Small-Increment Electric Soil Sampler

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Measurement of soil bulk density and volumetric water content in small (≤2-cm) depth increments is tedious and time consuming. Most methods require compositing several subsamples to control measurement error, and few are feasible with loose, dry soils. We developed and tested a sampler that uses an electric linear actuator to push an intact soil core out of the sampling tube. The soil core is maintained in an upright position and protected from fracturing by remaining inside the tube until sectioned with a cutting saw. Precise length increments and flat cuts are easily obtained, even in loose soils. Compared with existing incremental sampling technology developed 30 yr ago, the electric sampler reduced sample variability by half. The electric sampler requires only 7 min to collect a 26-cm core and section it into 2-cm increments, compared with 20 min per core with the older sampler.

Accurate measurement of near-surface soil bulk density, volumetric water content, or both is critical for many investigations. Monitoring soil C and quantifying seed-zone environments are prime examples of this need, but assessment of plant nutrients, chemicals, and pollutants are other important topics. In addition, accurate near-surface volumetric measurements are needed to model heat, water, and air flow. Since bulk density fluctuates spatially and temporally, it is important to make multiple measurements across space and time.

Many useful incremental soil samplers have been developed. Most work best when soil water content is high enough to produce low soil strength but not so wet that the soil adheres to the inside of the sampling tube (Doran and Mielke, 1984; Elliott et al., 1999; Grossman and Reinsch, 2002). This poses a problem when soil samples need to be obtained under dry or changing conditions. Most sampling methods depend on the soil remaining as an intact core while it is laid horizontally and sectioned into depth increments. This is not possible under dry, loose conditions such as those found in the tilled mulch layer of summer-fallowed soils, where the surface soil sometimes flows as freely as dry beach sand.

Pikul et al. (1979) developed a tool capable of sampling loose soil in increments of ≤2 cm. The device has a 5-cm-square steel tube that is driven vertically into the soil to capture the soil core. After removing the sampler with the soil core inside, thin metal blades are inserted horizontally through slots at each depth increment. The soil from each increment is then removed sequentially. This sampler has been used successfully in numerous field studies during the past 30 yr.

Our objective was to design a faster and more accurate sampling method capable of determining bulk density in 2-cm increments in both loose and dry, consolidated soil. We compared our design with reports on other methods in the literature and also with the Pikul et al. (1979) sampler, since it is the regional standard for such sampling.

MATERIALS AND METHODS

The three essential components of the electric sampler are a clamp to hold the soil sampling tube, an electric linear actuator, and a switching device to stop the actuator at specific intervals (Fig. 1). The sampling tube containing the intact soil core is clamped in an almost vertical position to preserve the integrity of the core. As it is clamped into position, the bottom end of the tube is fitted over the piston of the linear actuator (Fig. 2), pushing the soil core up until it is flush with the top of the sample tube. Power to the linear actuator is routed through a microswitch that rides on a rod attached to the top of the piston. Notches placed at specific intervals on the rod stop the advance of the piston so that depth increments of the soil core can be cut at the top of the tube.

Two features of the sampler aid in cutting precise depth increments and also make it possible to incrementally sample unconsolidated soil. First, the soil core below the increment being cut remains inside the tube where it is prevented from shattering, sloughing, or fracturing. The end of the tube is the cutting guide and, with care, the face of the core can be made completely flat and in perfect alignment with the end of the tube. Second, the entire cutting operation can be performed with the sampling tube in an upright position, which preserves the intact core and also helps prevent the portion of the soil core being cut from breaking at a natural fracture.

We found a soil core angle of 20° from the vertical to be practical (Fig. 1) as this causes the cut sample to fall into a funnel that is positioned over the receiving container. Even a sharp knife will cause dry, consolidated soil to fracture. To avoid such undesirable random fracturing, we use a serrated blade (Fig. 2) to saw horizontally across the end of the tube. With care, it is even possible to saw through soil clods that are imbedded within loose soil. Our cutting saw is made from a section of a woodworker's coarse-tooth saw with the teeth flattened (i.e., a rip saw with the set removed) and dulled slightly.

The electric sampler is adaptable to a range of core lengths and diameters. We used sample tubes made from 51-mm o.d., 46-mm i.d. steel tubing, the bottom end of which had been hammered to reduce the opening to 44.8-mm i.d. The cutting edge was then sharpened without disturbing the 44.8-mm opening. To keep the sample from sliding out the bottom of the tube when being pulled from the soil, 6-mm-long metal fingers cut from 0.15-mm shim stock were soldered

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projecting upward into the inside of the tube just above the narrowed bottom end. Adhesive tape can be fashioned in the same way and also works well, but becomes dislodged and must be replaced often. We drive the sample tube using a 1.5-kg dead-blow, soft-face mallet, and pull it from the soil using a lever attached to the tube by a chain. When taking cores 30- to 50-cm long, soil compaction within the tube is usually <5 mm. Larger diameter, thinner wall tubes are recommended if compaction needs to be reduced in a particular application (Grossman and Reinsch, 2002).

