AGRICULTURAL APPLICATIONS OF REMOTE SENSING -A TRUE LIFE ADVENTURE-

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ABSTRACT

In mid-1973, General Electric undertook a study of agricultural applications of remote sensing with a major US agricultural firm. The study continued for eighteen months, and covered the areas of crop monitoring and management as well as large scale crop inventories. Pilot programs in the application of aircraft remote sensing and LANDSAT data were conducted. An operational aircraft survey program for ranch management has subsequently been implemented by the agricultural firm. LANDSAT data was successfully used to produce a ninety-seven percent accurate inventory of cotton over 4.8 million acres of California's San Joaquin Valley.

INTRODUCTION

During the eighteen month period from June 1973 to December 1974, General Electric was engaged in an agricultural remote sensing program with a major US agricultural firm. The principal purpose of this effort was to conduct a pilot program in the application of remote sensing to crop monitoring and management as well as crop inventories, and to evaluate the feasibility of a full-scale, operational program. The study was centered in California's San Joaquin Valley. The crops involved were cotton, safflower, and alfalfa.

The study divided naturally into two phases, coinciding with 1973 and 1974 crop seasons, respectively. Phase I was a learning and experimentation period, with emphasis on establishing a sound definition of the data and information requirements of this specific ranching operation. Phase II, carried out during 1974, was a period in which several operationally-oriented, pilot programs, using both aircraft and LANDSAT data, were conducted and evaluated.

PHASE I - THE LEARNING PHASE

The first season of the study was the learning phase, designed to promote a meaningful, bi-directional transfer of technology between the ranch personnel and GE project staff. GE personnel were located on-site at the firm's major ranching location and worked side-by-side with the ranch manager, agronomists, and district managers from June to October of 1973.

The Ranch

The ranching operation is one of the largest in the area with over 50,000 acres in cultivation. The principal crops covered in the study were cotton, safflower, and seed alfalfa, although wheat, barley, and milo are also grown.

The ranching operation, itself, is highly automated and capital intensive, with a minimum of labor input. This is achieved in large part by a significant economy of scale. Almost all crops are grown in full sections, each one square mile (640 acres) in area, and all of the practices and equipments used are designed for this size operation.

The San Joaquin Valley has been described as one of the most fertile regions in the world, and the careful rotation of cotton and safflower, supplemented by chemical fertilization, has resulted in maintenance and, more often, improvement of overall soil fertility.

The company continually conducts a long-range land improvement program which operates on a sliding, multi-year basis.

From May through September, the weather in the area is repetitiously rain-free, cloud-free, hot and dry. Daytime highs in July and August often range between one hundred five and one hundred twelve degrees Fahrenheit, with nighttime temperatures in the seventies. Flood irrigation is used throughout the area, with water from snow-melt in the Sierras.

Phase I Tasks

In addition to the major task, that of developing an understanding of the farming operation and practices, a number of other tasks were carried out during this Phase I period. Principal among these was the collection of ground truth data for subsequent correlation with LANDSAT imagery, later in Phase I and in Phase II. The ranch personnel, both individually and collectively, keep amazingly complete and accurate records covering literally every aspect of their operations. All of this data was made available for the current as well as past years, and this was supplemented by data collected by GE project personnel.

This ground truth activity was complemented by an experimental aircraft survey task which was conducted throughout Phase I. This experiment utilized a hand-held, 35mm camera with color-infrared film. The photos were obtained from an altitude of eight thousand feet on a nine day schedule which was timed to coincide with LANDSAT-1's eighteen day cycle. Each photo mission covered 25 full section fields selected for the purpose. In order to give this experiment an operational flavor, the photos were processed and reviewed with ranch personnel within twenty-four hours after acquisition.

Although this Phase I aircraft remote sensing experiment was simple by design, it proved highly effective in introducing the ranch personnel to the capabilities of infrared data and the advantages of repetitive aircraft coverage. The imagery did provide early detection of weeds and areas of rodent and certain insect damage. In addition, the photos permitted measurement of the areal extent of these problems.

The aerial photography also helped in identifying and assessing numerous operational ranching problems such as planter and fertilizer skips, checks missed in irrigation, and high (dry) and low (wet) areas. In several instances this resulted in modification of the particular procedure and/or equipment involved.

Variations in crop vigor were also clearly defined and, as a result, ranch personnel requested coverage over additional fields to monitor test plots and problem areas.

Throughout Phase I, LANDSAT MSS data in the form of black and white and color composite transparencies was obtained and analyzed visually. The most current imagery available was some three to four months behind the actual date and of little value for other than research and historical purposes. No operational use for this data was found. Late in Phase I, however, LANDSAT imagery which coincided with the aerial photography was obtained and showed excellent correlation with the 35mm photographs where relatively large scale phenomena were involved. In addition, the scale of the LANDSAT imagery allowed ranch personnel to qualitatively compare their results with those of neighboring ranches on a broad scale for the first time.

