COMMUN. IN SOIL SCI. PLANT ANAL., 22(5&6), 409-418 (1991)

VIRRIB: A SOIL MOISTURE SENSOR AND ITS APPLICATION IN AGRICULTURE

Tomáš Litschmann

Moravaský Žižkov 53, 691 01, Czechoslovakia

INTRODUCTION

Until recently, irrigation operators had to calculate the moisture needs of individual crops by different methods, considering also the impact of those methods on the reserve of moisture in the soil. Based on meteorological data developed after decades of use, the methods of determining crop moisture needs had attained an acceptable level of reliability. Yet several problems in calculating the reserves of soil moisture were identified:

1. At the beginning of the vegetation season, the amount of moisture differs not only in different individual plots but also in different sections of the same plot.
2. Using the irrigation methods available in some countries, workers are never sure exactly how much moisture has been delivered to crops. In Czechoslovakia, differences of from 5-10 mm are not uncommon.
3. Similarly, the Czech network of rain-gauge stations, particularly after thunderstorms and showers, do not always provide workers with an accurate measure of the amount of precipitation at different localities. It is also difficult to determine the proportion of the total amount of precipitation that soaks in the soil. After a heavy rain, errors in calculating the moisture balance of the soil may amount to 10-20 mm.

4. The accessibility of ground water differs in different individual fields, thus affecting the irrigation of crops with deep roots, such as alfalfa and vines, which obtain part of their moisture from deep-seated reserves of ground water.

Thus, it may be assumed that the above discrepancies can cause great deviations in the measurement of the moisture balance available in individual plots. One solution is found in direct monitoring of soil moisture reserves at the individual plots. To ensure its use in both research and farming, the monitoring device should be reliable, accurate, cheap, accessible, and simple to operate.

Such a monitoring device does exist, and the object of this paper is to introduce it—the soil humidity sensor VIRRIB—to specialists. VIRRIB is manufactured and supplied by the agricultural cooperative Velké Bílovice, District Břeclav, Czechoslovakia, and this paper chronicles an experiment of its use in this country.

DESCRIPTION OF THE SENSOR

VIRRIB is based on the principle of propagation of electromagnetic waves through the medium. The sensor consists of two stainless-steel concentric circles, connected in the body of the sensor, where the electronics proper is located. The body of the sensor is mechanically fixed with the embedding material, which also prevents water from penetrating to the electronic part. The diameter of the outer ring is 280 mm; its measurement capacity is 15-20 liters of soil. The sensor uses DC current with a voltage of from 12 to 20 volts from an external source. The output data is measured by means of a current loop, the intensity of the output current being directly proportional to the measured volume of moisture.

The individual sensor measures the humidity in a space exceeding by about 60 mm the outlines of its active elements. VIRRIB can measure a layer of soil that is 120 mm thick when the sensor is placed in a horizontal position; a layer 400 mm thick can be measured when the sensor is in a vertical position. Of course, the sensor cannot measure the humidity conditions above and below this layer. However, by using two sensors located above each other, the technician can obtain information on moisture conditions to a greater depth in the root zone. In cases involving a crop with a shallow root system, the second sensor may be situated deeper in the soil to determine water soaking.

TESTING THE SENSOR

Tests were made to verify the accuracy, repeatability of results, independence of other effects, and long-term stability of the VIRRIB device. These characteristics are important if the sensor is to be a valuable tool, both in practice and in research.

An isolated block of soil with the installed sensor was placed on a balance. The reading was recorded every 10 minutes by an automated measuring station and transferred from the analog to the digital form with the numbers ranging from 0 to 255. Simultaneously, workers placed a gypsum block into the block of soil. The small gypsum block is supplied with the automatic meteorological station ARAX, manufactured in the United States.

Figure 1 provides data from the measurements, which were conducted from January to June, 1989. Whenever the mass (weight) of the soil block dropped below a designated value, soil moisture was increased by pouring in water and the whole measurement was repeated. The experiment demonstrated that the sensor responded well to the change in moisture. However, with the use of the gypsum block, due to its considerable inertia, the data are shifted in such a way that in the minimum moisture the block shows rather the maximum, and vice versa. Only after a long-lasting dry period does the plaster block start to dry and show a lower moisture level.

