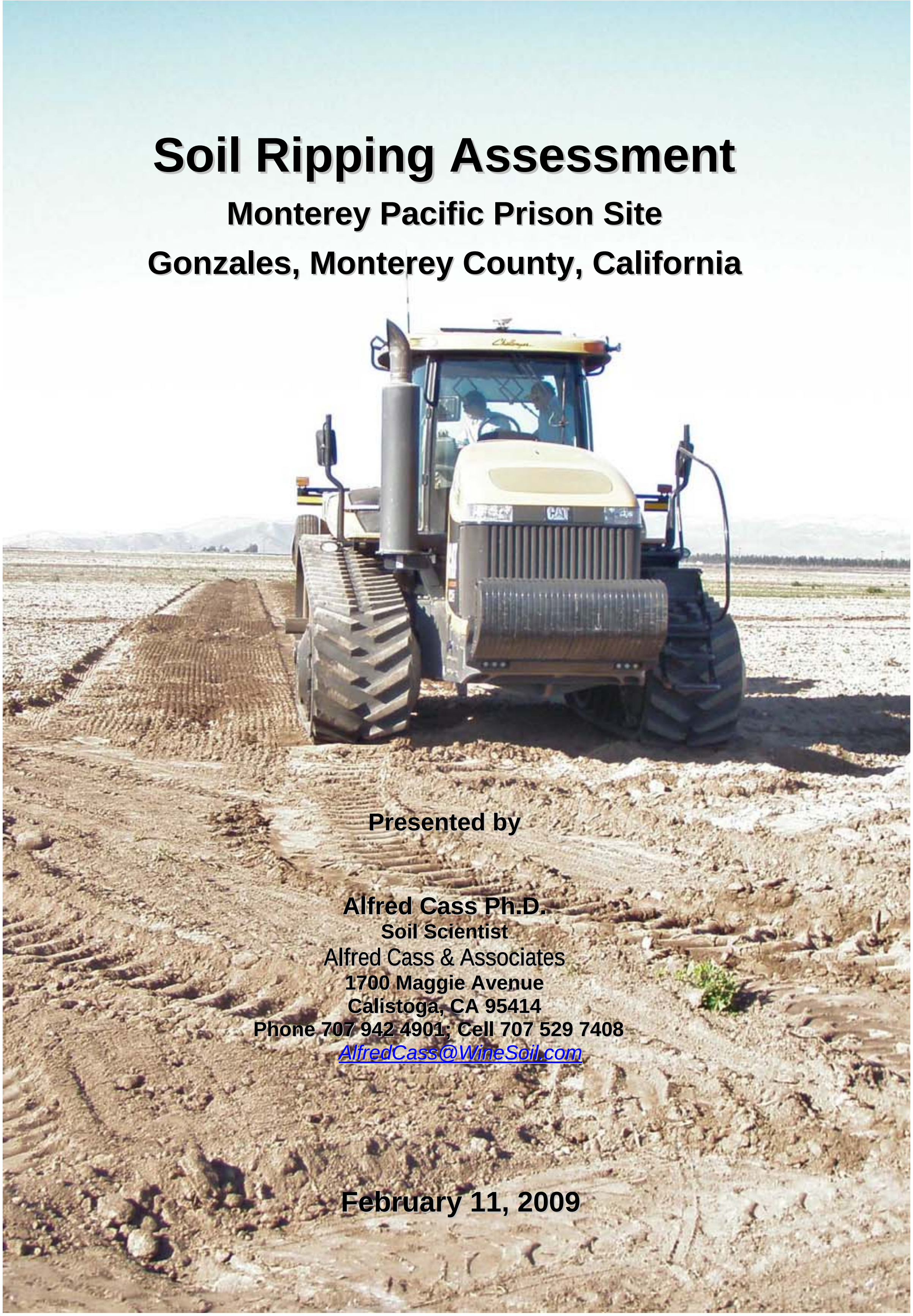

Soil Ripping Assessment

Monterey Pacific Prison Site

Gonzales, Monterey County, California

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Evaluation of Ripping Quality on Monterey Pacific Prison Site

Summary

The importance of ripping as an essential component of site preparation in establishing vineyards focuses attention on the need to routinely evaluate the quality of ripping. The quality of ripping largely reflects the future quality of the root systems of the vines.

Several numerical parameters are available for judging the effectiveness of ripping:
- volume of soil decompacted (size of the root zone),
- extent of decompaction (the strength of the soil in the root zone),
- Sustainability of decompaction (persistence of favorable root growth conditions).

We evaluated these parameters on the Monterey Pacific Prison Site after ripping soil using standard slip plows and a SoilWorks 700 mm ripping tool. The SoilWorks tool created better conditions for vine root growth as judged by these parameters.

However, the soil water content on much of the development site is too high for optimum ripping conditions using the SoilWorks tool and certainly too wet for the slip plow operation. A cover crop should be sown to dry the site to the soil plastic limit water content and further ripping should be delayed until then.

Introduction

Site preparation is a fundamental activity in establishing vineyards. The type of work and attention to detail in site preparation has a profound impact on the future success of the vineyard. In particular, soil tillage by ripping is an intrinsic component of site preparation and a critical part of other preparatory activities including amendment addition and row configuration. The basic aim of soil “ripping” in establishing vineyards is to decompact and loosen soil to create a vine root zone that will facilitate survival, growth and performance of the vines to sustain fruit production for as many years as possible. Achieving this objective involves considerations relating to promoting root growth, creating optimum root volume and enhancing sustainability of the vineyard.

Each of these concepts has considerable ramifications that will affect fruit production capacity and quality and future management of the vineyard. Consequently, the effect of any particular ripping operation needs to be closely tied to the overall business plan for the vineyard and the design of the vineyard being established.

The purpose of the work reported here was to characterize, in quantitative terms, the effects of different types of ripping on the soils of the “Prison Site” near Soledad, California and to select an optimum tool configuration to ensure best possible site preparation quality.

The site is a level alluvial plain of about 400 acres situated just north of the Salinas Valley State Prison and lying between Highway 101 and the Gabilan Mountains. The soils have been evaluated for viticultural production and those soil observation points closest to the ripping observation points have been cross-referenced to the ripping evaluation observation points. Broadly, the soils in the northern and eastern areas where ripping was evaluated are dominated by sandy clay and sandy clay loam textures and are designated as “Clay N” and “Clay E”. In the southern parts, sandy loam soil textures predominate and are referred to as “Sand S”.

Two ripping tools were in use for developing the site. A pair of standard slip plows (Figure 1) powered by two D8 Caterpillar steel track tractors, were used to rip soil at 45 degrees to the proposed row direction in the Clay N and the Sandy S areas, receptively. On both these areas a Challenger rubber track tractor powering a SoilWorks “Curved Flat 700 mm” Vibrosoiler with low-set secondary wing (Figure 1) was used to rip experimental lines for evaluating the tool performance. However, a 500 mm wing was fitted for a test rip on clay soils on the eastern side of the block (Clay E).

Figure: 1 Standard slip plow (left) and a SoilWorks “Curved Flat 700 mm” Vibrosoiler with low-set secondary wing (right).

Parameters for Evaluating Ripping Quality

The essential aim of soil ripping is to create a favorable root zone for vine growth to facilitate in survival, growth and performance of the vines that will be established on the site. In these terms, the quality of soil ripping can be judged by considering the volume of soil decompacted (“breakout”), the effectiveness of the decompaction (soil strength), and the sustainability of the decompacted condition (persistence through time). Numerical criteria can be defined for these factors that enable ripping quality to be evaluated objectively.

Increased Root Volume ("Breakout")

Vines need a certain optimum root volume to function properly but there is no absolute root volume that can be defined as a criterion for judging ripping quality. The optimum root volume is site and enterprise specific, depending on many factors related to climate, vine type, rootstock and soil type. Consequently, criteria for defining the root volume created by ripping must be related to the performance characteristics of the ripping tool.

If we consider a hypothetical ideal ripping profile, a reasonable postulation would be that the width of decompaction should be at least twice as wide as the depth of insertion below the surface. In this ideal model, the ripped profile is a rectangle, twice as wide as it is deep. This ideal model provides a standard against which we can evaluate real ripping tines and we can define the Decompacted Area Index (DAI) as

$$DAI = 2D_{rip}^2/A_{decom}$$

where D_{rip} is the depth from the original soil surface to the level where soil properties have been measurably changed and A_{decom} is the decompacted area (rip profile) where soil properties have been measurably changed, notably soil strength.

