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A Mobile Field Spectrometer Laboratory

The design and testing of a field spectrometer laboratory housed in a trailer.

Introduction

The recent development of interest in remote sensing has led numerous investigators to devise methods for remote sensing surveying and applications to the problems found in the present-day natural resource scene. In particular, the application of remote sensing techniques to vegetation study has been advancing rapidly, mainly in the agricultural areas.

Abstract: *A mobile, ground-based, field spectrometer laboratory has been constructed to collect in situ radiance and reflectance data from various natural scenes. The equipment assembled for this spectrometer system included a spectral radiometer with telescope viewing optics, a mini computer-based digital data acquisition system, calibration and logistical support systems, and a specially designed 13.5-foot trailer to house all the equipment in the field. The system has been field operated for several field seasons and has been shown to be a versatile and sturdy field instrument.*

There were not enough resources available to sponsor a ground study of a natural prairie scene using remote sensing methodology until several years ago when the United States International Biological Program (IBP), founded by the National Science Foundation, was started to study natural ecosystems by several different methods including remote sensing. The IBP Ecosystem Analysis Program has been subdivided into several ecological zones or biomes, and the Grassland Biome Program has sponsored this study. This biome was organized to study a typical prairie ecosystem-its components, driving forces, internal processes, and interactions-using systems analysis techniques, and to formulate a computerized model for digital simulation of the ecosystem.

One system variable, aboveground forage or plant biomass, was selected for study because of its importance to other trophic levels in the ecosystem.

Primary forage production of an ecosystem has traditionally been measured by the increase in plant biomass per unit of land area measured in units such as kg/ha. This determination has been made by the destructive sampling or clipping of a measured area which, when sampled and weighed, gives the desired measurement (dry biomass, root biomass, total biomass, etc.). Unfortunately, once an area has been sampled, it cannot be used again, preventing the remeasurement of a fixed set of plots throughout a growing season. It is evident that a nondestructive sampling technique would be very benefi-

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cial for determination of primary productivity. It is for this reason that the field spectrophotometer laboratory described in this paper was proposed, funded, and constructed by the Grassland Biome Program of the IBP.

The primary purpose of the field spectrometer was to collect *in situ* radiance and reflectance data and to determine the two or three optimum wavelength bands (less than 0.1 μm wide) of visible and near visible electromagnetic radiation (0.2 to 1.6 μm) which could be used by a simple hand-held radiometer for remote determination of per cent cover. This radiometer would measure the radiance from a grass plot in only these optimum wavelength bands and then would measure the irradiance incident on the plot in these same optimum bands. Using these measurements the operator could then go to a nomogram or table to obtain the per cent cover of functioning green vegetation on the plot. Alternatively, the simple hand-held radiometric instrument could be programmed to perform automatically the sampling and conversion to units of biomass (Pearson *et al.*, 1976a; Pearson *et al.*, (1976*b*).

Design

The field spectrometer subsystems are grouped and reviewed in three categories: spectroradiometer, computer controlled digital data acquisition system, and trailer and logistical support equipment.

Spectrometer Hardware

The spectroradiation measuring instrument used in the field spectrometer system was an EG&G model 580-585 spectroradiometer (Figure 1). This instrument consisted of the following modular subsystems:

- A reflective telescope with a variable field of view from 7.5 minutes to 2 degrees and an on-axis viewing eyepiece through which the operator could see the exact area for which spectroradiance was collected by the telescope.
- A monochromator housing which accepted one of the three gratings used to cover the spectral region of 0.18 μm to 1.6 μm.
- A high sensitivity detector head housing an S-10 photomultiplier detector sensitive from approximately 0.2 μm to 0.8 μm and an associated power supply.
- A high sensitivity detector head housing an S-1 photomultiplier detector sensitive from approximately 0.7 μm to 1.6 μm, a separate power supply, and a cooling controller.
- A readout unit which contained a six-decade low-level current amplifier which measured the detector current.
- A fiber optics probe of one meter in length with a 3-mm diameter viewing port which replaced the telescope module.

