INTERNAL REPORT 24

A 92-FOOT DOUGLAS-FIR IN A WEIGHING LYSIMETER

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ABSTRACT

A soil container 12 feet in diameter and 4 feet deep was constructed around the root ball of a 92-foot Douglas-fir tree in a naturally regenerated stand. The weighing mechanism, consisting of 550 feet of 2.5-inch butyl rubber tubing filled with water connected to a standpipe, was placed under the soil container. A 1/32-inch change in water within the standpipe is equivalent to a weight change of 15.5 pounds or 1.89 gallons of water. The container, soil, and tree weighed 63,638 pounds.

WHY INSTALL A TREE IN A LYSIMETER?

Weighing lysimeters have been used for many years in agriculture to determine evapotranspiration from cropped surfaces (Harrold and Dreibelbis 1951; King et al. 1956; Pruitt and Angus 1960; Van Bavel and Meyers 1962; Libby and Nixon 1962; Hanks and Shawcroft 1965; Rose, Byrne, and Begg 1966; Lourence and Goddard 1967; Tanner 1967). Lysimeters are the best method to obtain accurate evapotranspiration rates either for short- or long-term periods. Lysimeters, however, are difficult to install and maintain to insure reliable and representative results. Weighing lysimeters have not been used in forestry previously because of installation difficulties. An attempt to install a lysimeter seemed desirable, because a large portion of the earth's surface is covered by forests, the increasing population relies on forested lands for water, knowledge of evapotranspirational rates in relation to soil and meteorological factors is not available, and other techniques such as meteorological methods need further testing in forested terrain.

WHAT PROBLEMS NEED TO BE SOLVED BEFORE INSTALLING A TREE IN A LYSIMETER?

Requirements for proper installations have been discussed by Van Bavel (1961). Different types of lysimeters have been tested in agriculture. Harrold and Dreibelbis (1951), Pruitt and Angus (1960), Van Bavel and Meyers (1962), and Ritchie and Burnett (1968) discussed mechanical weighing systems. Hanks and Shawcroft (1965) discussed hydraulic weighing systems. King et al. (1965) and Lourence and Goddard (1967) discussed floating-type lysimeter systems. Similarly, installation techniques have been perfected. The major problems are: a tree species or site, or both, had to be selected where rooting depth was restricted to 2 or

3 feet; seriousness of horizontal root pruning was answered by trenching studies (Dr. David Scott, College of Forest Resources, University of Washington, Seattle, Washington, personal communications); interlocking of limbs had to be minimized; and finally, windthrow had to be prevented.

With solutions to these problems, it was decided to install a 92-foot Douglas-fir that was growing on glacial outwash in a hydraulic-type weighing lysimeter.

WHAT IS THE SITE LIKE?

The site is located on the lower portion of the Cedar River Watershed near Seattle, Washington. The soil, a Barneston, gravelly, loamy sand, which originated from glacial outwash laid down at the end of the Vashon glacial period (Paulson and Miller 1952), generally restricts the root system above the 3-foot depth (Gessel and Cole 1965). The lateral extent of the root system is restricted largely to the basic tree spacing. The area is fairly level (± 10 feet) and has a uniform canopy density, which makes it desirable for micrometeorological investigations.

The trees are 35-year-old Douglas-fir, which regenerated naturally after logging. Thin areas were spotted in. The average tree spacing is 10 feet. Ground vegetation consists of fern, salal, huckleberry, and mosses.

HOW WAS THE TREE PUT IN A LYSIMETER?

To quote one of the students working on the project, the tree was put in a lysimeter "with great difficulty." Harrold and Dreibelbis (1951) described the construction of monolith lysimeters near Cochocton, Ohio, between 1937 and 1940. Later, Libby and Nixon (1962) described modification of the monolith technique. A combination of both types of construction was used and is further described.

A trench about 2 feet wide and 6 feet deep was dug around the tree, which left a soil core 12 feet in diameter. On one side of the soil core the trench was widened and extended to form a rectangle 4 feet wide by 16 feet long and 7 feet deep. Trenching was started by hand to minimize disturbance, but a backhoe was used to finish the digging because of the large rocks encountered, the largest of which was about 3 feet in diameter and 5 feet in length.

The soil core container consisted of two halves of a right cylinder and 12 bottom pieces. The two half cylinders were set upon the soil core and bolted together. The cylinder was lowered around the soil core as it was trimmed to the exact size. Because of the slope of the terrain, the top of the cylinder was even with the soil surface on one side and 2 inches above on the opposite side. Next, two 7-inch by 15-foot I-beams were located horizontally, 2 inches below the bottom of and 2 inches inside the edge of the cylinder, one on each side of the cylinder and perpendicular to the large trench.

