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Detection of Soil Macropores Using Smoke

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ABSTRACT:

Smoke bombs and a blower were used to demonstrate the presence of soil macropores. Smoke was blown into subsurface tile drains on several farms under a variety of soil conditions. Smoke emerged from the ground in a band over the tiles. This band varied in width from isolated spots to as wide as two metres. The technique has great potential as a demonstration to farmers.

DETECTION OF SOIL MACROPORES USING SMOKE

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BACKGROUND

Various studies have implicated soil macropores in the preferential flow of contaminants from the soil surface to tile drains and groundwater. Dean and Foran (1991) suggested that liquid manure was gaining quick access to subsurface tile drains because of macropore flow. Priebe and Blackmer (1989) found that macropore flow was an important factor affecting the movement and fate of nitrogen in Iowa soils.

Macropores are large continuous openings in field soils. They can be formed in a variety of ways: pores formed by soil fauna, pores formed by plant roots, cracks and fissures, and natural soil pipes (Beven and Germann, 1982). The size of these pores is quite variable. For the most part, macropores are considered to have an equivalent pore diameter of greater than 1,000 μm.

It is difficult to visualize the importance of macropore flow in a field or even the presence of soil macropores. Sometimes cracks are present on the soil surface but there is no way of knowing how extensive these cracks are below the surface. The same applies to wormholes.

Municipalities have for some time used the technique of blowing smoke into sewage pipes to detect leaks or illegal connections. With this in mind the following objectives were developed:

1. Investigate the feasibility of using smoke blown into field tiles to demonstrate the presence of soil macropores.

2. Investigate the use of the technique to show differences between soil types, surface conditions, soil moisture levels, etc.

3. Develop photos and other audio-visual material to be used as a graphic demonstration of the presence of soil macropores.

PROCEDURE

Selection of farms - During the fall of 1991 smoke tests were performed at four farms in the Exeter area of southwestern Ontario. Farms were chosen so as to give a variety of soil conditions. Information gathered at each farm included: crop cover; soil surface conditions; weather; and depth, length, material, and diameter of drainage tile. Soil samples at the surface and at a depth of 600 mm were collected for determination of soil moisture content.

Equipment setup - A source of nontoxic smoke was needed. The method chosen was to use smoke candles, available from a local safety supply company. During one of the farm visits a smoke generator was used. This consisted of a fogger using mineral oil as the source of smoke. These foggers are intended to be used with insecticide for backyard pest control.

The blower was a readily available rental unit. It consisted of a three horsepower gasoline engine powering a 15" centrifugal fan. The original intended use of this blower is for manhole ventilation. The rated capacity is in the order of 1500 cubic feet per minute. No fan performance chart was available to plot fan output against static pressure.

The farms in the study all had a site which provided easy access to a subsurface drain. In three of the four cases, the drain was 100 mm diameter plastic tubing. In the fourth case it was a corrugated steel pipe with a diameter of 200 mm (Farm 3).

A 100 mm diameter flexible metal pipe was used between the blower and the drainage tile. Figure 1 shows a typical setup. The blower was placed near the access point to the subsurface drain tile. Any necessary transitions were connected and

