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STUDY: COMPARISON OF SOIL BULK DENSITY WITHIN AND WITHOUT 'SHANK TRACE' SOIL ZONES

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I. INTRODUCTION

A long standing concept within fumigation circles is the notion of a "shank trace." This refers to the idea that when fumigants are injected into the soil, the metal shank which assists in delivering the fumigant below the soil surface, is dragged through the soil resulting in a zone above the injection point where the bulk density is lower than the surrounding less disturbed soil.

If this concept is true, then it has implications for estimating flux through the use of models because lower bulk density leads to higher flux. While the concept was explicitly incorporated into a recent modeling effort (Cryer and Wesenbeeck 2007), a literature search in my review of their model was unable to locate any field studies directly measuring the potential impact of shank application on localized soil bulk density (Johnson 2008, comment 8). In a rebuttal to my review, Cryer and Wesenbeeck (2009) acknowledged the lack of measured field data with regard to the shank trace concept. They state: "As verified by Cal-DPR in their literature review, this is an area where little to no historical research has been conducted, and thus it lacks appropriate quantification in terms of the disturbed soil geometry and the amount of disturbance (with respect to the soil bulk density) that derives following pulling a 24" steel blade through soil, but this nonetheless does not negate the fact that the soil properties can be significantly altered by the conventional practice of pulling knife blades through soil (e.g., the shank trace)." (pg 5-6)

The EM Air Program is looking more intensively into modeling in order to estimate flux. The potential impact of a shank trace on flux needs to be investigated. But the lack of direct field studies is an impediment to this area of modeling investigation. Thus it is important to obtain field measurements to determine what impact there may be on soil bulk density from the shank application of fumigants.

II. OBJECTIVE

The objective of this study is to compare soil bulk densities from within the shanked zone to adjacent outside the shanked zone.

III. PERSONNEL

Project Leader – Bruce Johnson
Field Coordinator –
Research or Senior Scientist – Frank Spurlock
Statistician – Bruce Johnson
Quality Assurance/Laboratory Liaison –
Chemist – (Name) or Analytical Laboratory Supervisor – (not needed)

IV. STUDY PLAN

This study plan intends to take advantage of fumigant flux studies where EM personnel may be able to conduct soil sampling on shanked applications.

Field coordinator must request that an extra pass of the shanking equipment be made with no pesticide injection and no tarpaulin. The extra pass should be through an area adjacent to the treated field, which has received the same preparation as the treated field. During this pass, careful observation and marking must be made of the position of each shank in the soil. Stakes can be driven into the soil at the start and end of this extra pass to denote where the shanks entered the soil. It may not be necessary for this extra pass to extend fully along the field, but should be at least 40m. Measurements should be made of the shanking apparatus to define (1) the distance between multiple shanks (2) the location of and dimension of any horizontal shanks (as in the case of the Noble plow) (3) the depth of the shank into the soil (4) the number of shanks. Pictures should be taken of the shank apparatus. Careful observation should be made of any mechanical devices following the shanks which are designed to smooth over the shank trace.

If other sampling or types of activities will occur adjacent to the field, one or more areas should be delineated using stakes and marking tape in order to preserve the soil without foot traffic until soil sampling can be conducted. A delineated rectangular sampling area with the shank lines should start and end away from the where the blades first entered the soil in order to avoid edge or end effects.

Given a rectangular area, then with one or more lines where a shank has been dragged through the soil, a random number table should be consulted to obtain 30 samples in the shank line. If there are multiple, parallel shank lines, then sampling should occur randomly from these lines, excluding the two outside lines. That is, for each sample, first a random number determines which line to sample from, then a second random number specifies the distance from the end to take the sample. See Figure 1.

Another method for chosing random sampling locations suggested by a reviewer is to divide the area up into equal sized squares (for example, 1 m2 or whatever is convenient). Systematically (on paper) number each square and randomly choose a subset of 30 from the list

Given the same rectangular area, each sample in the shank line will be accompanied by a paired sample which is nearby, but between the shank lines. This second sample should be midway between two shank lines, but at the same distance from the end as the paired shank line sample. A coin flip or equivalent can be used to determine from which side of the line to take the paired sample.