Installation of the bottom of the soil container proved difficult. The bottom consisted of 24 pieces of tubular steel 2 inches by 6 inches by 12 feet, 3/16 inch thick. Pairs of these pieces were shopwelded to form planks and minimize fieldwelding. A cutting edge (2-inch piece of steel cut at a 45-degree angle) was welded on one of the planks. This plank was laid on top of the I-beams with the beveled edge up and was forced between the I-beams and the bottom of the cylinder. Two 25-ton mechanical jacks blocked against the large trench bank supplied the force when operated by four men. We expected to encounter pea-size gravel at the 4-foot depth and that the bottom could be forced through the gravel. The reality was that rocks up to boulder size were encountered. As a result, the bottom plate had to be undermined as the planks were forced under the tree to remove rocks from in front of the cutting edge. After the bottom was forced under the tree about 1 foot, another plank was welded to it. This procedure was repeated until the bottom was completely under the soil core. The bottom was then welded to the cylinder and cut in the form of a disc.

When two-thirds of the bottom was under the soil core, it broke loose. Soil core, tree, and container were shoved against the opposite bank. A winch truck had to be used to pull it back into position. During this operation, one of the 1/2-inch chains holding the tail block broke. Compared to getting the bottom in place, everything else was easy.

Next, the soil container and tree were lifted 30 inches. Two I-beams (13 inches by 20 feet), with lifting eyes welded to match those of the soil container, were shackeled to the container. Cross bracing was welded between the I-beams. Cribbing was built up from the bottom of the trench with railroad ties to form jacking points for three of the I-beam ends. The fourth end was on the soil surface. A 20-ton hydraulic jack was used to lift one corner at a time in 4-inch increments.

Provisions for draining the soil column were provided by installing eight filter candles around the periphery of the inner container. The filter candles were ceramic tubes 2 inches in diameter and 8 inches long.

After the soil container and tree were raised, the area underneath was backfilled and leveled. Then the bottom of the outer container was installed. It consisted of a pair of half-discs of 12-gauge iron with a 2-inch by 6-inch angle iron welded around the circumference. The bottom was 12 feet 3 inches in diameter, which allowed a 1.5-inch gap between the containers.

The hydraulic transducer was placed on top of the bottom of the outer container. The transducer consisted of eleven 50-foot lengths of 2.5-inch butyl rubber tubing with a valve stem vulcanized 12 inches from one end. The tubing had been filled with water and de-aired previously. The tubing was coiled on the bottom, starting at the center. Holes were cut in the bottom to allow the valve stem to pass through. After the hydraulic tubing had been coiled, a piece of 1-inch foam plastic rod was located between the tubing and angle iron to prevent the tubing from working up between the containers. The bottom, containing the hydraulic tubing, was lifted and fitted to the bottom of the soil container. It was held in place with cables. Thick-walled plastic tubing (0.375-inch inside diameter) was fastened between the valve stem and a shutoff manifold. The plastic tubing was underneath the bottom of the outer container.

The completed assembly was lowered back in place with the hydraulic jack. The two halves of the outer container cylinder were bolted together and welded to the angle iron of the outer bottom. A butyl rubber gasket was used to seal the gap between the top of the inner and outer container.

A manhole, of 3-foot-diameter tubing, was located vertically next to the outer container. The manhole housed the hydraulic manifold, standpipes, and connections for the filter candles.

After completion, the trenches were backfilled and the area leveled. When the fall rains begin, ground vegetation, ferns, salal, and mosses will be transplanted to the disturbed area.

To prevent the tree from blowing or falling over during construction, it was guyed from a yoke at 35 feet to the base of adjacent trees. After construction, four climbable (12-inch triangular) towers were built around the tree. The lysimeter tree was guyed to the towers with horizontal cables. The cables were loose enough to allow 6-inch motion at 35 feet.

Presently, the readout is a visual comparison of water level in the active and dummy standpipes. The dummy standpipe is used for temperature compensation. Pictures of the water level in the standpipes are taken at 30-minute intervals with a 16-mm motion picture camera. In the future, a differential pressure transducer will be installed between the active and dummy standpipes. The signal from the pressure transducer will be recorded on a magnetic tape along with weather station data.

WHAT ARE THE VITAL STATISTICS?

The tree is about 35 years old, 92 feet tall, and 15 inches dbh. The container is 12 feet in diameter and 4 feet deep. It has a surface of 113.04 square feet. The tree, soil, and container at "field capacity" weigh 63,638 pounds. Sensitivity of the system is as follows:
1 inch of water = 496 pounds or 60.28 gallons,
1/32-inch of water = 15.5 pounds or 1.89 gallons,
1 cm of water = 94.01 liters, and
1 cm of water at 25°C = 55,850 calories.

It is easy enough to read a ruler to one thirty-second or even one sixty-fourth of an inch when the movie film is projected. This would yield a sensitivity of 15 or 7 pounds or 110 ppm. The Tempe lysimeters have a sensitivity between 10 and 20 gm or 0.01 to 0.02 mm or 7.7 ppm. Sensitivity of the Coshocton lysimeter is given as 0.25 mm or 35 ppm. That of the Davis lysimeter is 0.03 mm or 6.2 ppm.

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