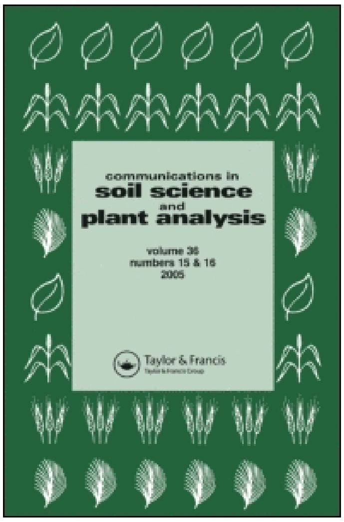

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Hydraulic Core Extraction: Cutting Device for Soil–Root Studies

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Abstract: A critical objective of belowground research is to collect and process representative soil samples. Mechanical devices have been developed to quickly take soil cores in the field; however, techniques to rapidly process large-diameter soil cores are lacking. Our objective was to design and construct a soil extraction–cutting system that could effectively reduce processing time. Soil cores were extracted from large diameter steel core tubes using a custom hydraulic cylinder device that vertically pushes the soil core to a desired depth increment before cutting in a horizontal direction with another hydraulically driven device. As many as eight large cores per hour could be processed with this system. This system has been effectively used in processing soil samples from both agricultural and forestry sites to meet desired experimental goals.

Keywords: Large-diameter soil cores, root sampling, soil processing

INTRODUCTION

An important aspect of soil research is to obtain representative field samples to study root distribution patterns, soil carbon storage patterns, fertility status, and soil physical characteristics in agricultural and forestry environments. This process can be time-consuming, tedious, and labor intensive. Mechanized devices that reduce time and labor have been developed to take soil cores (Bohm 1979).

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There are both commercially available (e.g., Clements Associates Inc., Newton, Iowa; Concord Inc., Fargo, N.D.; Giddings Machine Co., Fort Collins, Col.) and custom-made hydraulic cylinder devices (e.g., Schickedanz et al. 1973; Ginn, Heatherly, and Russell 1978; Vaughan, Murali, and Wilson 1984; Swallow, Kissel, and Owensby 1987; Prior et al. 2004) that have been developed to insert and retrieve soil core tubes of various diameter sizes. Although these systems are commonly mounted on trucks or tractors, other systems have been developed that are either manually operated systems (Wells 1959; Hayden and Heinemann 1968; Jackson 1986; Karahashi et al. 1987; Prior and Rogers 1994) or use hand-operated power drivers (hammers) and core-extraction systems (winches); these systems tend to be more portable and do not require mechanized vehicles (Prior and Rogers 1992). Commercially available small-diameter steel core tubes have been designed to hold clear plastic liners that hold the actual soil sample; this system facilitates processing and storage of soil samples. However, methods to handle large-diameter soil cores are lacking. Continued development of belowground methods is needed to reduce processing time of soil cores.

Our objective was to develop a system to aid in the processing of large-diameter soil cores. Here we describe a hydraulic-based system that can quickly process large-diameter soil cores into desired depth increments.

MATERIAL AND METHODS

The hydraulically operated core extraction-cutting system was developed to handle large-diameter soil cores that were collected in the field to assess desired belowground root or soil variables (Figure 1). The system design

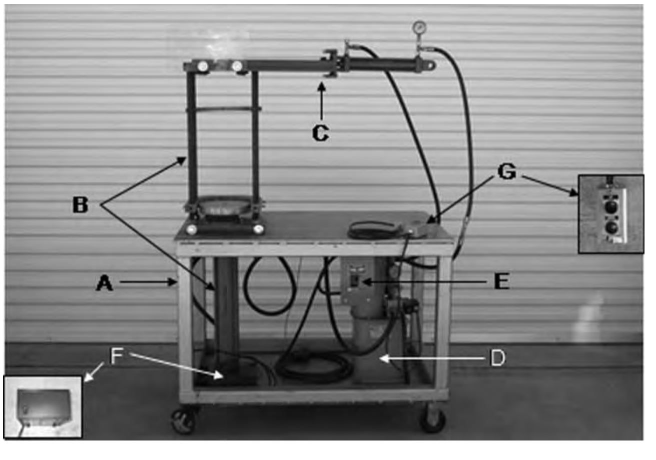

Figure 1. Photograph of the hydraulic core extraction–cutting device: (A) steel table, (B) vertical hydraulic device, (C) horizontally oriented hydraulic device, (D) pump system, (E) pump power supply switch, (F) switch box to select for vertical or horizontal hydraulics, and (G) control box for movement of either the vertical and horizontal cylinder rods.