The expected range in values for DAI is between 0 and 1. An efficient ripping tool would be expected to have a Decompaction Area Index (DAI) of about 1 although an exceptionally efficient tool might exceed 1. Poor ripping tools exhibit DAI of less than 0.5. A subjective interpretation of the expected range of DAI for ripping evaluation is given in Table 1

Decompaction

Decompaction of soil involves fracturing the inherent soil structure of an element of soil to increase the volume, so reducing the bulk density (mass of soil per unit of volume) and increasing the air-filled porosity. Effective fracturing of the soil structure and manufacture of large air-filled pores reduces the strength of soil and enhances root growth of plants established in the soil after ripping.

The most convenient way of measuring compaction and decompaction is via soil strength measurement. A standardized method for quantifying soil strength is to measure penetration resistance using a cone penetrometer (Weaich et al. 1992). A cone penetrometer has a standard steel cone on a relieved shaft (ASAE 2000) attached to a device that records the force on the cone (strain gauge) as it is inserted into soil at a slow rate. Calibration of the strain gauge output allows the force to be expressed as a pressure (kPa, MPa or psi).

The ability of grape vine roots to grow through soil has been determined and calibrated against a standard cone penetrometer. Van Hussteen (1983) reported this critical limit to be 2.5 MPa but Myburgh et al. (1992) reported more convincing data that showed vine root growth stopped at 2.0 MPa. This information provides criteria for evaluating soil strength reduction after ripping. However, because soil strength is so variable in soil, we need to consider the average and peak values as well as the variability. A criterion for quality evaluation in soil preparation is the need to create uniformity of soil conditions as well as to achieve absolute levels of soil quality.

So, in evaluating decompaction we evaluate soil penetration resistance in terms of the average value measured in a particular penetrometer insertion into various locations on the face of a ripped profile as well the maximum value obtained and the standard error of the average. The critical absolute penetration resistance value we use, for a moist soil, is PR_o less than or equal to 2 MPa (2000 kPa or 290 psi). But we wish also to reference this critical value to the soil strength outside the ripped profile. So, we define a "Decompaction Index" (DI) as

$$DI = PR_{out}/PR_{in}$$

where PR_{out} is the average or the maximum of penetration resistance outside the rip zone and PR_{in} is the average or the maximum or the standard error of penetration resistance inside the rip zone.

The Decompaction Index (DI) is dimensionless and in practice may range between about 1 and about 10. If the DI is 1 then essentially no decompaction has occurred in ripping. If DI is greater than 1 and penetration resistance is greater than 2 MPa then the ripping operation did decompact the soil but not enough to enhance root growth. If DI is greater than 1 and penetration resistance is less than 2 MPa then the ripping operation has been successful and a measure of success is the magnitude of the DI. If the DI is less than 1, the ripping operation caused compaction instead of decompaction. If DI is 1 and penetration resistance is 2 MPa or less, the soil did not need ripping.

Not only do we wish to decompact soil by ripping, but we would like to create uniform conditions in the root zone to promote uniform vine growth and uniform fruit ripening. Uniformity of decompaction, UDI is defined as

$$UDI = SEPR_{out/}SEPR_{in}$$

where $SEPR_{out}$ is the standard error of penetration resistance outside the rip zone and $SEPR_{in}$ is the standard error of penetration resistance inside the rip zone.

As for DI, the Uniformity of Decompaction (UDI) is also dimensionless and may also range from about 1 to 10. If UDI is 1, there has been no change in uniformity of penetration resistance from ripping. If less than 1, more variability has been created by ripping. If UDI is greater than 1 then the ripping operation has been successful in creating uniformity and the magnitude of the UDI is a measure of success.

Table 1: Parameter values for judging ripping quality.

Ripping Quality	Penetration Resistance (PR)			Decompaction Index (mean or maximum PR) (DI)	Uniformity Decompaction Index (UDI)	Decompaction Area Index (DAI)
	MPa	kPa	psi			
Excellent	< 0.5	< 500	< 70	> 6	> 6	> 0.75
Good	0.5 to 1.5	500 to 1500	70 to 200	3 to 6	3 to 6	0.5 to 0.75
Moderate	1.5 to 2.5	1500 to 2500	200 to 350	1 to 3	1 to 3	0.25 to 0.5
Poor	> 2.5	> 2500	> 350	< 1	< 1	< 0.25

Sustainability of Ripping Improvement

Sustainability of decompaction created by ripping is usually addressed by application of amendments such as gypsum and compost and incorporating them into the ripped profile. Sustainability of ripping can also be promoted by adopting subsequent management practices such as cover cropping and traffic management that promote good soil structure. These practices stabilize and protect the beneficial soil aggregates created by ripping against the tendency of wetting and drying and vineyard traffic to re-compact the soil over time. Consequently, the sustainability of the physical improvements to soil properties created by ripping can really only be measured as a function of time which we could not do here.

However, soil moisture at the time of ripping can have an effect on sustainability. Dry soil behaves as a brittle solid and fractures explosively to produce large hard clods and fine powder. If soils are ripped when dry, much of the soil will fracture into fine aggregates (< 1 mm, < 0.04 inch) that will rapidly coalesce (weld together) when wetted, reducing the sustainability of the ripping. Soils ripped too wet will not fracture optimally either since they are plastic enough to tend to flow past the ripping tool and may compact in the process.

Ripping at the correct subsoil moisture content is critical for effective decompaction of all soils with significant clay content (sandy clay loams through to clays). This optimum water content is called the (Lower) Plastic Limit. It is the water content at which the soil mechanical behavior changes from brittle to plastic. At this water content the soil will fracture correctly to yield moderate (5 to 25 mm diameter) fragments necessary for optimum root penetration. The texture of soil affects the Plastic Limit water content. Sandy soils have quite low Plastic Limit water contents, generally around 10 % or less and loamy soils 10 to 20 % depending on clay content while clayey soils only show plastic behavior at more than about 20 % volumetric water content.

Other factors which have a bearing on sustainability are the weight of machinery used for ripping and the number of passes necessary to create acceptable conditions. Generally heavier machinery damages soil structure more than lighter machinery, creating more dust and powder. The more passes needed to complete the work, the greater the structural damage and the greater the chance of creating dust and powder.

Measurement of Ripping Quality Parameters

We excavated trenches at right angles to rip lines produced by the slip plows and the SoilWorks ripping tools. Some slip plow profiles were excavated at right angles to the future row direction to obtain a perspective on root zone size. This means they were at about 45 degrees to the rip direction.

The rip profile was identified by feel using a geological hammer and demarcated with white paint sprayed onto the soil surface. The extent of the rip profile was verified using a hand-held penetrometer fitted with a standard cone (ASAE 2000) and representative values recorded. The original soil surface was also located and demarcated with white paint. The dimensions of the rip profile were determined and recorded. A photograph was taken of the rip profile, identified by a code consisting of the date (20090203) and a unique number (01 to 19).

The penetrometer consists of a stainless steel 6 mm scaled down version of the standard ASAE (2000) cone fixed to a 3 mm stainless steel shaft 200 mm long. The shaft is attached to a small computer via a 250 N strain gauge which measures the force on the cone and passed the signal to the computer. The computer converts the force to a pressure (kPa) via a preprogrammed calibration factor unique to the cone and strain gauge. The computer measures the pressure on the shaft at regular intervals (5 to readings over 200 mm) and calculates a mean value and the standard error of the mean to enable assessment of the variability of the chain of readings. The maximum value of the set of readings is also recorded. These measurements were made at 3 levels down the depth of the rip profile, both within and outside the decompacted profile as shown in Figure 2.

Volumetric water content of the soil in the ripped profile was also measured at selected sites. A Stevenson Hydroprobe sensor connected to a hand-held computer was used for this purpose.

The data obtained are listed in the Appendix tables attached to this report. Table A1 is a catalogue of all the data obtained, Table A2 is a record of the profile photographs, Table A3 is a record of all the computed data and Table A4 is a reference description of the soil profiles data obtained near the rip sites during the soil evaluation.

