

Remote Sensing for Agriculture:
An Assessment of Socio-Economic Impacts of
Agricultural Management Systems'
Technological Trial
in Imperial County, California

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Executive summary

The purpose of this report is to provide a rural sociological perspective on the trial of Agricultural Management Systems' (AMS) remote sensing system for detecting stress on agricultural crops. The trial took place in Imperial County, California during the fall of 2001 on selected lettuce fields, and the results of this experiment are reported elsewhere. The trial involved a new proprietary technology being developed by AMS that measures far infrared radiation emitted from fields and plants. The AMS innovation involves hardware breakthroughs in highly sensitive instrumentation cooled by liquid nitrogen to around -350 degrees below zero, software innovations that help process and interpret the raw data and compile it in to useful maps, and system innovations that use the technology in processes that are useful to the farmers, including flying planes at night guided by satellite GPS coordinates and good geo-coding to permit scouts to identify on the ground areas identified from the air. Results are reportedly positive with all stresses being identified and no problems identified which were not found in the fields. Three questions were addressed in this rural sociological study: the impacts from the perspective of the farmer, community level benefits or problems, and employment changes.

First, the research from the perspective of the average lettuce farmer showed that the trial produced accurate information but not yet knowledge that would enable farmers to change behavior enough to justify spending money for the remote sensing. Farmers are likely to be interested in technologies that are beneficial to their operations, but a clear benefit needs to be demonstrated. Many possible opportunities were identified where remote sensing could produce value and benefit to farmers in other crops or using other cultivation systems such as precision agriculture. Water management and crop estimation also good opportunities.

Second, from a community level the research did not find that farmers are likely to use remote scanning data to reduce pesticide use, but the implications of the technology for the community are much greater in water management and economic development (assuming a strong market develops for remote sensing).

Finally, from an employment perspective, the research found that savings in the time spent by scouts in the field were probably less important than that the remote sensing technology would provide another tool for scouts to do their job better and to be able to provide better and more accurate services.

In conclusion, during the two or three months that the trial was being conducted in Imperial county, much was learned about the use of remote sensing to detect stress in fields of lettuce. In short order, remote scanning efforts on other crops and in other areas of the country will lead to incrementally significant new knowledge which goes hand in hand with the physical instruments, software, and scanning techniques. This information will be essential to the successful introduction of the technology to farmers, precision agriculture firms, water districts, and other groups for whom the knowledge will lead to immediate cost savings.

Remote Sensing for Agriculture:
**An Assessment of Socio-Economic Impacts of *Agricultural Management Systems*' Technological Trial
in Imperial County, California**

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I. Introduction.

The purpose of this report is to provide a rural sociological perspective on the trial of Agricultural Management Systems' (AMS) remote sensing system for detecting stress on agricultural crops. The trial took place in Imperial County, California during the fall of 2001 on selected lettuce fields, and the results of this experiment are reported elsewhere. According to reports on these trials, the remote sensing technology developed by Agricultural Management Systems detected stresses which were independently verified in the field, and avoided detecting stresses which could not be identified (false positives). The protocol for the experiment involved independent monitoring of the fields by scouts already working in the area who are certified Pest Control Advisors (PCA)--specialists in identifying crop problems. This report utilizes the results obtained by others working on the project to offer a preliminary evaluation of the potential impact of the technology.

This is a preliminary study of the potential impacts of the AMS deployment of the next generation of remote sensing technology on farming, communities, and employment in the areas in which it is utilized. The broad question being addressed is what social and economic impact

the new technology will have because of its higher reliability and resolution than previous remote sensing efforts. Three questions are addressed in this report:

1. What are the attitudes of the initial users to the new remote sensing technology and the results produced at this point in time? Specifically, the study addresses three sub-questions from the farmer's point of view. A) What are the perceived benefits of the technology and how extensive are these benefits likely to be? B) What are the barriers to adoption of the technology, and how can these economic and sociological barriers be overcome? C) Are there special benefits to certain groups of potential users such as small farmers?
2. What are the direct and indirect consequences of the technology for the communities, in which it is being utilized, including issues of health, environmental impacts, and economic development?
3. Will the technology create changes in employment, including the number of workers in different occupations, the skill level of workers, and the training requirements of the workforce in farming communities.

