INSTRUMENTATION USE IN A COMPREHENSIVE DESCRIPTION OF PLANT-ENVIRONMENT INTERACTIONS

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1. SUMMARY

The definition of the word instrument is stretched to include use of a leaf-environment model to aid in monitoring leaf status in the field. A set of equations that couple photosynthesis, stomatal conductance, the leaf energy balance, and leaf and soil water status are briefly described for a typical C3 plant. The Basic language code for these equations, which was developed on a Radio Shack Model 100 microcomputer, is included with documentation including input and output values of all important variables along with a sample session. Some representative output from the model is discussed along with limitations of the equations.

2. INTRODUCTION

Instruments extend our senses to reveal consistent relationships among factors in our environment. Since the topic of this volume is Advanced Agricultural Instrumentation, one expects to find discussions of electronic, mechanical or electrochemical gadgets that will help us probe into the inner workings of plants. I should like to take the liberty of using a very broad definition of the word "instrument," albeit the last definition in my American College Dictionary - "A device for measuring the present value of the quantity under observation." Thus, an instrument is used to measure—to estimate the relative amount or value of something by comparison with some standard. This process of comparison with some standard may require a model or representation of whatever is under investigation to determine the appropriate standard or even the appropriate measurement. Certainly the interpretation of any measurement implies a model of what is being observed. This model may be physical, chemical, intuitive, or just plain "common sense," and may not
always be apparent. It is interesting to note that even we humans incorporate "models" so that the brain can interpret information fed to it by our senses. Psychologists spend much time trying to reveal such "models." Thus, the development of models to interpret data amounts to using an image of ourselves to create an understanding of the world in our minds.

This broad definition for the word instrument does not imply any upper level of complexity for the model, which is used to determine the appropriate standard or interpret the observations. Thus a comprehensive soil-plant-atmosphere model may be part of an instrument for observation of quantities that cannot yet be observed by simpler instruments, which use simpler models for interpretation.

One example of such a complex model being an essential part of an instrument is a device to indirectly and nondestructively measure the leaf area index and leaf angle distribution of a canopy. To use such an instrument, a one, two or three dimensional canopy radiative transfer model must be used as a "kernel" in the integral inversion of the radiation measurement. A direct frontal attack on this problem of measuring canopy architecture with mechanical devices can be quite frustrating because of rapid leaf movements in the wind, heliotropic leaf movements, leaf rolling or wilting from water stress, leaf surface irregularities, and stems and petioles, to name just a few of the confounding factors. All of these factors can be incorporated in the indirect measurement. Clearly without this complex radiative transfer model, we do not have an instrument for indirectly measuring canopy architecture. Further, a model part of this canopy architecture instrument is indistinguishable in character from the very simple model of a mechanical spring movement that is implicit in the old dial volt meters, which we rarely encounter in this modern electronic age of digital voltmeters.

The development of our understanding of plant processes is closely tied to the instruments that we have for observations. Unfortunately a whole ensemble of complex processes are intimately coupled with each other and all the environmental factors, and our simple instruments relate to only one or perhaps a few of these essential processes. The interconnectedness of all these processes makes it impossible to observe one while maintaining all other invariant. We attempt to reduce confounding effects of natural environmental variations by conducting experiments in controlled environments, but we then add another confounding factor in that our plants are adapting to this artificial environment and not the natural environment that is our main interest (1). Perhaps we can consider that detailed plant-environment models are to field research what controlled environments are to laboratory research: a method for monitoring many factors that would be impractical to measure in detail. Thus, a physically-based, plant-environment model may permit us to track detailed processes under field conditions while requiring only a few simple routinely measured inputs along with some more easily measured checks on the model outputs. Figure 1 contains a diagramatic representation of the use of such an "instrument."