It is important that soil texture be determined at the depth of sampling. A single auger sample should be taken from the rectangular area from between 2-8” in depth.

V SAMPLING METHODS AND DATA ANALYSIS

Soil bulk density will be sampled between 2 and 8 inches depth according to SOP FSSO00.00. The shank trace sample should be centered over the shank line. The non-shank trace sample should be centered over the area between shank lines. If the plow is a Nobel type plow, then the sample should be taken centered above the horizontal wings and 2 inches below the surface where the central shank will have passed through. Soil texture can be sampled using FSSO02.00. Each field will yield 30 sample pairs (60 samples total). The number 30 is a rule of thumb for obtaining a normally distributed mean value. Each sample pair will be combined by subtracting the in-line bulk density from the corresponding not-in-line bulk density. If there is a measureable effect on the bulk density, the expectation is that the bulk density in-line will be lower than the bulk density not-in-line. Thus, the mean of the differences will be positive.

Each field will be considered a block. The difference data should first be tested for normality. If the data is not normal, non-parametric methods may have to be employed unless a suitable transformation can be determined.

Assuming that the data are normally distributed, a one-way ANOVA using the blocks (fields) as treatments will be performed. For example, assume that there are two fields.

Source	df	SS	MS	F
Field	1	FS	FS/1	FS/(ES/58)
Error	58	ES	ES/58	
Total	59			

This would test for a field effect. If there is no block (field) effect, then a simple t-test will be performed with the combined data. The t-test will will

H0: mean of differences not different from 0
H1: mean of differences > 0

If there is a block (field) effect, then each field will be analyzed separately, using the t test as described above. It will be particularly important to understand why there might be field differences and what, if any, corresponding variables such as soil moisture or texture relate to these differences.

Method FSSO00.00 requires use of method METH001.00 for determining soil water and soil texture determination uses SOP METH004.00. The soil water data should be clearly retained on the data sheets in order to enable subsequent analysis of any relationships between bulk density, shank trace, and soil moisture or texture.

VI TIMETABLE

Soil sampling: Aug 2010-Nov 2010
Bulk density and texture determination: Jan 2011-Mar 2011
Data analysis: Apr 2011-May 2011
Report Preparation: Jun 2011-Jul 2011

VII REFERENCES

Cryer, Steve and Ian van Wesenbeeck. 2007. Simplifying the implementation of CHAIN_2D with Modifications Specific to Soil Fumigation Practices. Chloropicrin Manufacturers Task Force, Consortium Number 65353, CMTF2007-4

Cryer, Steve and Ian van Wesenbeeck. 2009. Letter to USEPA,Office of Pesticide Programs,Regulatory Public Docket 7502P,1200 Pennsylvania Avenue, NW,Washington, District of Columbia 20460-0001 dated February 8,2009.

Johnson, Bruce. 2008. Memorandum to John Sanders on Dow AgroSciences-Chain2D Review dated November 14, 2008.