II. The Technology and Trial

Information for this report was obtained from a field visit on December 5, 2001 to the test site in Imperial County, California. Interviews were conducted with all of the main people associated with the trial from the farming community, and the data reported in this report include their reactions as well as information provided by AMS. I did not attempt, nor would I be able, to provide an independent verification of field results or the technical qualifications of the trial, but I have utilized the trial information provided to me for this report. The data from the trial is

supplemented as necessary by follow-up phone interviews and some additional review of published materials.

The trial involved a new proprietary technology being developed by AMS that measures far infrared radiation emitted from fields and plants. Healthy plants show different levels of radiation than stressed ones, and moisture shows up differently than dry areas. Much of the technological advances of the AMS technology involves increasing sensitivity of the instruments to small changes in the radiation emissions from the field and the elimination of “clutter” which includes readings from atmospheric and other phenomena that make ground readings unreliable.

The AMS innovation involves hardware breakthroughs in highly sensitive instrumentation cooled by liquid nitrogen to around -350 degrees below zero, software innovations that help process and interpret the raw data and compile it in to useful maps, and system innovations that use the technology in processes that are useful to the farmers, including flying planes at night guided by satellite GPS coordinates and good geo-coding to permit scouts to identify on the ground areas identified from the air. Night time flights at about 3000 foot elevations, for example, are important because far-infrared is readily absorbed by moisture in the air and clouds; moisture tends to be found less often at night at the flight elevation, improving reliability of the data collected. In addition, knowledge and experience from the tests allows more sophisticated interpretation of the remote sensing results to identify more accurately problems in the fields.

The farmer involved in this project was Mike Sudduth, a sophisticated and well educated professional with multiple plots of land under contract for many different crops. His participation was on selected lettuce fields that he had farmed for many years, and he knew the peculiarities of the soils and growing conditions on the fields from long experience. He was

assisted in this project by Dan Jungers, a PCA or scout, who specializes in pest management and has worked in the area for many years including scouting the fields utilized in the test. Dan works as an independent consultant to many farms in the area and he selects samples of soil and crops for analysis, identifies problems in the field, and recommends applications and amounts of pesticides and fertilizers. Assisting the project as well, and my primary informant, was Robert Braun, a PCA working on the trial independently of the farmer. He worked as a consultant to AMS on the project and was in frequent contact with the farmer and other scout. In addition I interviewed Charles Sanchez, Director of the Yuma Agricultural Center of the University of Arizona.

The trial involved weekly flights over several fields planted in head lettuce during late summer 2001. The flights were initially delayed by the grounding of all aircraft after the terrorist attacks of September 11. From early October until harvest in early December, the project regularly flew over the fields and produced results that were interpreted initially by project staff and verified by scouts on the ground.

III. Farmer response to AMS Remote Sensing Technology

The first question to be addressed in this research report is if there are any benefits and barriers to adoption of the technology by the farmers using it, and if there is any additional benefit to special classes of farmer such as operators of small farms. The complete answer to this question is only hinted at by the available data from this one trial, since it was only used by one farmer on one specialized crop. Any extrapolation from this one experience to other farmers must be done cautiously, especially since the farmer who participated in the trial stands out from other farmers by his interest in new technology and willingness to participate in a trial.

Nonetheless, introducing a new technology into any industry is a gradual process where adoption comes when there is a clear benefit perceived by the person and firm adopting the technology.

The conclusion of this report is that positive trial results are appreciated by the farmers and to a large extent farmers can see that there are benefits to the technology, but at the present state of the technology these benefits are still general and hypothetical rather than a clear cost savings that would translate into high demand for the technology.

