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DATE: September 22, 2014

SUBJECT: EVALUATION OF SOIL BULK DENSITY AND SOIL WATER STATUS IN FIELD STUDY ENTITLED "DIRECT FLUX DETERMINATION OF CHLOROPICRIN EMISSIONS FROM SHANK, BEDDED, NON-TARPED APPLICATIONS", DOCUMENT # 0199-0137.

Summary

Evaluated was a field study conducted in Florida and submitted by the Chloropicrin Manufactures Task Force entitled "Direct Flux Determination of Chloropicrin Emissions from Shank, Bedded, Non-Tarped Applications". This evaluation assessed soil textural conditions for consistency between the field study site in Florida and soils in Fresno and Tulare Counties, California, soil bulk density and soil water status.

The field study report noted that the soil was analyzed to a depth of 18 inches. Textural classification was sand with a composition of up to 97% sand and 1 to 2% clay. Soil texture at the field study site in Florida was consistent with areas of Fresno and Tulare Counties, California where soils contain up to 96% sand.

Reported soil bulk density from the field study was considerably lower than that expected for undisturbed sand-textured soil. However, the bulk density was reported in the field study as being from 'disturbed' soil samples and presumably obtained of the pre-cultivated formed beds.

Soil moisture just prior to chloropicrin application was reported as >75% field capacity at the 6-12 inch depth as determined by the USDA Feel and Appearance method. A water balance procedure was utilized to evaluate soil moisture content during the field study. Based on conditions in Field #1, estimated soil moisture was relatively high from the period of chloropicrin application through to approximately 5 days post-application. Soil moisture conditions were dry for the following period until being restored by rain on day 10. Progressive drying of the soil occurred from days 10 to 14 after which the field study was concluded. Estimated soil moisture conditions at Field #2 were questionable as reported soil moisture content at field capacity was uncharacteristically low.

Discussion

The field study was conducted near Elkton, Florida at two sites approximately 950 meters apart. Air sampling was conducted over a 14 day period beginning on December 3, 2009.

Soil

Several soil parameters were characterized and presented in Table 6 of the field study report. In this table the USDA soil texture classification at both sites was reported as sand. One study site (Field #1) maintained a sand content of 97% from the surface to a 12-inch depth, then transitioned to 93% sand to the 18-inch depth. The other study site (Field #2) maintained a sand content of 97% to the full 18-inch depth. The clay content at these sites was 1 to 2% with the balance of the texture composition being silt. The high sand component of this soil is not untypical of some soils of California's Central Valley where intensive agriculture occurs. The area of interest in Figure 1 represents approximately 50,000 acres south of the city of Fresno. As can be observed a significant area contains soil with a sand content of 85.8 to 96%.

Soil Bulk Density

The field study utilized a non-tarped, bedded application method for chloropicrin with soil sealing accomplished using a bed shaper/compactor. Chloropicrin injection and bed shaping/compaction occurred simultaneously. Soil samples collected for characterization several hours before the chemical application and bed shaping/compaction were lost prior to analysis. Soil analyses presented in Table 6 of the field study report were from samples collected post chemical application. Presumably, these soil samples were collected directly from the treated bed because under soil bulk density analysis in Table 6 of the study report they were termed as being 'disturbed' soil samples. Soil bulk density reported in the study ranged from 1.26 to 1.32 g/cm^3 and 1.33 to 1.37 g/cm^3 for Fields #1 and #2, respectively. Despite the compaction of the bed during chemical application, these bulk density values were low and not consistent with those of undisturbed sand-textured soils. Korevaar et.al. (1983) reported bulk density for sand-textured soils to be approximately 1.6 g/cm^3. Bulk density of an undisturbed soil in a recent Department of Pesticide Regulation field study conducted in Fresno County on a soil with a sand content of 96% ranged from 1.56 to 1.81 g/cm^3 (report not yet published).