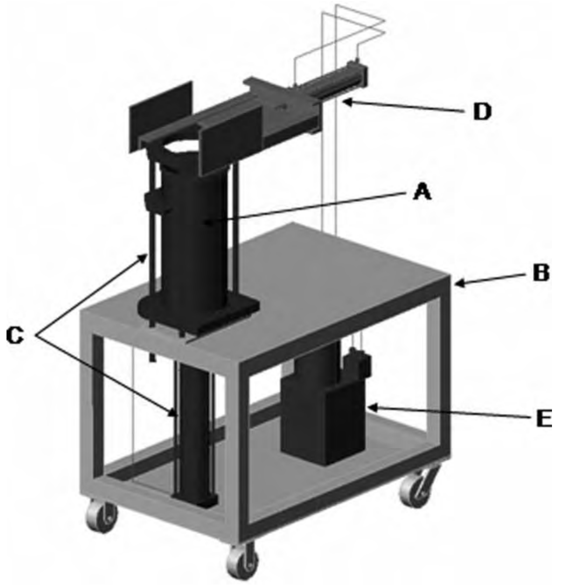

Figure 2. Schematic showing a positioned steel core tube and the major components of the hydraulic core extraction–cutting device: (A) steel core tube, (B) steel table, (C) vertical hydraulic device, (D) horizontally oriented hydraulic device, and (E) pump system.

(Figure 2) had four major components: steel table to house the system, a vertically oriented hydraulic device to push soil cores out of steel core sampling tubes, a second hydraulic device (horizontally oriented) to section soil cores after being pushed out of steel core tubes to a predetermined depth interval, and a pump system to power the hydraulic devices. Detailed specifications of these major components are discussed here. Initial testing was done at the soil bin facilities of the USDA-ARS National Soil Dynamics Laboratory, Auburn, Ala. (Batchelor 1984), followed by several field tests.

Table

The table was constructed from square steel tubing (63.5 mm × 63.5 mm × 5.0 mm) and steel plates. The table was 0.9 m in height, and the top work surface (Figure 3A) was 0.8 m by 1.2 m in size. The table frame (Figure 3B) was constructed from welded square tubing (0.7 m × 0.8 m × 1.2 m). The top work surface was a steel plate (12.7 mm thick) that was spot welded to the table frame. This top work surface also had a 106-mm-diameter hole cut out (Figure 3C) to allow for passage of the vertical cylinder rod used to push the soil out of the steel core tube; four 15.9-mm diameter holes were drilled

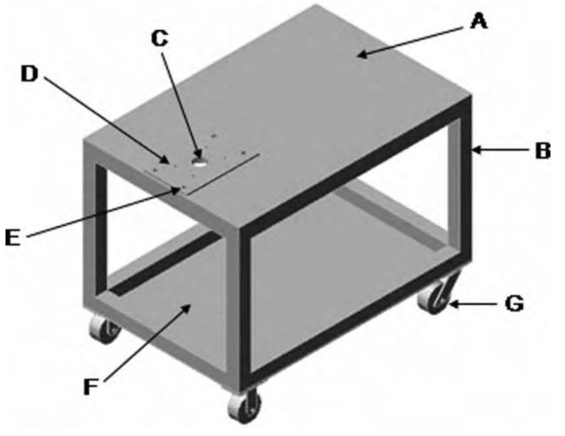

Figure 3. Schematic of the steel table showing its components: (A) top work surface, (B) frame, (C) cut out in top work surface, (D) holes for hydraulic cylinder attachment, (E) holes for support rod attachment, (F) bottom shelf, and (G) casters.

around this opening (Figure 3D) to attach the hydraulic cylinder to the underside of the top work surface. In addition, four larger holes (28.6 mm in diameter) were drilled around this opening (Figure 3E) to accommodate support rods. A second shelf (3.2 mm thick; Figure 3F) 165 mm from the ground surface was fabricated to support the pump system and the bottom end of the vertical hydraulic device. For ease of mobility, the table was fitted with casters (Figure 3G).