A. Benefits

The positive results of the trial that are appreciated by the farmer and by extension would be appreciated by other farmers is that the AMS remote sensing is accurate information and it corresponds to the farmers historical experience on his land as well as the confirmation of the pest control advisors who worked with him. The areas of the field on which stress was found by remote sensing were independently verified to be areas of stress. Interestingly, one period while the farmer was letting the lettuce fields dry out in order to force the heads to close was detected from the scanning as a stress, but in this case it was intended and was closely monitored using existing ground level techniques. Similarly, the farmer (and reportedly his colleagues) were familiar with other remote sensing techniques, which did not have as good a reputation for accuracy.

Although the farmer indicated that the technology was not useful enough to his current operation to create an immediate demand, in discussions we discovered a number of strong benefits to his operations and by extension to many farmers who face similar farming conditions and could utilize such a technology. These include.

- Farmers in general are innovative and interested in new technologies, which can save, them time and costs. There was little evidence that this farmer or his colleagues would

resist the use of accurate remote sensing data simply because it is new or different. There is virtually no generalized technology resistance that was reported to me during the interviews, and in fact several times it was pointed out that farmers are continually innovating in the use of new seeds, fertilizers, crop rotations, and other new technologies, so there is hardly a problem of resistance to innovations.

- Many of the farmers in the Imperial Valley are young and well educated and are interested in and aware of the benefits of remote sensing. They are waiting until there is a proven application that can save them significant money, and they will be willing to adopt the technology once it is available. In regions with mostly older and poorly educated farmers, these findings may not hold.
- Farmers know their fields and crops, and in the case of lettuce, their fields are small and high value so this knowledge covers most aspects of the ways they farm their land. The fact that the remote sensing corresponded to their knowledge of the fields reinforced the validity of the technique, although it did not add much that they did not already know.
- In discussion of this fact, the farmer did suggest, however, that remote sensing technology once he became used to it would be helpful for new fields that he did not know so well from many years of experience. Farmers continually take on management of new fields and some old ones are taken over by other farmers. While in some parts of the country a farmer might continually manage only fields he owns, in the Imperial valley most farmers work a continually shifting set of fields which makes gaining additional information increasingly important.
- Farmers claimed that the technology would not help them very much with the management of pests, but it could add considerable information and benefit in their use

of water and avoiding water stress on plants from either over watering or under watering. For example, the farmer said that if better watering information for carrots, for example, might lead to efficiencies in avoiding one watering cycle once a year, then the cost savings from that alone would be enough to pay for the remote sensing. The water in the case of this farmer is relatively inexpensive, and the savings in terms of water use now would not be significant. However, the labor costs associated with irrigation would be substantial and they would benefit the overall profitability of the crop and might justify remote sensing.

- Remote sensing that is accurate and reliable may also assist the farmer in the management of new crops or custom products that have a higher than average value and thus have more need for information on the crop. In short, when the farmer's product is not ordinary, the role of specialized information goes up.
- One of the most interesting potential uses for remote sensing information may be in crop estimation. For some purposes, accurate estimates of productivity of a field may be needed, and identifying the level of stress in specific parts of a field may allow more accurate modeling of the size and maturity of a crop.
- Several possibilities were suggested for how the technology would be useful in conjunction with precision agriculture operations. In some crops and locations, farmers and consulting firms develop information that can be applied differentially over parts of the field. Remote sensing could assist these farmers and firms. However, the farmer involved in the trial did not use precision agriculture techniques, saw the cost of the specialized equipment that would be added to tractors or other machinery too high for the benefit it would provide, and precision agriculture firms offered little additional

value. In part this may be because the inputs to lettuce were small from this type of agricultural practice. Trees and other crops may give higher returns to precision agriculture, however.