Soil Moisture Status

A spreadsheet-based water balance was generated for each of Fields #1 and #2 to examine the soil-water content during the study period (December 3 to 16, 2009). The water balance operates on a daily time step and is based on procedures given by Allen et.al. (1988) for assessing water relations in bare ground. Daily water application or rainfall is partitioned into the components of evaporation and drainage and adjustments to soil-water content. The water balance centers on the use of a reduction coefficient limiting evaporation when the soil-water content drops below a threshold. Required data for the water balance included initial soil moisture content, reference evapotranspiration, and volumetric water content at field capacity and wilting point. Field capacity and wilting point were measured data given in Table 6 of the field study report, averaging 4.1% and 1.9%, respectively for Field #1, and 2.1% and 1.7%, respectively for Field #2. Reference evapotranspiration for the period in question was obtained from the Florida Automated Weather Network station in Hastings, Florida, approximately 3.5 miles from the study site. Initial moisture content was given in the field study report and determined from the USDA Feel and Appearance method to be greater than 75% field capacity.

For Field #1 total rainfall amounted to 67.1 mm, which was partitioned into 19.6 mm of evaporation, 52.9 mm of drainage below the estimated soil evaporative depth of 0.3 m, and 5.4-mm change in soil moisture content. Overall, estimated soil moisture content was high for the first 3 days of the study due to rainfall and then gradually declined to the wilting point by day 9. Soil moisture was restored on day 10 by rainfall to then gradually decline to the wilting point by day 14 (Figure 2).

For Field #2 total rainfall was again 67.1 mm, which was partitioned into 12.5 mm of evaporation, 57.5 mm of drainage, and 2.9-mm change in soil moisture content. Overall, estimated soil moisture content was low relative to the wilting point. Unlike Field #1, reported soil moisture content at field capacity was extremely low at 2.1%, which was not consistent with the value estimated by the USDA ARS soil water characteristics index for a loose packed sand-textured soil of 7.0%. With moisture content at the wilting point reported at 1.7%, very little water was available for evaporation. Consequently, wilting point or drier soil moisture conditions were estimated during most of the field study period (Figure 3).

Conclusions

Soil textural composition at the field study site was representative of some extensive agricultural areas in California's Central Valley. A low soil bulk density at the field study site was not consistent with undisturbed sand-textured soils. However, reported values were from disturbed soil samples and therefore possibly obtained directly from the pre-cultivated, formed beds. Soil moisture content at Field #1 was initially high during chloropicrin application and for the following 3 days, but then gradually depleted until being restored on day 10 by rainfall. Estimated soil moisture conditions at Field #2 are questionable due to an unusually low reported value for soil moisture content at field capacity.

References

Koorevaar, P., G. Menelik and C. Dirksen. 1983. Elements of soil physics. Developments in Soil Science 13, 3rd ed., vol 13. Elsevier Science Publishers, Netherlands.

Allen, R.G., L.S. Pereira, D. Raes and M. Smith. 1998. Crop evapotranspiration – Guidelines for computing crop water requirements – FAO Irrigation and drainage paper 56. Food and Agriculture Organization of the United Nations, Rome, Italy.