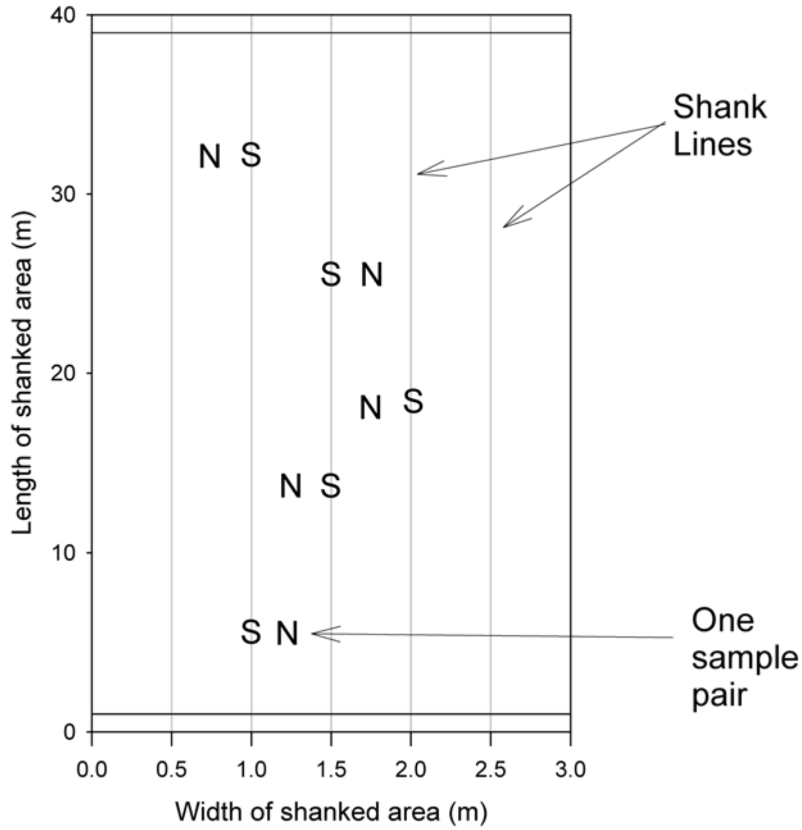

Fig. 1. 5 shank lines, outside 2 are excluded. S=shank line sample, N=non-shank line sample (paired to S), Shank lines at 1, 1.5 and 2.0m sampled. Sampling area starts in 1m from ends of treatment. Only 5 pairs shown.

Appendix 1. Review of Protocol for Shank Trace Study

Jing Tao   09/02/2009

Here are two points for statistics in the protocol:

1. Random sampling

The protocol uses two sets of random numbers to respectively determine the line to sample from and the distance from the end to take samples. An alternative method is to use one set of random numbers. Divide the designed sampling area to squares with the same area (e.g. 1 m*1 m) and number every square in the order (e.g. the total is 40). Extract 10 random numbers from 1 to 40, which is the number of square to take samples. The sample location (center or edge) in a square can be decided ahead and should keep consistent for all the squares. The side of the line can be determined by the coin flip or equivalent as the protocol.

2. ANOVA and t-test
   1) The difference data should be tested for its normality before using t-test. If they are not normal, other methods (e.g nonparametric) is better to use.

   2) The protocol tries to use ANOVA to eliminate the effect of field. ANOVA consider the data as a model like this:

$$Y_{ij} = \mu + \tau_j + \varepsilon_{ij}$$

   Where Y_{ij} is the difference between pairs
   μ is the constant
   τ_j is the effect of j field on μ
   $\varepsilon_{ij} \sim N(0, \sigma^2)$ mutually independent

   In this model, we can estimate the contrast between the effects of different fields, but μ and each τ_j are not individually estimable. The mean of Y_{ij} is the estimate of $\mu + \tau$ and MSE can not be used as its variance in the t-test. There is no appropriate way to separate μ and τ but difference between field effects can be analyzed. So

   3) I think we can just look at if the field effect exists first. If it does not, use t-test or other method to determine if Y>0. If it does, we may analyze each field individually or ignore the effect with proper discussion. If it is possible, a pilot study is good to see the pattern, variance and possible result of the data, which will be helpful to choose the analysis method.

Appendix 2. Response to review

1. Agree. I don't really care how randomization is performed as long as it's done. I added your text.
2. (1) Agree. Test for normality first. I added text.
   (2) Agree. Cant separate field effect from shank trace effect.
   (3). I did not initially agree with this, I still wanted to use an error term estimate which was free of field effects. In other words, using the MSE from the ANOVA, instead of using the estimated standard deviation from the combined t-test. In order to investigate this, I set up a Crystal Ball simulation with two fields, each field with 10 paired samples. I used 1.5 g/cm3 bulk density for everything. I used -0.2 g/cm3 as the 'true' population parameter effect of the shank trace (mu). I let the two field effects (tau1 and tau2) range from -0.2 g/cm3 to +0.2 g/cm3, giving 25 combinations. Note that when tau1 or tau2 is 0.2, this nullifies the shank trace effect. Perhaps this could be thought of as dry sandy soil, which would not hold any structure, for example. By symmetry, only the diagonal and 12 combinations need to be examined. I analyzed the data in two ways: t-test based on anova MSE (shown as t(anova) in Table 1) or t-test based on combined data (shown as t(comb) in Table 1) from both fields (n=20). In both cases, I tested whether the mean of the 20 differences was significantly greater than zero (t with 19 degrees of freedom, 95th percentile is 1.73). I simulated 10,000 times for each combination of tau1 and tau2 and kept track of the fraction of times that a significant result was obtained.(i.e. the null hypothesis of no difference was rejected). In other words, I determined the power of each test for a variety of values of tau1 and tau2.