On March 3, 1989, to determine how the sensor would behave when the chemical composition of the soil block is changed, technicians poured 1 liter of vinegar into the soil block. This intervention was not reflected on the response proper of the sensor; therefore, 0.25 liter concentrated sulfuric acid was added on

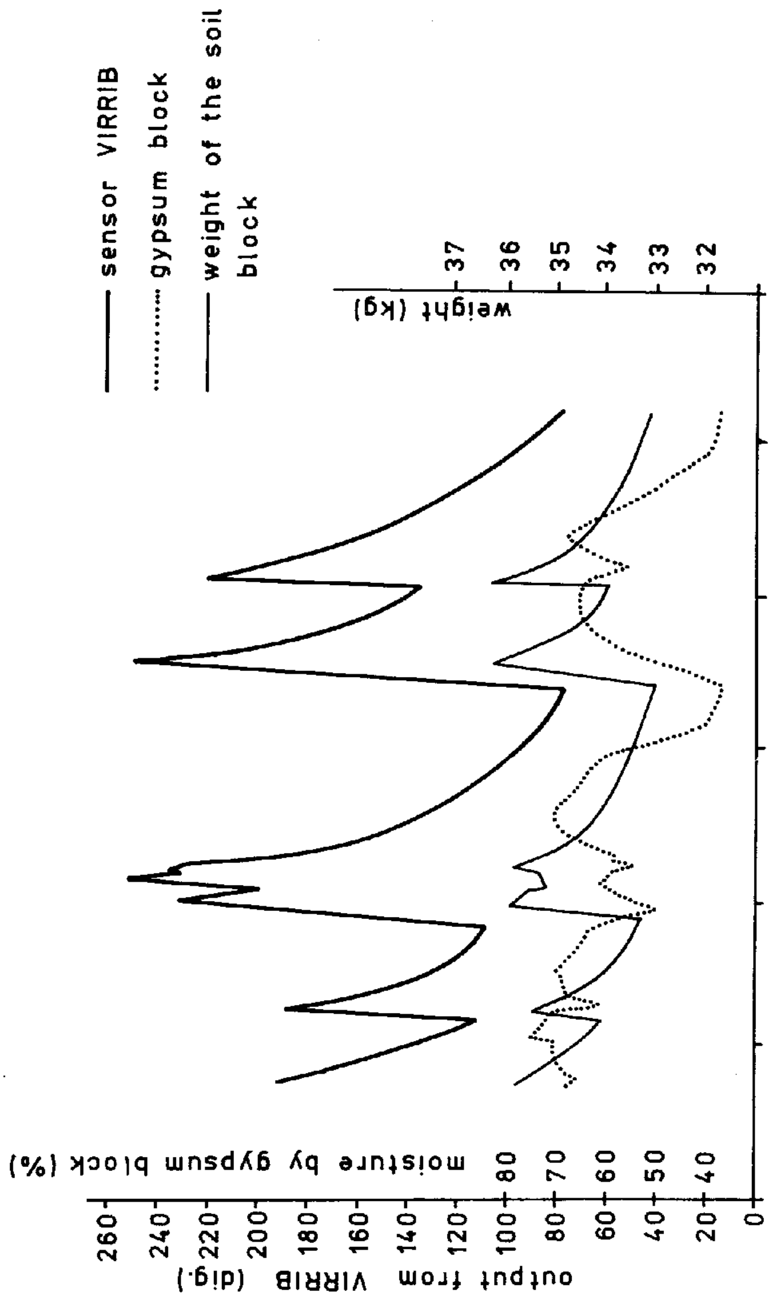

Figure 1. Relationship between the output from VIRRIB versus time (months).

April 12, 1989. Figure 2 contains plotted measured values of the sensor output, depending upon the weight of the soil block. Neither action had a significant effect on the measured values, which oscillated around the calculated regression straight line. In order to make the figure more instructive, a reliability belt was drawn around the regression straight line on the level of 0.95 significance. The line limits an interval in which 95% of all measured values will be situated. Taking into consideration the fact that the volume of soil in the block was approximately 20 liters, the change in weight by 0.1 kg represents the change in volume moisture by 0.5%. In the narrowest place of the reliability belt, i.e., in the place of average moistures, its width is about 1% of the volume moisture; at higher and lower moistures, its width doubles.