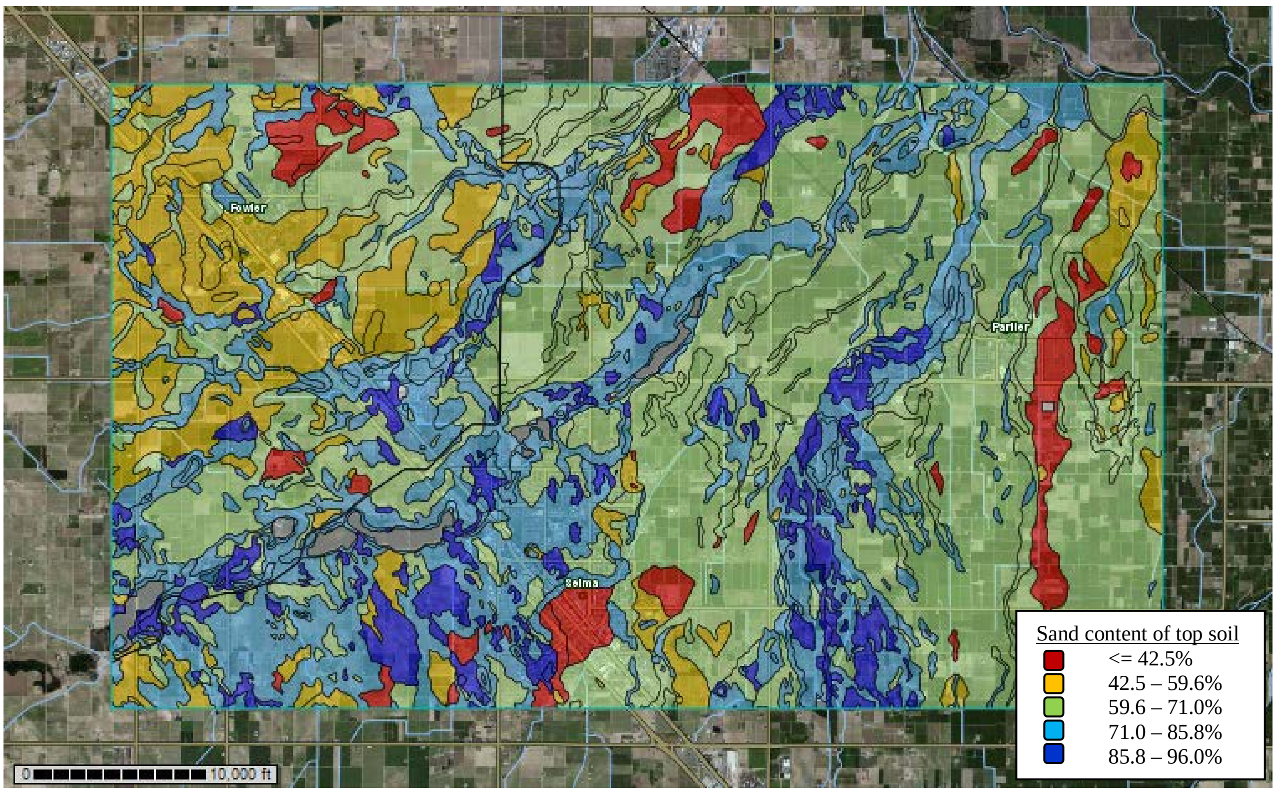

Figure 1. USDA NRCS soils map of south-eastern Fresno County and northern Tulare County, California depicting the cities of Fowler in the north-west, Selma in the south and Parlier in the east. Area of interest represents approximately 50,000 acres and illustrates the sand content of the top soil. Mapping data: <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>.

<< Enter appropriate values into boxed cells >>

Water balance for chloropicrin study, Elkton, Florida. Chloropicrin 100 Plot Field #1, Pomona fine sand series. Irrig/rain occurs at start of day.

Depth of soil layer subject to processes of evaporation is 300 mm. FC theta est at 0.041, WP theta est at 0.019, OM est at 1.2%.

TEW = 9.45 (total evaporable water) — Stage 1 = REW (energy is limiting factor)

REW = 4.92218 (readily evaporable water) — Stage 2 = TEW-REW (soil moisture content is limiting factor)

Kc max = 1.05 (see below)

Kcb = 0 (see below)

Kc max=maximum crop coefficient as influenced by water application frequency which ranges from 1.05 - 1.2 when grass is the ETo. For infrequent waterings >4 days apart us 1.2; for 1-4 days apart use 1.05 to 1.15.

Kcb=basial crop coefficient is the ratio of crop evapotranspiration over the reference evapotranspiration (ETc/ETo). For bare soil Kcb=0.

Kr=evaporation reduction coefficient

Ke=soil evaporation coefficient = Kc max - Kcb(basial crop coefficient). For bare soil Kcb=0. Therefore, when soil moisture is not limiting Ke=kc max.