Vertical Hydraulic Device

The vertical hydraulic device consisted of three major components, 1) hydraulic cylinder, 2) extractor disc, and 3) core tube support bracket (Figure 4). The hydraulic cylinder (model TZ09HM, Vickers Inc., Decatur, Ala.; Figure 4A) was mounted with four bolts (15.7 mm) to the table. The cylinder rod projected upward through the tabletop hole shown in Figure 3C. The extractor disc (240 mm in diameter; Figure 4B) was tapped and screwed onto the end of the cylinder rod; this disc was made from an aluminum plate (38.1 mm), and its diameter was slightly smaller than the inner diameter of the large core tube (247 mm). The core tube support bracket consisted of four upright steel rods (0.9 m long and 25.4 mm in diameter; Figure 4C) that were bolted through the table top. Three machined aluminum braces were attached to these rods; the base brace (which was square with a detachable face; Figure 4D) was located near the table surface, while another was located more than midway up the rods (Figure 4E), and the top brace (Figure 4F) was attached to the top of the

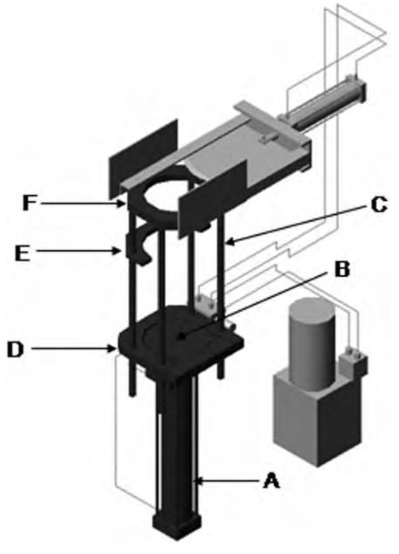

Figure 4. Schematic of the vertical hydraulic device: (A) hydraulic cylinder, (B) extractor disc, (C) support rods, (D) bottom support brace, (E) middle support brace, and (F) upper support brace.

rods. The bottom and middle braces had openings that were slightly larger than the diameter of the steel soil core tubes; both acted as guides during the soil extraction process. In addition, the detachable face of the bottom brace allows the operator to load the steel core tube; each arm of the open face was tapped (15.9 mm) to bolt on the detachable face to minimize lateral movement during extraction operations. The upper brace was attached to the rods and had an opening that matched the diameter of the soil core being pushed out of the steel core tube. The underside of this brace was machined to catch the rim of the steel core tubes. In addition, four serrated-end step clamps (MSC Industrial Direct Co., Melville, N.Y.) for 15.9-mm studs were mounted to the underside of the top brace. These clamps could be easily slid into place and tightened to hold the steel core tube stationary during the soil core extraction process.

Horizontal Hydraulic Device

The horizontal hydraulic device consisted of three major components: shield guides, blade guide bracket, and hydraulic cylinder (Figure 5). The shield guides (Figure 5A) were attached to each side of the blade guide bracket. These guides were made of Plexiglas® (355 mm × 203 mm × 6.4 mm) and were used to prevent the soil core section from spilling sideways during the