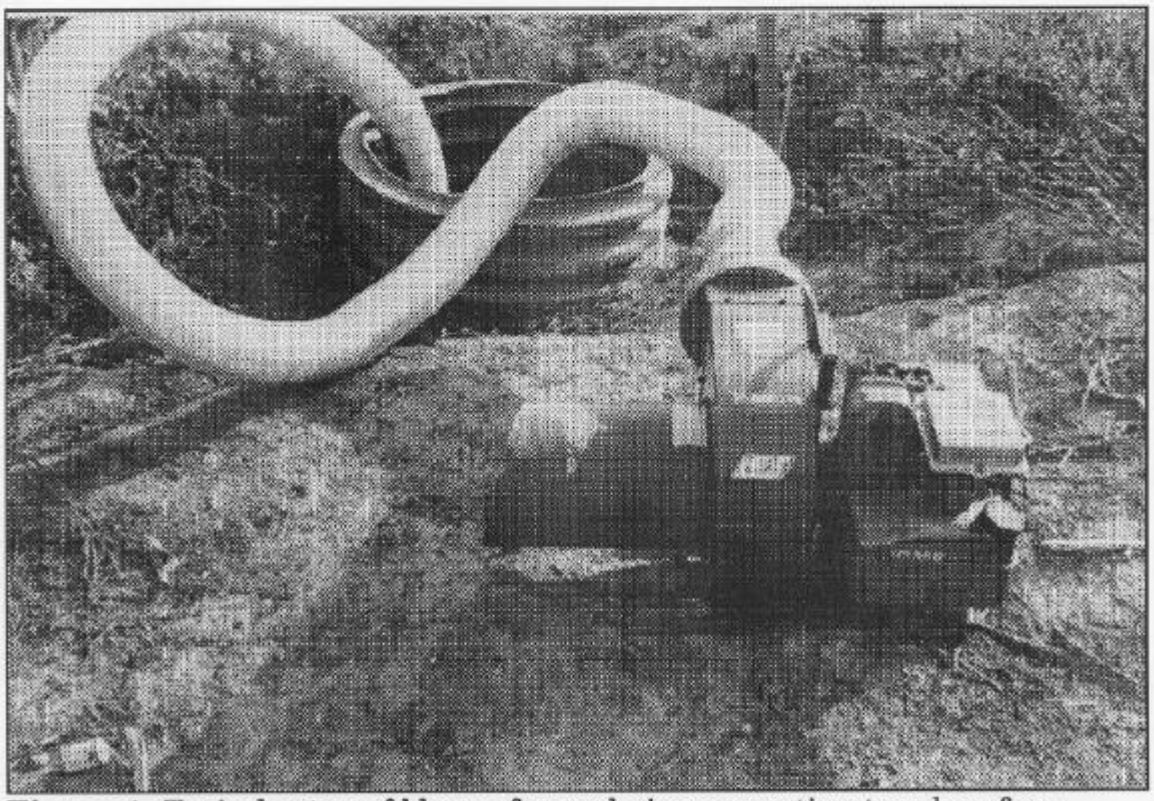

Figure 1 Typical setup of blower fan and pipe connecting to subsurface drain.

the pipe joints were taped liberally with duct tape. At the entrance to the subsurface drain, a special adapter was made. This was tapped so that a plastic tube could be fastened. This tube was connected to a manometer which was located at ground level. The manometer facilitated the measurement of static pressure generated by the blower. To make a tight connection in the drainage tile, a plastic bag was fastened to the end flange. As the system was pressurized, the bag expanded inside the corrugated drain tile, thus preventing loss of pressure. Figure 2 shows a view looking down into an observation pipe on one of the farms.