KeETo=daily evapotranspiration

drainage=daily water movement below 300 mm — total evpotranspiration 19.6 — total water application 67.1 — total drainage 52.9

ETo=reference evapotranspiration

Initial soil water depletion (cell H14) based on study report of water content at > 1.9

date	(1) day	(2) Depl start mm	(3) stage	(4) Kr	(5) Ke	(6) KeETo mm	(7) Depl end mm	irrig mm	rain mm	(8) predicted drainage mm	ETo mm
12/03/09	1	1.9	1	1.00	1.05	1.6	3.5	0.0	0	0.0	1.5
12/04/09	2	0.0	1	1.00	1.05	1.1	1.1	0.0	20.1	16.6	1.0
12/05/09	3	0.0	1	1.00	1.05	1.3	1.3	0.0	26.2	25.1	1.3
12/06/09	4	1.3	1	1.00	1.05	1.3	2.7	0.0	0	0.0	1.3
12/07/09	5	2.7	1	1.00	1.05	1.3	4.0	0.0	0	0.0	1.3
12/08/09	6	4.0	1	1.00	1.05	1.6	5.6	0.0	0	0.0	1.5
12/09/09	7	3.3	1	1.00	1.05	1.9	5.2	0.0	2.3	0.0	1.8
12/10/09	8	5.2	2	0.95	0.99	1.5	6.7	0.0	0	0.0	1.5
12/11/09	9	6.7	2	0.61	0.64	0.7	7.3	0.0	0	0.0	1.0
12/12/09	10	0.0	1	1.00	1.05	1.3	1.3	0.0	18.5	11.2	1.3
12/13/09	11	1.3	1	1.00	1.05	1.9	3.2	0.0	0	0.0	1.8
12/14/09	12	3.2	1	1.00	1.05	1.6	4.8	0.0	0	0.0	1.5
12/15/09	13	4.8	1	1.00	1.05	1.6	6.4	0.0	0	0.0	1.5
12/16/09	14	6.4	2	0.67	0.71	0.9	7.3	0.0	0	0.0	1.3

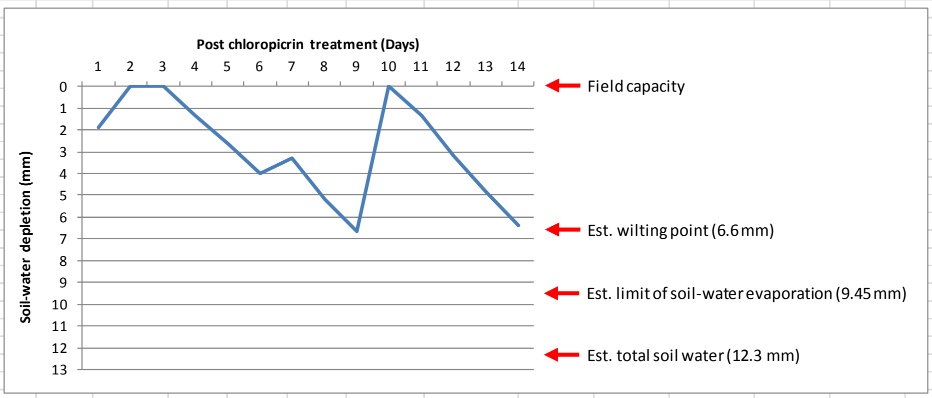

Figure 2. Water balance for Chloropicrin 100 plot at Field #1. Plotted estimates of soil water depletion are for the early morning period of each day. Values for total evaporable water (TEW) and readily evaporable water (REW) based on field capacity and wilting point values given in field study report and on an estimated evaporable depth of 0.3 m. Reference evapotranspiration (ETo) obtained from Florida Automated Weather Network station in Hastings, Florida, approximately 3.5 miles from the study site. Calculation procedures given by Allen et.al. (1998).

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Water balance for chloropicrin study, Elkton, Florida. Pic Plus plot Field #2, Tocoi fine sand series. Irrig/rain occurs at start of day.

Depth of soil subject to processes of evaporation is 300 mm. FC theta est at 0.021, WP theta est at 0.017, OM est at 1.0%.

TEW = 3.75 (total evaporable water) — Stage 1 = REW (energy is limiting factor)

REW = 2.20866 (readily evaporable water) — Stage 2 = TEW-REW (soil moisture content is limiting factor)

Kc max = 1.05 (see below)

Kcb = 0 (see below)

Kc max=maximum crop coefficient as influenced by water application frequency which ranges from 1.05 - 1.2 when grass is the ETo. For infrequent waterings >4 days apart us 1.2; for 1-4 days apart use 1.05 to 1.15.

