SOME NEEDS FOR EXPANDING AGRICULTURAL REMOTE SENSING RESEARCH

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Research in remote sensing conducted since the First Michigan Symposium four years ago has established many potential applications in agriculture. Present state of the art multispectral instrumentation operating in aircraft can on a given day record measurable differences in ground conditions that have important meaning to agricultural crop production statistics. These include differentiation of:

(1) fields of bare soil and fields with vegetative cover
(2) fields of uniform crop species such as wheat, oats, corn and soybeans
(3) meadow crops such as alfalfa and clover from drilled and row crop species like wheat and corn.

These demonstrated capabilities have been encouraging and have warranted support for planning and design of remote sensing instruments for agricultural sensing experiments from spacecraft in NASA's Earth Orbital Program. In this planning activity it has been evident that there are large gaps and voids in our knowledge of agricultural applications. At this early stage we should identify the problems associated with these applications and set about to solve them. If research can be initiated at an early period, the results will guide us more surely and soundly in planning toward operational sensing systems for agricultural purposes.

Up to now we have adopted parts of the information now regularly provided by the USDA Statistical Reporting Service and the U. S. Agricultural Census as examples of important data on agricultural crops that might be gathered by remote sensing. These choices are valid, for these statistics have evolved during a century of crop reporting activity in the United States. These types of data are also highly indicative of those needed in agricultural regions of the developing countries, although the number of crop species will be expanded and the crop production systems will be more variable. Currently U. S. statistics on crops include:

(1) acreage intended for planting
(2) acreage planted
(3) forecasts of yield based on condition of the crop
(4) acreage harvested

(5) total production (yield per acre × acres harvested)

(6) disposition

  (a) sold

  (b) stored on farms

Contributions of remote sensing either by aircraft or spacecraft to these functions place certain obvious requirements on the instrument systems. First, the resolution of the sensors must be fine enough to sample adequately the individual fields ranging upwards from one acre depending upon the type of farming area. Further the number of samples it is necessary to gather per crop field will depend upon the variability in soil type and in vegetative cover. If soil and plant growth are uniform the number of samples per field can be far less than if one or the other is highly variable.

A major requirement of the Crop Reporting Service is the positive identification of the crop species and the condition of the crop. Since a given field is generally planted to a single crop, the resolution requirements for crop species identification are similar to that for fields. However, the requirement to determine condition of the crop imposes more severe restrictions. Crops may be damaged in many ways. Certain agents generally affect the field uniformly. Others may inflict permanent damange only in restricted areas of the field. In certain years damages of either type may be sufficiently extensive to affect yield predictions for the crop in the region under study. Consequently, a more severe limitation on resolution down to a minimum of a few feet instead of one acre is actually needed if our data on condition of crop are to be valid.

Crop species identification and identification of crop damaging agents places heavy requirements on the spectral design of the remote sensing system. From the outset, we have conceded that our sensing system must be multispectral to permit identification of crop species. But how many spectral channels of information are necessary and what spectral regions should be chosen? Certainly fewer spectral channels will be needed if the numbers of crops to be differentiated are small. In the middle Corn Belt region in early May the types of vegetative cover consist primarily of woods, grassland, wheat, oats and meadow. A predominance of fields at this time are freshly tilled in preparation for planting corn or soybeans. In this and many other agricultural regions the numbers of crops and soil conditions to be differentiated will be small throughout the growing season.

However, we are called upon to assess the condition of the crop as a basis for yield forecasts. It is at this point that our existing knowledge of crop sensing fails. We have almost no information on the variability of multispectral signatures of individual crops such as corn and soybeans as affected by agents of damage like weeds, disease or drought. If the damage occurs in well-defined areas of fields, such as that caused by excessive rains resulting in "drowning-out" of the crop in low spots, we might expect to detect it. The contrast here will be between normal growth of crop and no-growth or dead plants in the low spots. Even later in the season when the damaged low areas are covered with a uniform weed stand we might expect sufficient contrast to detect the damaged area. But if the damage occurs uniformly over the field as in the case of drought, remote detection of the degree of damage will be more difficult. There will be no areas of normal growth in the vicinity to which we can compare the drought-damaged fields.

This problem of assessing the condition of the crop, presented here in a simple elementary form, is broad and complex. To solve it we must become prepared to determine accurately the statistical range of variability of multispectral signatures of crops and soils and their interaction as the crop plants grow and develop from seeding through harvest. This will require a continuing research effort of major significance in each important crop producing region from which one expects to gather accurate and meaningful data. The research must involve a rather large number of locations because often the conditions affecting crop signatures are peculiar to the region. Research projects will be difficult to staff because the combined talents of the physical scientists and agricultural scientists will be needed.

The approach to be used in the expanded research can likely be patterned after the agricultural research program now getting underway under NASA-USDA sponsorship. Basically the scheme of this program is to make ground-based photographic and spectrophotometric observations at 50 foot heights over crop fields and compare these observations with sensor data gathered by aircraft at selected intervals during the crop growing season. The ground-based instrumentation provides a relatively low cost method of studying multispectral signatures of crops as affected by damaging agents, soil types, fertility levels, moisture variations, plant population densities, crop varieties, plant development phenomena (flowering, fruiting, maturity), previous cropping histories, etc. Yield records of the crops studied may be gathered and correlations made with crop signature changes during the growing season.

Data handling and analysis studies are also being emphasized in the agricultural remote sensing program now underway. These include data from ground-based cameras and spectrophotometers as well as aircraft sensors. We can expect that the results of these studies will provide methodology guidelines for the projected expanded research.

Plans for the expanded agricultural remote sensing research should be laid down at an early date and funds sought to start the projects as early as 1968. The program should provide up to four aircraft with remote sensing equipment. The number of principal agricultural research stations should be at least 8, with as many as 4 substations cooperating with each principal station.

The cost of the program during the first year is estimated at $8 million (exclusive of costs of aircraft frames) with an annual need thereafter of about $6 million. The duration of these intensive studies should be planned for at least 5 years. Thereafter, the level of activity could be rescheduled to conform with that required to support the operational ground-aerospace systems that might be expected to evolve.

The number and extent of the possible agricultural applications of operational remote sensing systems appear to be very great even when one considers the systems only from the viewpoint of gathering statistical data on crop production in the U. S. One can speculate, however, that the application benefits to be derived from use of the technique in domestic agricultural research and development, farmer education and information, and in aiding and guiding U. S. and world technical assistance to agriculture in the developing countries of the world will be many times greater. Expansion of the U. S. agricultural remote sensing research in a manner such as that proposed would constitute a logical next step toward defining these applications.