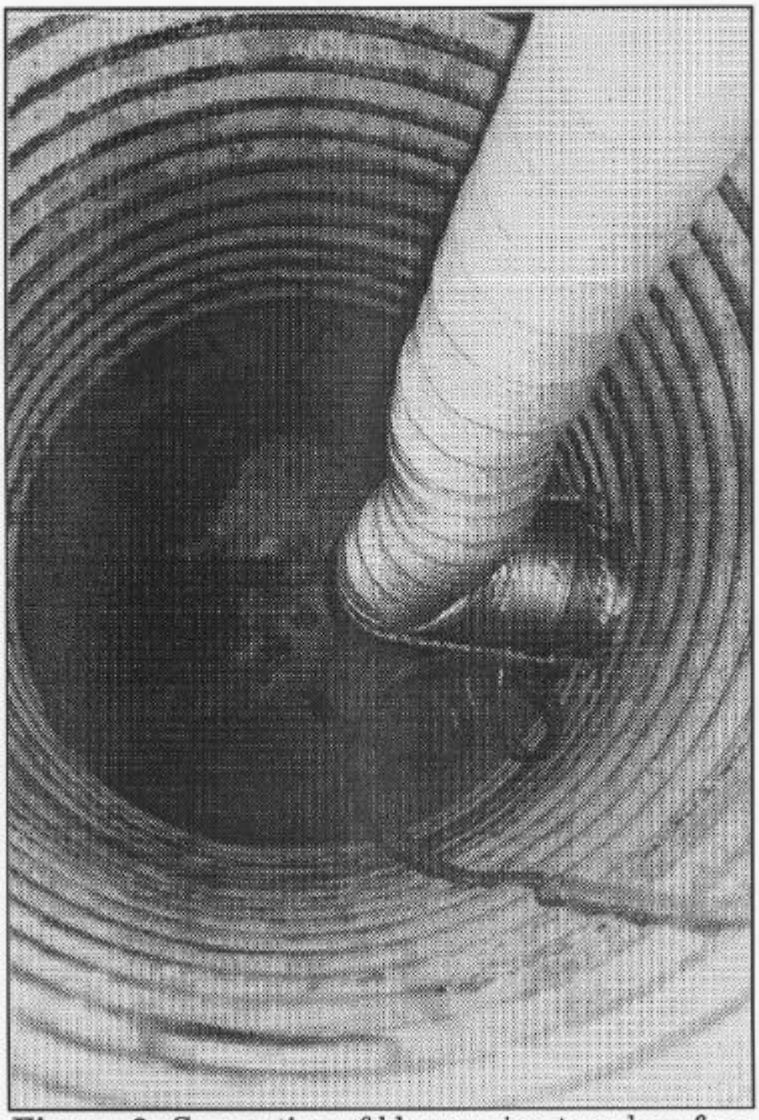

Figure 2 Connection of blower pipe to subsurface drain.

OBSERVATIONS AND RESULTS

Test setup - For the first farm, one minute smoke candles were used. These were rated at 8,000 cubic feet of smoke. The smoke candles were lit and inserted into the intake for the blower. In approximately ten seconds smoke had blown through the pipe, through the ground, and was coming out at the surface of the ground near the location of the blower. Over the following twenty seconds the smoke moved up the field and at about thirty seconds from start-up, the smoke had reached the furthest place where it was coming out of the ground. It soon became obvious that the one minute smoke candles would be inconvenient to use because of their short duration. For subsequent work, three minute smoke bombs were used. These were rated at 40,000 cubic feet of smoke.

As smoke emitted from the ground, small flags were pushed into the ground to mark the furthest location from the tile drain that smoke was seen. Two people walked down the field, one on each side of the smoking section of ground. By placing flags at regular intervals it was easy to see the area of soil over the tile drain through which smoke was moving. Figure 3 shows the location of the flags looking down the field away from the entry point for the smoke.

The static pressure varied from one farm to the next. In three of the six cases it was at 125 mm. On Farm 3, because of the larger diameter tile and because the drainage system was so extensive, only 25 mm of static pressure could be achieved.

As the distance from the point of origin increased, the amount of smoke coming from the ground decreased. This was to be expected, presumably resulting from the drop in pressure inside the tile. Farm 1 had the widest area of soil affected by the smoke. For several meters of length near the smoke inlet, the width of affected soil was approximately 2 m. The widest band found on any of the other farms was 1.2 m. This is shown graphically in Figure 4.

Farm 4 was tested in three separate ways. These are denoted by Farm 4A, Farm 4B, Farm 4C. In the case of 4B and 4C the static pressure was equal to that found on Farm 1 (i.e. 125 mm). However, the width of smoke pattern was much less. The different soil conditions suggest reasons for the apparent differences in macropore properties. Tests 4B and 4C were conducted when the soil was considerably wetter. In these two cases, the tiles were actually running (i.e. water was flowing through the tile drains). 4C had been chisel-plowed less than one week before the test. This seemed to make it harder for the smoke to move through the soil than was the case in 4B.

Some of the data gathered at the different sites is shown in Table 1. It is interesting to compare the numbers on the maximum distance from point of entry that smoke was detected coming out of the ground. In the case of 4C, smoke was found 190

meters from the point of entry. Compare this to 70 meters for Farm 2, which was the shortest distance.

While some trends do appear obvious, it is difficult to draw conclusions about differences between soil types, soil moisture levels, and soil surface conditions.

Figure 5 shows the soil surface on Farm 1. Smoke is coming from some of the cracks, while others are unaffected. This was the pattern observed on all of the farms. In some cases smoke could be seen emitting from wormholes while in other cases it was not. One thing that became clear was that even though there were differences from farm to farm, smoke could be seen coming from the ground in all cases. This does not necessarily mean that macropore flow of liquid down through the soil would have occurred to the same degree on all of the farms tested. It merely points out that soil macropores were present.

