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
Hours

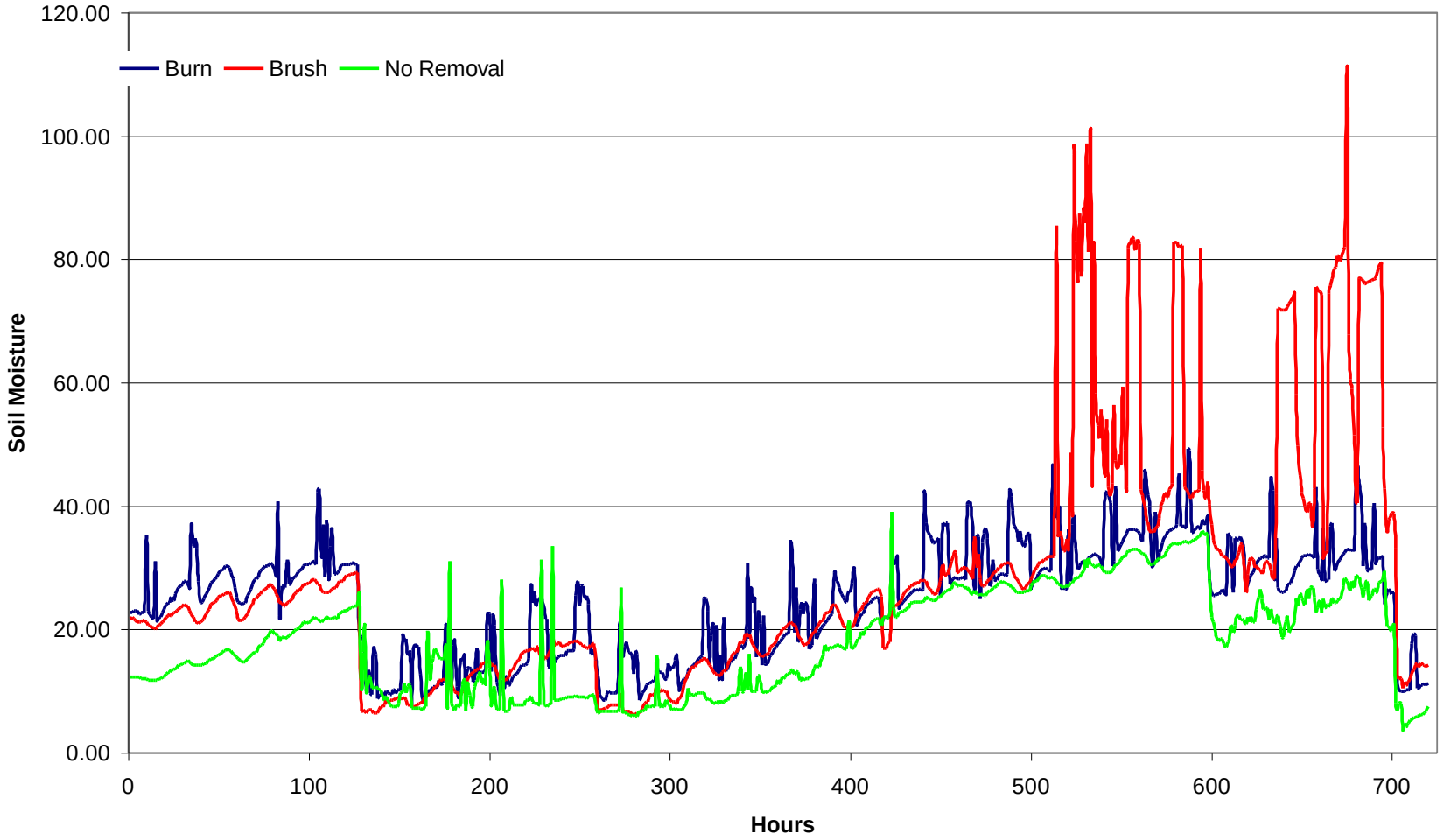

Richard Farms Soil Moisture - May, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
100
200
300
400
500
600
700
Hours