Table 2, in the body of this report, summarizes the important physical data obtained in this investigation

Table 2: Average of the mean, maximum and standard error pentration resistance values measured in the ripped profiles of two ripping tools: two standard slip plows working in sandy and clayey soils and one SoilWorks Vibrosoiler working in the same clayey and sandy soils

-X.XX Ripping has caused compaction

🟥 Marginal benefit from ripping

🟩 Substantial benefit from ripping in terms of ripping quality parameters

Trench ID	Texture and Location on Site	Tine Name	Penetration Resisistance inside and outside the rip zone (MPa)												Decompacted Profile Dimensions		
			Average of Mean PR				Average of Maximum PR				Average Standard Error				Depth (inch)	Nominal Area	Decompacted Area Index
			Outside Rip Zone	Inside Rip Zone	Difference	Average Decompaction Index	Outside Rip Zone	Inside Rip Zone	Difference	Max Decompaction Index	Outside Rip Zone	Inside Rip Zone	Difference	Uniformility Decompaction Index	Outside Rip Zone	Inside Rip Zone	
1	Sandy S	Slip plow #1	2.0	1.1	0.86	1.8	3.4	1.8	1.6	1.9	0.40	0.28	0.12	1.4	47	940	0.21
2			2.7	0.77	1.9	3.5	4.0	1.4	2.7	3.0	0.53	0.26	0.27	2.1	48	1176	0.26
3			1.9	0.67	1.2	2.8	3.5	1.1	2.4	3.1	0.39	0.17	0.21	2.2	44	1320	0.34
4			1.4	0.81	0.60	1.7	2.2	2.1	0.18	1.1	0.30	0.28	0.03	1.1	36	1008	0.39
14	Clay N	Slip Plow #2	1.6	1.4	0.21	1.2	2.4	2.1	0.30	1.1	0.29	0.25	0.04	1.2	29	841	0.50
5			1.9	1.3	0.66	1.5	3.1	3.3	-0.17	0.9	0.40	0.39	0.01	1.0	45	1800	0.44
6			1.6	1.1	0.48	1.4	2.8	2.3	0.43	1.2	0.37	0.47	-0.09	0.8	46	1380	0.33
7			2.4	2.2	0.2	1.1	4.0	3.2	0.85	1.3	0.46	0.51	-0.05	0.9	39	1034	0.34
8			2.4	1.2	1.2	2.0	4.3	1.9	2.4	2.3	0.51	0.32	0.19	1.6	38	893	0.31
17			1.9	1.5	0.41	1.3	3.1	2.4	0.70	1.3	0.33	0.28	0.05	1.2	35	1050	0.43
9	Sandy S	SoilWorks First Pass	1.9	0.59	1.3	3.3	3.0	0.78	2.3	3.9	0.46	0.15	0.31	3.0	43	1763	0.48
10			2.9	1.2	1.8	2.6	4.9	2.3	2.6	2.2	0.60	0.36	0.24	1.7	44	2024	0.52
11		SoilWorks Second Pass	3.5	0.65	2.9	5.5	5.5	1.0	4.5	5.7	0.73	0.16	0.57	4.7	46	2047	0.48
12			3.4	1.0	2.4	3.4	5.2	1.6	3.6	3.3	0.59	0.27	0.32	2.2	46	2047	0.48
13	Clay N	SoilWorks Second Pass	1.7	1.1	0.56	1.5	2.6	1.9	0.76	1.4	0.42	0.37	0.05	1.1	39	2184	0.72
16			3.3	0.94	2.4	3.5	5.0	1.2	3.8	4.3	0.51	0.13	0.38	4.0	36	2142	0.83
18	Clay E	SoilWorks Second Pass No Mounding Train	2.4	0.83	1.5	2.9	4.2	1.3	2.9	3.2	0.43	0.18	0.24	2.3	34	884	0.38
19			2.4	0.87	1.5	2.8	3.9	1.4	2.5	2.7	0.46	0.24	0.23	2.0	35	1260	0.51

Average Values:

Slip Plows overall # 1 and 2	2.0	1.2	0.77	1.8	3.3	2.2	1.1	1.7	0.40	0.32	0.08	1.3	41	1144	0.35
Slip Plow #1, Sandy S	2.0	0.84	1.1	2.5	3.3	1.6	1.7	2.3	0.40	0.25	0.16	1.7	44	1111	0.30
Slip Plow #2, Clay N	2.0	1.4	0.5	1.4	3.3	2.5	0.75	1.3	0.39	0.37	0.02	1.1	39	1166	0.39
SoilWorks overall	2.7	0.9	1.8	3.2	4.3	1.4	2.9	3.3	0.53	0.23	0.29	2.6	40	1794	0.55
SoilWorks 1st Pass, Sand	2.4	0.9	1.6	2.9	4.0	1.5	2.4	3.0	0.53	0.26	0.27	2.4	44	1894	0.50
SoilWorks 2nd Pass, Sand & Clay	2.8	0.9	1.9	3.3	4.4	1.4	3.0	3.4	0.52	0.22	0.30	2.7	39	1761	0.57
SoilWorks Sandy Soil, 1st & 2nd Pass	2.9	0.8	2.1	3.7	4.6	1.4	3.2	3.7	0.60	0.24	0.36	2.9	45	1970	0.49
SoilWorks Clayey Soil, 1st & 2nd Pass	2.4	0.9	1.5	2.7	3.9	1.4	2.5	2.9	0.45	0.23	0.23	2.4	36	1618	0.61
Slip Plow & SoilWorks, all data	2.3	1.1	1.2	2.4	3.7	1.8	1.9	2.4	0.45	0.28	0.17	1.9	41	1433	0.44

Discussion of Results

The data in Table 2 and the images in Appendix Table A2 show that, generally the SoilWorks ripping tool created a better quality root zone than the slip plow. The area of the rip profile created by the SoilWorks tool is greater than that for the slip plows and the absolute strength of the soil is generally less. The Decompaction, Uniformity and Area Indices for the SoilWorks tool were superior to the slip plow Indices and the rating of the SoilWorks is generally "Good" according to the class limits shown in Table 2, although the Uniformity of Decompaction Index for the SoilWorks ripper is just below 3 due largely to high soil moisture in the "Clay" areas. The data suggest that uniformity of soil strength is increased by two passes of the SoilWorks ripper.

The poorer performance of the slip plows is not unexpected since this tool has been falling from favor for at least 10 years because of several undesirable characteristics, notably the tendency to bring subsoil to the surface and the large operational draft. The data obtained for the slip plows reflects poor performance characteristics for decompaction, uniformity and root zone volume. There was some evidence in the data of recompaction in previously ripped lines because the tractor tracks ran in previously ripped lines.

The moist conditions prevalent on the site might have interfered with the flow of soil up the slip plows. A soil body seems to have built up on the slip plane (see Figure 1) which deformed the soil-engaging profile of the tool and which might explain the considerable soil disturbance and mixed decompaction results. The deeply disturbed soil surface will require considerable reworking to create a smooth surface for planting. Part of the reworking will need to address the recompaction problem. This raises questions about the sustainability of slip plow ripping, whether done when the soil is dry or moist.

The soil water content of the "Clay" areas to the north and East was high. For example at Rip Profile 13 water content was 30 % at a depth of about 24 inches and at Rip Profile 19 water content was over 20 % in the top 12 inches (Appendix Table A1). Since these soils have a sandy clay or sandy clay loam texture, this indicates that the soil water content is greater than the Plastic Limit and the best results from ripping are not likely until the overall water content on site has declined. Since there was no vegetation established on the site when the evaluation was done and further rain was expected, significant soil drying is unlikely unless a cover crop is planted.

To ensure the best possible ripping result before establishing vines, a cover crop needs to be sown as soon as possible. Drying the soil to the plastic limit can be accomplished using an appropriate cereal cover crop growing through the winter and spring months. The plastic limit will be reached some weeks after the last spring rains and will be indicated by a decline in the color and condition of the cover crop. Because the surface soil will usually be much drier than the plastic limit at this time, ripping at these low water contents is very destructive to surface soil structure. Precautions should be adopted to preserve surface structure such as minimizing the number of passes of the tractor and application of as much compost as possible, provided it is low in salinity and nitrogen (see Cass and Roberts 2005).

It was not possible to evaluate the optimum SoilWorks tool configuration because too few options were available for testing. The only difference in the way that the tool was configured was substitution of 700 mm wings for 500 mm wings (see Appendix Table A1). There were too few 500 mm test rips to fully evaluate the effect of this configuration and it was treated as part of the overall SoilWorks dataset. A proper evaluation of the various options available from the SoilWorks tools should be made with more test runs and when soil water content is at the plastic limit.

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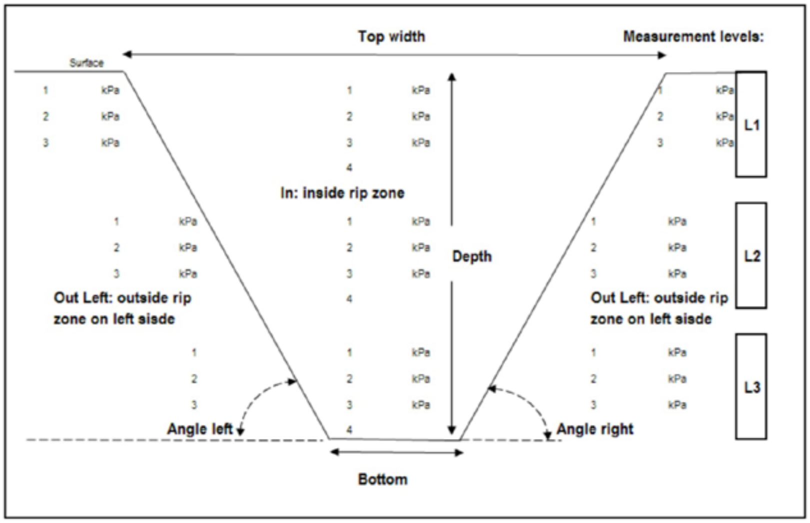


Figure 2: Data plan for soil strength measurements (1=mean value, 2=maximum, 3=standard error, 4=volumetric water content ratio) and dimensions of ripped profiles.