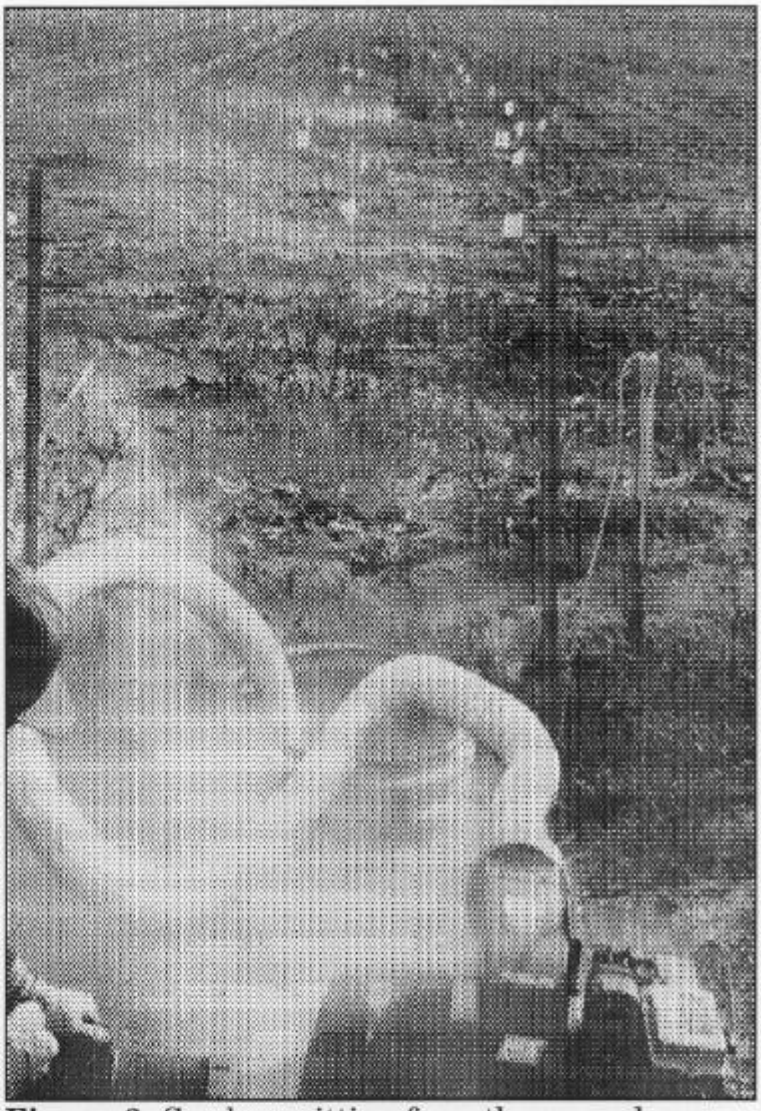

Figure 3 Smoke emitting from the ground following pressurization of the system.

On the day of the first test at Farm 1, a strong breeze was blowing. This did not seem to affect the performance of the technique. It was still quite easy to see where the smoke was coming out of the ground.

Farm 3 involved a larger diameter "Main" tile. This was a tile which had smaller 100 mm diameter tiles connecting to it. It was possible to see smoke coming out of the ground over the location of these lateral tiles. Actually, the smoke was detected a short distance up these laterals. This suggests that the technique of using smoke could be used to help locate field drainage systems.