- The farmer I interviewed indicated that a use of remote sensing that might benefit him would be its ability to identify minor element deficiencies in the soil which could be remedied by specialized applications of the missing minerals as needed. Since many of these minor elements are expensive, but crucial to specialized crops, an efficient means of detecting them would be appreciated.

In conclusion, the interviews and analysis I conducted was limited to the persons involved with one lettuce crop in a plot which prior to the test was well understood from a soils and growth perspective. The applicability of remote sensing to other crops may be either more or less attractive depending on the particular crop. For example, commodity crops which are either larger acreage or lower value may be able to use remote sensing where there is less information available from scouts. Or, other high value crops may demand more information for effective management which would lead to more demand for accurate remote sensing. Some of these issues will be discussed in the barriers below.

B. Barriers and Limitations to the technology

Accurate remote sensing technologies explored in this trial showed several limitations that would restrain farmers from adopting the technology. These are not necessarily barriers that would restrict the introduction of the technology completely; they are limitations or factors that need to be considered and overcome.

- The farmer found that the information was accurate, but it did not tell him much that he did not already know. In short, the stresses identified by remote sensing were ones the

farmer already knew because of areas of poor soil, or rot that were anticipated. While the finding of areas of stress that confirmed previous knowledge was reassuring, it also showed that much of the remotely generated information did not add new information to the farmer's management tools.

- Sometimes the additional information from remote sensing will still be something the farmer can not act upon because spray times need to be scheduled in advance when equipment is available, and because other practices are uneconomical to change at short notice. Farmers also said that much of the information on stress that was generated concerned things that were interesting but which the farmer could do nothing to change. For example, in one area where there was fungus and rot, the only treatment was at the time of planting or when the plant was small, not when it was mature. Similarly, many nutrition deficiencies are not able to be corrected until the field is plowed.
- Some of the problems the farmer faces are ones, which do not appear as stresses. For example, in lettuce cosmetic concerns such as insect bites and holes in the lettuce leaves are of great concern, but the fact that a hole is eaten in a healthy leaf does not register as a stress in the remote sensing.
- Pesticide applications and conserving on pesticide applications is over rated. According to the farmer, PCAs, and university extension specialist, there is a widespread myth that large amounts of unnecessary pesticides are being applied on crops, and that the reduction of the amount of these highly toxic substances in the environment would be a widespread good. While they admitted that there was excessive treatment of agricultural crops, their concept was that the environmental regulations governing pesticides have gotten increasingly strict, and that substitution of more environmentally friendly

pesticides has had, and will have, much more positive benefit to the environment than any marginal gains of precision pest control. It is not my expertise to evaluate the validity of this concept, but according to the people I interviewed the prevalence of sprays that have a 4 hour period before farmworkers are allowed back into the fields rather than ones with a 4 day period illustrates this phenomenon.

- With the new integrated pest management technologies and special pesticides that work on only certain pests at certain stages of emergence (larval, for example), the detection process to determine the pest and its vulnerability requires more accurate information than can be obtained from a remote sensing of a field. In short, the information needs are much greater than simply identifying if there is stress or not.
- Even with more detailed information on pest outbreaks, farmers may not be able to alter their spraying patterns because of the liability involved with their particular crop. In the Imperial Valley, crops are usually grown under contract to a buyer, and the buyer wants assurance of the quality of the crop by mandating certain protocols for managing pests. These strategies are insured and chemical companies and purchaser of the crop assume some or all of the risk for a crop if the farmer follows the protocol. Thus the chemical companies and their scouts or PCAs have responsibility for the quality of a crop, and the additional information from remote sensing is not likely to alter when and how much a field is sprayed. There are many non-farmer interests who will not want to use more accurate information because their general treatment of the fields has been working and is something they can guarantee with known risk. Farmer acceptance of this type of new technology may be easier than acceptance by others who control what the farmer does.