Appendix Table A1: Field Data for plow, tine configuration, rip profile dimensions and image (see Legend below and measurement diagram in Table 2)

Tine Name	Trench ID		Tractor/Wing Configuration		Wing Dimensions (inch,degrees)		Rip Dimensions (inch, degress)		Data Statistic	Penetration Resis Out Left			Penetration Resis In Rip			Penetration Resis Out Right		
										Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
Slip plow #1	Rip No.	1	Speed mph	3	Width	17.5	Top	28	Mean	1482	1863	2098	893	1471	997	1327	1361	3755
	Location	Sandy S	1st Wing Des	Slip	Length	97	Bottom	12	Max	3458	2786	3277	1773	2364	1342	2383	2287	6379
	Near Pit #	12, 7	2nd Wing	0	Angle	45	Depth	47	SE	531	291	369	255	362	212	242	293	666
	Alignment	45	2nd Pos	0	Oscillation	0	Angle L, R		VWR				0.1	0.15	0.16			
Slip plow #1	Rip No.	2	Speed mph	3	Width	17.5	Top	43	Mean	683	3859	4123	427	1249	629	683	1100	5666
	Location	Sandy S	1st Wing Des	Slip	Length	97	Bottom	6	Max	1243	5200	7475	701	2316	1041	1044	1827	7473
	Near Pit #	12, 7	2nd Wing	0	Angle	45	Depth	48	SE	178	473	1011	115	472	178	145	274	1088
	Alignment	45	2nd Pos	0	Oscillation	0	Angle L, R		VWR				0.11	0.17	0.19			
Slip plow #1	Rip No.	3	Speed mph	3	Width	17.5	Top	48	Mean	214	700	3696	309	749	954	588	1336	4724
	Location	Sandy S	1st Wing Des	Slip	Length	97	Bottom	12	Max	1219	1217	7473	424	1398	1542	1084	2619	7478
	Near Pit #	12, 7	2nd Wing	0	Angle	45	Depth	44	SE	77	173	907	49	206	268	130	288	756
	Alignment	90	2nd Pos	0	Oscillation	0	Angle L, R		VWR									
Slip plow #1	Rip No.	4	Speed mph	4	Width	17.5	Top	42	Mean	272	764	1732	114	811	1494	303	1464	3883
	Location	Sandy S	1st Wing Des	Slip	Length	97	Bottom	14	Max	385	1043	2771	416	1723	4031	469	2454	6273
	Near Pit #	12, 7	2nd Wing	0	Angle	45	Depth	36	SE	52	152	362	36	274	526	68	267	923
	Alignment	90	2nd Pos	0	Oscillation	0	Angle L, R		VWR									
Slip plow # 2	Rip No.	5	Speed mph	4	Width	17.5	Top	50	Mean	344	1400	4563	880	1652	1310	580	1610	3129
	Location	Clay N	1st Wing Des	Slip	Length	97	Bottom	30	Max	583	2559	7256	2508	2691	4641	843	2781	4624
	Near Pit #	4	2nd Wing	0	Angle	45	Depth	45	SE	88	341	873	344	397	432	142	396	575
	Alignment	90	2nd Pos	0	Oscillation	0	Angle L, R	90	VWR									
Slip plow # 2	Rip No.	6	Speed mph	4	Width	17.5	Top	46	Mean	1642	1713	2625	621	1533	1257	255	1595	1849
	Location	Clay N	1st Wing Des	Slip	Length	97	Bottom	14	Max	3434	2477	4243	1689	2499	2822	701	2945	2790
	Near Pit #	4	2nd Wing	0	Angle	45	Depth	46	SE	478	376	562	295	425	678	105	330	388
	Alignment	90	2nd Pos	0	Oscillation	0	Angle L, R	90, 45	VWR									
Slip plow # 2	Rip No.	7	Speed mph	4	Width	17.5	Top	47	Mean	1058	1201	3990	2327	2623	1790	1743	2322	4111
	Location	Clay N	1st Wing Des	Slip	Length	97	Bottom	6	Max	1638	1583	6488	3588	3868	2031	3602	3759	6974
	Near Pit #	4	2nd Wing	0	Angle	45	Depth	39	SE	217	208	820	464	531	528	445	367	678
	Alignment	45	2nd Pos	0	Oscillation	0	Angle L, R	45, 45	VWR									
Slip plow # 2	Rip No.	8	Speed mph	4	Width	17.5	Top	35	Mean	2362	1848	2924	1644	1127	759	1817	1184	4018
	Location	Clay N	1st Wing Des	Slip	Length	97	Bottom	12	Max	4446	3357	5927	2657	2021	988	3820	1874	6176
	Near Pit #	4	2nd Wing	0	Angle	45	Depth	38	SE	517	451	588	504	308	154	558	209	747
	Alignment	45	2nd Pos	0	Oscillation	0	Angle L, R	45, 45	VWR									
SoilWorks First Pass	Rip No.	9	Speed mph		Width	700 mm	Top	70	Mean	1225	1149	1616	525	430	809	984	1460	5064
	Location	Sandy S	1st Wing Des	Flat Curved	Length	0	Bottom	12	Max	2128	1600	2400	730	551	1070	1624	3053	7475
	Near Pit #	12, 7	2nd Wing	Yes	Angle		Depth	43	SE	335	243	419	152	56	242	227	450	1067
	Alignment	90	2nd Pos	Low	Oscillation		Angle L, R	30, 45	VWR									

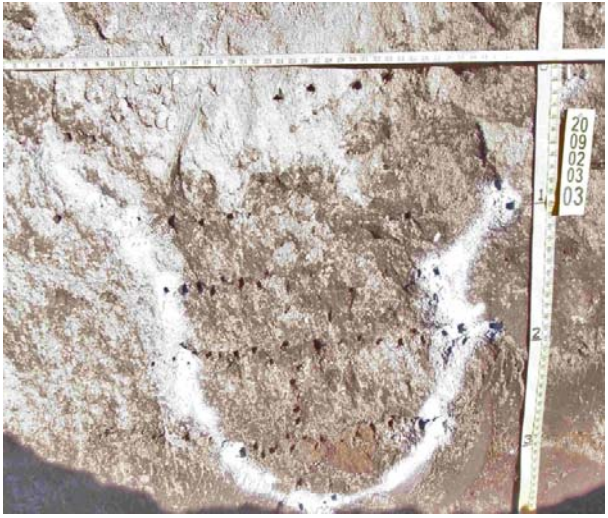
Appendix Table A1: Field Data for plow, tine configuration, rip profile dimensions and image (see Legend below and measurement diagram in Table 2)