UTILIZING THE SENSOR

Sensors installed at individual plots can be utilized in several ways. At the simplest level, the worker makes a direct reading in the field by means of a small portable evaluation unit which is supplied with the sensor by the manufacturer. Thus he can determine the reserve of soil moisture directly in the irrigated plot. The output from the sensor is produced by a current loop, and the measured values can be transferred and recorded at a measuring center, using the current loop or a voltage input. In the RC of the system of irrigation machines, the data from the sensors are transferred via the DAP 128 M (Banske strojirny Ostrava) to a distance of as much as 10 km to the screen of the controlling computer. Then, using this input, the irrigation machine operator operates the irrigation machines by means of the same (R/C) computer.

Also, by connecting the sensors to different electronic equipment, it is possible to switch on stable irrigation systems by means of electrovalves. Electronic devices, which are supplied together with the sensors by the agricultural cooperative Velké Bílovice, enable the operator to determine the levels of soil moisture at which irrigation starts and stops. The time of application of irrigation can be regulated by means of a switch clock, and the irrigation can be limited to

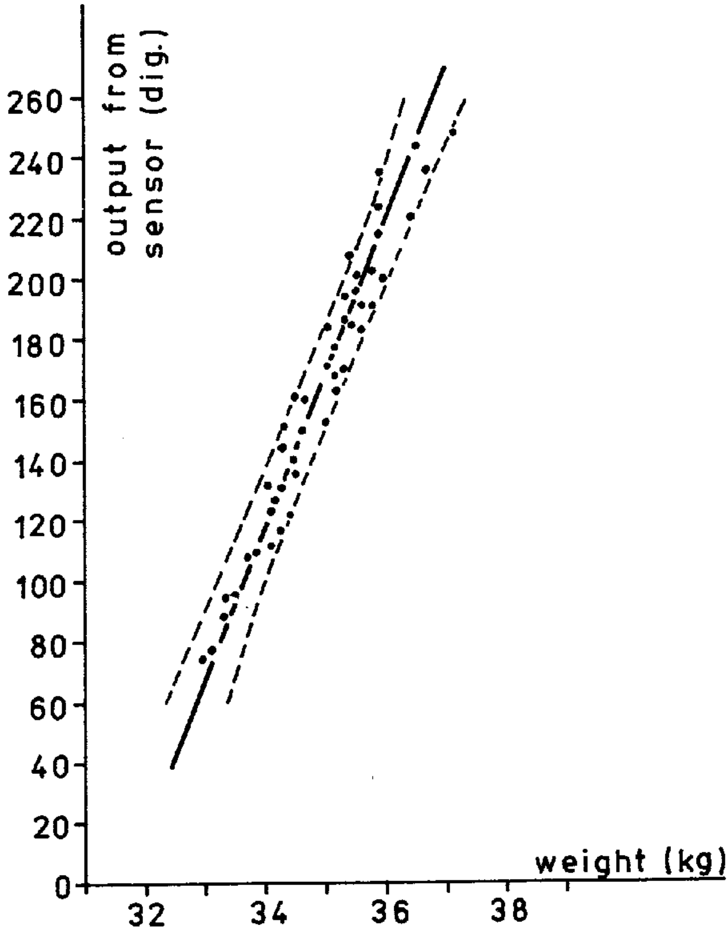

Figure 2. Output of VIRRIB versus the weight of the soil block.

a certain time of the day. The system is particularly effective with crops with shallow root systems, but it will also find application in orchards and greenhouses.