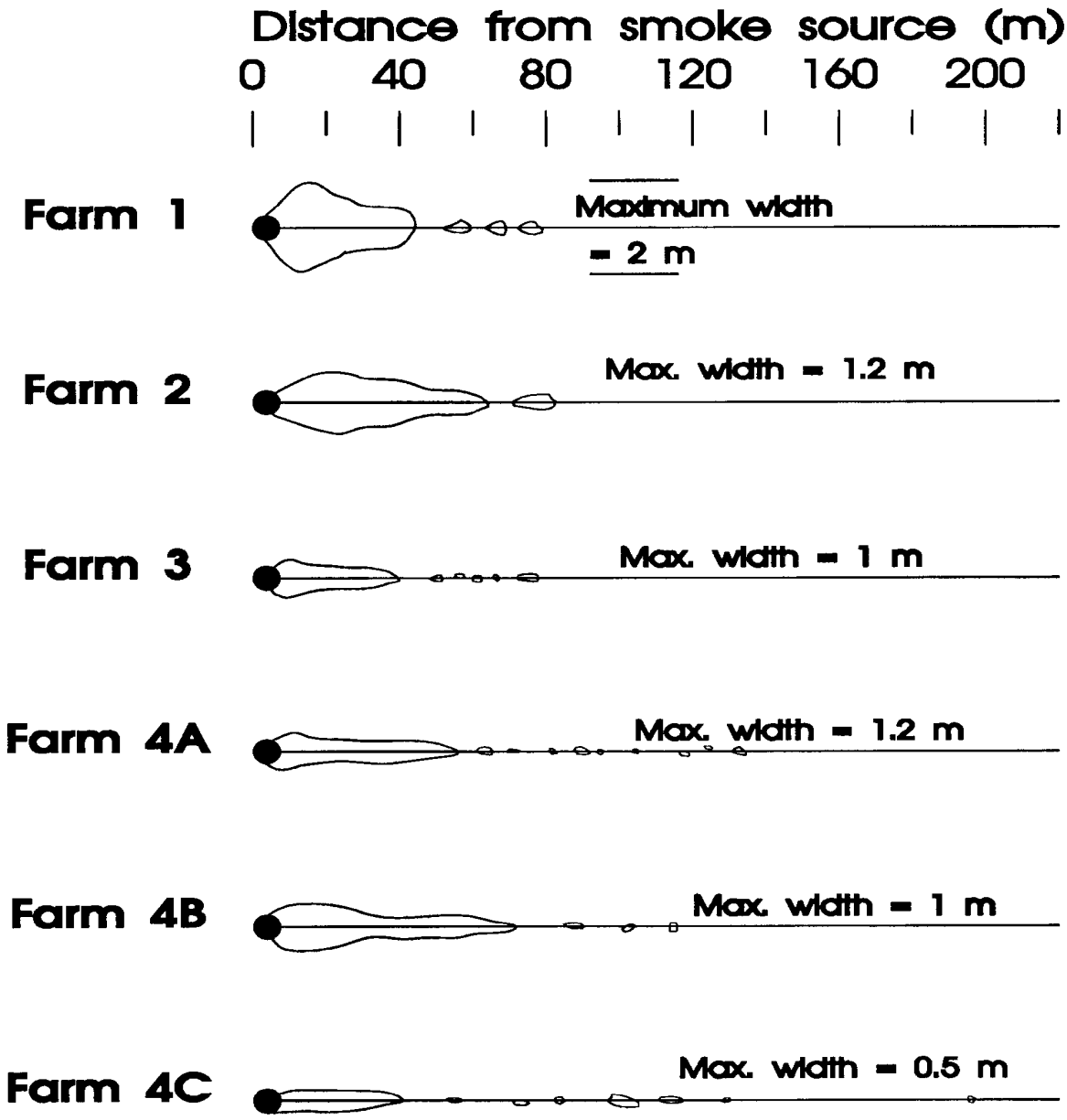

Figure 4 Schematic representation of area of soil affected by smoke for the six study locations (not drawn to scale).

Table 1: Summary of Selected Observations and Measurements Taken at the Six Test Sites.

	Farm 1	Farm 2	Farm 3	Farm 4A	Farm 4B	Farm 4C
Date (1991)	Oct. 22	Oct. 22	Oct. 23	Oct. 30	Dec. 12	Dec. 12
Soil type	Huron Clay Loam	Huron Clay Loam	Perth Clay Loam	Guelph Loam	Guelph Loam	Guelph Loam
Ground cover	silage corn stubble	freshly plowed corn ground	fall wheat 75 mm high	wheat stubble	wheat stubble	freshly chisel-plowed wheat stubble
Soil surface	dry, with small cracks	rough, dry	dry, cracks, wormholes	damp	wet	wet
Tile depth	900 mm	760 mm	900 mm	760 mm	760 mm	760 mm
Tile length (approx)	230 m	90 m	very long	300 m +	300 m +	300 m +
Tile diameter	100 mm	100 mm	150 mm	100 mm	100 mm	100 mm
Tile material	plastic	plastic	_	plastic	plastic	plastic
Soil moisture: *						
surface	23.2%	23.3%	20.1%	28.9%	32.9%	32.9%
600 mm depth	13.3%	18.3%	17.8%	21.2%	24.7%	24.7%
Water flowing in tiles	No	No	No	No	Yes	Yes
Max. static pressure	125 mm	88 mm	25 mm	100 mm	125 mm	125 mm
Max. dist. smoke detected	75 m	70 m	77 m	137 m	115 m	190 m

* Soil moisture = $\frac{\text{weight of soil water}}{\text{weight of dry soil}}$

There remain some unanswered questions about the use of smoke and the test setup that was used in this study. It appears as though a band of soil up to one meter on each side of the tile drain can contribute macropore flow to the tile drain. It is not clear what would have happened if a larger fan were used (i.e. that could generate a higher static pressure). It is possible that an even wider band of soil may have been affected. Also there was no attempt made to tap into the tile at various points to measure the pressure drop along the drainage tile. It is possible this could have given some indication of the porosity of the soil.