Tine Name	Trench ID		Tractor/Wing Configuration		Wing Dimensions (inch,degrees)		Rip Dimensions (inch, degress)		Data Statistic	Penetration Resis Out Left			Penetration Resis In Rip			Penetration Resis Out Right		
										Level 1	Level 2	Level 3	Level 1	Level 2	Level 3	Level 1	Level 2	Level 3
SoilWorks First Pass	Rip No.	10	Speed mph		Width	700 mm	Top	80	Mean	1181	3081	4969	1034	1024	1408	2007	1747	4692
	Location	Sandy S	1st Wing Des	Flat curved	Length	0	Bottom	12	Max	2347	4844	7389	1956	2156	2645	3583	4169	6897
	Near Pit #	12, 7	2nd Wing	Yes	Angle		Depth	44	SE	374	584	678	328	388	374	550	584	853
	Alignment	90	2nd Pos	Low	Oscillation		Angle L, R	45, 45	VWR									
SoilWorks Second Pass	Rip No.	11	Speed mph		Width	700 mm	Top	71	Mean	2573	1750	5915	204	816	927	1309	4840	4880
	Location	Sandy S	1st Wing Des	Flat curved	Length	0	Bottom	18	Max	4711	2728	7466	400	1337	1171	3111	7466	7466
	Near Pit #	12,7	2nd Wing	Yes	Angle		Depth	46	SE	679	449	966	72	188	210	388	902	999
	Alignment	90	2nd Pos	Low	Oscillation		Angle L, R	45, 70	VWR				0.11	0.14	0.14			
SoilWorks Second Pass	Rip No.	12	Speed mph		Width	700 mm	Top	71	Mean	2016	3042	5461	610	1169	1203	2096	2299	5407
	Location	Sandy S	1st Wing Des	Flat curved	Length	0	Bottom	18	Max	3588	5256	7148	1053	1899	1797	3776	3821	7473
	Near Pit #	12,7	2nd Wing	Yes	Angle		Depth	46	SE	350	637	750	169	315	333	467	501	845
	Alignment	90	2nd Pos	Low	Oscillation		Angle L, R		VWR									
SoilWorks Second Pass	Rip No.	13	Speed mph		Width	700	Top	76	Mean	1156	2444	2458	1443	968	992	522	1885	1723
	Location	Clay N	1st Wing Des	Flat Curved	Length	0	Bottom	36	Max	2306	3366	3733	2685	1506	1447	640	2836	2952
	Near Pit #	10	2nd Wing	Yes	Angle		Depth	39	SE	452	640	401	524	297	286	62	412	559
	Alignment	90	2nd Pos	Low	Oscillation		Angle L, R	90, 90, 45,	VWR				0.16	0.3	0.21			
SoilWorks Second Pass	Rip No.	16	Speed mph		Width	700	Top	79	Mean	1864	4238	2598	1191	938	684	2343	3725	5092
	Location	Clay N	1st Wing Des	Flat Curved	Length	0	Bottom	40	Max	2641	6788	4239	1479	1327	710	3574	5432	7222
	Near Pit #	10	2nd Wing	Yes	Angle		Depth	36	SE	453	667	535	107	250	25	341	405	650
	Alignment	90	2nd Pos	Low	Oscillation		Angle L, R	60, 60	VWR									
Slip Plow # 2	Rip No.	14	Speed mph	4	Width	17.5	Top	52	Mean	702	2223	2110	515	1612	1947	618	1813	1944
	Location	Clay N	1st Wing Des	Slip	Length	97	Bottom	6	Max	1139	3434	3299	770	2581	3017	951	2884	2817
	Near Pit #	10	2nd Wing	0	Angle	45	Depth	29	SE	214	355	338	127	232	379	187	278	360
	Alignment	90	2nd Pos	0	Oscillation	0	Angle L, R	30, 30	VWR									
Slip Plow # 2	Rip No.	17	Speed mph	4	Width	17.5	Top	36	Mean	1326	1699	3143	435	2332	1637	196	313	4620
	Location	Clay N	1st Wing Des	Slip	Length	97	Bottom	24	Max	2132	2730	6497	1038	3521	2773	537	749	6205
	Near Pit #	10	2nd Wing	0	Angle	45	Depth	35	SE	302	282	621	204	327	321	82	158	557
	Alignment	90	2nd Pos	0	Oscillation	0	Angle L, R	75, 75	VWR									
SoilWorks 2 Pass No Bed Former	Rip No.	18	Speed mph		Width	500	Top	44	Mean	770	2998	3703	696	370	1425	951	2629	3206
	Location	East	1st Wing Des	Flat Curved	Length	0	Bottom	8	Max	1433	5159	7471	1009	662	2224	2031	3966	5157
	Near Pit #	29, 30	2nd Wing	Yes	Angle		Depth	34	SE	203	407	814	153	103	298	279	423	437
	Alignment	90	2nd Pos	Low	Oscillation		Angle L, R	45, 45	VWR									
SoilWorks 2 Pass No Bed Former	Rip No.	19	Speed mph		Width	500	Top	48	Mean	1044	1586	5154	928	902	779	613	1724	4346
	Location	East	1st Wing Des	Flat Curved	Length	0	Bottom	24	Max	1443	3246	7468	1559	1450	1289	1154	3010	7075
	Near Pit #	29, 30	2nd Wing	Yes	Angle		Depth	35	SE	251	429	877	264	224	222	187	334	696
	Alignment	90	2nd Pos	Low	Oscillation		Angle L, R	60, 30	VWR				0.21	0.19	0.16			

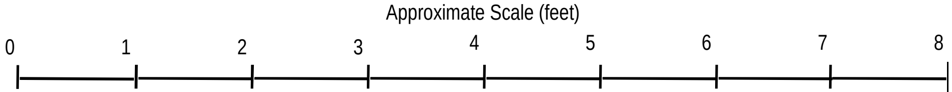
Appendix Table A2: Plow, tine configuration, rip profile dimensions and image

Approximate Scale (feet)

0 1 2 3 4 5 6 7 8

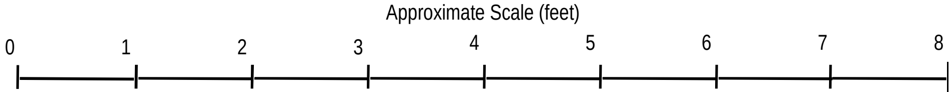
Slip plow #1	Rip No.	1	
	Location	Sandy S	
	Near Pit #	12, 7	
	Alignment	45	
Tractor/Wing Configuration	Speed mph	3	
	1st Wing Des	Slip	
	2nd Wing	0	
	2nd Pos	0	
Wing Dimensions (inch,degrees)	Width	17.5	
	Length	97	
	Angle	45	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	28	
	Bottom	12	
	Depth	47	
	Angle L, R	0	
Slip plow #1	Rip No.	2	
	Location	Sandy S	
	Near Pit # Pit	12, 7	
	Alignment	45	
Tractor/Wing Configuration	Speed mph	3	
	1st Wing Des	Slip	
	2nd Wing	0	
	2nd Pos	0	
Wing Dimensions (inch,degrees)	Width	17.5	
	Length	97	
	Angle	45	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	43	
	Bottom	6	
	Depth	48	
	Angle L, R	0	
Slip plow #1	Rip No.	3	
	Location	Sandy S	
	Near Pit # Pit	12, 7	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	3	
	1st Wing Des	Slip	
	2nd Wing	0	
	2nd Pos	0	
Wing Dimensions (inch,degrees)	Width	17.5	
	Length	97	
	Angle	45	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	48	
	Bottom	12	
	Depth	44	
	Angle L, R	0	

Appendix Table A2: Plow, tine configuration, rip profile dimensions and image



Slip plow #1	Rip No.	4	
	Location	Sandy S	
	Near Pit # Pit	12, 7	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	4	
	1st Wing Des	Slip	
	2nd Wing	0	
	2nd Pos	0	
Wing Dimensions (inch,degrees)	Width	17.5	
	Length	97	
	Angle	45	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	42	
	Bottom	14	
	Depth	36	
	Angle L, R	0	
Slip plow # 2	Rip No.	5	
	Location	Clay N	
	Near Pit # Pit	4	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	4	
	1st Wing Des	Slip	
	2nd Wing	0	
	2nd Pos	0	
Wing Dimensions (inch,degrees)	Width	17.5	
	Length	97	
	Angle	45	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	50	
	Bottom	30	
	Depth	45	
	Angle L, R	90	
Slip plow # 2	Rip No.	6	
	Location	Clay N	
	Near Pit # Pit	4	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	4	
	1st Wing Des	Slip	
	2nd Wing	0	
	2nd Pos	0	
Wing Dimensions (inch,degrees)	Width	17.5	
	Length	97	
	Angle	45	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	46	
	Bottom	14	
	Depth	46	
	Angle L, R	90, 45	

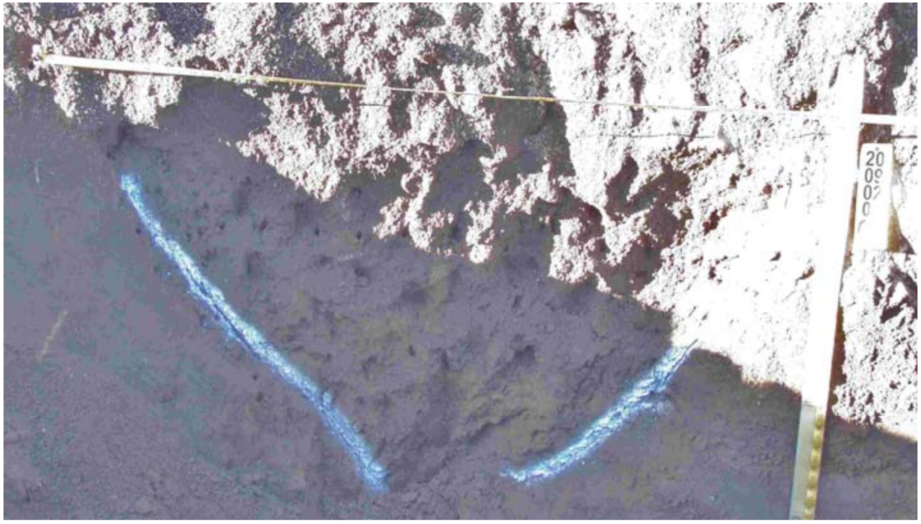
Appendix Table A2: Plow, tine configuration, rip profile dimensions and image