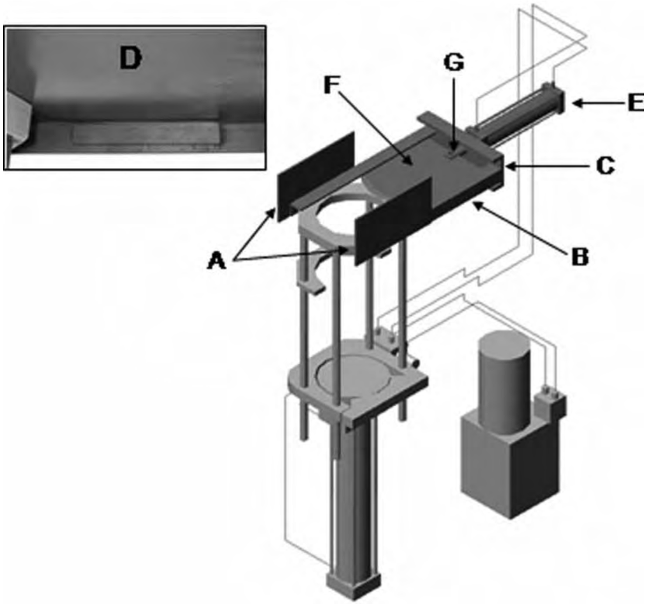

Figure 5. Schematic of the horizontal hydraulic device: (A) shield guides, (B) steel angle, (C) steel channel, (D) insert photo showing flat bar guides, (E) hydraulic cylinder, (F), sectioning blade, and (G) clevis.

sectioning process. The blade guide bracket was made from two pieces of steel angle (50.8 mm × 6.4 mm × 635 mm; Figure 5B) that were welded to a piece of steel channel (50.8 mm × 127 mm × 12.7 mm × 356 mm; Figure 5C); the other ends of the steel angles were bolted to the top brace of the core tube support brace (Figure 4F). Further, short pieces of flat bar (178 mm × 25.4 × 12.7 mm) were welded to the vertical component of the two pieces of steel angle to prevent vertical displacement of the sectioning blade, creating a channel to act as a guide for the sectioning blade during core cutting (Figure 5D). The steel channel had four holes (9.5 mm in diameter) drilled for attachment of the horizontal hydraulic cylinder (model SAE-8610, Prince Mfg., Sioux City, S.D.; Figure 5E); a fifth hole (38.1 mm in diameter) was drilled to allow passage of the cylinder rod. The soil sectioning blade (Figure 5F) was connected with a clevis (Figure 5G) to the rod of the horizontal hydraulic cylinder. The blade was made from steel plate (356 mm × 343 mm × 6.4 mm) that was rounded off and sharpened at the cutting edge.

Pump System

The pump system consisted of five major components: electrical disconnect, hydraulic Polypac power unit, push button control switch, DC operated

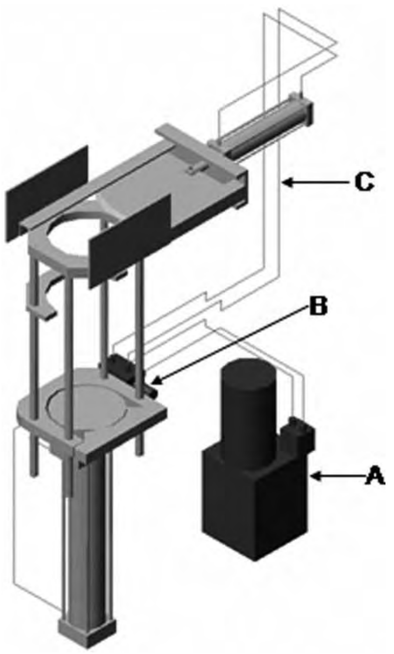

Figure 6. Schematic of the pump system: (A) Polypac power unit, (B) DC-operated directional control valves, and (C) hydraulic lines.

directional control valve, and DC power supply. These components are shown in either Figure 1 or Figure 6.

Main power (single phase, 230 V, 30 A) to the Polypac power unit (model G1.0-020S-3V-V1R, Continental Hydraulics, Savage, Minn.; Figure 6A) was supplied from an electrical disconnect (QO Load Center, Square D Co., Palatine, Ill.; Figure 1E). The Polypac power unit included a directional control valve, which, when wired to a push button control switch (model CR2943, General Electric, Fairfield, Conn.; Figure 1G), actuated the upward or downward movement of the vertical hydraulic cylinder (Figure 1B). "Downstream" from this was a DC operated directional control valve (model 1643T-6-12, Waterman Hydraulics, Niles, Ill.; Figure 6B). Hydraulic lines from the Polypac power unit passed through the directional control valve to the vertical hydraulic cylinder; additional lines were plumbed into the top of the directional control valve and fed into the ports of the horizontal hydraulic cylinder (Figure 1C). In all cases, standard hydraulic hoses and couplings were used (Figure 6C).