This spectroradiometer, as presently configured, could measure spectroradiance with a band width or spectral resolution of one per cent of the wave-length set on the grating over the range of 0.2 μm to 1.6 μm.

Computer Controlled Data Acquisition System

The large number of spectroradiance measurements taken by the spectroradiometer in scanning a single curve were sampled, stored, and subsequently reduced to yield

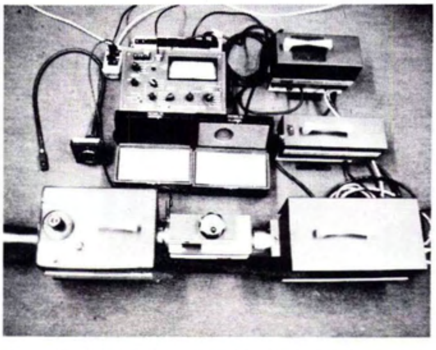

Fig. 1. Modular spectroradiometer system. Composite view showing all available modules and components.

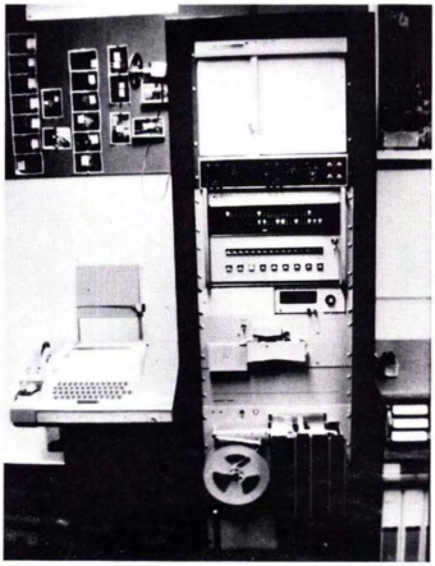

Fig. 2. Computerized digital data acquisition system. The system is shown in a rack used for laboratory operation indoors during the winter months.

curves which were plotted, printed, and punched on-line in the field using a computer digital data acquisition system (Figure 2). This Hewlett-Packard system consisted of:

- A Model 2114A general purpose digital computer with 8192 words of 16 bit memory.
- A low level analog-to-digital converter for conversion of the analog signals from the spectroradiometer and other analog input sensors to digital computer input with 12 sensitivity ranges from 10 mv to 10 v and an A/D conversion rate of 10kHz.
- A multiplexer for selecting, under program control, the analog input channel to be digitized at a maximum switching rate of 10 kHz.
- A Model ASR-33 teletype for keyboard input to and printed output from the computer.
- A high-speed punched paper tape reader used primarily for program input to the computer.
- A high-speed paper tape punch for recording the processed data for subsequent transfer to the central university computer system.
- An analog X-Y plotter interfaced to the computer and used to plot the raw spectral curves as they were measured or to plot the reduced curves produced by the computer.

The software used with the computer was written in any one of four languages (FORTRAN, ALGOL, Basic, and Assembler). A main program in FORTRAN controlled the experimental procedure and the data collection used in these experiments and subsequently output the reduced spectroradiometer measurements to the teletype, high-speed paper tape punch, and X-Y plotter. The X-Y display allowed a continual monitoring of the experiments as the curves were collected.

SPECTROMETER TRAILER

A specially designed 13.5-foot trailer housed all the equipment in the field (Figure 3). The trailer had both heating and air conditioning equipment to maintain the ambient temperature of 22°C. The air conditioner was large enough to provide a positive pressure gradient from the inside to outside during the summer to keep dust out of the trailer and out of the optical and electronic equipment which it housed. A separate, portable 3.5-kw alternator supplied operating power when the trailer was used more than 100 feet from a line power souce.