- New pests whose behavior is not familiar in an area, or patterns in the data that have not been evaluated previously are ongoing problems. For example, in the test an area of lettuce became overgrown with weeds in the ditches. In this area the weeds showed up as very healthy vegetation and were not initially identified as a problem, largely because their remote signature was not known. As more research takes place and more fields are evaluated, the unknown patterns will be better identified.
- Farmers have a hard time processing all the information that the remote sensing gives them, and they are generally limited in the time they can spend looking at the images and gaining the expertise to evaluate all problems. In the experience of several interviewees, this overloading of information was perhaps the most serious problem, and it mandates working with an intermediary organization whose professionals can simplify the data presentation. End users are often technologically sophisticated, but they must see a clear benefit to justify the time it takes to sort through large data sets to get information that is otherwise unavailable.

In conclusion, the barriers to adoption of the technology are mainly that lettuce farmers currently see few applications of the remote sensing technology to their needs at the present time given the limited experience with applying the technology to real farming conditions. This is not to imply that the mature technology would have no application; it simply reports the conclusion of those we talked to that the applications of the technology need to target crops and places where the value of the information will lead to substantial cost savings and thus large profits for growers who use remote sensing. Right now, the applications for lettuce are not compelling in spite of the many improvements in the technology and the much broader applications as field-testing and knowledge of the results develops.

C. Special Benefits for Small Farmers and others

This analysis aimed to identify special benefits that the technology might provide to small farmers or others using the technology. Given that the case study so far has found that the technology provides highly accurate data but the benefits of the technology are ambiguous to farmers, the differential value of the technology to special groups of farmers such as small farmers is hard to assess. Note that this statement does not imply that small farmers or other groups might not gain advantages at some point in the future, it simply states that the benefits that are most likely were not ones tested in this trial and so calculation of differential benefits to selected groups is premature.

If small farmers were to collectively contract for flights over their land, it is conceivable that they would benefit in the same way that large farmers would benefit. Also, it may benefit small farmers who own their own small plane.

Summary

The research from the perspective of the average lettuce farmer showed that the trial produced accurate information but not yet knowledge that would enable farmers to change behavior enough to justify spending money for the remote sensing. However, many possible opportunities were identified where remote sensing could produce value and benefit to farmers in other crops or using other cultivation systems such as precision agriculture.

IV. Community Consequences of Technological Adoption

The second question asked in this research is if there are community-wide consequences that would be beneficial from the technology. Initially, it was anticipated that the identification of areas of crop stress would lead to more precision applications of pesticides, which would reduce farmworker exposure to toxic chemicals. As noted in the previous section, the farmers involved in this trial were not convinced that pesticide applications would be significantly reduced, and that the major benefits to farmworker health and community exposure to toxic chemicals was likely to come instead from new chemicals and treatments that are more environmentally and community friendly. Thus, estimation of environmental and farmworker health benefits from the technology seem minimal based on the data provided by the trial. This is not to imply that other data based on new information or other crops might not prove a benefit, only that this trial did not identify this type of community benefit.

Water savings benefits

The significant benefit identified in the trial was a potential benefit from water savings. Currently in the Imperial Valley, water is reportedly inexpensive and savings from small amounts of conservation were reportedly negligible. However, water rates are going up and with changes in water marketing as well as greater pressures on water allocations, there may be financial and other incentives to conserve some of the water that is now considered inexpensive. This is coupled with the additional incentive that more efficient water management is likely to improve crops that are stressed by over or under watering.

Water shortages have been one of the most persistent problems facing California over history, and battles for water provoked some of California's most heated political fights. The

Colorado River, which supplies Imperial County, is overdrawn and is facing competition for existing allocations with Arizona and urban areas. While urban conservation has gone a long way to reducing some of these pressures, state and national pressures for additional conservation by farmers is increasingly likely.

Interestingly, according to the interviews, one of the groups most interested in supporting the remote sensing technology is the Irrigation District, whose interests in saving water in the agricultural areas relates to both political and financial pressures.