After the soil core had been pushed from the core tube to the appropriate depth, a 12-V DC power supply (model RS-10A, Astron Corp., Irvine, Calif.; Figure 1F) was switched on. This actuated the DC directional control valve to divert the hydraulic pressure to the horizontal hydraulic cylinder, allowing the user to cut the soil core using the same push button control switch as described before.

After cutting, the blade was retracted, and the power supply was switched off (diverting hydraulic pressure back to the vertical hydraulic cylinder). The process was then repeated until the entire core had been sectioned.

Operation

Large soil cores (24.5 cm in diameter × 60 cm deep) were collected using a tractor-mounted hydraulic coring system as described by Prior et al. (2004); this system was used to insert and pull large-diameter soil core tubes out of the ground. Extracted core tubes were placed into buckets (to minimize loss of soil from the bottom of the tube) and moved to the hydraulic core extraction–cutting device described herein (Figure 7A).

The large-diameter steel core tube containing the soil core was positioned in the extraction–cutting device (Figure 7B). The steel core tubes were manually lifted and placed over the extraction disk. While being held stationary, the vertical hydraulic device was activated until the rim of the steel core tube rested in the recessed portion of the upper brace (Figure 7C). Next, the safety catches were positioned under the rim of the core tube to hold it in place during the extraction process (Figure 7C). The vertical hydraulic device was reactivated to push the soil out of the core tube to the desired depth (e.g., 15 cm; Figure 7D). Upon reaching the desired depth, the DC power supply was switched on to divert hydraulic pressure to the horizontal hydraulic cylinder. The horizontal hydraulic device was then engaged to slice off this depth increment (Figure 7E and F). When this action was

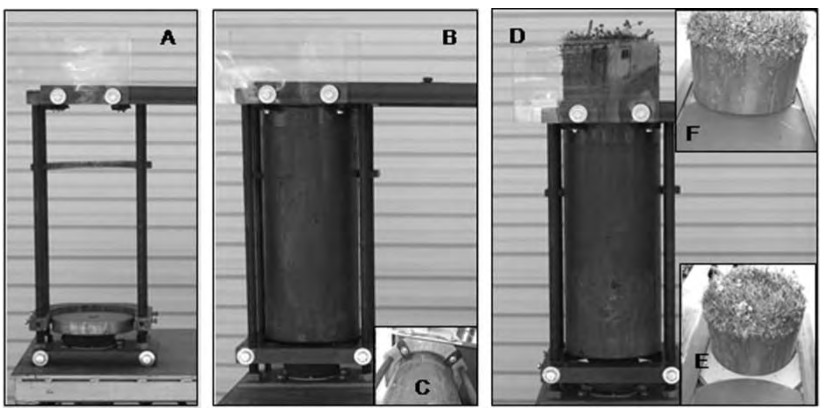

Figure 7. Photographs of core processing: (A) prior to core positioning, (B) core in place, (C) core tube locked into machined recess in underside of top brace, (D) extracted core section, (E) sectioning blade prior to sectioning, and (F) sectioning blade in action.

completed, the blade was retracted, and the power supply was switched off to divert hydraulic pressure back to the vertical hydraulic cylinder. The vertical hydraulic cylinder could then be engaged to continue the sectioning process. This procedure was repeated until the whole core had been sectioned. Afterward, the blade was retracted, the extraction disc was lowered, the empty steel core tube was removed, and the next core sample was positioned in the device.

These operational procedures have been followed to meet objectives in field experiments. For example, about 100 large soil cores were collected and sectioned to evaluate rooting patterns in a 3-year-old model regenerating longleaf pine ecosystem (Runion et al. 2006). In an ongoing cropping system experiment, further test have been conducted using this system to model the migration and redistribution of simulated weed seeds (i.e., small-diameter glass beads) as affected by soil tillage events. In this case, the researchers felt that adequate quantification would best be achieved by sectioning large-diameter soil cores (Andrew Price, personal communication). To date, about 50 large soil cores have been successfully processed for this project.

CONCLUSIONS

This system was designed to handle large soil cores by extracting them from large-diameter steel core tubes using a custom hydraulic cylinder device that vertically pushes the soil core to a desired depth increment before cutting in a horizontal direction with another hydraulically driven device. The system has performed efficiently and reliably in the processing of soil cores collected from different soil types in agricultural and forest field sites. The system can process as many as eight large cores per hour.

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