Late in 1973 the first LANDSAT CCT's over the area were obtained and input to IMAGE 100, General Electric's Multispectral Image Processing System. The IMAGE 100 analysis involved classification testing of signatures for the major study crops, experimentation with signature extension techniques between two of the firm's ranching areas, and differentiation of variations in vigor within crops. All of the IMAGE 100 work done at this point was part of the learning phase effort and was purposefully experimental and preliminary in nature.

The transition from Phase I to Phase II was marked by a visit of key ranch personnel to the GE IMAGE 100 facilities, during which time extensive analysis of the several tapes acquired was conducted. The visit was interesting in two aspects. Until this point, the ranch people had only been exposed to LANDSAT data in photographic form, and although transparencies and prints, at various scales both black and white and color, had been acquired, the ranch personnel found little of interest in the data. This was due at least in part to the fact that the data was always several months old. Once they were exposed to the capabilities of machine processing, however, the entire picture changed. They began immediately to understand the concept of multispectral data and to recognize what could be derived from it. In this respect this three day visit not only marked the transition from Phase I to Phase II, but more important, it marked a significant shift in emphasis toward the application of LANDSAT data.

The second important aspect of this visit was the amount of information which these professional ranchers were able to derive from the data using machine processing capabilities. Until this time, GE staff personnel who had spent the summer on site had used IMAGE 100 to operate on the data as described above, and had reported excellent results. For the most part, their efforts had been directed at signature development and classification of the major study crops.

The ranch personnel, working with the help of GE staff people, tended to concentrate on individual crops and even individual fields, and their knowledge and recall of conditions and events provided a wealth of new information from the LANDSAT data. Classification of major crops was quickly demonstrated and dispensed with, and the analysis sessions moved toward the identification of crop varieties. Three separate varieties of seed alfalfa were discriminated and accurately classified, all within the same image and all planted at the same time. Two adjacent fields of safflower showed considerable spectral differences, although no difference had been noted in visual inspection of the field at the time. This was especially significant since one of the fields had produced a much lower yield than anticipated.

Inyo and Anza, two varieties of wheat, were readily separated, as were several areas of lodged wheat. This, too, was important since the lodged condition was not known at the time, and the field had been irrigated and a large section had been destroyed.

PHASE II - THE PILOT PROGRAMS

Phase II took place from March through December 1974, and consisted primarily of two separate but related pilot programs: routine aircraft remote sensing for "real-time" farm management, and the use of LANDSAT data for large scale crop inventories.

Aircraft Survey Program

The aircraft survey program began with the installation of a nine inch camera in one of the ranch aircraft in April 1974 and continued through September 1974, the major part of the growing season for cotton. Color infrared film (2443) was used almost exclusively. The flight plan covered thirty-five thousand acres of the main ranch, plus twenty thousand acres of another of the firm's ranches some eighty miles to the south, every nine days, on a schedule which coincided, again, with the LANDSAT eighteen day coverage cycle.

As each photo mission was completed, the film was flown to a photo lab for processing and returned to the ranch for examination by GE and ranch personnel within twelve hours after acquisition. The results of the analysis were recorded and subsequently developed into a set of photo interpretation references, or keys, for use by ranch personnel. The film was indexed and filed by field with a mission number cross reference.

The imagery found application across the spectrum of ranch operations. The early detection of weeds and insect and rodent damage were among the first results. Cultivation problems such as planter and fertilizer skips were also quickly identified.

Perhaps even more important, a number of subtle, but significant phenomena were identified and monitored by virtue of the repetitive coverage provided. The affects of various crop rotation patterns, for example, were clearly depicted in the imagery, providing a qualitative if not quantitative assessment of the impact. The evaluation of several experiments involving crops, cultivation practices and/or equipment also benefited from the repetitive imagery.

In another application, soil types and certain mineral deficiencies were identified and mapped over both the major areas in cultivation and several new areas being developed. These results provided valuable new data for the company's land improvement program, and caused several changes in the projected program schedule.

Near the end of the season, repetitive aircraft imagery was used to map the drying patterns in both safflower and cotton. These maps, in turn, were used to schedule the application of desiccants prior to harvest.

Clearly, quality, repetitive coverage by aircraft provided valuable new data for ranch management, andwhile it is unlikely that this will ever replace the ground level, visual inspection to which they are accustomed, it does provide new data from a new viewpoint. It has also provided a permanent photographic record of the 1974 season - an exceptional season in view of the unusually low incidence of insects, disease, and other problems - as a basis for comparison in future years.