Kcb=basial crop coefficient is the ratio of crop evapotranspiration over the reference evapotranspiration (ETc/ETo). For bare soil Kcb=0.

Kr=evaporation reduction coefficient

Ke=soil evaporation coefficient = Kc max - Kcb(basial crop coefficient). For bare soil Kcb=0. Therefore, when soil moisture is not limiting Ke=kc max.

KeETo=daily evapotranspiration

drainage=daily water movement below 300 mm — **total evpotranspiration** 12.5 — total water application 67.1 — **total drainage** 57.5

ETo=reference evapotranspiration

Initial soil water depletion (cell H14) based on study report of water content at > 0.9

date	day (1)	Depl start mm (2)	stage (3)	Kr (4)	Ke (5)	KeETo mm (6)	Depl end mm (7)	irrig mm	rain mm	predicted drainage mm (8)	ETo mm
12/03/09	1	0.9	1	1.00	1.05	1.6	2.5	0.0	0	0.0	1.5
12/04/09	2	0.0	1	1.00	1.05	1.1	1.1	0.0	20.1	17.6	1.0
12/05/09	3	0.0	1	1.00	1.05	1.3	1.3	0.0	26.2	25.1	1.3
12/06/09	4	1.3	1	1.00	1.05	1.3	2.7	0.0	0	0.0	1.3
12/07/09	5	2.7	2	0.70	0.74	0.9	3.6	0.0	0	0.0	1.3
12/08/09	6	3.6	2	0.09	0.10	0.1	3.8	0.0	0	0.0	1.5
12/09/09	7	1.5	1	1.00	1.05	1.9	3.3	0.0	2.3	0.0	1.8
12/10/09	8	3.3	2	0.28	0.30	0.4	3.8	0.0	0	0.0	1.5
12/11/09	9	3.8	2	0.00	0.00	0.0	3.8	0.0	0	0.0	1.0
12/12/09	10	0.0	1	1.00	1.05	1.3	1.3	0.0	18.5	14.8	1.3
12/13/09	11	1.3	1	1.00	1.05	1.9	3.2	0.0	0	0.0	1.8
12/14/09	12	3.2	2	0.36	0.37	0.5	3.8	0.0	0	0.0	1.5
12/15/09	13	3.8	2	0.00	0.00	0.0	3.8	0.0	0	0.0	1.5
12/16/09	14	3.8	2	0.00	0.00	0.0	3.8	0.0	0	0.0	1.3

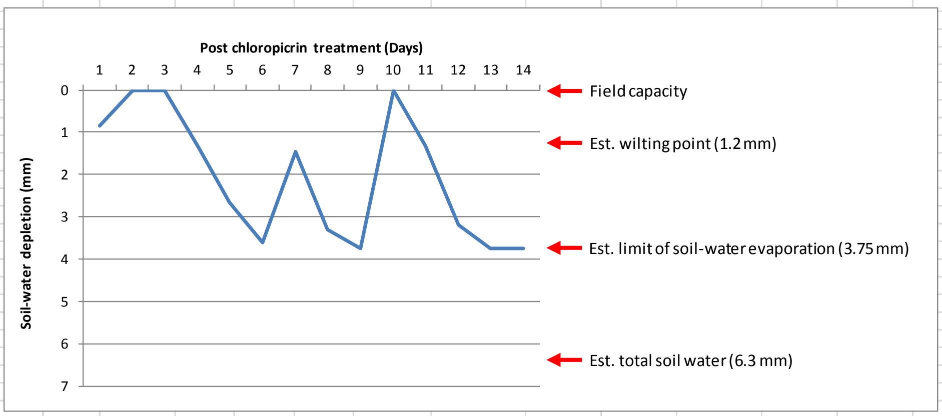

Figure 3. Water balance for Pic Plus plot at Field #2. Plotted estimates of soil water depletion are for the early morning period of each day. Values for total evaporable water (TEW) and readily evaporable water (REW) based on field capacity and wilting point values given in field study report and on an estimated evaporable depth of 0.3 m. Reference evapotranspiration (ETo) obtained from Florida Automated Weather Network station in Hastings, Florida, approximately 3.5 miles from the study site. Calculation procedures given by Allen et.al. (1998).