The other simulation details are the error terms were all normal with 0 mean and standard deviation of 0.15 g/cm3. This is equivalent to a 10% CV, which is a ballpark value for bulk density measurements (Folegatti et al. 2001, Wang et al. 2008). The equation for the in-line measurements is the one you gave in your review:

$$Y_{ij} = \mu + \tau_j + \varepsilon_{ij}$$

With j=1,2 for two fields. The equation for the not-in-line measurements is simpler

$$Y_{ij} = \mu + \varepsilon_{ij}$$

Table 1. Comparison of fraction of results which yielded rejection of the null hypothesis at the alpha=0.05 level using a t-test based on either MSE from a one-way ANOVA (t(anova)) or the estimated standard deviation from combining 20 measurements from two fields with respective field effects of tau1 and tau2.							
			Tau2				
			-0.2	-0.1	0.0	0.1	0.2
Tau1	-0.2	t(anova)	1.00				
		t(comb)	1.00				
	-0.1	t(anova)	1.00	1.00			
		t(comb)	1.00	1.00			
	0.0	t(anova)	1.00	1.00	0.99		
		t(comb)	1.00	1.00	0.99		
	0.1	t(anova)	1.00	0.99	0.92	0.65	
		t(comb)	1.00	0.99	0.91	0.65	
	0.2	t(anova)	0.96	0.93	0.66	0.27	0.05
		t(comb)	0.99	0.84	0.59	0.25	0.05

Table 1 shows that the detection of significant differences ranged from 1.00 to 0.05. The 0.05 fractions resulted when tau1 and tau2 were both 0.2, which nullified the shank trace effect of -0.2. Generally, where there were differences in the power of the test, the t-test which relied on the MSE from the ANOVA performed somewhat better than the t-test based on the combined data with no field effects removed. This was my original goal in proposing to utilize the MSE from the ANOVA. It was to remove field effects from the variance estimate so that the mean (even though it includes the field effects) would be tested agains the 'within' group variance. The maximum difference between the estimated standard deviations occurred in the case where tau1=+0.2 and tau2=-0,2. In that case the average over the distribution of standard deviations based on MSE was 0.209 compared to the corresponding average over the distribution of standard deviations based on the combined t-test of 0.292. However, in the corresponding cell in Table 1, both tests had high power (0.96 and 0.99) because of the apparently overwhelming combined effect in field 2 of -0.2+-0.2=-0.4.

After conducting this simulation, it strikes me that the difference between the two methods does not yield a large difference in terms of statistical power. Therefore, I can accept your proposal to perform ANOVA to test for field effects and if there are no effects, then combine the data. If there are field effects, then analyze each field separately. I have modified the proposed statistical analysis to reflect this.

References Appendix 2.

Folegatti, Marcos Vinícius, René Porfirio Camponez do Brasil and Flávio Favaro Blanco. 2001. SAMPLING EQUIPAMENT FOR SOIL BULK DENSITY DETERMINATION TESTED IN A KANDIUDALFIC EUTRUDOX AND A TYPIC HAPLUDOX. Scientia Agricola, v.58, n.4, p.833-838

Wang Z., B. Zhang, K. Song, D. Liu, F. Li, L. Hu, H. Yang, Z. Liu. 2008. SOIL BULK DENSITY IN CROPLANDS OF NORTHEAST CHINA UNDER DIFFERENT LANDSCAPE ATTRIBUTES. Bulletin UASVM, Agriculture 65(1):345-350.