Economic Development Benefits

This technology has a number of economic development benefits that are likely if it were to be implemented at full scale, assuming that it finds an appropriate market serving precision agriculture and specialty crop markets, along with water districts. Community economic development benefits may come from three areas associated with a new technology.

A. Farming contributions to the local economy. If the remote sensing technology were beneficial to farmers it would increase profitability of crops in agricultural regions in which it is used. This would assist the economic base of some of the areas of the state and country, which historically have been poor and plagued by high unemployment. The use of the technology could have significant implications for farm strength and competitiveness, especially in specialty crops, which are facing intense pressure from other areas.

However, it is not yet clear how remote sensing would generate new competitive advantages for farmers in the areas in which remote sensing was available. Once these quantifiable results are available, an estimate of the extent it will benefit regional agricultural competitiveness can be calculated.

B. Industrial benefits in the non-agricultural sector associated with agricultural remote sensing technology. The emergence of an effective remote sensing technology has been awaited for a long time by agriculturalists and researchers interested in increasing the efficiency of agriculture. If we assume that the reports from the technological test of the technology are correct, this technological innovation may be the breakthrough that will expand remote sensing to new markets. If this happens the areas that are at the cutting edge of innovation are likely to benefit first and with sustained advantages over time. How large this will be is not calculable at this time but some of the components of an emerging industry cluster are as follows¹:

1. The core of the remote sensing industry will have significant benefits to the community in which it is located. Included in the core of the industry is the firm (or firms) that makes the remote sensing sensors and other hardware, writes and maintains the software, and processes the initial images. This core industrial firm or group of firms will tend to concentrate in one or several areas, drawn together by initial markets and investors. While AMS is in Oklahoma City, it is not clear that that will be the core of the industry as agricultural remote sensing achieves maturity as an industry.
2. The remote sensing industry will be supported by contributing industries such as optics and electronics, as well as aerospace and computer programming. These support industries nearby help to determine where the geographical advantage of the industry will be located, since being near the firms that deliver advanced inputs are critical. At a

¹ The concept of an industrial cluster is at the core of much modern economic development theory and research. A cluster is a group of firms in related industries that are geographically concentrated and highly competitive. The core firms are supported by industries that contribute to the production of the core products, some of which may be clusters themselves. The core cluster and supporting industries are both supported by specialized infrastructure including University research, financing (eg, venture capital), legal expertise, government sponsorship, skilled labor force, available natural resources, and physical infrastructure such as airports and highways. In addition, clusters are closely tied to markets and market institutions such as industry associations, publications, conventions, and marketing firms. See Ted Bradshaw, et al, Catching on to Clusters, Planning Feb 1999.

small scale the location of the cluster is not very important, but as it reaches a high growth rate proximity to these supporting firms is essential.

3. The marketing of the product will have to be near associations and consumers, including innovative firms that are most likely to first adopt the technology. The links to associations such as integrated pest management or precision agriculture are important, as the early decisions regarding how to market remote sensing will shape the early evolution of the technology.
4. Specialized infrastructure including university research, extension, financing, early adopters, and labor force will support all the other components of the technology. This geographically specific capacity will be essential. While many of the most important cluster components will be in urban areas, the possibility of a cluster developing in farming areas is also particularly attractive.

The notion of a cluster is an important way to approach the economic development impacts of the potential agricultural remote sensing industry. Communities are finding that their best economic development strategies are to assess how they can build a cluster rather than attract a firm, and once they do so the economic development benefits are significant.