SPECTROMETER OPERATION

Normally, the spectroradiometer was housed inside the trailer and telescopically viewed the *in situ* plant- or grass-plot through a small hole in the side of the trailer (Figure 4). The horizontal view of the telescope was folded down normal to the ground's surface or at some other angle of incidence by a mirror mounted on a tripod. The telescope had a variable field of view from 7.5 minutes to 2 degrees in five steps,

Fig. 3. Field spectrometer trailer and support equipment. A tripod-mounted, first surface mirror (a and b) was used to fold the horizontal field-of-view of the spectroradiometer down onto the sample. A 3500-watt power plant supplies field power. A cable locker (not shown) has been added atop the rear bumper to store the trailer's main power cable (90 m), a remote site power cable (90 m), and a remote site data and communication cable.

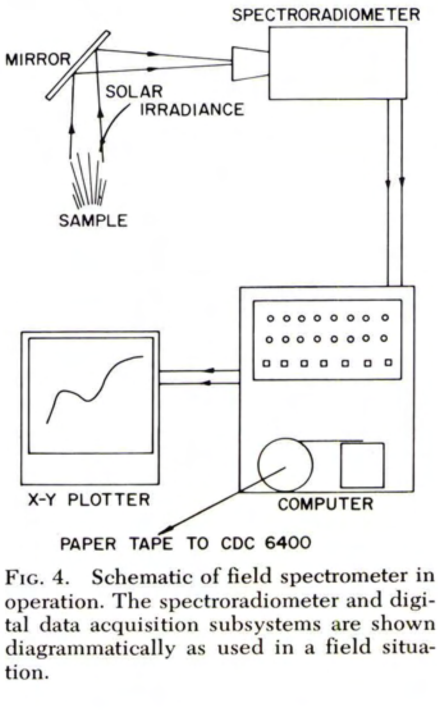

Fig. 4. Schematic of field spectrometer in operation. The spectroradiometer and digital data acquisition subsystems are shown diagrammatically as used in a field situation.

allowing the selection of a wide number of fields-of-view. The upper size limit of the sample area measured was limited by the dimensions of the available folding mirror to approximately 50 cm.

The detector in the spectroradiometer outputs an analog signal proportional to the spectroradiance collected from the sample at the wavelength determined by the angular position of the interference grating. A second analog signal was output proportional to the gain setting of the detector amplifier. The wavelength transducer, mounted on the grating, outputs a third analog signal proportional to its angular position which was the wavelength of the detector output. The wavelength transducer had a knob atop it which was turned by hand to rotate the grating and scan the spectrum across the detector or to set off a particular wavelength on the detector. While the operator scanned the spectrum by turning this knob, the computer, under program control, sampled the output of the wavelength transducer and converted the analog signal to digital computer words at a rate of 10 kHz. This digital value of the sampled wavelength was tested by the software to see how much it had changed from the previous wavelength at which the prior spectral value was taken. If the output had changed by a predetermined wavelength increment entered via the teletype by the operator, the software stored this new wavelength and converted and stored the output of the radiometer detector and its gain setting. These incoming values could be multiplied by a stored tabular detector sensitivity curve to yield a calibrated curve of spectroradiance for the sample viewed by the telescope at the angle of inclination determined by the mirror angle. The measured values, with or without conversion to spectroradiance, were stored for comparison with the next curve to be measured and could be listed on the teletype punched on paper tape, or plotted on the X-Y plotter.

Field Results and Summary

The previously described field spectrometer laboratory has been field tested to study the feasibility of measuring plant cover and aboveground biomass spectro-optically. Results of these experiments have been reported elsewhere (Tucker and Miller, 1974; Tucker *et al.*, 1975; Pearson *et al.*, 1976*a*; and Pearson *et al.*, 1976*b*). The field spectrometer system has been found to be a versatile and sturdy experimental laboratory. The computer-based data acquisition and control system has proven to be invaluable because it is extremely flexible and affords on-line checks of experimental results.

Acknowledgments

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