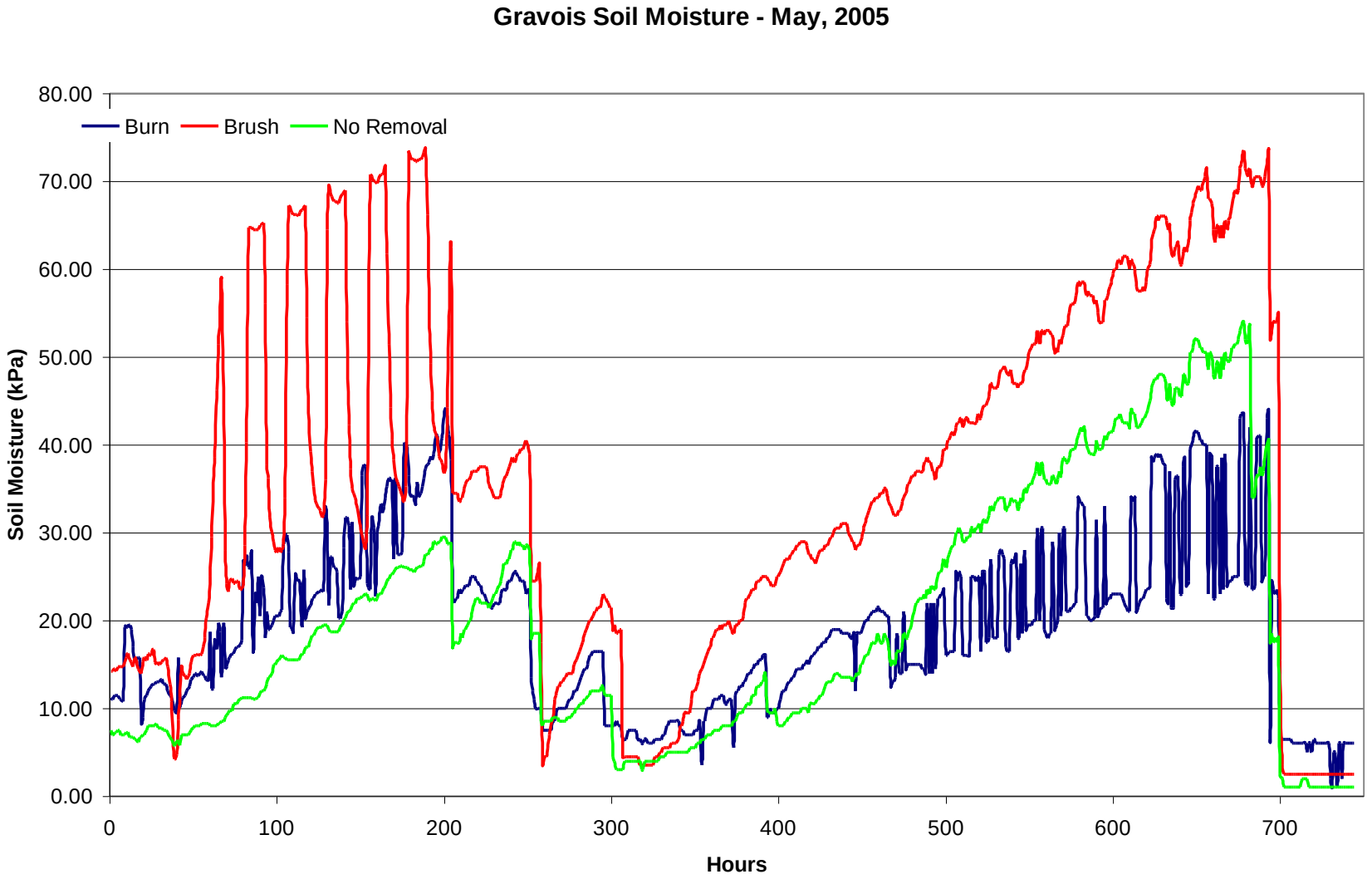

Richard Farms Soil Moisture - June, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
Hours