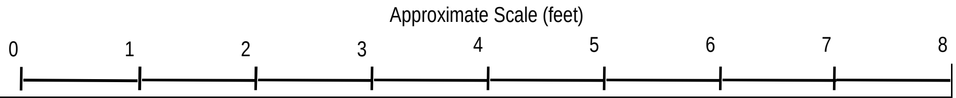
Slip plow # 2	Rip No.	7
	Location	Clay N
	Near Pit # Pit	4
	Alignment	45
Tractor/Wing Configuration	Speed mph	4
	1st Wing Des	Slip
	2nd Wing	0
	2nd Pos	0
Wing Dimensions (inch,degrees)	Width	17.5
	Length	97
	Angle	45
	Oscillation	0
Rip Dimensions (inch, degress)	Top	47
	Bottom	6
	Depth	39
	Angle L, R	45, 45

Slip plow # 2	Rip No.	8
	Location	Clay N
	Near Pit # Pit	4
	Alignment	45
Tractor/Wing Configuration	Speed mph	4
	1st Wing Des	Slip
	2nd Wing	0
	2nd Pos	0
Wing Dimensions (inch,degrees)	Width	17.5
	Length	97
	Angle	45
	Oscillation	0
Rip Dimensions (inch, degress)	Top	35
	Bottom	12
	Depth	38
	Angle L, R	45, 45

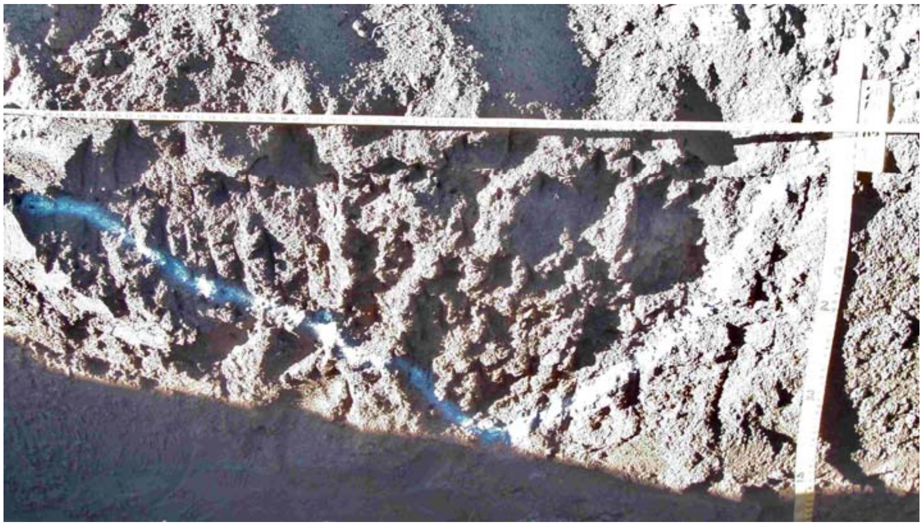
SoilWorks First Pass	Rip No.	9
	Location	Sandy S
	Near Pit # Pit	12, 7
	Alignment	90
Tractor/Wing Configuration	Speed mph	0
	1st Wing Des	Flat Curved
	2nd Wing	Yes
	2nd Pos	Low
Wing Dimensions (inch,degrees)	Width	700 mm
	Length	0
	Angle	0
	Oscillation	0
Rip Dimensions (inch, degress)	Top	70
	Bottom	12
	Depth	43
	Angle L, R	30, 45



Appendix Table A2: Plow, tine configuration, rip profile dimensions and image



SoilWorks First Pass	Rip No.	10
	Location	Sandy S
	Near Pit # Pit	12, 7
	Alignment	90
Tractor/Wing Configuration	Speed mph	0
	1st Wing Des	Flat curved
	2nd Wing	Yes
	2nd Pos	Low
Wing Dimensions (inch,degrees)	Width	700 mm
	Length	0
	Angle	0
	Oscillation	0
Rip Dimensions (inch, degress)	Top	80
	Bottom	12
	Depth	44
	Angle L, R	45, 45



SoilWorks Second Pass	Rip No.	11
	Location	Sandy S
	Near Pit # Pit	12,7
	Alignment	90
Tractor/Wing Configuration	Speed mph	0
	1st Wing Des	Flat curved
	2nd Wing	Yes
	2nd Pos	Low
Wing Dimensions (inch,degrees)	Width	700 mm
	Length	0
	Angle	0
	Oscillation	0
Rip Dimensions (inch, degress)	Top	71
	Bottom	18
	Depth	46
	Angle L, R	45, 70

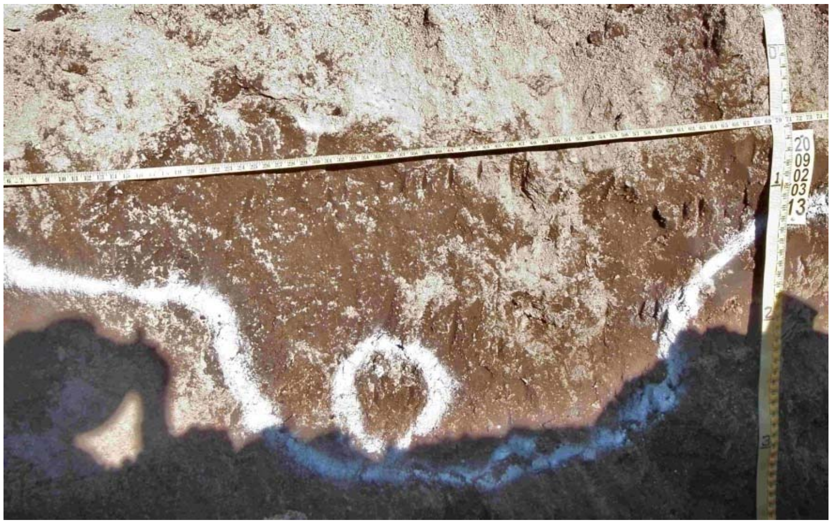
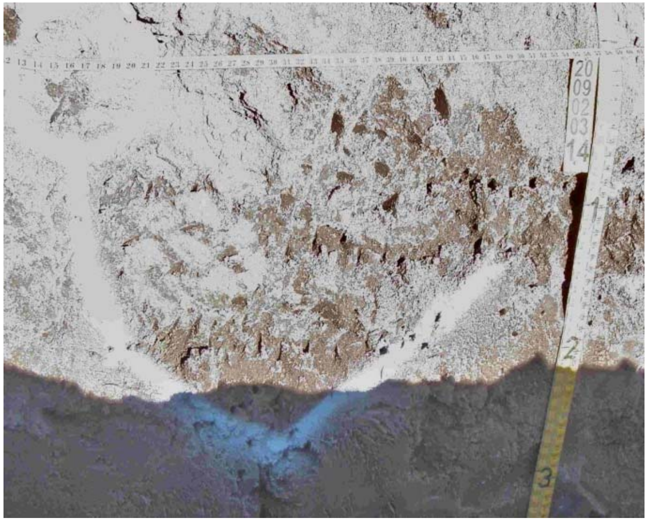
No photo available

SoilWorks Second Pass	Rip No.	12
	Location	Sandy S
	Near Pit # Pit	12,7
	Alignment	90
Tractor/Wing Configuration	Speed mph	0
	1st Wing Des	Flat curved
	2nd Wing	Yes
	2nd Pos	Low
Wing Dimensions (inch,degrees)	Width	700 mm
	Length	0
	Angle	0
	Oscillation	0
Rip Dimensions (inch, degress)	Top	71
	Bottom	18
	Depth	46
	Angle L, R	0

Appendix Table A2: Plow, tine configuration, rip profile dimensions and image

Approximate Scale (feet)