PRACTICAL SENSOR OPERATION

In 1990, technicians located VIRRIB sensors at several stations of the cadastre

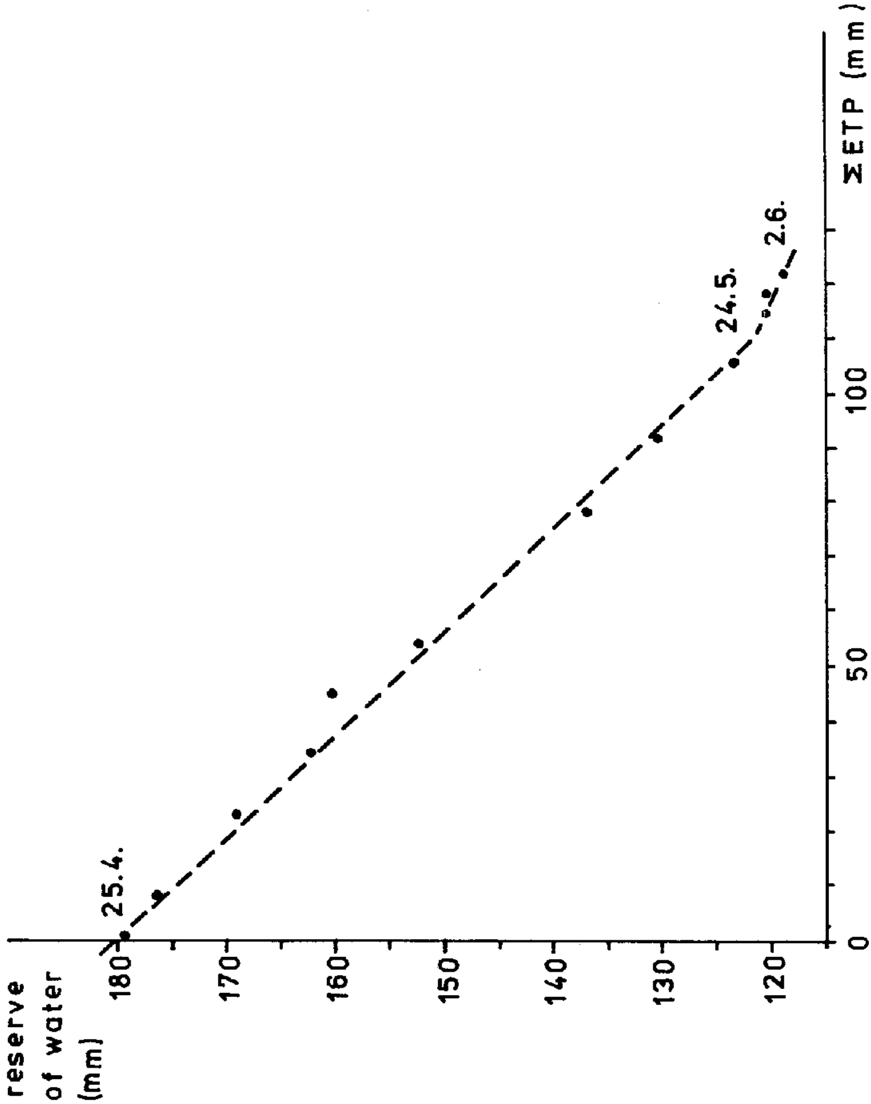

Figure 3. Change in soil moisture in April and May, 1990.

of the agricultural cooperative. Figure 3 shows the course of soil moisture in a plot in which winter wheat was sown. The sensors were located above each other in a vertical position so that one occupied the space from 10 to 40 cm and the other from 50 to 80 cm. Technicians noted the change in the reserve of soil moisture in a layer from 5 to 85 cm, as indicated by the two sensors, from April to June 1990. Vertical lines indicate the amount of precipitation in the individual days.

From the analysis of the two curves, several conclusions were drawn. At the beginning of April, due to the preceding dry period, the reserves of soil moisture in the two layers were very low. After a hard rain, the moisture of the upper layer increased, but this precipitation started soaking into the lower layer only later and only slightly. Only after further precipitation on May 19 and 20 did the moisture conspicuously increase also in the lower layer. After another hard rainfall on May 23, the moisture in the upper layer increased sharply, but on the following day it dropped quickly and a moisture increment appeared in the lower layer. Thus, the field water capacity, about 22% by volume, was reached. Beginning on May 25, a dry period began and the soil moisture started dropping, first in the upper layer until May 20, when the decreased of soil moisture slowed down. The decrease of moisture in the lower layer was reflected from May 14 on. The experiment brought out the need to monitor irrigation watering so that the field water capacity of the moisture level in the soil (22% of the volume in this case) will not be exceeded.