Economic development places a large emphasis on multipliers in the local economy. Multipliers represent the total of all stimulated inputs to an increase (or decrease) in sales to one industry from the total of all other industries affected by this increase. Thus, more remote sensing will buy more electronics, which will buy more wafer manufacturing, which buys more electricity, which buys more natural gas, etc, cumulated until all the inputs are negligible. Employees of each firm stimulated by the additional input also buy things with their wages, which cycles through the economy. Typically multipliers for manufacturing industries in rural

communities are 1.25 to 1.5 while in urban areas they may reach 2.0. A multiplier of 1.5 means that for every dollar increase in sales by the remote sensing industry, an additional half dollar of sales are stimulated in other industries as that dollar of goods are produced. The reason that multipliers are low in rural areas is that many of the inputs are purchased outside the local area, a process economic developers call leakage.

Thus, from an economic development perspective, the center of the new remote sensing industry may develop a cluster which will have significant multipliers associated with it, but the location of this cluster core is not determined at the moment and it may or may not be in California. If it does locate in southern California or Arizona, it would be an attractive magnet for further economic development.

C. Adoption of the Technology by related industries. One of the interesting possibilities of the development of the remote sensing technology is that it may be useful in other applications besides agriculture. Several options include monitoring care of golf courses, examining fire danger in forest and urban-wild land interface zones, locating areas where wildlife are threatened, or modeling urban energy conservation efforts. None of these are proven in any way, but serve to illustrate how a technology once developed can find new uses. Firms developing these applications may be spin-offs from AMS or independent firms, located near each other so that they can share technological advances.

In sum, the major community impacts of the remote sensing technology are not likely to be in toxics or pesticide management but in water conservation and economic development. At this stage of the technological development, it is too early to validate these community impacts or the extent to which they will benefit communities using them.

V. Employment impacts from better remote sensing

To the extent the AMS remote sensing technology finds a market niche, one of the potential savings will be in labor. The model of this trial included efforts to obtain estimates (not available at the time this is being written) of the efficiencies in the use of scouts who have access to good remote sensing data compared to scouts who worked the fields in the traditional way. The results of this test will be available elsewhere, but in conversations with scouts interviewed in this project these labor benefits are likely to be elusive.

From the scout perspective, remote sensing may provide a significant advantage to the accuracy and speed with which they can complete their analysis of a field. However, they see remote sensing as another tool that they can utilize to do their job. Few see it as a substitution for their work, though it might allow them to save time on some tasks while they expand the time they spend on other tasks. Based on what I learned, scouts often work as independent consultants or for pesticide manufactures, under contract with farmers over a period of years. The following views are expressed by the scouts and reflect their perspective, and I was not able to confirm this with others. However, they are reasonable based on my understanding of how new technologies alter employment.

- Remote sensing provides information not otherwise available to the scout to improve the accuracy and sensitivity of their analysis. Scouts with the technology will be at an advantage, and will likely have more work, while those lacking it may be less competitive. The tension felt by the scouts is for accuracy since the crop's value depends on the quality of the produce that is grown. A few bugs in certain crops can mean that a whole load cannot reach the retail market. This has huge consequences and scouts are

driven more by assuring accuracy than cutting a few percent off the time they spend in a fields.

- Remote sensing can confirm predicted patterns of stress so the scout does not need to physically visit each spot in a field. The fact that an expected phenomena appears as predicted can be learned from the remote sensing, can be monitored, and in some circumstances can be seen in advance of physical manifestations.
- Remote sensing can allow scouts to focus on other issues such as detecting if an infestation is in the larval stage or not, information which is necessary with new chemicals which have narrower applications. Again, this may change the character of what scouts do, but it may not decrease their numbers.
- Remote sensing will not create labor surpluses. There appears to be a relatively good balance of scouts and the persons or firms providing scouting services. The people I interviewed said that they had plenty of work to do and that their workload was increasing, especially as they were being asked to do more for other farmers.
- General knowledge of fields and pest infestations can be obtained from trained farmworkers who are in the fields, and this can add more information to help scouts make informed and accurate judgments about the condition of fields.
- Other occupations in addition to scouts may have employment consequences, but at the present time the actual cost savings that will arise due to remote sensing and the labor consequences of these savings are not clear.