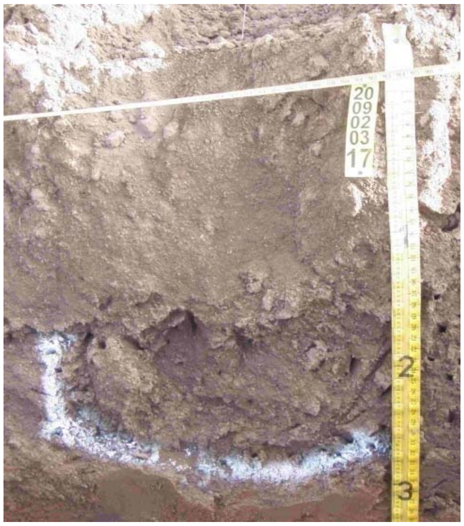
0 1 2 3 4 5 6 7 8

SoilWorks Second Pass	Rip No.	13	
	Location	Clay N	
	Near Pit # Pit	10	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	0	
	1st Wing Des	Flat Curved	
	2nd Wing	Yes	
	2nd Pos	Low	
Wing Dimensions (inch,degrees)	Width	700	
	Length	0	
	Angle	0	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	76	
	Bottom	36	
	Depth	39	
	Angle L, R	90, 90, 45, 45	
SoilWorks Second Pass	Rip No.	16	
	Location	Clay N	
	Near Pit # Pit	10	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	0	
	1st Wing Des	Flat Curved	
	2nd Wing	Yes	
	2nd Pos	Low	
Wing Dimensions (inch,degrees)	Width	700	
	Length	0	
	Angle	0	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	79	
	Bottom	40	
	Depth	36	
	Angle L, R	60, 60	
Slip Plow # 2	Rip No.	14	
	Location	Clay N	
	Near Pit # Pit	10	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	4	
	1st Wing Des	Slip	
	2nd Wing	0	
	2nd Pos	0	
Wing Dimensions (inch,degrees)	Width	17.5	
	Length	97	
	Angle	45	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	52	
	Bottom	6	
	Depth	29	
	Angle L, R	30, 30	

Appendix Table A2: Plow, tine configuration, rip profile dimensions and image

Approximate Scale (feet)

0 1 2 3 4 5 6 7 8

Slip Plow # 2	Rip No.	17	
	Location	Clay N	
	Near Pit # Pit	10	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	4	
	1st Wing Des	Slip	
	2nd Wing	0	
	2nd Pos	0	
Wing Dimensions (inch,degrees)	Width	17.5	
	Length	97	
	Angle	45	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	36	
	Bottom	24	
	Depth	35	
	Angle L, R	75, 75	
SoilWorks 2 Pass No Bed Former	Rip No.	18	
	Location	East	
	Near Pit # Pit	29, 30	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	0	
	1st Wing Des	Flat Curved	
	2nd Wing	Yes	
	2nd Pos	Low	
Wing Dimensions (inch,degrees)	Width	500	
	Length	0	
	Angle	0	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	44	
	Bottom	8	
	Depth	34	
	Angle L, R	45, 45	
SoilWorks 2 Pass No Bed Former	Rip No.	19	
	Location	East	
	Near Pit # Pit	29, 30	
	Alignment	90	
Tractor/Wing Configuration	Speed mph	0	
	1st Wing Des	Flat Curved	
	2nd Wing	Yes	
	2nd Pos	Low	
Wing Dimensions (inch,degrees)	Width	500	
	Length	0	
	Angle	0	
	Oscillation	0	
Rip Dimensions (inch, degress)	Top	48	
	Bottom	24	
	Depth	35	
	Angle L, R	60, 30	

Appendix Table A3: Averaged data for mean, maximum penetration resistance, standard error and root zone dimensions (see Legend below and diagram in Fig. 2)

Tine Name	Trench ID		Tractor/Wing Configuration		Wing Dimensions (inch,degrees)		Penetration Resisistance inside and outside the rip zone (MPa)												Root Zone Dimensions		
							Average of Mean PR				Average of Maximum PR				Average Standard Error				Depth (inch)	Nominal Area	Area Index
							Out-side	Inside	Difference	Average Decompaction Index	Out-side	Inside	Difference	Max Decompaction Index	Out-side	Inside	Difference	Uniformility Decompaction Index	inch	inch^2	
Slip plow #1	Rip No.	1	Speed mph	3	Width	17.5	1981	1120	861	1.8	3428	1826	1602	1.9	399	276	122	1.4	47	940	0.21
	Location	Sandy S	1st Wing Des	Slip	Length	97															
	Near Pit #	12, 7	2nd Wing	0	Angle	45															
	Alignment	45	2nd Pos	0	Oscillation	0															
Slip plow #1	Rip No.	2	Speed mph	3	Width	17.5	2686	768	1917	3.5	4044	1353	2691	3.0	528	255	273	2.1	48	1176	0.26
	Location	Sandy S	1st Wing Des	Slip	Length	97															
	Near Pit #	12, 7	2nd Wing	0	Angle	45															
	Alignment	45	2nd Pos	0	Oscillation	0															
Slip plow #1	Rip No.	3	Speed mph	3	Width	17.5	1876	671	1206	2.8	3515	1121	2394	3.1	389	174	214	2.2	44	1320	0.34
	Location	Sandy S	1st Wing Des	Slip	Length	97															
	Near Pit #	12, 7	2nd Wing	0	Angle	45															
	Alignment	90	2nd Pos	0	Oscillation	0															
Slip plow #1	Rip No.	4	Speed mph	4	Width	17.5	1403	806	597	1.7	2233	2057	176	1.1	304	279	25	1.1	36	1008	0.39
	Location	Sandy S	1st Wing Des	Slip	Length	97															
	Near Pit #	12, 7	2nd Wing	0	Angle	45															
	Alignment	90	2nd Pos	0	Oscillation	0															
Slip plow # 2	Rip No.	5	Speed mph	4	Width	17.5	1938	1281	657	1.5	3108	3280	-172	0.9	403	391	12	1.0	45	1800	0.44
	Location	Clay N	1st Wing Des	Slip	Length	97															
	Near Pit #	4	2nd Wing	0	Angle	45															
	Alignment	90	2nd Pos	0	Oscillation	0															
Slip plow # 2	Rip No.	6	Speed mph	4	Width	17.5	1613	1137	476	1.4	2765	2337	428	1.2	373	466	-93	0.8	46	1380	0.33
	Location	Clay N	1st Wing Des	Slip	Length	97															
	Near Pit #	4	2nd Wing	0	Angle	45															
	Alignment	90	2nd Pos	0	Oscillation	0															
Slip plow # 2	Rip No.	7	Speed mph	4	Width	17.5	2404	2247	158	1.1	4007	3162	845	1.3	456	508	-52	0.9	39	1033.5	0.34
	Location	Clay N	1st Wing Des	Slip	Length	97															
	Near Pit #	4	2nd Wing	0	Angle	45															
	Alignment	45	2nd Pos	0	Oscillation	0															

Appendix Table A3: Averaged data for mean, maximum penetration resistance, standard error and root zone dimensions (see Legend below and diagram in Fig. 2)

Tine Name	Trench ID		Tractor/Wing Configuration		Wing Dimensions (inch,degrees)		Penetration Resisistance inside and outside the rip zone (MPa)												Root Zone Dimensions		
							Average of Mean PR				Average of Maximum PR				Average Standard Error				Depth (inch)	Nominal Area	Area Index
							Outside	Inside	Difference	Average Decompaction Index	Outside	Inside	Difference	Max Decompaction Index	Outside	Inside	Difference	Uniformility Decompaction Index	inch	inch^2	
Slip plow # 2	Rip No.	8	Speed mph	4	Width	17.5	2359	1177	1182	2.0	4267	1889	2378	2.3	512	322	190	1.6	38	893	0.31
	Location	Clay N	1st Wing Des	Slip	Length	97															
	Near Pit #	4	2nd Wing	0	Angle	45															
	Alignment	45	2nd Pos	0	Oscillation	0															
SoilWorks First Pass	Rip No.	9	Speed mph	0	Width	700 mm	1916	588	1328	3.3	3047	784	2263	3.9	457	150	307	3.0	43	1763	0.48
	Location	Sandy S	1st Wing Des	Flat Curved	Length	0															
	Near Pit #	12, 7	2nd Wing	Yes	Angle	0															
	Alignment	90	2nd Pos	Low	Oscillation	0															
SoilWorks First Pass	Rip No.	10	Speed mph	0	Width	700 mm	2946	1155	1791	2.6	4872	2252	2619	2.2	604	363	241	1.7	44	2024	0.52
	Location	Sandy S	1st Wing Des	Flat curved	Length	0															
	Near Pit #	12, 7	2nd Wing	Yes	Angle	0															
	Alignment	90	2nd Pos	Low	Oscillation	0															
SoilWorks Second Pass	Rip No.	11	Speed mph	0	Width	700 mm	3545	649	2896	5.5	5491	969	4522	5.7	731	157	574	4.7	46	2047	0.48
	Location	Sandy S	1st Wing Des	Flat curved	Length	0															
	Near Pit #	12,7	2nd Wing	Yes	Angle	0															
	Alignment	90	2nd Pos	Low	Oscillation	0															
SoilWorks Second Pass	Rip No.	12	Speed mph	0	Width	700 mm	3387	994	2393	3.4	5177	1583	3594	3.3	592	272	319	2.2	46	2047	0.48
	Location	Sandy S	1st Wing Des	Flat curved	Length	0															
	Near Pit #	12,7	2nd Wing	Yes	Angle	0															
	Alignment	90	2nd Pos	Low	Oscillation	0															
SoilWorks Second Pass	Rip No.	13	Speed mph	0	Width	700	1698	1134	564	1.5	2639	1879	760	1.4	421	369	52	1.1	39	2184	0.72
	Location	Clay N	1st Wing Des	Flat Curved	Length	0															
	Near Pit #	10	2nd Wing	Yes	Angle	0															
	Alignment	90	2nd Pos	Low	Oscillation	0															
SoilWorks Second Pass	Rip No.	16	Speed mph	0	Width	700	3310	938	2372	3.5	4983	1172	3811	4.3	509	127	381	4.0	36	2142	0.83
	Location	Clay N	1st Wing Des	Flat Curved	Length	0															
	Near Pit #	10	2nd Wing	Yes	Angle	0															
	Alignment	90	2nd Pos	Low	Oscillation	0															