To check the precision and speed of the electric incremental sampler, we compared it to the Pikul et al. (1979) sampler. Six side-by-side soil cores were taken from a tilled summer fallow field near Lind, WA, using both sample techniques. The comparison was repeated in an adjacent no-till summer fallow field. The soil was a Shano silt loam (coarse-silty, mixed, superactive, mesic Xeric Haplocambid) typical of the low-precipitation (<300-mm annual precipitation) crop production region of the Pacific Northwest.

RESULTS AND DISCUSSION

The electric sampler provided more precise determination of depth increments and, therefore, produced a lower standard deviation in bulk density estimates than the Pikul et al. (1979) sampler (Fig. 3). As noted by Raper and Erbach (1988) and Grossman and Reinsch (2002), it is difficult to determine the exact accuracy of a bulk density measurement method, but, in what is believed to be a relatively uniform soil, the method giving the lowest variance is assumed to be adding less measurement error to the natural spatial variability. This is not a logical necessity, because a given method might disturb the soil in a way that makes it more consistent, but if a method homogenizes samples it will result in uncharacteristic bulk densities that should be obvious to the observer.

In our comparison, the electric sampler produced a CV of 4%, and the Pikul et al. (1979) sampler a CV of 8%. Levene's test for homogeneity of variance (SAS Institute, 1998) indicated the variances were significantly different ($P > F = 0.002$). The MSE remaining after removing the depth effect is much lower for the electric sampler (Fig. 3).

Most reports of variance for bulk density measurements are derived from multicore-composite data points. Compositing several cores into one measured sample is a way to greatly reduce variance. Larger depth increments are also likely to reduce experimental error because the length-determination error is a smaller proportion of the entire increment. Pikul et al. (1979) composited four cores into each measurement and reported a CV of 6.6% for 1-cm increments. Allmaras et al. (1988) composited 8 to 16 cores per sample with a CV of 5% for 2-cm increments. The Pikul et al. (1979) and Allmaras et al. (1988) data were from soils similar to those used in the present study. Doran and Mielke (1984) composited 10 cores in each measured sample and reported CVs of 1 to 5% for 7.5-cm increments.

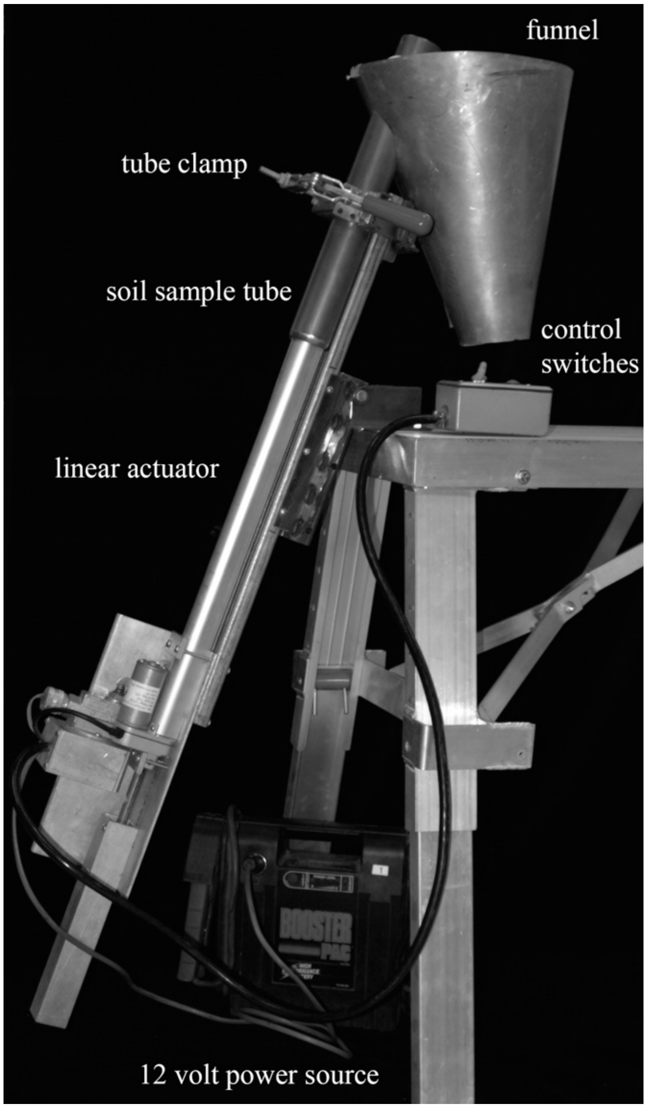

Fig. 1. Small-increment electric soil sampler mounted on a bench for use in the field. The soil core in the sampling tube is pushed out the top of the tube by the linear actuator. A switch controls stopping points at predetermined intervals, and the operator cuts the soil core flush with the top of the sample tube.