In sum, based on information collected in this limited study there is no reason to assume that the introduction of remote sensing technology may have serious employment consequences. Knowledge and the management of systems based on knowledge seems to increase rather than

decrease employment in occupations and industries involved with that knowledge. Over the long term, employment changes in agriculture are likely to continue with low skill work being replaced by higher skill workers, and fewer of them. Changes due to remote sensing are not likely to be as large as due to other changes in agriculture, though the data are not adequate to make this a definitive statement.

VI. Conclusion

In conclusion, remote sensing is an interesting source of information for farmers and there are few reasons to expect that it will have trouble being adopted once the right use for it is discovered. This is the single largest challenge for AMS at the present: to demonstrate that farmers can save money and /or produce a higher quality, more reliable crop using remote sensing compared to current ways of managing their crops.

It is important to keep in mind that this paper was written after just the first field trial of the new technology and it was utilized on only one crop. What was learned about the interpretation of the remote scanning results is considerable, and further analysis of the data as well as application of the technology to other crops will similarly lead to a better understanding of the information that is collected and the potential markets for this information. In short, the research and development (R&D) on this technology is just beginning, and as it matures better answers to the three questions addressed in this report will be available.

Put another way, in the two or three months that the trial was being conducted in Imperial County, much was learned about the use of remote sensing in lettuce. In short order, remote scanning efforts on other crops and in other areas of the country will lead to incrementally significant new knowledge which goes hand in hand with the physical instruments, software, and

scanning techniques. This information will be essential to the successful introduction of the technology to farmers.

Finding the market niche

Based on the limited research done in Imperial County, I have no reason to conclude that there are significant socio-economic barriers to the adoption of the technology. Indeed, there may be significant economic development advantages for communities participating in the early commercialization of the technology, especially if the community is appropriately located to support the development of an industrial cluster. I do not anticipate farmer resistance, community opposition, or labor force problems. However, at the present time it is not clear what the market will be for remote sensing information since it is not yet clear that it provides a clear benefit to farmers. This may be due to the peculiarities of lettuce or the Imperial Valley. It may also be that early development and implementation needs to be done in partnerships with people and firms introducing new farming techniques such as precision agriculture or water districts.

Many crops may better benefit from remote sensing compared to lettuce. New trials should maximize the information gained from tree crops, commodity crops, and very high value crops such as wine grapes. Extension agents interested in these issues would be a good source of assistance in determining priorities for future program development.

Other farming regions may be more useful for the technology than the Imperial Valley, which is desert ideally suited to growing winter vegetables. Because of this specialization, farming practices may be different than elsewhere.

Finally partnerships with organizations already interested in the type of information provided by remote sensing may prove useful. We know for example that precision agriculture firms specialize in treating parts of fields in different ways, and the information provided by

remote sensing may be better suited for their technology and equipment than for independent farmers. In addition, water districts may be interested in partnering to discover ways to use remote sensing to reduce water waste. Crop forecasting firms may also be interested.

The first field tests of the AMS remote sensing technology demonstrated the successful application of new hardware and software to agricultural fields at a level of accuracy that appears to be well above that of previous technologies. This significant technological breakthrough, if it is confirmed by repeated tests, continues the process of providing farmers with more information more quickly than has been possible in the past. However, the challenge is to demonstrate to farmers and other decision makers in the agricultural industry that this new information is valuable to their operations and that it will lead to significant costs savings. In modern agriculture, this information does not necessarily create a market for those providing it.

The challenge it seems to me from a rural sociological perspective is not to overcome farmer, community, or labor force opposition, but to create market niches in which the technology will lead to clear and significant cost savings within the current overall structure of modern agriculture. These potential market niches, some of which were identified in this report, may provide additional information that will help expand the market for accurate remote sensing and provide agriculture with new tools to expand production and quality while reducing costs. This goal of using remote sensing to expand agriculture seems more possible than ever, but much work still remains to demonstrate its commercial viability.