When the portable smoke generator was used as the source of smoke, it gave very similar results to the smoke candles. However, it was difficult to maintain the same volume of smoke production. This, therefore did not appear to be a viable alternative as the smoke source.

The value of the technique as an extension tool was demonstrated when a class from Centralia College was at one of the farms during a test. The students were quite

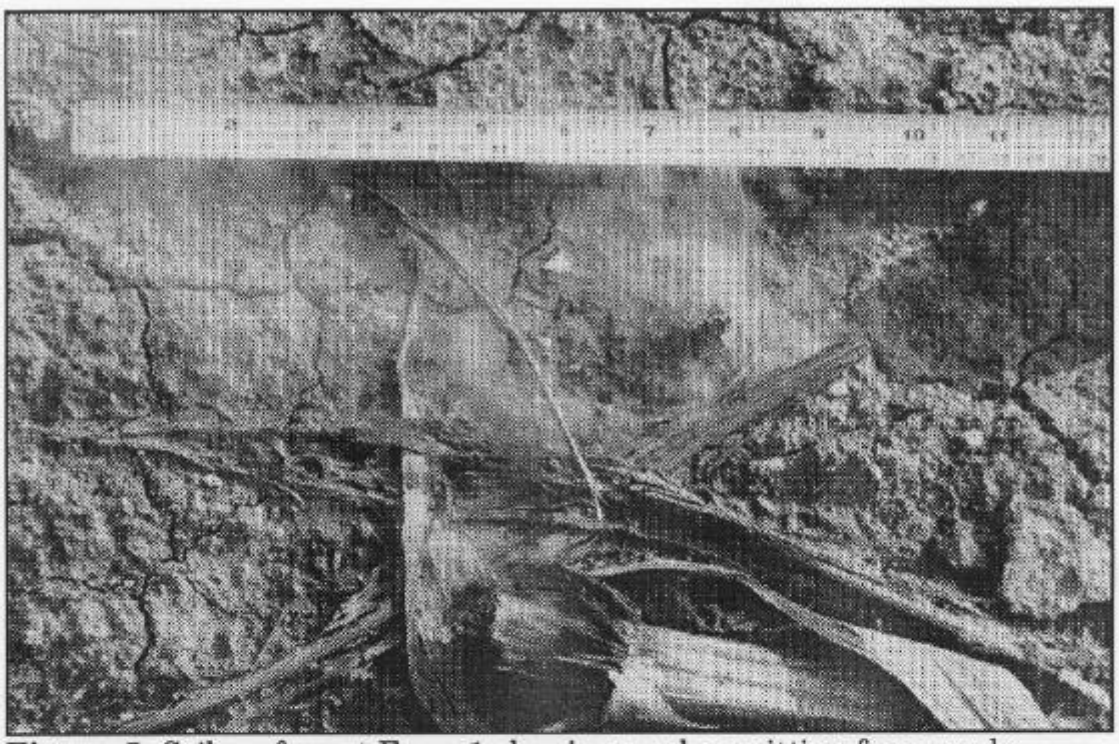

Figure 5 Soil surface at Farm 1 showing smoke emitting from cracks.

amazed with the graphic demonstration of smoke coming out of the ground. The speed that the smoke moves through the system and the volume of smoke coming from the ground is quite impressive to see.

Several photographs (black and white prints, colour prints, and colour slides) were taken at the various farms. As well, a television video tape was made. These will be used in future extension programs to try to educate people about the importance of macropores. The most dramatic demonstration however is still the field demonstration. This can be done fairly easily in most fields as long as a tile access point is available.

SUMMARY AND RECOMMENDATIONS

Four farms were visited during the fall of 1991. Smoke was blown into subsurface tile drainage systems and observations were made about the amount of smoke emitting from the soil surface. This smoke helped to point out the extent of soil macropores. The maximum width of the band of smoke above the tile drains varied from farm to farm. It was as narrow as .5 meters and as wide as 2 meters. Also, the length of area affected varied between 70 meters and 190 meters. The technique has great potential for demonstrating to farmers the presence of soil macropores and the amount of macropore flow that is possible. This technique is probably best used as an extension tool and is likely not as appropriate for conducting specific comparisons

between different fields. It may have a use on some farms as a technique to help locate subsurface drainage systems.

ACKNOWLEDGEMENTS

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