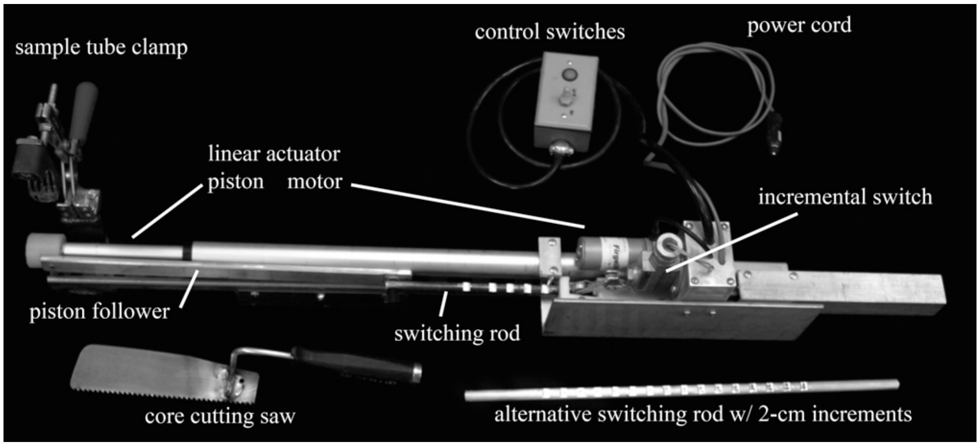

Fig. 2. Small-increment electric soil sampler with the sample tube removed. The switching rod can be changed when different depth increments are desired. Also shown is the saw used to cut dry, consolidated soil flush with the end of the sample tube without uncontrolled fracture of the soil core.

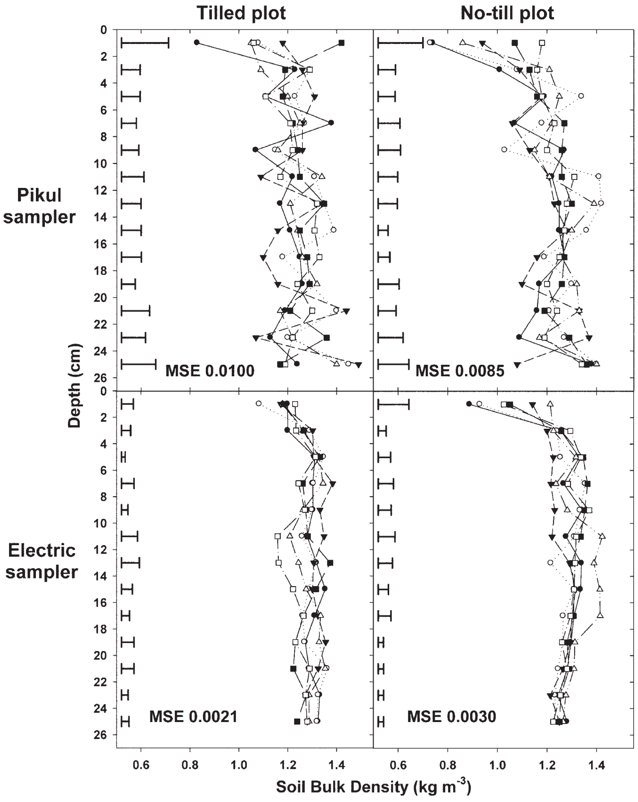

Fig. 3. Bulk density of six paired cores from a tilled summer fallow plot using two different soil samplers, shown on the left. Samples in each pair were taken within 60 cm of each other and are marked using the same symbol. Another set of six paired cores was obtained from an adjacent no-till summer fallow plot, shown on the right. Error bars are the standard deviation of the six cores from each depth. Coefficients of variation using the Pikul et al. (1979) sampler ranged from 3 to 20% and averaged 8%, whereas the CV of the electric sampler ranged from 1 to 12% and averaged 4%. Mean square error (df = 65, an estimate of variance between replications) from analysis of variance of depths is shown in each graph.

Our results for the Pikul et al. (1979) sampler are representative of CVs reported by others despite the fact that we did not composite samples but instead report the standard deviation between six single cores. With a CV of 4% between individual cores, the electric sampler appears to have excellent precision when compared with other methods.

The time required to collect a core and sample 13 2-cm increments using the electric method was 7 min per core, compared with 20 min per core for the Pikul et al. (1979) method. Doran and Mielke (1984) reported 30 min to composite 10 cores for each measurement of four 7.5-cm increments.

CONCLUSIONS

The electric sampler allows fast and accurate division of soil samples into depth increments. Increment lengths are determined by an electric switch, reducing human error. Soil cores remain vertical within the sampling tube until cut, reducing disruption of the intact core. Scientists currently collecting samples for water content or chemical analysis may find that they can add volumetric data with little or no additional effort using an electric incremental sampler.

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