This simple method of analysis can be used under favorable weather conditions or during irrigation to determine in a short period of time the hydrolimit of the field water capacity, or the stabilized state of moisture of the natural soil section after excessive irrigation from the top. Determining the state of moisture at which irrigation should begin is more difficult. In the present study, technicians used the data from the measured field to plot the graph for the period from April 25. Their input compared the reserve of water in the layer (from 5 to 85 cm) with the sum of daily evapotranspiration calculated from the measured

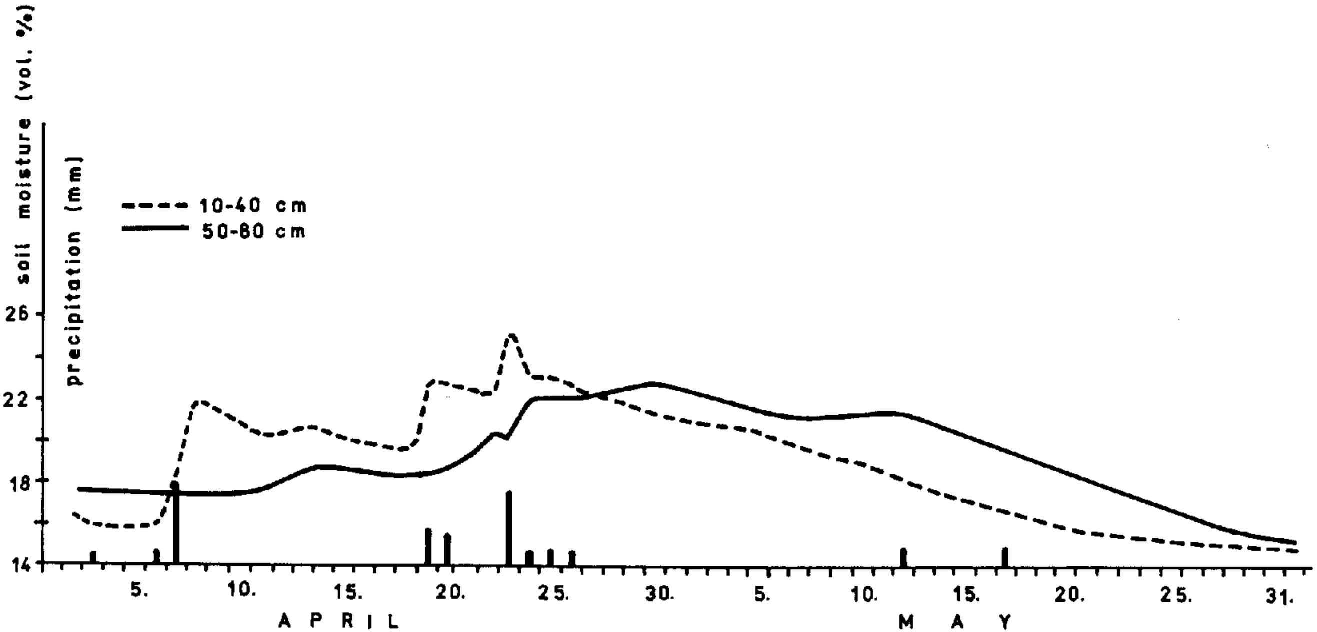

Figure 4. Reserve of water in the 5-85 cm layer of soil versus the sum of daily evaporation, calculated from meteorological data.

meteorological data (see Figure 4).

This method assumes that a limit in plant growth will be correlated to a change in the decrease in the reserves of soil moisture and in the amount of moisture available for evapotranspiration, which will differ from a preceding period when sufficient moisture was present. The method holds true only in cases when no conspicuous influx of ground water is assumed. In the present study, the points were ordered along a straight line until May 28, when it appeared that the decrease in the reserves of soil moisture no longer corresponded to the increments of evapotranspiration. It can, therefore, be assumed that the critical value of soil moisture was reached at that point and that it was necessary to start irrigation.

CONCLUSION

The present study shows that direct monitoring of soil moisture by means of the VIRRIB sensor can help the worker to control the course of crop irrigation. Also provided by the manufacturer with this sensor is a temperature-humidity sensor that measures the temperature of the soil at the same depth.