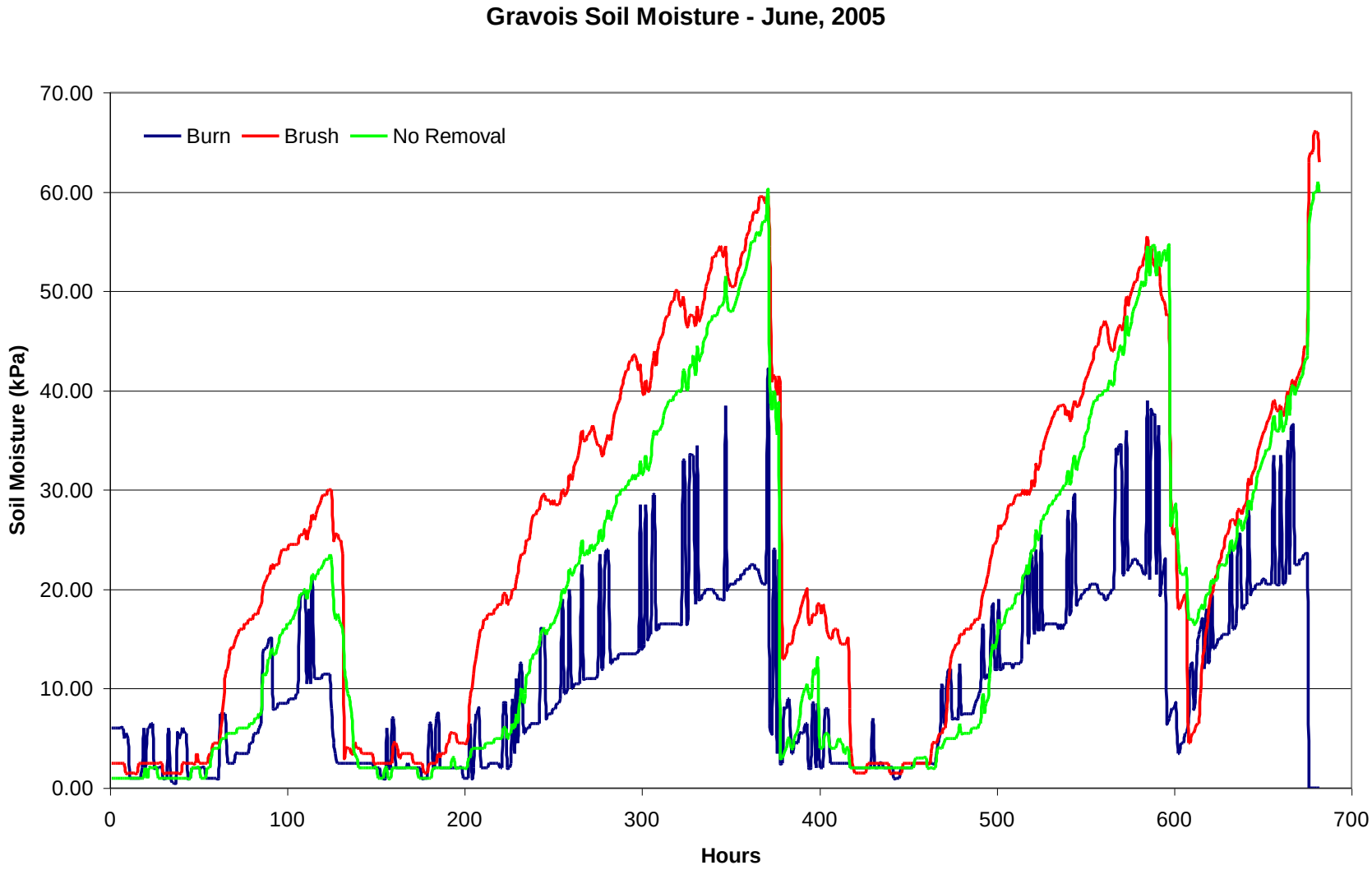

Gravois Soil Moisture - January, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
0
2
4
6
8
10
12
14
16
18
20
0
20
40
60
80
100
120
140
160
180
Hours


Gravois Soil Moisture - February, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
Hours


Gravois Soil Moisture - March, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
100
200
300
400
500
600
700
Hours


Gravois Soil Moisture - April, 2005
Burn
Brush
No Removal
Soil Moisture
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0
100
200
300
400
500
600
700
Hours


Gravois Soil Moisture - May, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
Hours


Gravois Soil Moisture - June, 2005
Burn
Brush
No Removal
Soil Moisture (kPa)
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
0
100
200
300
400
500
600
700
Hours