The results of this pilot program have led to the establishment of an operational survey program. The flight schedule has been refined to maximize coverage during critical crop growth periods, supplemented by periodic monitoring and special purpose flights. The operational program is being carried out entirely by ranch personnel.

Crop Inventory Program

The utilization of LANDSAT data for large scale crop inventories was of great interest to the firm's management. Their requirements for the inventory were two-fold: the earliest inventory of acres planted, with a corresponding accuracy of ninety-seven percent or higher. It is interesting to note that the emphasis throughout was on "acres planted", as opposed to yield. This results from the fact that sufficient historical data concerning yield already exists for their purposes, and only a measure of acres planted is required.

The pilot program in large scale crop inventories took the form of an inventory of cotton over some 4.8 million acres of the San Joaquin Valley. The inventory was carried out with LANDSAT computer compatible tapes and IMAGE 100.

The company's ranch served as the training and test site for signature development. Six different signatures were developed and employed to test extendability. These involved various spectral resolutions (32, 64, and 128 levels), as well as standard and band-ratioed combinations. All six signatures were applied over the study area, so that, in reality, six inventories were performed. The results were compared against data obtained from the California Department of Agriculture.

This pilot study did, in fact, produce an inventory of ninety-seven point two percent accuracy in measuring 650,000 acres of cotton in the 4.8 million acre study area. This was accomplished using LANDSAT data from early September, six to eight weeks before harvest.

A pilot study using multi-temporal classification techniques on a sample basis was also carried out. This showed that the same inventory could be produced as early as July, with the same or even higher accuracy, using data obtained on only two dates. The study also showed that operational inventories of this type could be carried out at a cost of much less than one cent per acre inventoried.

This activity demonstrated both the effectiveness and the efficiency of LANDSAT data for large scale crop inventories for the purposes of this particular agricultural firm. Certain technical developments are currently underway which will even further improve efficiency and reduce the time required to produce the operational inventory results. What remains is the need for a steady flow of LANDSAT digital data, in a timely manner, to make operational inventories a reality.

SUMMARY

The program described here represents the efforts of one major agricultural firm to become familiar with and apply remote sensing technology in its primary business activities. Certainly this is not an isolated case, but the study as a whole, and certain of the results are significant.

This particular agricultural firm is one of the largest and most successful in its field. Until this study began the company had no form of remote sensing activity other than the ranch manager's visual inspection of the field from the air two or three times per season. The success of this company is due largely to fertile land, an ideal climate, and a group of dedicated, experienced professionals, many of whom have been farming this land for almost twenty years. The ranch manager, for example, predicts the average yield for each field in August, eight to twelve weeks before harvest, and consistently produces a 98% accurate forecast. Attempting to improve on this level of performance is difficult to say the least, yet the study did demonstrate, among other things, that a basic form of remote sensing, aerial photography, could provide valuable new data.

It is important to recognize, however, that from the company's point of view, the value of the data did not lie in the ability to detect weeds and pests. These benefits did not adequately justify the cost. The real value lay in the ability of the imagery to map the soils and minerals, to monitor growth in new development areas, and, in general, to add to the basic knowledge of the land. The benefits of much of what was learned cannot be measured in tangible terms, but were considered sufficient to support a continued, operational activity.

Machine processing of LANDSAT digital data demonstrated the potential for applications in both ranch management and large scale inventories. This was recognized early in the program and enthusiastically supported by the firm's management. LANDSAT was particularly suited to many management requirements at the ranch because of the large area involved and the full section fields. The correlation obtained between the larger scale phenomena identified in the aircraft imagery and those subsequently found in the LANDSAT data was excellent. This, of course, leads to the conclusion that LANDSAT data could supplant the aerial photography in many ranch monitoring functions if it were available in real time. As a sidelight, it should be noted that the combination of LANDSAT, aircraft, and ground truth data collected over the ranch in 1974 comprises perhaps the most comprehensive set of multistage sampled agricultural data ever acquired in that area.

The application of LANDSAT to crop inventories was amply demonstrated, and since the time that this pilot study was conducted, GE has performed a number of other inventory programs, all of which have confirmed or improved upon these results. The important conclusion to be drawn here is that LANDSAT data and the current machine processing technology satisfied the major inventory requirements of this particular company. It is reasonable to assume that

the requirements of other firms could be satisfied as well. Certainly more testing and verification are required, but it does appear that the tools are at hand to satisfy many of the inventory requirements of the agricultural community. The limiting factor, currently, is the lack of data, routinely, in the time frame which these users require. Operational applications in both ranch management and large scale inventories require data in a time frame measured in days and perhaps weeks, certainly not months. It is difficult to imagine how one can look for this kind of utilization among the professional agricultural community until this capability is provided.