Appendix Table A3: Averaged data for mean, maximum penetration resistance, standard error and root zone dimensions (see Legend below and diagram in Fig. 2)

Tine Name	Trench ID		Tractor/Wing Configuration		Wing Dimensions (inch,degrees)		Penetration Resisistance inside and outside the rip zone (MPa)												Root Zone Dimensions		
							Average of Mean PR				Average of Maximum PR				Average Standard Error				Depth (inch)	Nominal Area	Area Index
							Outside	Inside	Difference	Average Decompaction Index	Outside	Inside	Difference	Max Decompaction Index	Outside	Inside	Difference	Uniformility Decompaction Index	inch	inch^2	
Slip Plow # 2	Rip No.	14	Speed mph	4	Width	17.5	1568	1358	210	1.2	2421	2123	298	1.1	289	246	43	1.2	29	841	0.50
	Location	Clay N	1st Wing Des	Slip	Length	97															
	Near Pit #	10	2nd Wing	0	Angle	45															
	Alignment	90	2nd Pos	0	Oscillation	0															
Slip Plow # 2	Rip No.	17	Speed mph	4	Width	17.5	1883	1468	415	1.3	3142	2444	698	1.3	334	284	50	1.2	35	1050	0.43
	Location	Clay N	1st Wing Des	Slip	Length	97															
	Near Pit #	10	2nd Wing	0	Angle	45															
	Alignment	90	2nd Pos	0	Oscillation	0															
SoilWorks 2 Pass No Bed Former	Rip No.	18	Speed mph	0	Width	500	2376	830	1546	2.9	4203	1298	2905	3.2	427	185	243	2.3	34	884	0.38
	Location	East	1st Wing Des	Flat Curved	Length	0															
	Near Pit #	29, 30	2nd Wing	Yes	Angle	0															
	Alignment	90	2nd Pos	Low	Oscillation	0															
SoilWorks 2 Pass No Bed Former	Rip No.	19	Speed mph	0	Width	500	2411	870	1542	2.8	3899	1433	2467	2.7	462	237	226	2.0	35	1260	0.51
	Location	East	1st Wing Des	Flat Curved	Length	0															
	Near Pit #	29, 30	2nd Wing	Yes	Angle	0															
	Alignment	90	2nd Pos	Low	Oscillation	0															

Table A4: Summary of soil profile properties

Very low drainage ▥ Low draiange ▨ Questionable ▥ Undesirable ▤ Perched water table ▦ Water table ▤

Depth	Color	Texture	Rock	Soil Structure		Plasticity	Visible pores	Mottles	Free lime	Root density	TAW inch	pH	P	K	Ca	Mg	EC	ESP	Al
				Hardness	Type							-	mg/kg		cmolc+/kg		dS/m	%	mg/kg

in. Profile 4 Strong Brown Sandy Clay Loam ERD (in.): 24

24	Strong Brown	Sandy clay loam	10 % < 1 inch Fractured	Friable	Blocky	Moderate	No	No		Many	3.6								
60	Strong Reddish Brown	Sandy clay loam	15 % < 1 inch Fractured	Firm	Massive	Moderate	Few	No		Zero	4.2								
72	Strong Reddish Brown	Sandy loam	10 % < 1 inch Fractured	Loose	Massive	Low	Few	No		Zero	1.3								

in. Profile 7 Strong Grayish Brown Sandy Loam ERD (in.): 30

30	Strong Grayish Brown	Sandy loam	15 % < 1 inch Fractured	Friable	Massive	Low	Few	No		Many	2.9								
48	Strong Yellowish Brown	Sandy loam	20 % < 1 inch Fractured	Firm	Massive	Low	Few	No		Zero	1.7								
72	Light Reddish Brown	Sand	20 % < 1 inch Fractured	Loose	Massive	Low	Few	No		Zero	1.7								

Total available water, P=Phosphorous, K=Potassium, Ca=Exchangeable calcium, Mg=Magnesium, EC=Electrical conductivity, ESP=Exchangeable sodium %, Al=Aluminum, ERD=Effective root depth

Table A4: Summary of soil profile properties

Very low drainage ▥ Low draiange ▨ Questionable 🟨 Undesirable 🟥 Perched water table ▦ Water table ▤

in. Profile 10 Strong Reddish Brown Sandy Loam ERD (in.): 22

Depth	Color	Texture	Rock	Soil Structure		Plasticity	Visible pores	Mottles	Free lime	Root density	TAW inch	pH	P	K	Ca	Mg	EC	ESP	Al
				Hardness	Type							-	mg/kg		cmolc+/kg		dS/m	%	mg/kg
22	Strong Reddish Brown	Sandy loam	5 % < 1 inch Fractured	Friable	Blocky	Moderate	No	No		Many	2.5								
54	Strong Reddish Brown	Sandy clay loam	10 % < 1 inch Fractured	Hard	Massive	Moderate	Few	15 % No		Zero	4.0								
72	Light Reddish Brown	Sandy loam	5 % < 1 inch Fractured	Friable	Massive	Low	Few	No		Zero	2.0								

in. Profile 12 Strong Grayish Brown Sandy Clay Loam ERD (in.): 6

Depth	Color	Texture	Rock	Soil Structure		Plasticity	Visible pores	Mottles	Free lime	Root density	TAW inch	pH	P	K	Ca	Mg	EC	ESP	Al
				Hardness	Type							-	mg/kg		cmolc+/kg		dS/m	%	mg/kg
6	Strong Grayish Brown	Sandy clay loam	10 % < 1 inch Fractured	Firm	Massive	Moderate	Few	No		Many	0.7								
24	Strong Grayish Brown	Sandy clay loam	10 % < 1 inch Fractured	Firm	Massive	Moderate	Few	No		Few	2.2								
48	Strong Reddish Brown	Sandy loam	20 % < 1 inch Fractured	Friable	Massive	Low	Few	No		Zero	2.2								
72	Strong Grayish Br	Sandy clay	10 % < 1 inch Fractured	Firm	Massive	Moderate	Few	No		Zero	2.4								

Total available water, P=Phosphorous, K=Potassium, Ca=Exchangeable calcium, Mg=Magnesium, EC=Electrical conductivity, ESP=Exchangeable sodium %, Al=Aluminum, ERD=Effective root depth

Table A4: Summary of soil profile properties

Very low drainage ▥ Low draiange ▨ Questionable ▥ Undesirable ▤ Perched water table ░ Water table ▤

Depth	Color	Texture	Rock	Soil Structure		Plasticity	Visible pores	Mottles	Free lime	Root density	TAW inch	pH	P	K	Ca	Mg	EC	ESP	Al
				Hardness	Type							-	mg/kg		cmolc+/kg		dS/m	%	mg/kg
in.	Profile 29 Dark Grayish Brown Sandy Clay Loam								ERD (in.):	72									
18	Dark Grayish Brown	Sandy clay loam	10 % < 1 inch Fractured	Friable	Blocky	Moderate	No	No		Few	2.7								
32	Strong Grayish Brown	Sand	10 % < 1 inch Fractured	Loose	Massive	Low	Few	No		Zero	1.1								
72	Strong Reddish Brown	Sand	15 % < 1 inch Fractured	Loose	Massive	Low	Few	No		Zero	3.0								
in.	Profile 30 Strong Grayish Brown Sandy Clay								ERD (in.):	30									
20	Strong Grayish Brown	Sandy clay	10 % < 1 inch Fractured	Friable	Massive	Moderate	Few	No		Many	2.0								
42	Strong Reddish Brown	Sandy clay loam	15 % < 1 inch Fractured	Firm	Massive	Moderate	Few	No		Zero	2.6								
72	Strong Reddish Brown	Sandy loam	5 % < 1 inch Fractured	Friable	Massive	Moderate	Few	No		Zero	3.3								

Total available water, P=Phosphorous, K=Potassium, Ca=Exchangeable calcium, Mg=Magnesium, EC=Electrical conductivity, ESP=Exchangeable sodium %, Al=Aluminum, ERD=Effective root depth